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Travels of Learning

A Geography of Science in Europe

Edited by
Ana Simões, Ana Carneiro and
Maria Paula Diogo

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PREFACE

The idea behind this book grew out of a research project launched by the international group STEP (Science and Technology in the European Peripheries), established in 1999 by historians of science from Spain, Portugal, Belgium, Greece, Turkey, Italy, Russia, Sweden and Denmark. The aim has been to re-examine the historical, and we might also add, the geographical character of science and technology and their institutions in regions and societies within Europe, usually outside mainstream historical analysis. The intended activities of the group have been framed by the following issues: reconsidering the "centre-periphery" model which has been the dominant model in studies on the transfer of scientific knowledge; bringing to the fore the concept of scientific appropriation and attempting to study the construction of various local discourses; systematically examining the relationship between science, politics and the rhetoric of modernisation in societies in the European periphery; joining forces to find out more about scientific travels; using networks to further understand the dynamics and role of scholars on societies in the periphery of Europe; intensifying efforts to catalogue and make available to the international community the archival material in the peripheral countries (http://www.cc.uoa.gr/step, on page 2).

As a result of these programmatic guidelines, a meeting was held in Lisbon in September 2000 in which the topic of scientific travels was used as a particularly good unifying theme on which to base a discussion of case studies involving the European peripheries. By starting in some instances from papers delivered at the conference, and in others by inviting other historians to join the project, the idea of this book slowly took shape.

As editors, we want to thank all contributors to this volume as well as all those who presented papers at the meeting which were not finally incorporated in this book. We also want to express our deep gratitude to Kostas Gavroglu who took charge of the concluding remarks at the Lisbon meeting, and has been following this project ever since. Special thanks go to Paul Covill who took care of the language editing and revised many homemade versions of English, putting them in an acceptable form. We also wish to thank to the Kluwer staff, especially to Jolanda Voogd and Deborah Doherty for their kind assistance.

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TRAVELS OF LEARNING

Introductory remarks

Travels have without doubt been a perennial source of attraction not only to ordinary people but also to scholars in different fields, ranging from history, geography, anthropology, and literary studies to the history of science and technology. In the latter case travelling has played a prominent role in the context of colonialism and imperialism, but historians of science have seldom looked at travels within the European space, stretching from the Iberian Peninsula to the Balkans and the Scandinavian countries. This book will help to fill in this gap, by offering various case studies, which focus on travels of learning from some regions considered as peripheral to other regions recognised as centres of expertise. Before presenting the chapters in the volume, a general overview of the different types of travels and their respective backgrounds is provided, based on a review of the historical literature on travels, and the contributions to this volume.

Between the fifteenth and seventeenth centuries, travelling was normally associated with the voyages of discovery, which instigated the age of exploration for the Europeans. Astronomy and the sciences associated with nautical enterprises developed and the knowledge of new lands, peoples, animals, and plants resulted in narratives that often mingled the extraordinary and the supernatural.

In the wake of the age of reason, Europe was still immersed in the contradictions arising from the confrontation between a declining rural and feudal society and an increasingly powerful urban bourgeoisie. In this context, the theme of travel and travellers reveals a multiplicity of meanings going beyond the most obvious, that of geographical mobility. In fact, during the Enlightenment, travelling was essentially a means of establishing and reflecting on the boundaries separating an "enlightened space" from obscure regions where reason, the new sciences and technologies were gradually arriving but slowly and tortuously.

It is in this framework that the Grand Tour, as well as the wanderings of British, French and German travellers across Southern and Eastern Europe, should be understood. Despite the sharp differences marking their specific purposes, it was the tacit acceptance of the dichotomy between the

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"civilised"[1] and the "exotic" which justified and structured these travels. Thus, for those who travelled to the borders of what was perceived as Enlightened Europe it was the mesmerizing encounter with the exotic and the picturesque which was central to the travelling experience. Alternatively, on the Grand Tour,[2] the traveller usually visited France, the Netherlands, the German States, Switzerland and the Italian territories, in search of enlightenment and culture both in its academic form and in terms of social rules, manners and tastes. In this way the traveller aimed to reinforce his — much more often than her — social status and position in the community of the learned[3] men populating the Republic of Letters.

From the point of view of scientific travels, the Grand Tour is particularly interesting because it associated a strictly pleasure-seeking dimension with a socially recognised opportunity to observe, learn and reflect.[4] Both the nobility and the gentry[5] engaging in the Grand Tour visited places chosen by artists, men of letters and men of science. While wealthy people had the financial means to pursue their travelling endeavours, not all men of science possessed them, and they often sought the backing of monarchs and patrons.

To the extent that travels were steadily establishing themselves as "travels of learning,"[6] the cultural was subtly transformed into the cognitive. From the "discovery" of antiquity, a predilection for collecting art objects[7] developed, which later gave way, to a penchant for the collection of objects of the natural world, largely influenced by Linnaeus's *Systema Naturae* (1735).[8] The narratives of these trips became increasingly popular,[9] and appealed to readers not only as a way of fulfilling their curiosity, but mainly as a means of obtaining information and knowledge, in short as "steps towards enlightenment." Even those who did not travel participated in the spirit of the age, and immersed themselves in travel narratives to re-enact other people's experiences, and often discussed their readings in lively gatherings at academies and salons.

In this context, another group of travels emerged, sharing an educational purpose with the Grand Tour, but more focused in their specific goals and destinations. These were journeys made by intellectuals and men of science travelling from the European peripheries to the centres. This book explores numerous aspects of this particular kind of travelling, which was fundamental to enhancing the circulation, diffusion and appropriation of knowledge within the European space, ranging from tours seeking educational or training experiences to more or less straightforward spying missions.[10]

Still another dimension of eighteenth century travelling is associated with the journeys of exploration. While the Grand Tour embodied journeys within the confines of Europe, marking, after all, the encounter of the European "self" with itself, the voyage of exploration confronted the participant in the European Enlightenment with the "other," the "barbarian," the "savage," the wild and the wilderness. In this respect, the travels of exploration share with the travels to the fringes of the European continent, the same sort of attraction for the exotic and the picturesque.[11] Indeed, the Southern and Eastern European territories, with their borderline cultures, were perceived as an ambiguous space between civilisation, exoticism and barbarism. In a sense, by reference to an economic and cognitive world-system they were on the borderline between centre(s) and periphery (peripheries), and had to be taken into account in the debates over the construction of the various European identities and hierarchies.[12]

The notion of exploration in the strict sense entailed a considerable degree of professionalisation (evident in its Latin origin) associated with the notions of observation, information gathering and recording. The explorer, whose mission was funded by the State, religious institutions, a private patron, an association of traders and entrepreneurs or an academy, departed with a programme outlining specific tasks to enable him to fulfil very precise purposes. Sponsors expected to gain detailed information as a return for their investment. The romanticised idea of the explorer as an intrepid adventurer is more likely to be part of popular imagery than of history: while courage was part and parcel of the explorer's profile, the eighteenth century explorer was essentially a reporter, a note-taker of what he saw in far-away spaces, ranging from peoples and animals to plants and rocks.

Despite the overwhelming impact on the explorer of luxuriant landscapes, exotic animals and plants, investigation and making inventories played a prominent role in the missions carried out in the territories of Africa, Asia and America belonging to the European Empires.[13] It is this faint line separating the vision of the sublime[14] from objective descriptions, together with the awareness that the ordering of reality, natural and human, was necessarily marked by an Eurocentric perspective,[15] that combine to turn the travels of exploration into a "laboratory" of historical research on the role of travelling in the formation of the body of European scientific and technological knowledge.[16]

The nineteenth century was to re-contextualise the idea of travel in the framework of a growing professionalisation and specialisation in the sciences.[17] Often portrayed as the "era of revolutions,"[18] the nineteenth century came to symbolise a definite break from the *Ancien Régime*, by consolidating values which had emerged during the Enlightenment. These values were built on and were closely linked to industrial capitalism, the liberal bourgeoisie and the Saint-Simonian concept of progress.[19] The idea of progress based on science and technology increasingly called for an institutional and hierarchical organisation of science and technology. The professional man, striving to develop specific skills and to build up a career in the realm of the sciences, gradually replaced the dilettante, the polymath of the previous century, generally associated with Baconian principles.

Travel, like travellers, was reshaped, evolving into a more professionalized and specialised endeavour, to such an extent that the former combination of pleasure and learning was significantly reduced, giving way on the one hand to tourism,[20] and on the other to travel-based professional contacts, each operating in very distinct settings. As a consequence of this change, the kind of literature produced in this new context became the technical and scientific report or the textbook, instead of the classical travel literature of the previous century.

Together with the growing specialisation of the traveller, the concept of a centre was fragmented into that of multiple centres of expertise. In fact, to the extent that scientific and technical knowledge focused increasingly on well-circumscribed sub-fields within the boundaries of each discipline, the status of a centre was redefined both geographically and in terms of the functions it could fulfil, transforming the geographical reference into a cultural and cognitive one. Travel destinations were selected because specific aspects of a scientific or technical field had developed in a particular region or city, whose geographical location might or might not coincide with that of a country perceived as a centre.

In this context, it becomes apparent that contact with the "other" was no longer the motive for travelling in Europe. A growing industrial economy enhanced the standardisation of various European regions, by re-structuring the European space and establishing within it recognisable hierarchies. It was precisely this economic re-ordering, and the new perception of the role of European nations, which ultimately justified the concept of a *mission civilisatrice* underlying nineteenth-century travels to colonial territories: "collecting" gave way to "effective occupation." The scientist and the engineer who set off to the far-off lands of the Empire were not primarily knowledge-seekers, but people interested in profitable applications, in both political and economic terms. The figure of the eighteenth-century explorer extends into the nineteenth century, but transfigures itself within an increasingly complex institutional setting.

This book offers a collection of studies which focus on the travels of learning within the European space, in which scientific and technological training and expertise were sought, often by people who travelled from regions considered as peripheral to other regions recognised as centres of expertise. With the exception of three chapters, the first and the last two, the book is centred on the eighteenth and nineteenth centuries. Travelling is used not only to help in clarifying processes of appropriation of scientific ideas, instruments, practices and of technological expertise, but also to assess similarities and differences in the perceptions of science and technology in some countries of the European peripheries. All the chapters use travel as a conceptual tool to disclose aspects of the dynamics of science and technology often forgotten in the literature of history of science and technology. We hope, in this way, to outline a richer and more complete geography of science and technology in Europe.[21]

The first chapter, "A Periphery between Two Centres? Portugal on the Scientific Route from Europe to China," analyses the impact of the travels of Jesuits departing from Portugal from the mid-sixteenth century to the seventeenth century and heading for their missions in China. Jesuits were, indeed, scientific travellers of a very special kind, and in this respect this chapter addresses a type of travel very different from the others discussed in the book. On the one hand, for Jesuit missionaries, science was a means to both a religious and a political end; on the other, the Jesuit scientific enterprise did not aim at accumulating knowledge or collecting items, but it was certainly very effective in the dissemination of knowledge.

It was the need to send scientifically trained missionaries to China which put Portugal at the centre of a peculiar phenomenon of scientific travels. The diffusion of telescopic innovations, and of the telescope itself, is used in this chapter to illustrate the impact of the extensive network of Jesuit schools and of their travels from Europe to East Asia.

Henrique Leitão focuses on a period of remarkable scientific interchange relating to ideas, books, instruments and people between Portugal and important centres of scientific production. As this process left only a faint imprint in Portugal, it is argued that rapid, efficient and organised communication is not sufficient in itself to promote the formation of a local scientific community, whose development may be hindered by various local factors.

In "Scientific Travels of the Greek Scholars in the Eighteenth Century," Manolis Patiniotis draws conclusions from the analysis of a historical database of eighteenth-century Greek travellers, including two types of entries: identity of scholar (name, dates and places of birth and death, field of interest) and identification of travels (dates and places of departure and destination, and purpose of the trip).

He begins by discussing a number of questions pertaining to geographic considerations, political borders and national identity, and by pointing to the lack of scientific institutions in the Greek intellectual space which could sustain and support travels of learning. The Greek travellers under study are defined as scholars rather than scientists or philosophers: they were polymaths with a philosophical and theological education, who were aiming to build up careers as physicians or teachers.

The results of the methodology used in this paper clearly challenge current views on Greek historiography. According to the received view, many Greeks who studied in Venice, Vienna, Bucharest, France and the Netherlands brought back with them the spirit of the Enlightenment. According to the conclusions outlined in this chapter, Greek-speaking scholars were not interested in introducing a radically new philosophy, but in building a synthesis of neo-Aristotelian and Greek Orthodox traditions and proving its superiority in the European context. In this way, they strove to define a new intellectual profile, which enabled them to keep up with the demands of the emerging Greek society. In addition, Greek scholars did not actually travel "abroad," but visited places inhabited by Greek-speaking populations or Greek communities: their travels depicted a quasi-national intellectual space extending from Italian cities such as Venice and Padua to Austria-Hungary, Walachia-Moldavia, Constantinople and Macedonia.

The next chapter, "Yirmisekiz Mehmed Çelebi's Travelogue and the Wonders that make a Scientific Centre," describes the travels of the Turkish army officer Çelebi to France in the eighteenth century. It discusses his report on the "wonders of the centre," which he tries to process and interpret in the light of his own culture. In this case study, Berna Kılınç illustrates the multiple features of travelling in a period in which science was part of a wider field of interests ranging from the fine arts to technology, science, and politics. Çelebi's travelogue reveals his general appreciation of *ilim* (a Turkish word similar to *Wissenschaft*, and therefore referring to a more inclusive concept than natural philosophy) as practised by the French, especially in the realms of gardening and architecture, but not specifically in the sciences. Following his trip, Çelebi and his son apparently wanted to launch a printing press in Istanbul, but in contrast to what happened in the West, the printing press did not promote readership in the Ottoman Empire.

While the real impact of Çelebi's travel was negligible in this respect, it certainly paved the way to communication between Turkish and Western cultures.

Both this and the previous chapter are particularly revealing about the specificity of the Ottoman Empire, and point to a contrast between the cultural background of the East and the West in the eighteenth century.

The chapter "Emmanuel Mendes da Costa (1717-1791): A Case Study in Scientific Reputation" analyses the strategies involved in the attainment, maintenance and recovery of trust by the Jewish Portuguese émigré Emmanuel Mendes da Costa. After establishing his reputation as a palaeontologist (conchologist), da Costa managed to get himself appointed as clerk to the Royal Society. While holding this position he perpetrated a major fraud on the Society, was convicted, and imprisoned, and while in prison deployed various strategies in order to regain his lost credibility. Rhodri Hayward addresses how da Costa used his field trips, as a collector and conchologist, and shows that travelling is not simply a strategy of extending the power of a "centre of calculation." As the author argues, travel had a "transformational" effect on the powers of its agent: together with collecting and correspondence, it made da Costa himself into a centre of expertise.

The chapter "Embodied Skills and Travelling Savants: Experimental chemistry in eighteenth-century Sweden and England" focuses on blowpipe analysis, which was pioneered in Sweden and led to the isolation of various chemical elements by Swedish chemists. The correct use of the blowpipe demanded particular skills, which could only be learnt from hands-on training. Therefore, some British *savants* travelled to Sweden, a country whose achievements in chemical and mineralogical analysis were generally recognised in Britain by the late eighteenth century. Despite the complexity of choices and commitments, and the role played by factors such as fashion and cultural identity involved in the choice of a centre, in this, as in most chapters in the book, it is implied that a centre is selected primarily because it carries prestige, and is recognised as a place where science, technology, a technique or scientific and technological education excel.

Brian Dolan also shows how the blowpipe, a new analytic instrument, managed to dissolve disciplinary boundaries, both in Sweden and in Britain, with its use extending from chemistry to mineralogy and geology. Furthermore, it is shown how the attempts at embodying skills in the instrument, that is, at transferring human skills to a mechanical device, were a means of standardising and facilitating the use of the instrument, by reducing the difficulties inherent in the technique. In the end, embodied skills became a way of circumventing travelling as a means of hands-on training.

The chapter "Constructing the Centre from the Periphery: Spanish Travellers to France at the time of the Chemical Revolution" presents a collective analysis of the wanderings of the members of a network of Spanish travellers, including many who normally do not figure in current historical narratives. Antonio García Belmar and José Ramón Bertomeu Sánchez cover the main political changes which affected Spain roughly from the 1770s to the 1830s, and show in what ways these changes influenced the goals and activities of the *pensionados*, Spanish travellers living in the period of the Chemical Revolution. The authors discuss how their different motivations (intellectual, educational, technological, and/or utilitarian), as well as those of the local network of institutions sponsoring them, influenced the choice of specific travel destinations. They also address the kinds of arrangements which best suited them while abroad, as well as how the various processes of appropriation of new teaching and research practices by the *pensionados* related to different contexts of reception in Spain.

This case study is used to criticise both the standard account of the Chemical Revolution, which states it was an event restricted to a small number of French and British chemists, as well as the diffusionist model of science spreading from a creative centre to a passive periphery. On the contrary, the authors argue that the Chemical Revolution was a complex process involving different countries and various negotiations within an extended network of European chemists. The study of these different contexts of reception pays increasing attention to the structure of national communities, different professional groups and their reactions, and points to the relevance of distinct processes of learning, which may include tacit knowledge, personal contacts, institutional models and implicit values about science.

The next chapter, "Under the Banner of Catalan Industry. Scientific Journeys and the Transfer of Technology in Nineteenth-Century Barcelona," offers a close-up view of some case studies referred to in the previous chapter. It specifically addresses the relation between scientific travels and technology transfer (dyeing and calico-printing chemical technology and machinery) in the context of the Catalan textile industry in the early nineteenth century. As in the eighteenth century, most of these travels were funded by the Catalan Trade Board, the Spanish *Junta General de Comercio y Moneda*, or by private firms, and their aim was to imitate or copy foreign (mainly French) technology. In fact, travellers had to resort to more or less legal strategies to meet their objectives, at the same time overcoming the kind of secrecy involved in manufacturing. For that reason, espionage played a significant role in these travels, either explicitly or mingled with other aims.

Agustí Nieto-Galan offers a typology of travels based on the topics the *pensionado*s chose to study abroad: dyestuffs, chemical, and mechanical travels. In all cases the sponsoring entities carefully planned these trips and clearly defined their targets. Upon their arrival, many *pensionados* taught in the network of Barcelona's technical schools or worked in industry, organised courses and public lectures, produced textbooks, copied machines and built up mechanical prototypes for teaching purposes, contributing in many different ways to the appropriation of what they learnt abroad.

In the chapter "Travelling Interchanges between the Russian Empire and Western Europe: The Travels of Engineers during the first half of the nineteenth century," Irina and Dmitri Gouzévitch analyse the rise of engineering travels during the first half of the nineteenth century in Russia. In the reign of Alexander I, policies gave a prominent place to exchanges with France. Preference was given to the French system of technical training, French engineers were invited to set up technical schools for higher education in the Russian Empire, and at the same time students were being sent abroad. A typology of travels is provided based on the functions they fulfilled: hydraulic missions, missions of resident engineers and missions of legal reconnaissance. In the reign of Nicholas I the former routines were kept, but some innovations were introduced. A network of resident engineers working at the service of the Russian Empire was established in Western Europe. Their missions crowned the "golden age" of engineering travels. By the late 1820s, a movement in the opposite direction emerged and some French military engineers were entrusted missions in the Russian Empire. During this period, some engineers-travellers engaged in the writing of books in which they systematised all aspects involved in these technically-oriented missions, thereby providing guidelines for potential travellers. The authors conclude that one of the fundamental characteristics of the travels of Russian engineers and students was their integration in an institutional framework: some travellers were funded by the Ministry of Education in order to prepare for their future professorships in Russia; others were sponsored by various boards of the Russian Administration, and specifically by the state mining, military and transport departments.

"Babbage, the Analytical Engine and the Turin Academy of Sciences" discusses the encounter of Babbage with the Italian mathematicians of the Academy of Sciences of Turin, where he gave the first and only presentation of the Analytical Engine to an expert audience. By relying on new archival material, the paper refutes the received view according to which Babbage, the prestigious scientist from the centre, visited Turin at the invitation of the Italian mathematician Plana, in order to contribute to the scientific progress of a provincial scientific community in a peripheral country. On the contrary, Marco Segala argues, this is a case in which "the scientist who had fallen into disfavour [was] looking to regain his prestige from abroad." In fact, after 1833, British scientists, technicians and politicians lost interest in Babbage's calculating machine, and so when Babbage accepted the invitation of Plana he was looking for international prestige to counterbalance his declining reputation in Britain. The choice of Turin was a matter of profound intellectual and scientific affinities: Plana and his school were the heirs of the Langrangian tradition in Europe. Plana's example became a model for the mathematicians of the Cambridge Analytical Society, to which Babbage belonged, and who were involved in the modernisation of British mathematics.

The chapter "The Role of Travels in the Internationalisation of Nineteenth-Century Portuguese Geological Science" focuses on the importance of travelling in the process of internationalisation of Portuguese geology during the nineteenth century as practised at the Geological Survey of Portugal. In this case study, Ana Carneiro, Dores Areias, Vanda Leitão and Luís Pinto note how a discipline like geology is intimately associated with travelling, and proceed to offer a typology of travels according to their different purposes: the foundational travels to the centre of Carlos Ribeiro, immediately after the creation of the Geological Survey, an institution which aspired to act in accordance with international standards; the travels of negotiation with other peripheries and the centre of Néry Delgado, when the Geological Survey was consolidated and the work of its geologists recognised; the travels from the centre to the periphery of the Swiss geologist Paul Choffat, who became a staff member of the Geological Survey; and finally the expeditions to the Portuguese African colonies and the involvement of Survey geologists in the analysis of the materials brought back by the explorers.

The chapter "Discovering Switzerland: Internationalisation of Nordic Students prior to World War II" addresses the question of the influx of Nordic students to the ETH in Zurich from the mid-nineteenth century onwards. From the methodological point of view, the factors underlying the international mobility of Nordic students are analysed by recourse to pushing and pulling factors, concepts often used in the realm of emigration studies. The combination of these two factors is used to explain the reasons underlying these scientific-technological-educational travels. Timo Myllyntaus distinguishes various periods in the influx of students to the ETH and points to similarities and differences between the cases of Finland, Denmark, Norway and Sweden.

The final chapter, "Accommodation to a New Centre: Albert Szent-Györgyi's trip to the Soviet Union," focuses on the trips of the Hungarian biochemist Szent-Györgyi (Nobel prizewinner in 1937) to Britain and the Soviet Union. Gábor Palló also offers a typology of scientific travels: those motivated by an object of research, those motivated by people, or other scientists, and finally a third type which is a combination of the other two.

As in the chapter on the Spanish *pensionados*, or the chapter on blowpipe analysis, Gábor Palló also emphasises how tacit knowledge is an important factor motivating travels. Often, upon their return home, scientists bring back tacit knowledge, institutional paradigms for doing science, different scientific styles, tastes, and manners. The return of Szent-Györgyi from Britain in 1928 and the clash between his Anglo-Saxon behaviour and tastes, together with the mandarin-like style of Hungarian professors, exemplify this. Also, following his trip to the Soviet Union, Szent-Györgyi tried to implement in Hungary the Soviet model of a network of research institutes working under the auspices and management of the Academy of Sciences.

As Brian Dolan points out, "science does not travel but people do," and, therefore, travelling tells us as much about the natural world and culture as about travellers, taken individually or collectively. This is the underlying assumption of most chapters of the book which offer analyses of different cases, thereby contributing to a clarification of concepts and methodological questions relevant to the theme. It is therefore not surprising that the various contributions suggest different ways of discussing the meaning of "centre" and "periphery" or offer a typology of travels. None of these contributions intends to settle such a difficult problem in any definitive way, but merely to contribute new perspectives on these topics.

The concepts of "centre" and "periphery" are problematic. Peripheries like Spain, Russia and Portugal[22] differ fundamentally from a periphery such as the Ottoman Empire. In the former, travellers mostly aimed at learning scientific theories or practices, mastering new techniques, using instruments, or monitoring new experiments or technological processes in order to establish and apply in their own countries what they had learnt abroad. By contrast, the Ottoman Empire in the eighteenth century had a distinct peripheral character. For Greek scholars, travelling advanced their careers, but it scarcely favoured the unquestionable introduction of the new sciences into the Greek intellectual space. The scientific journeys of the eighteenth-century Greek travellers served the integration of the scientific attainments of the Enlightenment into the local religious and philosophical traditions, but this integration was aimed mainly at corroborating the continuing validity of the latter. As for Turkey, religious and conceptual idiosyncrasies prevented a character like Çeleby from including in his concept of *ilim* Western astronomy and astronomical instruments, favouring instead the latest developments in gardening and architecture.

The differences between peripheries to which we have referred reflect the very heterogeneity of the European space, with its marked contrasts between East and West as well as between North and South. Their different characteristics stem not only from geographical constraints but also, and predominantly, from historical contingencies dependent mainly on religious affinities. From the ninth century the separation between Roman and Orthodox Christians divided Europe: Western Europe set its face to Rome and Eastern Europe to Constantinople.[23] Later on, during the sixteenth century, it was again a religious conflict, associated with the rise of Protestantism, which fragmented Western Europe into North and South, closely following the limits of the Roman Empire. The case of Russia is the least straightforward of all three. The assumption that Russia, having become Orthodox, and therefore being under the influence of Byzantium since the tenth century, was a part of Eastern Europe, together with Greece and Turkey, does not hold. In religious as well as in political terms the case of Russia is quite unique: the Church intervened directly in the political life of the country, very much as happened in Western Europe, and also, from the time of Ivan III (1462-1505) onwards, strong ties developed between Moscow and Western Europe.[24] The affinities of Russia for Western Europe, and particularly for France, became even stronger during the eighteenth century, with Peter the Great and Catherine, and account for the westernisation of the Russian political elite and its intelligentsia.

Similar considerations apply to the centres. Leaving aside the notions of "centre" in economic[25] or geographic terms, which obviously does not exclude their considerable importance, a scientific or technological centre can be generally defined as a place which is recognised by its excellence. It might or might not be located in a country perceived overall as a centre. Sweden was a centre in relation to Britain in matters associated with blowpipe analysis and mineral chemistry, but this did not prevent Britain from being considered globally as a scientific and technological centre. In turn, Sweden was a periphery from the point of view of technical education, as the migration of students to the ETH analysed by Timo Myllyntaus has shown. But other questions can be raised, which Portugal, for example, typifies: despite its peripheral character within Europe, Portugal acted and was perceived as a centre in relation to its African colonies, and the same applies to Russia and Spain on the chessboards of their respective empires.

The notions of "centre" and "periphery" should be, therefore, taken as historical concepts, as categories employed or implied by the writings of travellers, such as the Spanish *pensionados*. However, when taking them as historiographical concepts the historian of science and technology should be very careful in using them. It seems to us that in any case some of the drawbacks of the centre-periphery dichotomy are avoided by centring the analysis on the concept of appropriation; in particular, the ways in which ideas, methods, instruments, and techniques originating in a specific cultural and historical setting were introduced into a different place with its own specific intellectual traditions, and its own political and educational institutions. From this viewpoint, travelling can be seen as a means to transform an asymmetrical relation between two regions, cities or countries, but not necessarily to eliminate it.

The contributions to this volume highlight the characteristics of the "receiving culture" which does not act as a passive and neutral recipient of whatever has been "received."[26] When addressing the impact of the Jesuits in Portugal, in particular their inability to create a local community of highly qualified astronomers (Henrique Leitão), one may surmise that the lack of an institutional setting arising from a local social dynamic, and not imposed from the outside, contributed to such a negligible impact. Pointing to the specificities of the local "receiving" culture has led, in some instances, to a revision of the standard account on different topics. In the case study offered by Manolis Patiniotis it is argued that eighteenth-century Greek travellers did not really travel abroad nor did they aim at bringing back home the spirit of the Enlightenment. Rather they attempted to put the new developments into negotiation with their own intellectual traditions, as the case studied by

Berna Kılınç also illustrates. For García Belmar and Bertomeu Sánchez, the travels of the Spanish *pensionados* are used to counteract the view according to which the Chemical Revolution was an event restricted to an elite of British and French chemists. In the case studies offered by Rhodri Hayward and Marco Segala, the authors show, *pace* Steven Shapin and Bruno Latour,[27] how trust and credibility are not universal values, and how much they are culturally dependent: da Costa continued to play an important role in the network of British naturalists, even after having perpetrated the fraud against the Royal Society of London, and Babbage could look for support in Italy where scientific affinities united him with the mathematicians of Plana's school. With regard to Babbage's case study, it is also shown how the received view, according to which Babbage's journey to Turin is an illustration of an episode in which a scientist from a scientific centre travels to a periphery, in order to contribute to its scientific progress, is at odds with archival evidence.

Finally, many of the contributions to this volume show how travels have had different aims and purposes throughout time, how travellers or sponsoring agents had various motives, influencing the choices made during their journeys as well as the results obtained. In some cases a typology of travels is offered based on their specific purposes (Agustí Nieto-Galan, Irina and Dmitri Gouzévitch, Ana Carneiro, Dores Areias, Vanda Leitão and Luís Pinto, Gábor Palló).

When looking at the specificities of the Spanish and the Russian case studies, a comment is in order. By late eighteenth and early nineteenth century, peripheries like Russia and Spain institutionalised the travels of learning by creating institutional frameworks to sponsor and define targets within strategies of economic development based on science and technology. Leaving aside royal and aristocratic patronage and the travels of explorers in overseas territories, it looks to us quite promising to investigate what happened in the centres regarding the institutionalisation of these travels within Europe, the period in which they took place, and the reasons behind them.

From a methodological point of view, the chapters in the volume use basically three approaches: analyses of detailed individual case studies; collective studies of groups of travellers; and finally more quantitative prosopographical approaches. The chapters included in the second category follow a more traditional prosopographical study and give the reader much information concerning the lives of various travellers, in such a way that the reader forms an impression of the relevant historical period or situation. In the third case, a "digital" approach is developed, by relying on quantitative analysis of a hard core of information concerning specific actions of historical actors, and ordering them in such a way that they become measurable. Through the cumulative examination of these isolated biographical "bytes," the general tendencies of the period under study are brought back into a non-narrative account.

In all these instances, the notion of a network[28] of practitioners, built up through the mediation of scientific and technological travelling, appears as another conceptual and practical tool, which offers new possibilities of historical analysis. By developing models of networks and studying their dynamics the historian of the European peripheries can unveil the relations between scientists in different local contexts, assess how scientific and technological practices are adopted through the consensus of their practitioners, and how localities become increasingly homogeneous, especially when they overcome the tensions between local discourses and the progressive internationalisation of science and technology.

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NOTES

[1] We have used the notion of civilisation in its original meaning, that is, as an expression of the European conscience, which perceived itself as unique, superior, and opposed to "barbarism." It was in this sense that the term was first coined by Turgot and later used by Mirabeau in his *Traité de la Population* (1756). About the opposition between culture and civilisation see Norbert Elias, *Über den Prozess der Zivilisation* (London, 1939).

[2] The expression "Grand Tour" was first used by Richard Lassels in *An Italian Voyage, or Complete Journey through Italy* (London, 1679).

[3] We use the term "learned" ("lettré") men in the sense in which Voltaire defined it in his entry "lettré" in the *Encyclopédie*, that is, a man who, despite not being an expert, has wide-ranging knowledge of various fields such as literature, art and the sciences.

[4] Observing is here used in the sense of describing what is seen; reflecting in the sense of thinking in political, aesthetic and moral terms about what is observed. See C. Batten, *Pleasurable Instruction* (Berkeley: University of California Press, 1978), p. 81.

[5] As the eighteenth century moved on, the Grand Tour or the *Giro* became less and less a privilege of the wealthy that used to travel accompanied by servants. The spectrum of travellers widened to encompass middle-class people, including young single women, leading a comfortable life. See B. Dolan, *Ladies of the Grand Tour* (New York: Harper Collins Publishers, 2001), pp. 4-5 and Batten, *op. cit.* (4), p. 2.

[6] The concept deliberately has a general meaning, since the form of cultural improvement sought by travelling people was also, with the exception of those attending schools or

academies, very vague. J. Black, *The Grand Tour in the Eighteenth Century* (New York: St. Martin's Press, n/d), p. 295.

7 The discovery of the ruins of Pompeii and Herculaneum, in 1738, the publication of the first treatises on objects of classical art (notably those by Johann Winckelmann, *Gedanken über die Nachahmung der grieschischen Werke in der Malerei und Bildhauerkunst (Reflections on the Imitation of Greek Works in Painting and Sculpture)* (1755) and *Geschichte der Kunst des Altertums (History of Ancient Art)* (1764), and by Anton Mengs, *Untersuchung des Schonen in der Mahlerey (Inquiry into the Beauty of Painting)* (1762), together with the dissemination of Roman architectural aesthetics (of which the engravings of Giovanni Piranesi are emblematic), stimulated the taste for the classical. Among the wealthy social elite and the learned, the taste for collecting classical items and for visiting their places of origin grew. In addition, it is worth mentioning that the interest in collecting extended to public institutions and museums such as the Prado, the Louvre and the British Museum. Napoleon's campaign to Egypt (1798-99), which greatly enriched European museums, beyond its obvious military and territorial purposes, may also be included in this movement of re-discovery of pre-classical and classical antiquity and of collecting rare objects.

8 Linnaeus's *Systema Naturae* (1735), by systematising the classification of known and unknown plants on the basis of their reproductive organs, led to a burst of interest in botanical collections. The herboriser with his bag and fieldwork notebook became a central character of travelling. See N. Jardine, J. A Secord, E. C. Spary, *Cultures of Natural History* (Cambridge: Cambridge University Press, 1996), pp. 145-162; M. L. Pratt, *Imperial Eyes* (New York: Routledge, 1992), pp. 24-28.

9 B. Dolan, *Exploring European Frontiers* (London: MacMillan Press, 2000), pp.3-15; J. Black, *op. cit.* (6), pp.1-6; P. Adams, *Travel Literature through the Ages* (New York, Garland Publishing, 1988), pp. XV-XXV; C. Batten, *op. cit.* (4), pp. 1-18.

10 J. R. Harris, *Industrial Espionage and Technology Transfer: Britain and France in the Eighteenth Century* (London: Ashgate, 1998).

11 As an example of these travels to the European periphery, see M. P. Diogo, A. Carneiro, A. Simões, "Sources for the History of Science in Portugal: One Possible Option," *Cronos*, 3 (1998), 115-224. Examples of these types of travels in other countries of the European periphery could be given.

12 The confrontation with the "other" entails the recognition of the "other," but also the awareness of the "self". See L. Wolf, *Inventing Eastern Europe* (Stanford: Stanford University Press, 1994).

13 Some of A. von Humboldt's letters illustrate this confrontation between awe and neutral observation. It was this dual reaction when facing the new that led Cuvier to find very suspicious the information obtained by "naturalistes-voyageurs." See D. Livingstone, W. Withers, eds., *Geography and Enlightenment* (Chicago: The University of Chicago Press, 1999), pp. 1-32.

14 We use the concept of the sublime in its classical sense, as defined by Edmund Burke in A *Philosophical Enquiry into the Origins of our Ideas of the Sublime and the Beautiful* (1758), and taken up by Kant, Diderot and the Romantics, that is, in the sense of a wonderful, stunning, inspiring event, able to uplift the soul. When applied to Nature it refers to a landscape whose overwhelming power is beyond human capacity to intervene, causing feelings of fear and fascination. Many described the 1755 Lisbon earthquake, and the fury of its seismic waves, as sublime.

[15] On this question see Pratt, *op. cit.* (8). We consider the notion of Eurocentrism, on which the analysis carried out by Marie Louise Pratt is centred, too simplistic. Taking Europe as a whole lacks historical accuracy: there is not one Europe, but many.

[16] Pratt, *op. cit.* (8); Bruno Latour, *Science in Action. How to follow Scientists and Engineers through Society* (Cambridge, MA: Harvard University Press, 1987); David P. Miller, H. P. Reill, eds., *Visions of Empire: Voyages, Botany, and Representations of Nature* (Cambridge: Cambridge University Press, 1996); Roy McLeod, ed., *Nature and Empire. Science and the Colonial Enterprise*, *OSIRIS*, 15 (2000); Marie Noelle Bourguet, C. Licoppe, H. O. Sibum, eds., *Science, Scientific Instruments and Travel* (London: Routledge, 2002).

[17] We can give as an example of the interplay between specialisation and professionalisation, the scientific periodicals which appeared by the end of the eighteenth century.

[18] We have in mind E. J. Hobsbawn, *The Age of Revolution* (1962), and its reference to the meaning of the Industrial Revolution and the French Revolution.

[19] Saint-Simon draws on the Enlightenment notion of progress, and especially on Turgot's *Tableau Philosophique des progrès successifs de l'esprit humain* (1750) and Condorcet's *Esquisse d'un tableau historique des progrès de l'esprit humain* (1793), introducing a key element—industry—as central to the march of humanity. See Saint-Simon, *De la réorganisation de la société européenne* (1814).

[20] The contemporary notion of tourism emerges from the concept of the Grand Tour during the nineteenth century by assuming a strictly recreational dimension.

[21] Livingstone, Withers, *op. cit.* (13); William Clark, Jan Golinski, Simon Schaffer, eds., *The Sciences in Enlightened Europe* (Chicago: The University of Chicago Press, 1999); M. Blay, E. Nicolaidis, eds., *L'Europe des Sciences: Constitution d'un Espace Scientifique* (Paris: Seuil, 2001).

[22] A. Simões, A. Carneiro, M. P. Diogo, "Constructing Knowledge: Eighteenth-Century Portugal and the New Sciences," *Archimedes*, 2 (1999), 1-40; A. Carneiro, A. Simões, M. P. Diogo, "Enlightenment Science in Portugal," *Social Studies of Science*, 30 (2000), 591-619.

[23] F. Braudel, *Grammaire des Civilisations* (Paris: Arthaud-Flammarion, 1987).

[24] Braudel, *op. cit.* (23).

[25] I. Wallerstein, *The Capitalist World Economy* (Cambridge: Cambridge University Press, 1979); G. Basalla, "The Spread of Western Science," *Science*, 156 (1967), 611-622; X. Polanco, "Une science-monde: la mondialisation de la science et la création de traditions scientifiques locales" in X. Polanco, ed., *Naissance et Dévelopement de la Science-Monde* (Paris: Éditions de la Découverte/Unesco, 1990); F. Braudel, *Civilisation Matérielle, Économie et Capitalisme, XV^e-XVIII^e siècles* (Paris: Armand Colin, 1979).

[26] Roy Porter, Mikulas Teich, eds., *The Scientific Revolution in National Context* (Cambridge: Cambridge University Press, 1992); Kostas Gavroglu, ed., *The Sciences in the European Periphery during the Enlightenment* (Dordrecht: Kluwer Academic Publishers, 1999); C.A. Lértora-Mendoza, E. Nicolaidis, J. Vandersmissen, eds., *The Spread of the Scientific Revolution to the European Periphery, Latin America and East Asia*, Proceedings of the XXth International Congress of History of Science (Belgium: Brepols, 2000); A.G. Kenwood, A.L. Lougheed, *Technological Diffusion and Industrialisation before 1914* (London: Groom Helm, 1982); N. Rosenberg, "Factors affecting the Diffusion of Technology" in N. Rosenberg, ed., *Perspectives on Technology* (Cambridge: Cambridge University Press, 1976); P. Kelly, M. Kranzberg, eds., *Technological Innovation: a Critical review of Current Knowledge* (San Francisco: San Francisco Press, 1978).

[27] Steven Shapin, *A Social History of Truth. Civility and Science in Seventeenth-Century England* (Chicago: Chicago University Press, 1994); Latour, *op.cit.* (16).

[28] Margaret Stacey, *Tradition and Change. A Study of Banbury* (Oxford: Oxford University Press, 1960); Derek de Solla Price, *Little Science, Big Science* (New York: Columbia University Press, 1963); Diane Crane, "Social Structure in a Group of Scientists: A Test of the Invisible College Hypothesis," *American Sociological Review*, 34 (1969), 335-352; Belver Griffith, Nicholas Mullins, "Coherent Social Groups in Scientific Change," *Science*, 177 (1972), 959-64; David Edge, Michael Mulkay, *Astronomy Transformed: the Emergence of Radio Astronomy in Britain* (New York: John Wiley & Sons, 1976); Harry Collins, "The Place of 'Core-Set' in Modern Science: Social Contingency with Methodological Propriety in Science," *History of Science*, 19 (1981), 6-19; Michel Callon, John Law, Arie Rip, eds., *Mapping the Dynamic of Science and Technology* (London: Macmillan, 1986).

HENRIQUE LEITÃO

A PERIPHERY BETWEEN TWO CENTRES?

Portugal on the Scientific Route from Europe to China (sixteenth and seventeenth centuries)

1. INTRODUCTION

Scholars interested in the history of science in Portugal frequently use the term "periphery." However, no careful analysis of this concept when applied to Portugal has ever been carried out. Its exact meaning is certainly very ambiguous. Some authors use it in a mere geographical sense; others as a label for Portugal's absence from major scientific debates; while still others seem to imply some type of ideological or religious constraint – an "epistemological obstacle," as a leading Portuguese scholar has put it.[1] Nevertheless, at the core of all these analyses one finds the notion that regardless of its exact nature (geographical, ideological, etc.) such a peripheral position is always intimately connected (whether as cause or as effect is never clear) with difficulties in *communication* with other scientific centres. What seems to be agreed upon as the unmistakable sign of Portugal's peripheral status is the long delay in the reception of the latest scientific discoveries. That is, Portugal's scientific peripheral position is, above all, connected with the paucity of interchanges and lack of communication with scientific "centres."

In this work I will contend that this notion is much too simplistic. By analysing a period of remarkable scientific interchange (ideas, books, instruments, and people) between Portugal and other centres of scientific production, I will try to show that even when rapid, organized, and efficient communication is available, local factors may inhibit the formation of mature and well-informed scientific communities. The period to be analysed is broad, the mid-sixteenth to the late seventeenth century, but sufficiently homogeneous to be treated uniformly. The origin of this network of scientific communication is intimately connected with the establishment of the Society of Jesus in Portugal and the Portuguese overseas empire, and with the travels and teaching of Jesuit mathematicians.

Ana Simões, Ana Carneiro, Maria Paula Diogo (eds.), Travels of Learning. A Geography of Science in Europe. (19-46)

The historiography of recent decades has led to a fundamental re-evaluation of the role played by the Society of Jesus in the cultural scenario of Europe in the late sixteenth and seventeenth centuries.[2] The traditional depiction of this religious order of the Catholic Church as a conservative – if not altogether retrograde – institution, at a loss when it came to taking part in the rapidly changing cultural world of early modern Europe, and even fiercely opposing these changes, is now considered naive and poorly informed. Old images of the Society as a monolithic bloc of men, ruled by militaristic discipline, subjected to tight censorship, and promoting *uniformitas et soliditas doctrinae* at all costs, have succumbed under the numerous studies of the past years. This is not to say that backward tendencies and resistance to intellectual novelty (scientific or otherwise) were absent among the Jesuit community. But recent research has pictured the Society in much more varied colours. Instead of being impermeable to the controversies of their time, it would appear that the Jesuits were resoundingly and deeply engaged in these same controversies, albeit within the boundaries of the orthodoxy they strove to maintain.

In particular, as far as the History of Science is concerned, it is today agreed that no description of that period called Scientific Revolution can ignore the complex, but certainly fundamental, role played by this religious order. Even in the case of the convoluted relationship between the Jesuits and Galileo, historians are today well aware that the intellectual debt of the Italian scientist to the Jesuits was great and, conversely, that the Jesuits actively pursued several of the new avenues of thought Galileo had opened.

Although the number of works dealing with scientific practice among the Jesuits, and its relevance to the scientific changes taking place in Europe at that time, has continued to increase, much remains to be analysed. In fact, some characteristics of this institution – its impressive network of learning centres, its uncommon attention to mathematical and scientific disciplines, the high mobility of its members, the international character of its composition and administration, its pioneering role in the meeting of non-European cultures, its massive production of printed works, its close connections to many European courts, etc. – defy any simple analysis.[3]

One of the more interesting notions that has emerged from the recent historiography on the Society of Jesus has been the emphasis placed on its *institutional* aspects – in particular its remarkable educational enterprise and the vast network of intellectual communications it created throughout the world – whereas older studies generally stressed the (negative) effects of doctrinal constraint. Without denying that the Jesuits operated intellectually within a defined orthodoxy which often clashed with the newest scientific discoveries, more recent studies have repeatedly drawn attention to the importance of the institutional setting and its consequences.

For those interested in a conceptual inspection of the development of science in terms of the notions of centre and periphery, of the complex and sometimes elusive relations between individual initiative and institutional context, of production and transfer of knowledge, etc. the study of the science practised by the Jesuits is of great interest. But this study is also prone to pitfalls, if a careful consideration of the Jesuits as practitioners of science is not taken into account.

Jesuit missionaries were "scientists" and "scientific travellers" of a very special kind. Despite the fact that in parallel with their theological and philosophical training many of these men had an extensive scientific education, and that several of them displayed advanced competence in scientific matters, and even despite the fact that some of them spent a large part of their lifetimes engaged in scientific activities, these men did not consider themselves primarily as scientists. They were missionaries, engaged in the task of spreading Christianity in order to turn all things *ad majorem Dei gloriam.* Science and other types of intellectual engagement were pursued only in so far as they enhanced the apostolic task that was the Jesuits' primary end.[4] Whatever the judgement that present-day scholars may make of such an essential trait of the Jesuits, this hierarchy of their objectives must always be kept in mind. But this subordination of scientific practice to a non-scientific goal tells us nothing about the "quality" of their science, or about the intensity of their commitment to science. As with any other scientific practitioners, this quality and this commitment can only be gauged by a careful inspection of individual cases. Regarding the Jesuits, it is now recognized that this quality ranged, as one would expect, from the mediocre to the excellent. While for some of these men the practice of science was surely a burden to be carried as an unpleasant obligation, others displayed a profound interest and a remarkable creativity in scientific matters; no general judgement is possible.

Jesuits do not fit easily within the category of scientific travellers for other reasons. As a group, they certainly travelled incessantly. Indeed, *mobility* was at the very heart of the definition of being a Jesuit.[5] But they were not travelling in order to gather information – although many of them in fact did so – nor were they travelling with the objective of finally returning to their native lands. The Jesuit scientific enterprise was not an enterprise concerned with accumulating knowledge; but it certainly was an enterprise of knowledge diffusion. In addition, one should note that their relationship with the civilizations and regions of the world where they eventually exercised their scientific expertise was very different from later European colonial and post-colonial experiences.[6] Jesuit missionaries were sent to very different regions, but Jesuit "scientists" were not sent to regions of "primitive" cultures. On the contrary, it was precisely the fact that some cultures were perceived as highly developed that created the need for intense scientific practice. Naturally, the vast majority of these missionaries never doubted the notion that European civilization was in a sense superior to all other civilizations, however sophisticated they might be. But the belief that others could and should be converted to Christianity is an affirmation that in a most profound sense they were considered the Europeans' equals.

Jesuit "scientific travelling" is especially significant to Portugal because in this country very few institutions had ever had the cultural influence and the logistic and administrative resources that the Jesuits had in the seventeenth century. Jesuit travelling – of which Jesuit "scientific travelling" is a subset – is one important feature of life in Portugal during this period.

In sum, although some caution needs to be exercised when attempting to integrate Jesuit practitioners of science in the framework of "scientific travels," it is undisputed that Jesuit missionary work turned out to be the first large-scale movement — and probably one of the most influential — of diffusion of European culture and European science in vast regions of the world and in many different cultures.

This article is organized as follows. First, I will provide a rapid overview of the scientific scenario in Portugal prior to the arrival of the Jesuits, by focusing in particular on its institutional setting. This will be followed by a description of the main characteristics of the Society of Jesus in Portugal and in the regions where the Portuguese had contacts. Particular attention will be given to the Jesuit missions in China. These were logistically and administratively dependent on Portugal, and in these missions scientific work had special relevance.[7] I will then proceed to analyse one specific set of events in some detail, associated with the diffusion of telescopic innovations and the telescope itself, which clearly typifies both the mechanics and the consequences of the Jesuit network of schools and Jesuit travels from Europe to East Asia. A few conclusions will be drawn from the historical evidence presented.

2. SCIENCE IN PORTUGAL BY THE MID-SIXTEENTH CENTURY

An evaluation of the structure and effects of the Society of Jesus upon the practice of scientific disciplines in Portugal, and especially an evaluation of the importance of Jesuit travels, requires a description of the scientific scene in Portugal at the time of the Jesuits' arrival. This is a task that at present cannot be carried out in a fully satisfactory manner. In Portuguese historiography the history of science has been treated superficially, only as a marginal chapter in the cultural history of the country. However, if one focuses mostly on the *institutional* scenario, a few observations can be made with some safety. I will also concentrate only on the "mathematical sciences" (mathematics, astronomy, nautical science, etc.). It is possible to identify different groups of individuals who were concerned about such matters or institutional settings where these matters were taught and discussed.

The University. Historically the first of these institutions is the University. The structure and organization of the University of Coimbra remained essentially the same from the date of its establishment in Coimbra (1537) until the major reforms put forward by the Marquis of Pombal around 1772, that is, during the period relevant to our present purposes. During this period the University was composed of four Faculties (Theology, Canons, Laws, and Medicine), a Chair of Mathematics, a Chair of Music, and a Course of Arts. Apparently, the first University Statutes pertaining to this establishment in Coimbra were promulgated in 1544, but they have been lost. The first extant University Statutes are from 1559.[8] In these University Statutes the material to be taught in the Chair of mathematics and the duties of the Professor of mathematics are very briefly described. The Chair of Mathematics is included in the Arts Course and it is stated that the professor should "read" the traditional texts on Arithmetic, Geometry, Perspective and the Sphere. Candidates to the position of teacher of mathematics should also be competent in the more advanced topics of Euclid and the Theory of Planets. Furthermore, the professor of mathematics had the obligation to examine students in the Theory of Music.[9] The Statutes determine the salary of the professor of mathematics to be fifty thousand reis per year.[10] This amount tells us something about the actual importance ascribed to mathematical teaching duties. Professors of any Chair of the Higher Faculties earned substantially more. The holders of the most important Chairs in Theology, Law or Medicine had salaries which were roughly double that stipulated for mathematics: one hundred or one hundred and twenty thousand reis per year. But compared with the Chairs of the Arts Course, the status of the professor of mathematics is, in general, equivalent to other prominent chair holders: the salary of the professor of mathematics is inferior to the salaries of most of the professors of Latin but is identical to the salary of the professor of Greek and the professor of Hebrew, and better than the salary of the professor of Music (forty thousand reis per year). From a strictly formal point of view, the study of mathematics at the University of Coimbra enjoyed conditions that were not much different from those at other European universities. However, when the facts are inspected in more detail, it becomes obvious that appearances are misleading. In fact, one of the most striking observations that awaits the historian interested in this period of Portuguese science is the negligible attention the University paid to mathematical studies during the late sixteenth and early seventeenth centuries.[11] Despite the fact that a Chair of mathematics existed and its importance is mentioned in all versions of the University Statutes, mathematical classes at the University of Coimbra never functioned well. A good example is provided by the mathematician Pedro Nunes (1502-1578). By the mid-sixteenth century Nunes dominated the mathematical scene in Portugal and throughout the Iberian Peninsula. Although he was appointed professor of mathematics at Coimbra in 1544 his status as a teacher of mathematics never rose to the level of his reputation as a mathematician. On the contrary, Nunes' classes in Coimbra seem to have been constantly plagued by poor attendance, both by students and by Nunes himself.[12] His teaching at the University failed to create a circle of disciples, and nothing resembling a "school" of mathematics. His duties in Lisbon as Cosmographer-in-Chief (Cosmógrafo-Mor) seem to have interested him much more than his obligations at the University of Coimbra – a fact that must be understood in view of Portugal's intense commitment to nautical activities at the time. Nunes was frequently away from Coimbra and others had to substitute for him in the teaching of mathematics, but none of the men that replaced Pedro Nunes in Coimbra became noted for their knowledge of mathematics.[13] After Nunes' retirement the situation worsened considerably. The chair of mathematics was held intermittently and a general climate of indifference to mathematical studies seems to have become the rule.[14] There were long periods when no professor of mathematics was appointed at all. According to an eighteenth century report, the chair of mathematics was vacant for 41 years, from 1612 to 1653, and after that period only three professors were appointed. The author of this report, written in 1777, also stated that for the previous 60 years there had been no lectures on mathematics at Coimbra.[15] These statements cannot be taken at face value, for their author was himself involved in the process of reform of the University and thus he systematically portrays the situation before 1772 in the worst possible terms. Nevertheless, the general picture of decline and lack of interest in the pursuit of mathematical studies in Coimbra during this period is confirmed by many other sources.

Court experts. Besides the University, the Royal Court was also the scene of some mathematical practice and the place where to find some experts, generally not affiliated with the University. These mathematicians and astronomers operated as tutors to princes and some noblemen, and as scientific advisors to the King. Many problems of political importance depended on a number of scientific issues, and these men provided the necessary technical advice to the Court. Examples include several questions related to the demarcation of Portuguese territorial possessions that required the solution of cartographical questions, and in some well-known cases, the accurate determination of longitude. A case in point was the negotiations in 1524 regarding the precise determination of the meridian of the Treaty of Tordesilla (the "Junta de Badajoz"), in which Portugal was represented by three mathematical experts: Francisco de Melo, Tomás de Torres and Simão Fernandes. Of these, only Melo had any connection with the University. The Court was a much more attractive environment than the University: proximity to power, lack of administrative burdens and much more rewarding salaries were some of the reasons that certainly attracted experts to use their scientific talents at the Court and not at the University.[16] Again using evidence from the career of Pedro Nunes, having investigated a sufficient number of relevant documents, one notes that his career started at the Court, that he received much Royal protection, and that around 1550 he was earning three times more from his duties as Cosmographer-in-Chief and tutor at the Court than from his position as holder of the Chair of mathematics at Coimbra. Court mathematicians and astronomers show up conspicuously in the fifteenth and sixteenth century records, but less so during the following centuries. At this point one can speculate that institutions other than the Court were being preferred as places for scientific practice.

Course of the Cosmographer-in-Chief [Aula do Cosmógrafo-Mor]. The technical demands associated with the overseas expansion and the lack of sufficient numbers of trained personnel eventually became a major problem in Portugal. The State's response to this need was the creation of the position of Cosmógrafo-Mor (Cosmographer-in-Chief). Not much is known in detail about the origins of this position. The two main sources of information about this course come from the "Regimentos do Cosmógrafo-Mor", and from the recorded certificates of examination of candidates for the posts of navigational pilots, cartographers or instrument-makers.[17] Legislation determining the duties of this position is known to have existed from as early as 1559, but the first extant document is the "Regimento do Cosmógrafo-

Mor" of 1592. According to this "Regimento," the Cosmógrafo-Mor was to examine makers of nautical instruments and cartographers; furthermore, it was his duty to authenticate all nautical charts, globes and instruments; penalties were stipulated for those not submitting their work to the inspection of the Cosmographer-in-Chief. The most interesting part of this regulation concerns the training in mathematics that the Cosmographer-in-Chief was supposed to give to future nautical pilots. According to these regulations, prospective pilots had to be taught elementary mathematics, the sphere, cosmography and astronomy. The Aula do Cosmógrafo-Mor remained in essentially the same form until 1779, when it was completely reformed. Inspection of the examination records and the career of some pilots shows, however, that their training could not have been very advanced, since many of them had had an extremely poor education.

Course of Architecture [Aula de arquitectura]. There is also information about the existence of a "school" for architectural studies in which the teaching of mathematical topics was also included. The term "school" should be used loosely here, since not much is known about the real functioning of this institution and no documents about its organization have survived. Nevertheless, it is clear that there was a group of people interested in the more theoretical aspects of architecture and that this school functioned in close association with the Court. Associated with this class some scientific issues were taught.[18]

Some observations are now in order. From an *institutional* point of view the situation in Portugal was not much different from that in other European countries in the same period. The fact, for instance, that it was only in 1544 that mathematics seems to have earned a place at the University as a relatively autonomous chair – a fact that Portuguese historiography frequently highlights as a manifestation of a poor scientific culture – has parallels in several other countries where a much more sophisticated practice of the mathematical sciences is acknowledged. The same applies to the salaries and privileges of the teachers of mathematics, compared with those of teachers of Theology, Philosophy or Humanities.[19] What is specific to Portugal is the fact that with the exception of the University, all other institutional scenarios where some scientific teaching was provided were closely connected with the Court or were established as a response to State or Royal needs. But at the University, where it was possible, in principle, to follow mathematical studies as an independent intellectual pursuit, these studies were neglected. By the mid-sixteenth century the mathematical sciences in Portugal were mostly a service to royal needs and were strongly oriented towards practical applications. To a great extent the narrowness of the subjects pursued and the parochial way in which science was practised are consequences of this bias. Scientific practice was conceived and supported only in so far as it pointed to nautical and military applications — a remark that needs to be fully grasped by noting that institutional setting and financial support determine social status and, possibly, the very definition of an intellectual discipline.

3. THE SOCIETY OF JESUS IN PORTUGAL AND IN CHINA

Established in 1540, the Society of Jesus soon engaged in numerous educational activities, eventually creating what is perhaps the most extensive network of educational centres ever. The Jesuit educational enterprise was born in response to fundamental changes occurring in Europe such as the emergence of a reasonably wealthy bourgeoisie who were aware that a sound education was one of the most important assets of a young man. The Jesuits soon realized the potential of this situation. Although their first schools were aimed at training the newly admitted members of the Society, it was only a matter of a few years before Jesuit schools especially designed to teach lay, non-Jesuit students were established.[20] One other reason has simply to do with the need for intellectual credibility. The Jesuits decided to take part in all intellectual controversies directly or indirectly affecting Christian faith. They realized that it was from within the ranks of the Society that competent intellectuals had to be found. This again placed strong demands on the education of a Jesuit.

Focusing more specifically on Portugal, one should first of all note that the Jesuits radically altered the cultural and educational scenario in this country. From 1540, the date of the arrival of the first members of the Society of Jesus in Portugal, to 1759, the date of the expulsion of the Jesuits from Portugal (anticipating the suppression of the Society by the Pope, in 1773), the Jesuits created a system of colleges whose main characteristics, from the point of view of the history of science, can be summarized as follows:

1. Establishment of the first organized and stable educational network at the "secondary" and "pre-university" levels.
2. Integration of the educational institutions located in Portugal into a large, supra-national context.

3. Establishment of the first truly *regular* teaching of mathematical disciplines in Portugal.
4. Decentralization of education with the creation of important colleges outside Lisbon and Coimbra.
5. Creation of a second University in Portugal, in Évora (1559), with regular mathematical and scientific lectures from 1700 onwards.

The complexity of the Jesuit educational enterprise in Portugal cannot be addressed here, but the sheer numbers are impressive, at least on the scale of Portugal. It is estimated that by 1759, when the Jesuits were expelled from Portugal, and their educational network disrupted, a total of around 20,000 students were attending Jesuit institutions. Comparable numbers of students attending schools in Portugal were only reached again more than a century later.[21]

Education in Jesuit colleges was planned along the rules of the *Ratio studiorum*, the famous Jesuit document that structured all aspects of education in Jesuit colleges and universities. This document went through various preparatory versions, finally attaining its definitive form in 1599. But the *Ratio studiorum* gave only general guidelines that left ample room for local variations and even for the initiative of isolated teachers.[22] Furthermore, as we shall see, even these guidelines were not always put into practice. Therefore, taking a broad view, one can say that all Jesuits had a similar training, but a more microscopic analysis shows that regional variations could be very marked. One such case where very different traditions coexisted is that of mathematical teaching.

In 1574, following a demand made by the King, the Jesuits created their first mathematical class in Portugal – the *Aula da Esfera*, (Course on the Sphere) – at the *Colégio de Santo Antão*, in Lisbon.[23] Unlike mathematical studies in Jesuit colleges in other countries, this class was not established in compliance with the *Ratio studiorum*, that is, with the Jesuits' own plan of mathematical studies, but with the objective of providing mathematical and technical training to personnel engaged in Portuguese maritime expansion. The mathematical curriculum in the Lisbon college was therefore substantially different from those of other Jesuit colleges in Europe. This point needs to be emphasised. Although part of a supra-national context, with specific regulations governing the nature of mathematical training, Jesuit scientific teaching and practice in Portugal was developed with *local* needs in mind and with disregard to the general rules applicable to all colleges.

In parallel with their educational enterprise the Jesuits were, from the very origin of their religious order, engaged in missionary work in the numerous regions that the Iberian overseas expansion had put within European reach. By the mid-sixteenth century the Portuguese Empire was at its climax. Portugal controlled the sea routes and had established positions in vast regions that ranged from Brazil to both coasts of Africa, to India, Southeast Asia, Japan and China.[24] Sooner or later all these areas would become missionary regions for the Jesuits.

The educational system the Jesuits established in Portugal is certainly of great importance. This is particularly true from the point of view of the history of science because unlike any other educational system ever implanted in Portugal, it was organically connected to other institutions in Europe and to missionary activities outside Europe. This is precisely the aspect that makes the Society of Jesus of such interest in the scientific history of Portugal.

Until the mid-seventeenth century, the leading scientific centre of the Society of Jesus was the *Collegio Romano*, in Rome. There, the German Jesuit Christopher Clavius had established a special course of advanced mathematics. Clavius himself was one of the most influential European mathematicians of the late sixteenth century. The so-called "Academy of Clavius" provided training in mathematics and astronomy that was much more advanced than in any other Jesuit institution, and it was from this Academy that the concept of the "Jesuit-mathematician," that is, a specialist in science to meet special apostolic needs, took form.

The notion that a Jesuit trained in scientific disciplines could be a decisive asset in the future of the missionary work emerged at an early date in Jesuit circles. As early as 1551, Francis Xavier had written from Japan to Europe mentioning that all missionaries heading to Japan should be competent in mathematics and astronomy, since the Japanese were very eager to hear and learn about those matters. Letters with the same type of remarks were sent from Japan to Europe in the following years, but it was with the establishment of Jesuit missionary work in China, in the late 1580s, that such demands became more intense, to the point that an organized and structured response had to be provided.

China was a formidable challenge to the European missionaries. It was an ancient and sophisticated civilization not willing to take lessons from anyone, much less from these newly arrived foreigners whose cultural level was very uncertain. Any hope of success in China required that the Jesuits should first of all establish their intellectual credibility. Raising even more difficulties was the fact that Chinese culture was deeply suspicious of foreigners. Chinese rulers and *literati* would not easily tolerate them and their awkward religious and philosophical notions, unless some profit could be gained.

Despite the evident signs of collapse of the Ming dynasty, late sixteenth-century China was a civilization proud of its scientific achievements, and justly so. Astronomy in particular had a brilliant tradition and enjoyed a place of distinction in scientific learning. In fact, all aspects of life in China were set at the pace of astronomical events and the calendar. The establishment and maintenance of the calendar was the responsibility of a special office of the Emperor's court, the Astronomical (or Mathematical) Bureau. This Bureau communicated the calendar to the Bureau of Rites which set the Emperor's daily life, and hence, the daily life of all China. It must be understood that the calendar included the prediction of celestial ephemerides and unusual events – eclipses and comets, for example – whose unpredicted occurrence represented a sign of upheaval and an omen of future tragedies. In a civilization dominated by the belief in a deep harmony between natural phenomena and the moral state of the Empire, the work of the astronomers had a transcendent importance. Indeed, in very few other civilizations has the role of astronomers been of such fundamental importance as in China. The Jesuits arrived in China when a number of circumstances made the need for some mathematical expertise urgent. Complaints about the inadequacies of the calendar used in China can be detected as early as the fourteenth century, and its shortcomings were becoming more evident each year.

One of the most fascinating aspects of the Jesuit presence in China is precisely their efforts, which ultimately succeeded, to get a position at the Astronomical Bureau, that is, at the very heart of the Emperor's Court. The possibilities that this move opened up for a successful presence of the Jesuits in China were enormous. This is indeed a remarkable story, but it is utterly impossible to summarize it here. It suffices to say that by the beginning of the seventeenth century this strategy was perfectly clear to the Jesuits who were in China, and that, after some spectacular performances and impressive work, the Jesuits took charge of the Astronomical Bureau. Only a total insensitivity to the importance of this Bureau and to the deep-rooted Chinese aversion to foreigners can obscure the uniqueness of this achievement.

In order to carry out this feat it was necessary to bring to China some Jesuits who were highly competent in scientific and astronomical matters. It was not, as was the case for example in India or in Japan, the need to respond to a local *curiosity* for scientific matters. Any missionary with a moderate training in science could provide an adequate response to such curiosity. In the case of China the stakes were much higher. True astronomical *specialists* were needed: men possessing the necessary expertise to build astronomical instruments and carry out astronomical observations with optimal accuracy; men who could perform elaborate mathematical calculations and were knowledgeable about the intricacies of calendar calculation; men who were completely at ease with astronomical phenomena.

The Chinese missions were under the responsibility of the Portuguese Province of the Society of Jesus. Due to ecclesiastical regulations all missionaries heading to China had to be either Portuguese, or had to sail from Lisbon. The same applied to the Jesuit mathematicians. It was therefore the Portuguese Province that had to answer these frequent appeals by sending Jesuits trained in scientific matters to China.

Whatever the sense in which we interpret the term, China was certainly a scientific "centre." Jesuits writing to the Society's headquarters in Rome, asking for mathematicians, were certainly addressing another scientific "centre." In between, Portugal had to provide a solution.

The sudden demand for missionaries with advanced technical skills in the fields of mathematics and astronomy posed an insoluble problem for the Portuguese Jesuits. It soon became apparent that the Portuguese Province could not meet such demands. In comparison with other European countries, scientific training in Jesuit schools in Portugal was modest. Furthermore, the main centre of scientific training the Jesuits had established in Portugal, the *Colégio de Santo Antão*, had been created with the specific purpose of training personnel for nautical activities, that is, pilots, cartographers, instrument-makers, etc. These were not the skills required by the missions in China.

By the beginning of the seventeenth century it was clear that the mathematical experts for the China missions had to be recruited from countries other than Portugal. The importance of the China missions was much too great to be compromised by the lack of experts in Portugal. In the following decades several highly competent mathematicians, mostly associated with the Roman College, were sent to China. On their way these men stayed in Lisbon for a certain period – which might range from only a few weeks to some years – before sailing to "the Indies." Thus, a unique historical situation occurred: Due to events that were happening literally on the other side of the earth, in China, Portugal became the focus and transit point of a remarkable movement of scientific experts.

In addition, the need to provide the China missions with mathematical experts introduced a new tension in the teaching of scientific matters in

Portuguese colleges. At the same time that the Society short-circuited the normal way of proceeding, sending missionaries directly from its headquarters in Rome, efforts were made to improve the quality, and to change the content, of the scientific courses taught in Lisbon. In order to do so, non-Portuguese teachers were assigned to teach mathematics in Lisbon. It should be pointed out that this represented an anomalous situation. In principle, each Province should have found among its members the teachers required to take care of all educational needs. Indeed, in Portugal, only the teaching of mathematics required the presence of non-Portuguese teachers. All other courses, philosophical or theological, were taught almost exclusively by Portuguese teachers. Among these foreign teachers one finds men such as Christoph Grienberger, one of the most influential Jesuit mathematicians of the early seventeenth century. He was to succeed Clavius as head of the Mathematical Academy in the Roman College, and was to become perhaps the most important Jesuit involved with Galileo during the cosmological debates of the 1620s. Also notable was Giovanni Paolo Lembo, who had built the astronomical instruments and telescopes in Rome in the hectic summer of 1610, who taught in Portugal from 1615 to 1617, and about whom more will be said below. But several other non-Portuguese, such as Richard Gibbons, Simon Fallon and Ignace Stafford, also became teachers in Portugal.

This set of events is remarkable for one more reason. The expertise that was required in China was in the field of theoretical and mathematical astronomy. The Society of Jesus was able to provide such men because its College in Rome had been deeply engaged not only in the Gregorian Reform of the calendar, but most importantly, in the crucial astronomical and cosmological controversies initiated by the famous telescopic observations of Galileo, in 1610. That is, the men that were sent to China were not just "any" astronomers. They were precisely the Catholic astronomers who had to face the deep questions raised by the new celestial observations. They were the men who had confirmed all the observations of Galileo and had declared the Ptolemaic system untenable. They were the men who had faced the challenge of having to choose between the system of Copernicus or of Tycho Brahe. In sum, they were some of the best-informed Europeans engaged in the cosmological debates at the time.

Until 1640, men such as Carlo Spinola, Giovan Antonio Rubino, Sabatino de Ursis, Giulio Aleni, Francesco Sambiasi, Giacomo Rho, Johann Schreck, Wenceslaus Kirwitzer and Adam Schall von Bell passed through Lisbon, en route to China. All these men had had advanced training in mathematics and astronomy at the Roman College, and most went on to play an important role in the mathematical activities of the Jesuits in Asia. Adam Schall, for example, was the man responsible for reforming and improving the Chinese calendar, thus becoming famous in China and an intimate of the Emperor. Others, such as Johann Schreck, a member of the *Academia dei Lincei*, were acclaimed scientists in Europe. In general, the men who were destined for "the Indies" were not engaged in teaching duties while in Portugal, but some of them did teach mathematical courses for short periods, including Cristoforo Borri, Jan Wremann and Johann Crysostomus Gall. From roughly 1610 until 1640 Portugal enjoyed the enviable situation of being on the route taken by a remarkable group of scientifically trained men. During this period, fellow Portuguese Jesuits, other scholars, university professors, students, and educated individuals, could all become familiar with the latest innovations in astronomy and cosmology: the controversies, the most recent works, new instruments, the latest discoveries.

4. JESUIT TRAVELS AND TELESCOPIC INNOVATIONS

The complex nature of the events described above have only allowed for a general description, but a more detailed account of the importance and consequences of the travels of Jesuit missionaries en route to China can be grasped by looking in detail into a particular case, namely, the first news about the telescope and telescopic observations in Portugal.[25]

Telescopes first appeared in Portugal at a relatively early date, most likely around 1610-1612.[26] Not surprisingly, the evidence for this statement is drawn primarily from events in regions very far from Portugal. This is a consequence of the fact that Portugal controlled vast maritime routes in many parts of the world and was the focal point for many European travellers heading for overseas destinations, the most interesting of whom were the Jesuit "scientist-missionaries."

In the opinion of a distinguished historian of Japanese science, the late Yoshio Mikami, telescopes were first introduced into Japan in 1613, most likely brought by Jesuit missionaries.[27] Since all missionaries heading for Japan (as well as all missionaries heading for India or China in this period) had to sail from Lisbon, and the trip to East Asia, including stops in Goa and Macao, lasted on average two years, this means that telescopes must have been known in Lisbon by 1611.

One of the first reports on the use of a telescope in regions under Portuguese rule comes from Brazil. In the report of the battle of Guaxanduba, fought on 19 November, 1614, Major Diogo de Campos Moreno mentioned that Commander Jerónimo de Albuquerque was observing enemy movements with "hum oculo de longa vista,"[28] literally, "an eyepiece for long-range view." The casual tone with which this information is mentioned leads one to suppose that telescopes were not a novelty among military men, and since this news originated in Brazil it is very likely that telescopes were already known in Lisbon at least some months before.

Regarding direct accounts of the use of telescopes for astronomical observations performed in Portugal, the first evidence available comes from the lecture notes of the Italian Jesuit Giovanni Paolo Lembo (c. 1570-1618), who taught mathematics in Lisbon in the years 1615-17.[29] In these lectures, telescopes were built and astronomical observations were performed for the benefit of students and other interested persons. As far as can be ascertained today, these were the first telescopic observations ever made in Portugal. Lembo's lectures provide evidence that at this time there was teaching on the new celestial findings and their cosmological significance, and he also gives us the first account on the construction of telescopes in Portugal. Giovanni Paolo Lembo is known to historians of science mostly because he was one of the four Jesuits who answered Cardinal Bellarmino's questions about the new celestial observations.[30] The mathematical course taught by G. P. Lembo in Lisbon in the years 1615-17 is very interesting. Lecture notes written in Portuguese by a student have been preserved in a codex, and remain in good condition.[31] The topics covered in Lembo's mathematical lectures diverge from the usual curriculum of the Lisbon Jesuit College.[32] In addition to topics pertaining to *De sphera*, and nautical issues, which were commonly taught in mathematical lectures at Santo Antão in this period, other topics were covered. The teacher taught trigonometry, Euclidean geometry and ecclesiastical *computus*. Of particular interest are the topics dealing with machines, which are quite lengthy and novel in the scientific tradition in Lisbon at the time. There is much more that is worthy of comment in this remarkable set of lecture notes, but I will concentrate solely on the telescope and telescopic observations.

After a careful discussion about the traditional systems of orbs, Lembo prepares an introduction to the new telescopic evidence by describing in detail the observations he had made in Rome in 1610, in particular the observations of the phases of Venus. This description is interesting, not only because the discussion on the phases of Venus is very detailed, but also because it confirms that the Jesuits in Rome had made these very observations before being informed about them by Galileo.[33] After the discussion on the phases of Venus, the Italian teacher states (fl. 33v):

> I have made the same observation in the past months, when I was already here in Lisbon, and I showed it not only to my students, but also to many other curious persons. They have all seen it [Venus] horned in the same way as the Moon, first smaller and then each time larger. I speak with eye-witnesses.[34]

This is the first documented reference to the making of astronomical observations with a telescope in Portugal. There follows a detailed discussion of the cosmological implications of these observations. This leads Lembo to reject both the Ptolemaic and the Copernican systems, and to adopt a semi-Tychonic arrangement of the orbs. All the discussion is essentially technical, with only rare mentions of theological or even philosophical arguments. The defence of a variant of a Tychonic model in Lisbon in 1616 should be noted since, as is well known, only in 1620 did the Society of Jesus "officially" adopt Tycho Brahe's cosmological model.[35] In the last folios of the manuscript of Lembo's lectures, notes on the construction of telescopes are included (fls. 135r-v). These are instructions of a very practical nature, without any discussion of the theoretical principles of the telescope. Later teachers of mathematics at Santo Antão were to include some discussion of these principles, but Lembo's instructions are a straightforward presentation of the practical way to polish the lenses, with important advice on the choice of materials, and a step-by-step description of the whole procedure. To follow the instructions in detail, several figures are provided in the manuscript. The inclusion of these instructions, the references to telescopic observations and Lembo's own expertise leave no doubts that in those years telescopes were built in Lisbon to be used for astronomical observations.

The first appearance of telescopes in a scientific context in Portugal is thus intimately connected with the travels of European Jesuits to Lisbon. But since the only account available is that of a single person, G. P. Lembo, this fact could be merely circumstantial. That is not the case; rather, what one is observing is a *pattern* of diffusion of scientific knowledge, which is unveiled by examining the dissemination of the knowledge of Galileo's new telescopic observations in Portugal. The diffusion of this new knowledge does not necessarily mean that telescopes were already available, although one can plausibly assume that such discoveries spurred the desire to obtain the new optical instrument. Again, in disseminating knowledge of the new astronomical observations in Portugal, the members of the Society of Jesuits played a crucial role.

In the Jesuit network of residences and colleges news of the telescopic findings circulated with exceptional speed. In 1614, in China, the Portuguese missionary Manuel Dias (1574-1659) wrote in Chinese the *Tianwen lüe*, a small compendium on cosmographic and astronomical matters in the tradition of the literature on the sphere. He includes at the end of his work a description, with figures, of the new telescopic observations. Dias reports on the unevenness of the Moon's surface, the satellites of Jupiter, the peculiar appearance of Saturn, etc. He ends by promising that when the new instrument arrives in China he will write more about its marvellous use.[36] This means that news about these new findings had reached Lisbon at least two years before, that is, by 1612. Other pieces of information confirm this scenario. On November 1612, in India, the Jesuit Giovanni Antonio Rubino (1578-1643), wrote:

> Mi scrissero d'Italia che s'inventarono certi occhiali con i quali se veggono le cose distintamente 15 e 20 miglia lontano et si scuoprono molte novità ne' cieli, principalmente nelli pianeti. Sarà grande charità mandarmeli Vostra Riverenza et insieme qualche tratatello sopra tali occhiali se v'è dimonstratione delle cose che si veggono. E se V. R. non me li può mandare, per non haver commodità o per non haver danari, la prego quanto posso che mi mandi *in scriptis et in figuris* il modo e l'inventione come si fanno, quanto più chiaramente sarà possibile; ch'io in questi apesi li mandarò fare, perchè non mancano officiali nè molta copia di cristalli.[37]

This letter means that news about the telescope and the new astronomical observations must have reached Lisbon in 1611. Both the book by Dias and the letter from Rubino show that, as one might have expected, the news of the telescope travelled faster than the instrument itself.

References to the telescopic observations by Rubino and Dias, and the actual telescope observations performed by Lembo, are remarkable in many ways, but they were not the only occasions for informed discussions about the new instrument and the new observations. En route to the Asian missions in April 1618, a remarkable group of missionaries sailed from Lisbon. On board the vessel *S. Carlos* were Giacomo Rho (1592-1638), Johannes Schreck (1576-1630), Wenceslaus Kirwitzer (ca. 1589-1626) and Johann Adam Schall von Bell (1591-1666). All these men were familiar with the new astronomical discoveries and their importance. Their voyage via Lisbon was certainly an occasion for discussions on these topics and an opportunity to disseminate these innovations in Portugal. During the 1620s the debate around cosmological issues was more intense and generalized. Of particular interest are the lecture notes of the German Jesuit, Johann Chrysostomus Gall (1586-1643), who taught mathematics in Lisbon between 1620 and 1627. Judging from the lecture notes that survive, the telescopic findings and their cosmological repercussions were regularly commented on in the Jesuit lectures in Lisbon.[38]

Finally, it is worth mentioning the Italian Cristoforo Borri (1583-1632). Borri taught mathematics in Coimbra in the year 1626-7. In Coimbra he made telescopic observations together with André de Almada, a well-known professor of theology at the University, with a strong interest in mathematical issues. He also taught mathematics at the College of Santo Antão, in Lisbon, in 1627-8. He was an important figure on the Portuguese scientific scene during this period and his book *Collecta Astronomica*,[39] published in Lisbon in 1631, is the first printed work in Portugal with a detailed description of Galileo's telescopic observations and their cosmological importance, as well as a careful description of the telescope and its operation.

5. CONCLUSIONS

The need to send scientifically trained missionaries to China put Portugal at the centre of a surprising phenomenon of "scientific travels." The immediate consequence of this phenomenon was the rapid spread of new scientific ideas, books, and instruments, from Europe to Portugal. After 1640, however, the political and ecclesiastical circumstances that had created this peculiar scenario changed, and the flow of scientifically trained men ceased. What was the result of these events?

It seems clear that the events of those three decades left an imprint on scientific training in Portugal. Regular teaching of scientific matters was occurring for the first time in Portugal, excellent scientific libraries were created, the number of practitioners of science increased, and the scope of scientific subjects widened. But all in all the aftermath is rather disappointing, both in Jesuit and non-Jesuit circles: astronomical work did not continue; debates were meagre and generally trivial; the University remained totally indifferent. Until the 1720s the torch of mathematical sciences was (timidly) carried only by some Jesuit institutions, and totally neglected by the rest of Portuguese society. Various reasons can be adduced to explain this state of affairs. Regarding the Jesuits, one important reason is that, after 1640, the Kings of Portugal turned again to the Society in the hope of solving a pressing educational problem: the urgent need for more men trained in military architecture and fortification to help fight the war then being waged against Spain. In the second half of the seventeenth century Jesuit mathematical practice in Portugal focused especially on these subjects. This and other circumstantial reasons – political, economic – can be invoked to explain the poor performance of Portuguese scientists. But they are not sufficient. In 1711, in a letter addressed to the Portuguese Province, the Jesuit General Michel Angelo Tamburini complained that he could not understand why the study of mathematics had decreased in Évora, and why some "elder members" of the Portuguese Province were reluctant to promote the study of mathematics.[40] This is all the more significant coming from within an institution that had a tradition of scientific teaching, and following a major reform of the teaching of mathematics in Portugal which had been set in motion, directly from Rome in the late seventeenth century. Jesuit corporate culture failed to implant in Portugal one of the most distinguishing features of that very culture: a solid tradition of training and practice of science. Clearly, in the development and consolidation of science in a country there is much more at stake than simply improving communication with other scientific centres.

The main goal of this work was to provide historical evidence of an interesting case of "scientific travels" and its consequences. I concentrated solely on the history of the telescope but other similar cases could have been provided: for example, the related subject of the study of geometrical optics, or the very different subject of hydraulic machines.[41] As with the telescope, it is possible to identify the transmission of knowledge and a surge of interest in these matters associated with the travels of Jesuit-scientists in Portugal. In all these cases, the logistical structure of the Society provided the means and the support for the efficient transmission of information. In all these cases, scientific travelling was at stake: experts in these subjects travelled from scientific "centres" to peripheral Portugal.

The brevity of the analysis presented here and the complexity of the subject do not allow for any substantial conclusions. Nevertheless, a number of points seem to be sufficiently clear to be proposed, if not as a conclusion, at least as a hypothesis to be tested by future work. First of all, a simple observation is warranted. If a network of intellectual institutions is sufficiently organic and efficient, demands arising from any part of it will rapidly be felt in other parts. It is today firmly believed that the creation of a scientific tradition is closely associated with the existence of efficient networks of communication. One could add that this is the easy part: provided there are sufficient resources and political stamina, the creation of an educational network can be accomplished. The story of the Jesuits in Portugal seems to confirm this notion.

However, this is far from being the whole story, and some further observations should be made. No amount of contacts with a scientific centre, no amount of interchanges with other institutions, no amount of recruitment of trained personnel seems to be sufficient *per se* to alter local constraints. These seem to prevail in all circumstances, even in the case of a disciplined and hierarchical institution such as the Society of Jesus. This is at odds with many common interpretations that attribute the lack of scientific development in a certain region to its scarce scientific contacts with other, more advanced regions. Communication with more advanced scientific centres, just by itself, is not enough. Scientific travelling – in the sense considered here – disseminates knowledge, arouses curiosity, but is unable to significantly alter the local practice of science.

Scholars familiar with Portuguese historiography may find this idea somewhat surprising. Portuguese historiography repeatedly insists on the importance of those who studied, travelled, or had contact with "more advanced" countries. At all times, but most especially in the eighteenth and nineteenth centuries, much hope was placed in these men. Without in any way diminishing their commitment to changing the conditions for the practice of science in Portugal, one cannot escape the impression that their efforts were doomed to failure. As the history of the Jesuits in Portugal shows, the importation of new scientific ideas, if not accompanied by changes in the local context of scientific practice, will be of limited value. If this is true in the case of a powerful and well-structured organization it would be even more so in the case of isolated individuals.

As a slight variation of these considerations one can perhaps make the observation that a rapid diffusion of the latest scientific discoveries is far from being a good measure of the scientific development of a particular region. Early seventeenth-century Portugal was certainly well informed about the latest astronomical discoveries and debates, but this was insufficient to start or establish a scientific tradition in Portugal. Acquiring knowledge rapidly about scientific results or discoveries is not equivalent to the existence of a sound scientific culture. Indeed, rapid and efficient communication of scientific knowledge may be the result of factors external to science, a simple outcome of favourable political, economic (or missionary) demands and conditions.

Regarding the development of science, the notion of "periphery" seems to denote more an *attitude* towards science than any feature or limitation imposed by any geographical or economic factors. To determine exactly what this attitude is certainly presents a much more difficult task. Nevertheless, the historical events we have analysed in this article seem to contradict one very common conception of Portuguese historiography, namely that the peripheral position of Portugal was due to some sort of religious constraints imposed upon scientific activity. As the case analysed shows, this is an excessively simple statement.

If one uses the case of the Jesuits in Portugal, one factor that seems appropriate to characterize this attitude has to do with the relation between power and science. Unlike other European Provinces of the Jesuits, in Portugal the interference of royal demands within the Jesuit system seems to have been much more pronounced. This is but one factor and certainly does not explain everything, but its relevance seems clear. Whereas the mathematical curriculum at, say, the Roman College was directed at training Jesuits in science, the mathematical lectures at the Jesuit college in Lisbon were designed to prepare technicians useful for the nation's needs. State needs and royal demands continuously conditioned and shaped the practice of science within the Society of Jesus in Portugal, turning it into a very different practice from the rest of Europe. Ultimately, for the Jesuits in Portugal, royal demands seem to have been more important than hierarchical instructions.

Acknowledgments

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University of Lisbon

NOTES

[1] The existence of such an "epistemological obstacle" is argued in several of J. S. da Silva Dias's works. See, for example, *Os Descobrimentos e a Problemática Cultural do Século XVI*, 3ª Ed. (Lisboa: Presença, 1988).

[2] The literature on the subject today is considerably abundant and there is no point in trying to summarize it. I will refer only to a few works, where many references to more specialized literature can be found: Ugo Baldini, *Legem Impone Subactis. Studi su Filosofia e Scienza dei Gesuiti in Italia, 1540-1632* (Roma: Bulzoni, 1992); Antonella Romano, *La Contre-Réforme Mathématique. Constitution et Diffusion d'une Culture Mathématique Jésuite à la Renaissance* (Roma: Ecole Française de Rome, 1999); Ugo Baldini, *Saggi sulla cultura della Compagnia di Gesù (secoli XVI-XVIII)* (Padova: CLEUP, 2000).

[3] For an excellent and up-to-date collection of essays that reflect the variety of Jesuit cultural activities, see John W. O'Malley, Gauvin Alexander Bailey, Steven J. Harris, T. Frank

Kennedey, eds., *The Jesuits. Cultures, Sciences, and the Arts, 1540-1773* (Toronto: University of Toronto Press, 1999). See also László Polgár, *Bibliographie sur l'Histoire de la Compagnie de Jésus, 1901-1980*, 3 vols in 6 (Rome, 1981-1990), continued annually by Polgár in *Archivum Historicum Societatis Iesu.*

4 This, of course, was most clearly stated in all Jesuit normative documents, such as the *Constitutions*. See Ignatius of Loyola, *The Constitutions of the Society of Jesus*, trans. George E. Ganss (St. Louis, 1970).

5 On this very important aspect of Jesuit self-identification see John O'Malley, *The First Jesuits* (Cambridge: Harvard University Press, 1993).

6 Compare, for example, with Mary Louise Pratt, *Imperial Eyes. Travel Writing and Transculturation* (London and New York: Routledge, 1992).

7 Jesuit scientific activities in China have become a subject of intense research over the past few decades. For an overview of the latest scholarship on this subject see Charles E. Ronan, Bonnie B. C. Oh, eds., *East Meets West: The Jesuits in China, 1582-1773* (Chicago, 1988); Federico Masini, ed., *Western Humanistic Culture presented to China by Jesuit Missionaries (XVII-XVIII centuries)* (Rome, 1996).

8 The history of the University in Portugal goes back to the thirteenth century. For our present purposes, though, it is sufficient to concentrate on the events after the decisive date of 1537. A brief summary of the history of the University of Coimbra is: Mário Brandão and M. Lopes de Almeida, *A Universidade de Coimbra. Esboço da sua história* (Coimbra, 1937).

9 "(...) o oppositor de Mathematicas lerá duas lisõis de ponto, huma em Euclides e outra na Theorica dos Planetas; e na opposição da cadeira de Musiqua não averá lição de ponto, porem o tal oppositor será examinado na Theoriqua de Musiqua pollo catedratico de Mathematicas", in Serafim Leite, ed., *Estatutos da Universidade de Coimbra (1559)* (Coimbra: Por ordem da Universidade, 1963), pp. 114-115.

10 Serafim Leite, *op.cit.* (9), p. 94.

11 The appreciation of the state of mathematical sciences in Portugal in the sixteenth century has been complicated by the fact that Portugal produced one of the most famous mathematicians of the period, Pedro Nunes (1502-1578). Historians were frequently led to believe that this was the consequence of the existence of a solid mathematical tradition in Portugal. But the fact that it is not clear where Nunes learned mathematics, that none of his pupils built a reputation in mathematics, that his relationship with the University was tense, and that he was always quick to criticize in harsh terms the poor scientific knowledge of nautical men, should at least introduce some caution. There are, however, important indications to be drawn from Nunes' career, and I will use them subsequently.

12 This has been clearly shown in several studies. For the best documented analysis of this issue see the discussion on Nunes' career in J. M. Teixeira de Carvalho, *Homens de Outros Tempos* (Coimbra: Imprensa da Universidade, 1924).

13 In fact, of the various men that are known to have substituted for Nunes in his absences – António de Sousa, Francisco Calado, Manuel de Pina, Pedro de Sousa, Pedro da Cunha, Nicolau Coelho do Amaral – only N. Coelho do Amaral published on mathematics – a rather uninteresting *Chronologia*, 1554.

14 Teófilo Braga, *História da Universidade de Coimbra*, 4 vols. (Lisboa, 1892-1902). See esp. vol. 2, pp. 812-835. Very few historians still accept Teófilo Braga's thesis, but his work is still useful as a source of information and documentation.

15 "Por que consta que desde o anno de 1612 até o de 1653, em que se passou o longo intervalo de 41 annos, esteve vaga a Cadeira de Mathematica sem Professor que a

regesse". Francisco de Lemos, *Relação Geral do Estado da Universidade, 1777* (Coimbra, por ordem da Universidade, 1980), p. 80.

16 I am not claiming that royal patronage is a specific Portuguese characteristic of scientific practice. To a great extent this is a common trait in European science during this period. It is sufficient to recall the careers of Tycho Brahe, Galileo and Kepler, to become aware of the importance of courtly connections. But, as I will stress below, in the Portuguese case this needs to be clearly explained, since the extremely poor performance of other environments (the University, for example) will create a much more unbalanced situation than what is observed in other countries.

17 The *Cosmógrafo-Mor* and, in general, the problem of nautical teaching are analysed in A. Teixeira da Mota, "Os Regimentos do Cosmógrafo-Mor de 1559 e 1592 e as origens do ensino náutico em Portugal," *Memórias da Academia das Ciências de Lisboa (Classe de Ciências),* 13 (1969), 227-291. See also Nuno Valdez dos Santos, *Setecentos Anos de Estudos Navais em Portugal* (Lisboa: Academia de Marinha, 1985).

18 See Rafael Moreira, *Um Tratado Português de Arquitectura do século XVI* (Dissertation, Universidade Nova de Lisboa, 1982) and Rafael Moreira, "A escola de arquitectura do Paço da Ribeira e a Academia de Matemáticas de Madrid," in Pedro Dias, ed., *As Relações Artísticas entre Portugal e Espanha na Época dos Descobrimentos* (Coimbra: Livraria Minerva, 1987), pp. 65-77.

19 On this matter see Robert S. Westman, "The astronomer's role in the sixteenth century: A preliminary study," *History of Science*, 18 (1980), 105-147.

20 On the early stages of the Jesuit educational enterprise, see John O'Malley, *op.cit.*(5). For more detailed studies, see Aldo Scaglione, *The Liberal Arts and the Jesuit College Systems* (Amsterdam, Phil.: John Benjamins, 1986); John W. Donohue, *Jesuit Education: An Essay on the Foundation of its Idea* (New York: Fordham University Press, 1963); Gabriel Codina Mir, *Aux Sources de la Pedagogie des Jésuites: Le "modus parisiensis"* (Roma: Institutum Historicum, 1968). For the Portuguese situation: Francisco Rodrigues, *A Formação Intelectual do Jesuíta: Leis e Factos* (Porto: Livraria Magalhães e Moniz, 1917); João Pereira Gomes, *Os Professores de Filosofia da Universidade de Évora* (Évora: Câmara Municipal, 1960).

21 António Leite, "Pombal e o ensino secundário," in *Como Interpretar Pombal?* (Lisboa, 1983), pp. 165-181. The reader will note that I am trying to avoid all types of *qualification*, to state, as far as possible, mere "raw" observations or numerical data. There are no such things as "bare facts," of course, but in the case of the Jesuits in Portugal the ravages of the dominant anti-Jesuit ideological historiography have been such that simple numerical estimates are systematically neglected. One consequence of this state of affairs is that Jesuit historiography (sometimes apologetic) is the only useful resource for those interested in trying to ascertain the dimension, logistics, and structure of the Jesuit enterprise in Portugal. Thus, the essential reference is still the massive, but somewhat dated, multi-volume work by the Jesuit historian Francisco Rodrigues, *História da Companhia de Jesus na Assistência de Portugal*, 4 vols. in 7 (Porto, 1931-1950). However, this situation seems to be changing. The recent work by Dauril Alden is a superb contribution which has become indispensable: Dauril Alden, *The Making of an Enterprise: The Society of Jesus in Portugal, Its Empire, and Beyond, 1540-1750* (Stanford, 1996).

22 See G. P. Brizzi, ed., *La Ratio Studiorum. Modelli Culturali e Pratiche Educative dei Gesuiti in Italia fra cinquecento e seicento* (Roma, 1981); Frederick A. Homann, ed.,

Church, Culture and Curriculum: Theology and Mathematics in the Ratio Studiorum (Saint Josephs University Press, 1999).

[23] The pioneer study on this Jesuit lecture is Luís de Albuquerque, "A 'Aula da Esfera' do Colégio de Santo Antão no século XVII," *Anais da Academia Portuguesa de História*, 21 (1972), 337-391. This is today largely superseded by the works of Ugo Baldini. See Ugo Baldini, "As Assistências ibéricas da Companhia de Jesus e a actividade científica nas Missões Asiáticas (1578-1640). Alguns aspectos culturais e institucionais," *Revista Portuguesa de Filosofia*, 54 (1998), 195-245; "The Portuguese Assistancy of the Society of Jesus and Scientific activities in its Asian missions until 1640," in Luís Saraiva, ed. *História das Ciências Matemáticas: Portugal e o Oriente* (Lisboa: Fundação Oriente, 2000), pp. 49-104; "L'insegnamento della matematica nel Collegio di S. Antão a Lisbona, 1590-1640," in *A Companhia de Jesus e a Missionação do Oriente* (Lisboa: Fundação Oriente/Brotéria, 2000), pp. 275-310.

[24] It is impossible, of course, to summarize the literature on the subject. I will limit myself to pointing out some works that are easily accessible to English-speaking readers that can provide good introductions. The late Charles Ralph Boxer was a master of the history of the Portuguese Empire; many of his works have by now been superseded by more detailed and modern studies, but continue to offer some of the most balanced analyses. For example: *The Portuguese Seaborne Empire, 1415-1825* (London: Hutchinson & Co., 1969), *The Golden Age of Brazil, 1695-1750* (Berkeley and Los Angeles: University of California Press, 1969), *The Christian Century in Japan, 1549-1650* (Berkeley and Los Angeles: University of California Press, 1967). See also Bailey W. Diffie, George D. Winnius, *Foundations of the Portuguese Empire, 1415-1580* (Minneapolis: University of Minnesota Press, 1977); A.J.R. Russell-Wood, *A World on the Move: The Portuguese in Africa, Asia, and America, 1415-1808* (Manchester: Carcanet Press, 1992); Sanjay Subrahmanyam, *The Portuguese Empire in Asia, 1500-1700* (London: Longman, 1993).

[25] I have examined this subject in more detail in H. Leitão, "Galileo's Telescopic Observations in Portugal," in José Montesinos y Carlos Solís, eds., *Largo Camino di Filosofare. Eurosymposium Galileo 2001* (La Orotava: Fundación Canaria Orotava de la Historia de la Ciencia, 2001), pp. 903-913.

[26] This subject has been generally overlooked in Portuguese historiography of science. In the most influential study on this question, the knowledge of the telescopic discoveries by Galileo in Portugal is dated around 1630. See Joaquim de Carvalho, "Galileu e a Cultura Portuguesa sua Contemporânea," *Biblos*, 19 (1943), 399-482. A systematic investigation of the archival sources in Portugal related to this question has never been performed and so other Portuguese scholars have accepted this opinion. For example: Luís de Albuquerque, "Sobre o conhecimento de Galileu e de Copérnico em Portugal no século XVII," *Vértice*, 256 (1965), 15-27.

[27] The most detailed study about telescopes in Japan is Yoshio Mikami, *Nihon sokuryo justu shi no kenkyu* [History of the Telescope in Japan] (Tokyo, 1948). I have not used this work and I have drawn all information from Shigeru Nakayama, *A History of Japanese Astronomy. Chinese Background and Western Impact* (Cambridge, Mass.: Harvard University Press, 1969), pp. 98-101. It seems that the first telescopes in Japan were more artifacts destined to arouse curiosity than scientific instruments; but this pattern is not significantly different from what happened during the early stages of the use of telescopes in Europe.

[28] D. Campos Moreno, "Jornada do Maranhão por ordem de S. Magestade feito o anno de 1614," in *Collecção de notícias para a história e geografia das nações ultramarinas que*

vivem nos domínios Portuguezes, ou lhes são vizinhas (Lisboa: Academia Real das Sciencias, 1814). This information was first noted by E. Sluiter, "The first known telescopes carried to America, Asia and the Artic, 1614-39," *Journal for the History of Astronomy*, 28 (1997), 141-145.

[29] The first person to notice that Lembo had taught in Lisbon, and to call attention to the relevance of this fact, was J. Pereira Gomes, "Aula da Esfera," in *Enciclopédia Luso-Brasileira de Cultura* (Lisboa: Editorial Verbo, 1968), Vol. 7, cols. 1012-3. In recent years, Ugo Baldini has also referred to this and added important information in his works on the "Aula da Esfera."

[30] Giovanni Paolo Lembo was born in Beneveto, Italy, around 1570, and was admitted to the Society of Jesus on the 22nd of February, 1600, in Naples. From 1604 to 1607 he studied philosophy in the Jesuit college in Naples, and was called to Rome in 1607 where he studied theology and attended Clavius' mathematical academy. At the Roman College he seems to have engaged mostly in instrument making (in the summer of 1610 he built the first telescope of the Roman College). In April 1611, together with Clavius, Grienberger and Maelcote, he was the author of the famous reply to Cardinal Bellarmine's inquiry about Galileo's observations. From 1611 to 1614 he was again at the college of Naples, with administrative duties. Around these years he met Giovanni Battista Della Porta (1535-1615). In 1614 General Acquaviva sent him to teach mathematics in Lisbon. Lembo's stay in Lisbon was short. He was a teacher of mathematics at the *Colégio de Santo Antão* in 1615 and in 1617, but in December returned to Italy, due to poor health. He died in Naples shortly afterwards, on May 31, 1618. Biographical data on Lembo is collected from the works by Ugo Baldini, "L'insegnamento della matematica nel Collegio di S. Antão a Lisbona, 1590-1640," *op.cit.* (23) and Romano Gatto, *Tra Scienza e Immaginazione. Le matematiche presso il collegio gesuitico napoletano (1552-1670 ca.)* (Firenze: Leo S. Olschki, Firenze, 1994), p.35.

[31] It is in Lisboa, Arquivo Nacional da Torre do Tombo, Manuscrito de livraria, 1770.

[32] 1r: Prologo em que se tracta da divisao das Mathematicas enventores e feitos exçelencias e Louvores que se lhe devem;

5v: Declaraçao da Sphera;

7r: Divizão da Sphera;

10r: Composição da Sphera Material;

15r: Accabado o Tractado da forma e Região Ellementar comessa o Author a disputa da Região Etherea;

15v: Do numero e movimento dos Orbes Caelestiais conforme a opinião dos antigos;

22v: Dos 4 movimentos do 8º Orbe conforme aos Modernos Astronomos;

29v: Da Ordem dos orbes Caelestes;

54r: Composição e huso de hum instrumento para achar a variaçao da agulha (de) marear assim na terra como no Mar;

57r: Dos sinos, tangentes e secantes;

59r: [Os Elementos de Euclides] (livros I-IV);

66r: Arte perpectua do Computo Ecclesiastico segundo a nova reformacao do anno do Senhor 1582;

71r: Breve tractado de Horologios de Sol;

95r: Tractado breve das Machinas Hydraulicas;

121r: O que mais se leo toccante ao tractado da Sphera no anno do Senhor de 1616 do principio de Outubro por diante [...];

135r: Ordem por se fazer a superfície concava no vidro do longe mira;

135v: Para se fazer vidro convexo do Longemira;

136r: Modo para nos Mappas ou globos se achar em legoas a distancia de alguns lugares a outros [...];

[33] This had been claimed by Cristoph Grienberger in the letter he addressed to Galileo on 22 January 1611, and in which Lembo is explicitly mentioned (See *Le Opere di Galileo Galilei* [Edizione Nazionale], Vol. XI, pp. 31-35). Therefore, it is interesting to note that, in a wholly different context and using a completely non-polemical tone, Lembo confirms Grienberger's statements. The relevant passage is in fl. 33r, when Lembo comments that he had observed the phases of Venus in Rome in October 1610.

[34] "A mesma observação fiz os meses passados estando já aqui em Lixboa e a mostrei não somente a meus ouvintes mas tambem a outras pessoas curiosas [muitas] que a virão com pontas do mesmo modo que a lua no princípio menores, depois maiores cada vez mais. Falo com testemunhas de vista."

[35] With the publication of *Sphera Mundi seu cosmographia* (1620), by Giuseppe Biancani. For detailed information on this question, see Michel-Pierre Lerner, "L'entrée de Tycho Brahe chez les jésuites ou le chant du cygne de Clavius," in L. Giard, dir., *Les Jésuites à la Renaissance. Système educatif et production du savoir* (Paris: Presses Universitaires de France, Paris, 1995), pp. 145-185; Baldini, *Legem Impone Subactis*, *op.cit.* (2), pp. 217-250; and O. Besomi, M. Camerota, *Galileo e il Parnaso Tychonico. Un capitolo inedito del dibattito sulle comete tra finzione letteraria e trattazione scientifica* (Firenze: Leo S. Olschki, 2000).

[36] Transcription and translation of the relevant parts of the *Tianwen lüe*, can be found in Pasquale d'Elia, *Galileo in China. Relazioni attraverso il Collegio Romano tra Galileo e i gesuiti scienziati missionari in China (1610-1640)* (Roma: Apud Aedes Universitatis Gregorianae, 1947), pp. 24-28. [English trans: *Galileo in China. Relations through the Roman College between Galileo and the Jesuit scientist-missionaries (1610-1640)*, by R. Suter and M. Sciascia (Cambridge, Mass.: Harvard University Press, 1960)]. One interesting point to note is that Manuel Dias had not had advanced training in mathematics. This means that interest in the new astronomical questions transcended the group of Jesuit mathematical experts.

[37] Quoted in P. d'Elia, *op.cit.* (36), pp. 23-24.

[38] Lecture notes of courses taught by C. Gall can be found in various documents in Portuguese archives. The most interesting are perhaps the ones in Lisboa, Biblioteca Nacional, Cod. 1869. I might also add that I have been conducting a thorough examination of all surviving manuscript notes of the mathematical courses taught at Colégio de Santo Antão. The documents thus far identified greatly extend the lists published in Albuquerque, "A 'Aula da Esfera' do Colégio de Santo Antão no século XVII," *op.cit.* (23), and Baldini, "L'insegnamento della matematica nel Collegio di S. Antão a Lisbona, 1590-1640," *op.cit.* (23). Besides many questions of detail, these notes taken together reveal a much livelier interest in scientific matters in Jesuit colleges in Portugal than scholars have traditionally tended to believe.

[39] The book was printed in 1631, but the licences are from 1629, and the book was presumably ready several years before. See *Colecta Astronomica ex Doctrina P. Christophori Borri; mediolanensis, ex Societate Iesu. De Tribus Caelis, Aereo, Sydereo, Empyreo* [...], (Apud Mathiam Rodrigues, Ulysipone, 1631).

[40] Códice 2135, Biblioteca Nacional, "Non sine doloris sensu intelleximus, quod studium Mathematicum in Coll°. Eborensi mirum in modum refrixisset. Et capere non possumus, cur multi seniores istius Prov^{æ}. ægre ferant ibi doceri Mathesim, quæ non solum inservit

ad splendorem; sed etiam magis necessaria est Lusitanis, quam multis aliis nationibus." General Tamburini to the Portuguese Province, Letter of 11 April 1711.

[41] Two examples of scientific subjects traditionally neglected in Portugal that became part of Jesuit teaching in the early seventeenth century, as the manuscript lecture notes of the Santo Antão College confirm.

MANOLIS PATINIOTIS

SCIENTIFIC TRAVELS OF THE GREEK SCHOLARS IN THE EIGHTEENTH CENTURY

1. INTRODUCTION

Unlike many other societies, which during the eighteenth century gradually found their way to a national constitution, the greater part of Greek society remained outside the borders of the Greek national state until well after its establishment in 1832. In fact, Greek society emerged from the setting of the Ottoman Empire as a result of re-stratifications and social changes which took place around various local centres of political and economic power. The eighteenth century was the crucial period during which Greek society refined its shape and produced the political and ideological conditions that, to a certain degree, led to the quest for a separate national identity. Nevertheless, this process was neither uniform nor linear. Different and often competing social groups, various economic interests and diverging political traditions worked out a network of communities which struggled to define a distinctive, though in many instances still vague, position within the context of the Ottoman Empire. It was this geographically scattered network, loosely unified on the basis of common educational and religious traditions — and not a well-defined structure with intrinsic hierarchies and reproductive mechanisms — which comprised Greek society of the period.

Under these circumstances, the concept of "scientific travel" acquires a highly idiosyncratic meaning when applied to Greek scholars of the eighteenth century. The particularities of a society seeking its identity in the intersection of multiple political and economic traditions and interests comprised the ground upon which these travels took place. A widespread assumption among contemporary Greek historians is that from the middle of the eighteenth century Greek scholars were conscious of the "forthcoming uprising of the nation" and did their best in order to "enlighten" their people by introducing into Greek intellectual life the attainments of the European Enlightenment. In this sense, the emergence of a new scientific discourse after 1750 is considered a manifestation of a "progressive" movement

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against ignorance and especially against the conservative agents of the Orthodox Church and "scholastic Aristotelianism" in education. However, although it is true that "scientific travels" formed an important part of the processes that led to the educational and ideological reform of the emerging society, the issue of intellectual interactions between the Eastern world and the "Enlightened West" is much more complex when viewed from the standpoint of the historian of science. The widely accepted assertion that "many Greeks studied not only in Venice (and other Italian cities), Vienna, Bucharest, and Iaşi but also in the universities of France and the Netherlands and brought back, on their return home, the lights of the European spirit"[1] is absolutely unfounded. There are two reasons for this: Firstly, the idea of a linear transfer of the sciences from their original source to the "underdeveloped" Greek intellectual milieu overlooks the fermentations that occurred in local philosophical thought due to its interaction with contemporary European philosophy. Secondly, the obscure notion of scientific or, to be more precise, of *intellectual* travel that stems from the above assertion veils the actual network along which intellectual interactions among the different cultural environments took place.

Leaving aside the first and relatively more complex issue,[2] I will attempt, in the present paper, to clarify the notion of "scientific travel" as far as the particular historical conditions of Greek-speaking populations of the period are concerned. I will focus mainly on the *typology* of the "scientific travels" in order to indicate the specific characteristics of the network built by these travels, the needs they satisfied, and the impact they exerted upon the intellectual life of the Greek-speaking populations of the Ottoman Empire.

Before I proceed, though, I would like to supply some preliminary clarifications of the terms and the methodology I applied in my study.

- *Scientific travel*: It is very doubtful whether this genre did actually exist in the Greek-speaking regions of the Ottoman Empire during the eighteenth century. The notion we ascribe today to the term denotes a change of place deliberately aiming at the acquisition of scientific knowledge or the exchange of scientific experience. However, as will become apparent below, only in very rare cases was scientific transaction the deliberate purpose of the Greek scholars. An important reason for this was the lack of scientific institutions in the Greek intellectual space. Scientific enterprise, at least as it was formed after the Scientific Revolution, presupposed the existence of appropriate collective structures, which could sustain the practice of the people who were involved in it. Although I do not intend to discuss the problems relating to the role of scientific communities here, it is certain that a degree of institutionalisation of the sciences is a prerequisite for systematic cognitive exchange among scientists. Otherwise, any specific scientific knowledge acquired through these exchanges either remains marginal or tends to be assimilated within various other fields of social activity. And this was exactly the case with most Greek-speaking scholars of the eighteenth century.

– *Scholars*: Later on I shall take the opportunity to describe more accurately the profile of these people; it would be useful, however, to touch here upon some issues related to the particular characteristics of their activity within the Greek society of the eighteenth century. I am concerned with *scholars* and not with "scientists," or even philosophers. The reason is that due to the aforementioned absence of proper institutionalisation and to the particularities of local cultural traditions, Greek intellectual life lacked the diversity of cognitive pursuits that characterised contemporary Western societies. Actually, the people I am referring to were mostly polymaths with a theological, philological, and philosophical education, who aimed almost exclusively at building a career as physicians or teachers. Given that physicians were mainly dedicated to their professional preoccupations, the only field in which scholarly endeavours and cognitive pursuits could flourish was education. And the protagonists of this enterprise were teachers. Therefore, the introduction of the new sciences and philosophy into Greek-speaking society was a process almost exclusively directed to their appropriation for educational purposes. Gradually, the upgrading of educational activities through the introduction of the intellectual attainments of the Enlightenment was associated with the quest for a concise identity that would mark the distinctiveness of certain Greek-speaking populations within the Ottoman Empire. However, contrary to what was taking place in most European societies, and probably owing exactly to this association, the purpose of the people who undertook this enterprise was not to introduce a radically new way of philosophising about human and natural affairs. Due to the fact that the Neo-Aristotelian tradition and the Christian Orthodox faith comprised basic cultural coordinates of their collective existence, the appropriation of the new ideas aimed mainly at the endorsement of these traditions and the confirmation of their superiority in the European setting. In this respect, the developments of the Enlightenment were not viewed as an intricate process, which implied a break with ancient philosophy and Christian religion, but rather as developments that came to verify the pronouncements of these traditions.

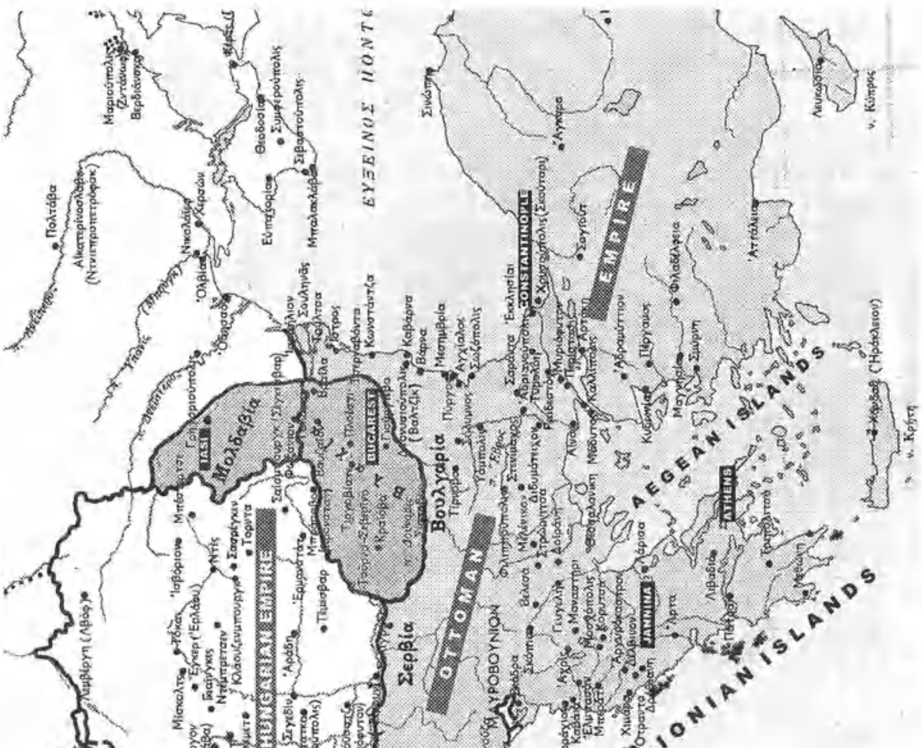
- *Methodology*: One of the purposes of this paper is to propagandise the use of databases in historical research or, better, to present a sample of this sort of work for further discussion in conjunction with history of science. The case study I shall develop is based on the conclusions that can be drawn from the processing of a large amount of data which has been stored in a properly constructed database. I worked basically with primary and secondary bibliography in order to reconstruct the itineraries of 67 Greek-speaking male scholars of the eighteenth century who were involved, one way or the other, with natural philosophy, mathematics and medicine.[3] All this information was recorded in a database that includes two groups of fields: The first group concerns the identity of each scholar (name, place of birth and of death, the respective years and subjects of interest) and the second his travels (destinations, years of arrival and departure and purpose of visit). The background structure is quite simple, especially if one takes into account that, in fact, the database contains only four kinds of information: names, times,[4] places and a field for qualitative data. Nevertheless, the outcome of the processing offers a fresh view on subjects that are considered to be adequately studied by conventional historiography. The reason is that the combinatorial processing of a large amount of data can reveal concentrations, distributions and regularities that cannot be shown through the study of isolated cases. As mentioned above, a widespread assumption among contemporary Greek historians is that the scholars of the eighteenth century travelled "abroad" in order to acquire the lights of European thought and to enlighten, upon their return home, their "enslaved people." The rest of this paper is concerned with the rejection of this simplistic description.

2. SCHOLARLY TRAVELS

2.1 A Quasi-National Intellectual Space

I wish to begin my narration with a map, since a discussion about scientific travels should result in the delineation of lines that depict the geographical shift of people and ideas. On the following map[5] the light grey area represents the Ottoman Empire, which, in actuality, includes the greatest part of the eastern Mediterranean basin. The dark grey area represents the semi-autonomous Danubian regions of the Ottoman Empire which, from the outset of the eighteenth century, were ruled by Christian Orthodox governors. The few dark grey islands located at the left of the southern part of the Balkan Peninsula are the Ionian Islands, which comprised part of the Venetian Republic for many centuries. The black points on the map represent regions inhabited by Greek-speaking populations or sites of Greek Diaspora. It is important to stress the dispersion of the Greek communities not only within the limits of the Ottoman Empire but also in central Europe, Italy and Russia. The emerging society of the period had not yet acquired a body; it consisted of a network of sites where Greek populations developed various economic and political activities. The unifying elements of those populations were mainly the Christian Orthodox faith and Greek-speaking education, although it is evident that common economic interests, which run along the branches of this network, played a significant role as well.

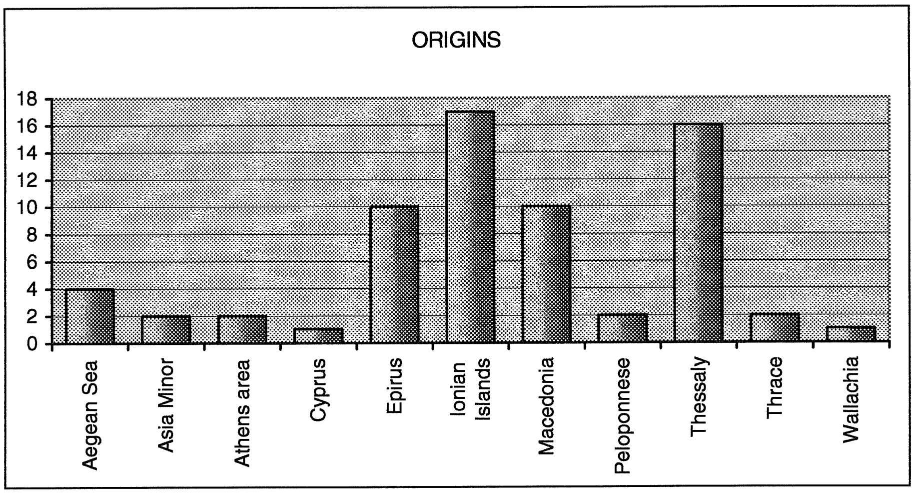
The first important observation that ensues from the projection of the results drawn from the database on this map is that the Greek scholars of the eighteenth century *did not travel "abroad."* Surprising as it may sound, the places those scholars tended to visit were almost exclusively the "nodes" of the above-mentioned network, namely places inhabited by Greek-speaking populations, or cities with large Greek communities. In this sense, the itineraries of the Greek-speaking scholars of the eighteenth century covered a broad European area, delineating a quasi-national intellectual space. They rarely abandoned this network in order to visit places like England or France in the West, Sweden in the North, or Egypt in the South. A unique systematic exception to this rule was the state of Saxony, as well as some other Germanic cities, where quite a few Greeks had ventured in order to study at the local universities.

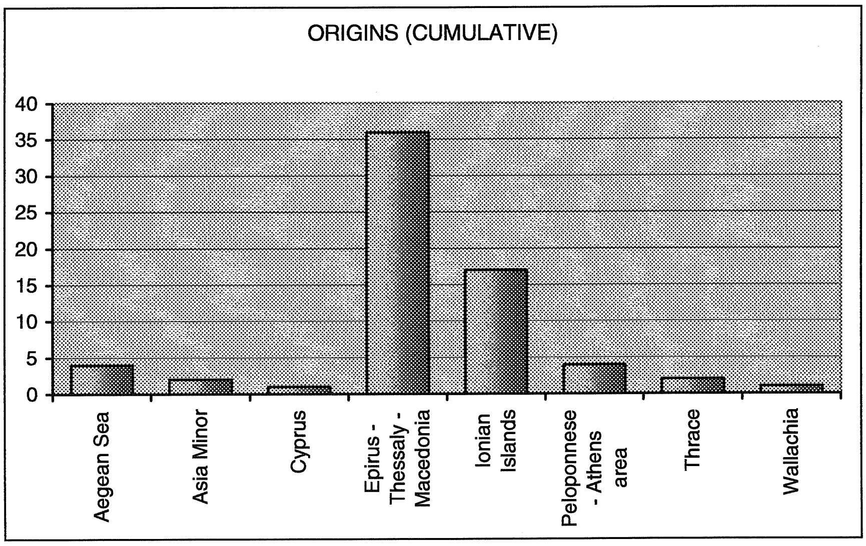

AUSTRO-HUNGARIAN EMPIRE
OTTOMAN
EMPIRE
AEGEAN ISLANDS
IONIAN ISLANDS
VIENNA
BUCHAREST
CONSTANTINOPLE
ATHENS
JANNINA
VENICE
ROME
LEIPZIG
ΒΑΣΙΛΕΙΟΝ
ΤΩΝ ΔΥΟ
ΣΙΚΕΛΙΩΝ
ΑΔΡΙΑΤΙΚΟΝ ΠΕΛΑΓΟΣ

2.2 Who Travelled?

As mentioned above, the subject of this study is the 67 scholars who were involved, one way or another, with natural philosophy, mathematics or medicine. Most of them travelled more than once in their lives for "scientific purposes." But where did these people come from? Surprisingly enough, the database informs us that almost all of them originated from a narrow geographic area, which is today known as north-western Greece.

Generally, Greek historians have a somewhat vague idea about the origins of the scholars of the eighteenth century, based more on ideological preferences than on a systematic survey. It is true that during this period there were many thriving centres of economic and political activity in the Greek-speaking regions of the Ottoman Empire. However, though many historians consider the contribution of these centres to the construction of the learned community self-evident, it seems that this is not generally the case. Interesting *absences* that can be observed in the above diagrams are those of Constantinople, of the Danubian regions and of the southern part of the Balkans. Indeed, Constantinople and the semi-autonomous Danubian regions were the most important centres of political and educational activity of the period. Nevertheless, the database tables contain only one scholar originating in these areas.[6] This does not imply, of course, that no scholars were born in these areas during the eighteenth century, but — and this is more important from our point of view — that no scholars *who dealt with the sciences* were born there. The same holds, to an even greater extent, for the Peloponnesus and the area around Athens. Notwithstanding their links to the ancient heritage, the general contribution of these places to the intellectual life of the Greek-speaking populations of the period was but little.





Thus, the places where our actors originated were limited to Epirus, western Macedonia and some parts of Thessaly on the one hand, and the Ionian Islands on the other. It is not our purpose here to seek a detailed interpretation of this fact, but we may certainly give some helpful hints. In the first place, the two areas comprised two culturally distinct regions. Let us call the former the "commercial triangle." It was an area with a long tradition in commercial and handicraft activities. The area gradually became an educational centre, since the wealth and the size of the local communities allowed them to establish many schools. However, from our standpoint, the most significant characteristic of the commercial triangle was that it comprised the most important migration centre of the Ottoman Empire. In fact, this area was the gate that connected the Ottoman territories with the European commercial routes. The people who lived there were traditionally the intermediaries of this communication and many generations immigrated to central Europe in order to establish or maintain the links of this commercial network.[7] Many other people from the commercial triangle immigrated to Walachia, which was one of the Danubian regions ruled by Orthodox governors. Due to the ethnic and linguistic relations with the populations of that region they moved there aiming at political careers in the courts of governors or other public offices.[8]

As far as the scholars of the period are concerned, it seems that they took advantage of the local tradition of migration. They followed the existing network and headed mainly to the communities of their compatriots in central Europe and Walachia. But there seems to be another important reason for this intellectual migration. The fact that the commercial triangle was located away from the traditional political and educational centres, and in closer contact with the European intellectual agitations, made the emergence of the quest for a modernisation of local intellectual life possible. We should not forget that we are talking about a population whose offspring were destined to live in a European milieu, and therefore to obtain a proper education.[9] Thus, regardless of whether the scholars who travelled about Europe for studies did actually return to accomplish their educational mission or not, the general tendency was in favour of the intellectual migration that would bring them in contact with the achievements of modern philosophy and, consequently, contribute to the upgrading of local education.

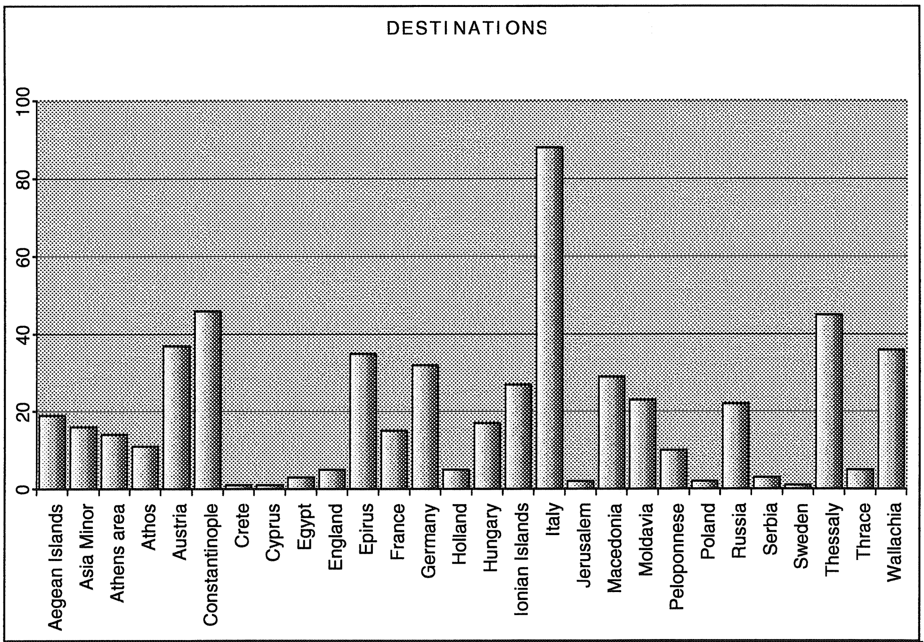
A different cultural unity was that of the Ionian Islands. Although many Greek historians tend to consider them a traditionally Greek territory, they actually belonged to the Republic of Venice, in some cases for a longer time than the time other lands were under Ottoman domination.[10] Their intellectual and social life was considerably different from that of other Greek-speaking regions and, most notably, was oriented towards different centres. The Italian peninsula with its many important sites of intellectual and economic activity was an attractive destination for many young people of the area. Within this context, the potential careers of the scholars displayed great diversity, which was quite unusual in other Greek-speaking regions. Besides the traditional professions of teacher and doctor, the scholars could also become professors in the Greek colleges of Venice and

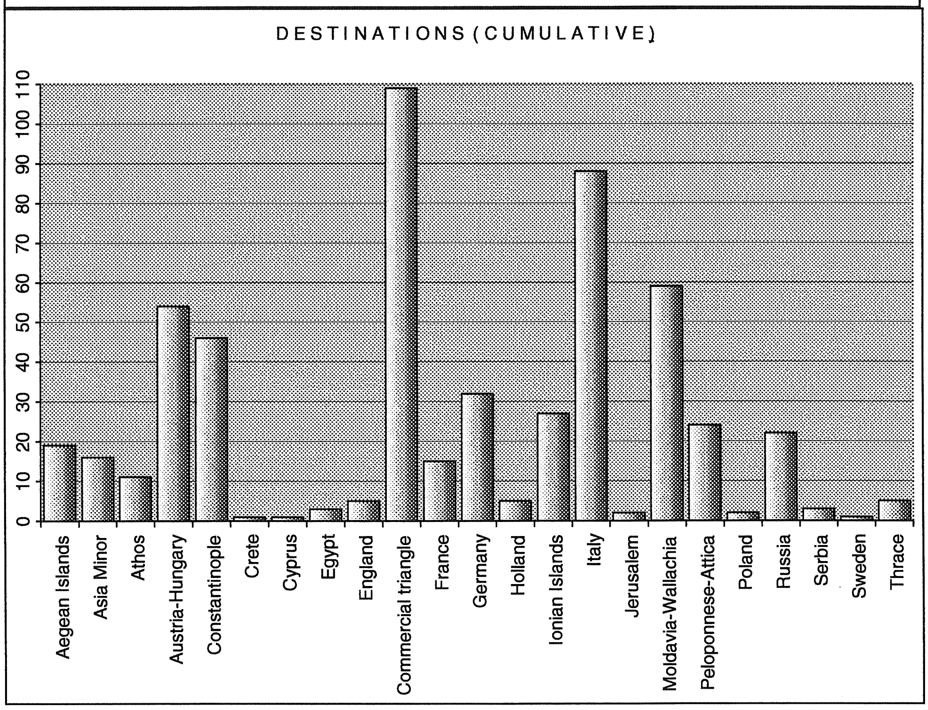
Padua, lawyers and civil servants in the Venetian bureaucracy, editors in the Greek printing houses of Venice, and professors in various Italian universities. There were no schools of higher education in the Ionian Islands; thus, for the majority of the young scholars who were born there, the first or second destination was Padua or Venice and the explicit purpose of their travels was almost always to study in a higher educational institution. It is important to stress, though, that the way the careers of these people eventually developed was a matter of the intricate historical conditions of the period, since in the second half of the eighteenth century the Republic of Venice entered the last phase of its decline, while other centres of political and intellectual activity drew the attention of scholars.

2.3 Where did People Go?

There are many ways to study the travels of a group of people. Being, however, convinced that a major parameter of such an enterprise should be the delineation of the *network* along which these people travelled, I have chosen to speak, at the present stage, of visits. The frequency of visits to various places will allow us to set points on the map, to draw lines between these points and, most importantly, to account for the reasons which made people travel.

Before we proceed with the study of the above charts, it would be useful to make a distinction between two kinds of places. There are places that received more (or many more) than 20 visits and places that received less than 10 visits. Between these two groups there is a gap which, at least to my interpretation, separates the cases of systematic visits from circumstantial ones. The only exceptions that seem to retain an intermediate position are France, Athos and the broader Aegean area, that is, the Aegean Islands and Asia Minor.[11] Henceforth, I shall concentrate mainly on the first group,[12] and I shall give, on occasion, some brief comments on the three intermediate cases.


DESTINATIONS
0
20
40
60
80
100
Aegean Islands
Asia Minor
Athens area
Athos
Austria
Constantinople
Crete
Cyprus
Egypt
England
Epirus
France
Germany
Holland
Hungary
Ionian Islands
Italy
Jerusalem
Macedonia
Moldavia
Peloponnese
Poland
Russia
Serbia
Sweden
Thessaly
Thrace
Wallachia


DESTINATIONS (CUMULATIVE)
0
10
20
30
40
50
60
70
80
90
100
110
Aegean Islands
Asia Minor
Athos
Austria-Hungary
Constantinople
Crete
Cyprus
Egypt
England
Commercial triangle
France
Germany
Holland
Ionian Islands
Italy
Jerusalem
Moldavia-Wallachia
Peloponnese-Attica
Poland
Russia
Serbia
Sweden
Thrace

There is a specific reason why I would like to start with the first of these intermediate cases, that is, the case of France. A widespread assumption among Greek historians is that the so-called neo-Hellenic Enlightenment was "imported" from France. According to the above chart, however, there were just 15 visits to France, an extremely low number in comparison to visits paid to other places, as we shall see below. From a different interpretation of the data, we realise that only 11 out of 67 scholars visited France. In most cases they spent some (short) time developing contacts with the Parisian circles of intellectuals, and occasionally attended classes in some educational institutions. We have no evidence, however, that any of them dealt with systematic scientific studies of any kind. In what manner, then, was French scientific thought transferred to the Greek world? The question becomes even more pressing if one takes into account that the Greek community of Paris was established no sooner than the last decade of the nineteenth century while, as we have seen, the Greek scholars of the eighteenth century kept contacts almost exclusively with places that belonged to the network of the Greek communities.

The real peak of the distribution of travel destinations is Italy: 88 visits paid by 37 scholars indicate a great concentration of interest. The explicit purpose of most of those visits (actually, of more than 60 of them) was studies. Many future scholars attended classes in the Greek colleges of Padua and Venice, while quite a few of them continued with philosophical or medical studies in the universities of Padua (mainly), Bologna or Naples. As a matter of fact, the majority of the Greek-speaking educated people of the period obtained their higher education in Italy and, therefore, it would not be imprecise to suggest that, for many years, the Greek and Italian schools of the Venetian Republic functioned as the higher educational institutions of the Greek world. A possible reason for this was the contiguity of the south-western Balkans with the Italian coasts. However, it seems that two other factors played a more important role.

The extended Venetian acquisitions in the southern Balkans and the islands comprised a historical situation that coexisted with the Ottoman domination of other Balkan regions. Despite the harsh rule of some of those areas by the Venetians, it seems that, by virtue of the similarity of religion, the Greek populations developed a positive disposition towards Italian cultural life of the period, a disposition which they retained even after the passing of these areas to the Ottomans. This situation was a result both of official Venetian policy and of spontaneous developments. In any case, however, the osmosis between the two groups was significant. In religious affairs, for example, the fusion of the two dogmata was sometimes so deep that it led either to common rituals or to the worship of common saints. Similar things happened in literature and painting, where the fusion of the Byzantine with the Renaissance tradition led to the emergence of new artistic movements, especially in Crete and the Ionian Islands.[13] This *cultural familiarity* was a strong motive for young scholars to continue with their higher studies in the educational institutions of Veneto, especially if one takes into account that one of them — the University of Padua — was still among the most prestigious universities of Europe.

The other factor that favoured intellectual migration had to do with the generally positive attitude of the Venetians towards Christian Orthodoxy. The religious policy of the Republic was always determined by political and economic circumstances. Thus, towards the end of the sixteenth century, when the Venetians lost Cyprus and it became obvious that they would need the co-operation of the Orthodox Christians in their military operations against the Ottomans, they started developing a favourable attitude towards the Eastern dogma. This attitude was strengthened by the traditionally secular character and the anti-papal policy of the Venetian State itself.[14] Under these circumstances, the Greek-speaking scholars who continued their studies in the region of Veneto felt their religious faith — the most important component of their collective identity — secured from the Uniat[15] policy of the Catholics. This is indeed an important reason why hardly any of these scholars visited Rome or studied in any of the Uniat schools that Catholics had established in the Eastern Mediterranean region.

Hence, it seems that a combination of geopolitical, cultural and religious factors contributed to the development of a long-lasting current of intellectual migration to the Venetian Republic. An additional factor that favoured this migration was the thriving publishing activity of the city. During the last decades of the seventeenth century, two large printing factories were established in Venice, while a third one was launched in the mid-eighteenth century.[16] All three belonged to Greek-speaking immigrants from Epirus and specialised in the production of Greek books. Having a good knowledge of the Eastern markets' demands, the publishers proceeded with the production of hundreds of religious and philosophical books, as well as many popular readings, which targeted the Greek-speaking populations of the Balkans and Asia Minor.[17] The activity of these printing houses gave rise to a circle of people who dealt systematically with intellectual production. We can assume, quite reasonably, that the activities of these people fit within a broader notion of *study*. Many of them were authors themselves who visited the reading-rooms of Venice and Padua in order to polish their works before delivering them to the printing house.

Others were editors who, for similar reasons, spent their time in the public libraries, putting the last strokes of the brush to various works on their way to the press. This kind of private study allowed these people to become acquainted with the new currents of European philosophy and contributed significantly to the reorientation of Greek thought towards natural philosophy and the sciences.

Another typical destination for the scholars of the period was the territories of Austria-Hungary. In this case, we have 54 visits paid by 26 scholars. Although the numbers are not as high as in the case of Italy, it seems that these areas were a standard destination not only for scholars but also for many Greek-speaking merchants and craftsmen, who emigrated from the commercial triangle of the southern Balkans. Actually, there was a continuous line of Greek-speaking communities along the (commercial) route that connected Macedonia with Vienna and this same line was also the typical migration route.[18] It is absolutely reasonable to suggest that many young people followed their families to the new settlements. There, they attended classes at the elementary schools that the Greek communities had established, especially in various towns of Hungary. A good command of Greek and other local languages was crucial for people who were destined to take over the commercial enterprises of their parents.[19] In this respect, a number of visits was devoted to elementary — especially linguistic and mathematical — education. But since these areas also comprised a potential market for the learned men, some of them (5 or 6 in our case) continued with higher studies in German universities, planning to return and offer their services to the Greek communities as teachers or doctors.

However, the destination of the greatest number of visits was actually Vienna. Vienna received 33 of the above-mentioned 54 visits to the Austria-Hungarian territories. Or, by a different reading of the data, 20 of the 26 scholars who visited the Austria-Hungarian territories were destined for Vienna. Why such a concentration? Vienna was not an educational centre in the sense of Padua. For the Greek-speaking immigrants it was mostly a convenient place for the development of their commercial and banking activities. This situation was a result of intricate historical developments. An aspiration of the Austrian government had always been to gain control over European commerce with Eastern territories. After a series of confrontations with the Ottomans, the Austrians managed to establish a balance of power in the area, governed basically by the treaties of Karlowitz (1699) and Passarowitz (1718), which opened the commercial route of the Danube and encouraged the movement of merchants across the borders. The Austrian merchants, however, were unable to take advantage of the new arrangements due to their ignorance of local economic and cultural conditions in Eastern Europe. Thus, the people who really profited from this situation were the various Greek-speaking Epirotes, Macedonians and Thessalians who traditionally conducted the commercial exchanges between the two Empires. The Austrian government adopted a favourable attitude towards these people and granted them special privileges in order to facilitate their economic activity. As a result, a pocket of Orthodox, Greek-speaking immigrants grew up in Vienna, and in the course of time they gained significant control over the financial and commercial issues of the city.[20] After 1787 the Greek community split into two parts, one consisted of Greek-speaking Ottoman subjects and the other of Greek-speaking Hapsburg subjects. Both groups originated in the same areas of the Balkans, they had similar economic activities and they were protected by their respective privileges. It seems, though, that most of the time they were at odds, due to economic antagonism and ideological differences.[21] Strange as it may sound, this peculiar and dynamic situation played a significant role in attracting Balkan scholars to the Austrian capital.

One reason for this was the attempt of various Greek-speaking merchants to promote their social status by helping the cultural revival of their hometowns. They did so by offering money for the establishment of schools and the printing of modern books. Thus, many scholars visited Vienna, especially after the decline of Venice towards the end of the eighteenth century, in order to complete and publish their works.[22] An additional factor that encouraged these visits was the two decrees of the Emperor Joseph II (1741-1790) securing religious tolerance (13-10-1781) and a free press (13-10-1781). Under these circumstances, Vienna soon became the new centre of the Greek book.[23] The intellectual environment of the printing houses and accompanying literary activities contributed significantly to the production of many important Greek works on logic, natural philosophy and mathematics. Although the scholars who visited the city did not aim directly at higher studies,[24] they were encouraged to get in touch with the new attainments of European thought and convey them to their compatriots. So, they had the motive *and* the opportunity to broaden their intellectual horizons by studying privately in the Academy of Vienna and in other public libraries that provided them with up-to-date literature on various philosophical and scientific topics.

Another increasingly significant aspect of Vienna's intellectual life was related to politics. The families of the Greek-speaking merchants of Vienna gradually acquired substantial economic power and by the end of the eighteenth century they came to occupy a significant position in the social and political hierarchy of the city. According to Olga Cicanci,

> mue par des intérêts en premier lieu économiques, l'administration impériale de Vienne a commencé par aider au progrès économique et culturel de cette bourgeoisie du Sud-est européen, dont les représentants s'établissaient de façon temporaire dans les grands centres de l'Empire. Puis, le temps aidant, cette bourgeoisie est devenue une force politique active, avec un programme préconisant la libération nationale et la fondation des Etats nationaux modernes.[25]

This does not mean, of course, that they were all in favour of the same political programme, nor that they were all affected by the expectation of a Greek national state.[26] The specific conditions of social and economic organisation of this population, however, as well as its proximity to the political agitations of central Europe, gave rise to the quest for new patterns of government. It seems that some of the scholars who visited Vienna got involved with this enterprise since the first political programmes aiming at a new type of organisation of the populations of the Ottoman Empire appeared there. What is important, however, from our perspective is that the same scholars who developed political activity were also active agents of the new ideas in philosophy and science, considering them substantial components of their political endeavours.

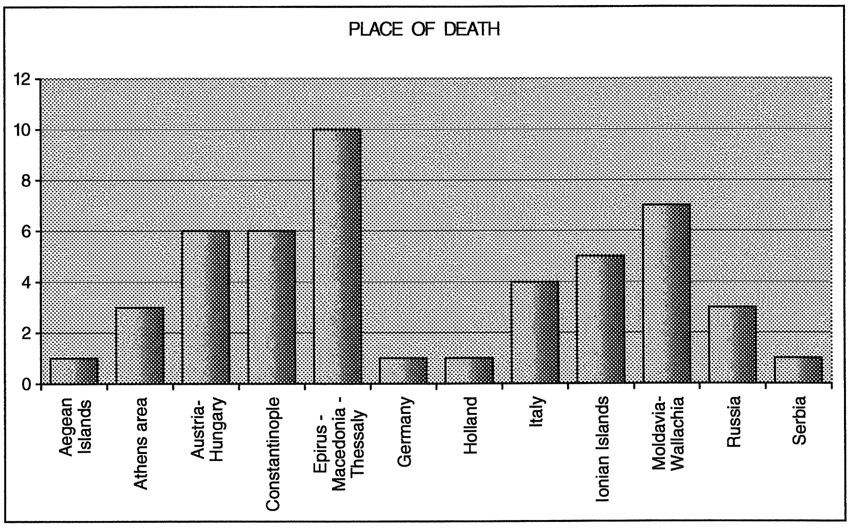
In Germany we also have quite a few visits. Twenty-two young scholars visited the German cities and the purpose of 21 out of a total of 32 visits was higher studies. The number of visits is not comparatively large but still cannot be explained by the existence of any organised Greek community in the area. In fact, the only Greek community, that of Leipzig, was established at the end of the eighteenth century while many Greek scholars had been visiting the state of Saxony and other German cities since the beginning of the century. It is true that between 1740 and 1780 many Greek-speaking merchants from Epirus and Macedonia travelled to the commercial fairs of Leipzig in order to acquire the famous "Leipzig cloth" and other textile products of Bohemia.[27] But, although this connection might have helped the transportation of the scholars, it is not enough to justify their preference for the German universities. Given the lack of local social support, this preference is probably evidence of deliberate choice. The positive disposition of the Orthodox Christians towards Calvinism in combination with their traditional rivalry with Catholicism comprises a possible interpretation for such a preference — which, it must be noted, coexisted with systematic avoidance of the (Catholic) French universities.[28] Another factor acting along the same lines was, in all likelihood, the positive attitude of some dominant groups of the emerging Greek society towards the ideal of enlightened despotism. They perceived the governing model of Frederick II (1712–1786) and some other German and Russian rulers as the best realisation of this ideal. It seems, therefore, that political sympathies also played a significant role in the determination of the itineraries of Greek-speaking scholars of the period.

Last but not least, another factor that favoured the intellectual migration of Greek scholars to Germany was the thriving printing community of Leipzig and Halle. Actually, almost all the visits that were not devoted to higher studies were related to some kind of publishing activity. Thus, we have again the same phenomenon seen above: private studies of scholars in public libraries aiming at polishing their works before delivering them to the printing house; or rendition of philosophical and scientific works which were considered important for the enlightenment of their compatriots. The familiarity with German philosophy, which was gained from these studies and, in some cases, from personal contacts between Greek scholars and German philosophers or scientists,[29] contributed considerably to the assimilation of many aspects of the German Enlightenment within the emerging Greek philosophical discourse of the eighteenth century.

So far we have been concerned with travels aiming at studies — in the broader sense ascribed to the term. Indeed, there is quite a clear distinction between these travels and those aiming at careers. Although some of the people who studied in Italy, Austria-Hungary and Germany remained there or returned later seeking jobs as teachers, doctors, or even university professors, the small number of these cases indicates that central Europe was not a professional destination *par excellence* for Greek-speaking scholars. It would be quite plausible to assume that most scholars returned to their homelands in order to exercise their professions in the Greek-speaking regions of the south-western Balkans. Our data seem to corroborate this suggestion to a certain degree. People who originated from the Ionian Islands returned there, although they did not necessarily return to their birthplaces. Sixteen cases out of a total of 27 visits concern professional travels of this kind — including some exploratory visits as well. Similarly, in the broader area of the commercial triangle (Epirus, Thessaly, and western Macedonia) we have 109 visits, two thirds of which were devoted to professional purposes.[30] Most of the scholars, however, did not settle permanently in these areas. Having spent many years in Europe acquiring a higher education, they also developed a consciousness of their own social particularity. They negotiated their stipends and moved from place to place looking for greater acknowledgement of their work. Actually, during the second half of the eighteenth century, we witness the emergence of a new generation of scholars who gradually became aware of the social value of the qualifications they had acquired during their scientific and philosophical studies, and now sought to define a new collective identity in contrast to the traditional figure of teacher.

Given that during the same period the social groups of merchants and craftsmen started exerting significant influence in the economic and political affairs of the emerging Greek society, it becomes quite clear that this generation intersected with the new intellectual orientations of these groups. But this is only partially true, as becomes evident from the short time many of these scholars spent in the geographical areas of the commercial triangle and the Ionian Islands. A more profound assessment of the data stored in the database leads to the conclusion that very few of the 48 scholars who visited those areas for professional purposes had a successful career there. Most of them turned their professional pursuits to other, wider social horizons.

The distribution of places of death[31] corroborates this dynamic situation. The small number of individuals who died in Austria and Germany indicates the general tendency of Greek-speaking scholars to return home after completing their intellectual mission in Central Europe. However, only 15 scholars (that is less than one third of those who returned) ended their lives in the commercial triangle and the Ionian Islands, while 16 of them died in the environment of the courts of Eastern Europe — Constantinople, Moldavia-Walachia and Russia.



Thus, it seems that although the social agitations of the period gave birth to a new generation of scholars, these scholars displayed relative autonomy concerning their physical and, most importantly, social origins. A linear scheme describing a social base that gives birth to an intellectual infrastructure which, in turn, contributes to the reproduction of this same social base is not absolutely valid in our case. The communities of the merchants and the craftsmen of the area comprised a *potential* social and political centre but not a *real* centre of power yet. The upgraded self-definition of the scholars, implied from the awareness of their higher philosophical and scientific education, oriented their social ambitions towards the *established* centres of power, where their value could be better acknowledged.

The established centres of power which gained their preference were Constantinople, the Danubian regions (Walachia and Moldavia) and Russia, namely some of the most important courts of Eastern Europe. In the case of Constantinople we have in total 46 visits paid by 32 scholars. Twelve visits concern elementary studies in the Patriarchal Academy. Despite its central position in the political and religious life of Greek-speaking populations of the Ottoman Empire, Constantinople *was not* a centre of higher education. Thus, most of the remaining visits were devoted to professional and political pursuits. But again, the scholars who visited the city did not look primarily for jobs as teachers. Actually, only 10 of them gained positions either as private instructors in rich families of the city or as teachers and directors in the Patriarchal Academy. Both posts were also considered political assignments. However, it seems that what basically attracted all these people to Constantinople were not professional endeavours *per se*. A qualitative analysis of the character of their visits brings to light their explicit intention to come into contact with the community of the Fanariots.

The Fanariots were noble Greek-speaking inhabitants of Constantinople who, from the end of the seventeenth century, had acquired an increasingly important role in the administration of the Ottoman State. Contrary to the way in which they tended to introduce themselves, only a few of them were in fact true descendants of the old Byzantine aristocracy. Most of them were rich people who had acquired their fortunes as traders and peddlers in the markets of the Aegean Sea, Constantinople, the Danubian regions and the Black Sea. Their initial aim when they had moved to the Ottoman capital was to secure their wealth by means of political friendships and to make sure that they would be able to pass their riches on to their own descendants.[32] In the course of time they became suppliers of the city, creditors of high officials and consultants of politically powerful men.

> Their ultimate goal was to transcend their purely mercantile functions and become a political bourgeoisie in possession of the functions of banking, governing the Danubian principalities, administering the civil and fiscal affairs of the Greek Orthodox Church, and counselling the authorities at imperial, provincial, and even municipal levels.[33]

Which they achieved: from the outset of the eighteenth century, members of the Fanariot elite were appointed governors of Walachia and Moldavia, and obtained a virtual monopoly of other significant offices of the Ottoman administration: high dragoman of Sublime Porte, under-secretary of the Grand Vizier, dragoman of the Fleet and chargé of Aegean affairs. Gradually they took the lead among the Orthodox populations dispersed in the Balkans and their political dominance reinforced the already strong influence of the Greeks in the economic as well as the cultural sphere in these regions. As administrators and diplomats the Fanariots were warm supporters of enlightened despotism and dreamed of the restoration of Byzantium as a new order of political and economic dominance in the Balkans.

Many of our actors who visited Constantinople aimed to develop close relationships with Fanariot families. The positions that offered them the opportunity to develop such relationships were those of private teacher, personal doctor or secretary of a Fanariot nobleman. Some other public positions, such as those of teacher in the Patriarchal Academy or doctor in the Greek hospital of the city, were also in favour of the same purpose. Hence, although there are no systematic studies of the patronage system of the period, it would be quite reasonable to suggest that the main goal of the scholars who visited Constantinople was their social ascent through their involvement in the patronage network of Fanariot society. This suggestion is corroborated by the visits of scholars within the broader Aegean area, namely the islands and Asia Minor. The Aegean archipelago being the main sphere of influence of the Fanariots, it attracted many Greek-speaking scholars as an intermediate station on their way to Constantinople. A qualitative analysis of their visits is quite telling. We have 35 visits paid by 13 scholars; less than one third of those visits were devoted to elementary studies in various schools of the region, while the remaining 22 visits were devoted to professional and political pursuits: The attitude of most actors makes clear that their primary aim was to develop contacts with important persons of the centre, in order to use their stay in the Aegean region as a channel of approach to the patronage system of the capital.

The same conclusions are reinforced by a series of similar phenomena in the Danubian regions. As a scholar of the second half of the century observed: "Fanari [the area of Constantinople where Fanariots mainly lived and operated] has been moved here, in Bucharest." Indeed, by virtue of the higher offices the Fanariots gained in the administrative system of the Danubian regions, a considerable part of their activity had been moved to the courts of Walachia and Moldavia. Thus, it was quite common for the scholars who visited Constantinople and came into contact with Fanariot circles to accompany their patrons to their new settlements when they were appointed officers in the Danubian regions. Other scholars just followed the links that connected Constantinople with Bucharest and Iaşi or travelled directly there seeking an aristocratic environment to offer their services.

During the eighteenth century, 29 people visited the broader area of Walachia and Moldavia. However, though Iaşi and Bucharest hosted two of the most prestigious schools of the Greek-speaking world, only 6 of their 59 visits were aimed at studies. The result of a qualitative analysis of these visits gives us the following distribution: 8 visits concern doctors who offered their services at the local courts; 25 visits concern teachers who were employed either directly in the courts or in highly regarded positions of the Academies of Iaşi and Bucharest, which operated under the supervision of the local rulers; the remaining 27 visits (slightly overlapping with the previous categories, for obvious reasons) aimed at the development of direct political contacts with Fanariot circles, and resulted in many scholars being appointed secretaries of local rulers or of other important Fanariot officers.

The above analysis seems to confirm the suggestion that many scholars of the period sought a professional career not mainly in the areas they originated from, but at the courts of Constantinople and of the semi-autonomous Danubian regions. Being acquainted with the most recent attainments of European philosophy and science, they aimed at the development of a new intellectual profile that would allow them to keep up with the demands of the emerging Greek society. It is evident, however, that by the end of the century, the rules of the game had not yet been clarified. The specific features of the social strata that converged in the construction of this society, as well as the distribution of the economic and social power among them, were still quite vague. This transitional stage was also represented in the intellectual production of the scholars. This is not the place to examine the character of this production, but it is most probable that the combination of such an examination with the study of the intellectual itineraries of the scholars could contribute substantially to a better understanding of the period.

It is worth closing this description with a brief comment on Russia. Actually, Russia deserves more than a short reference, since the number of visits there is not negligible. Besides, Russia comprises an important chapter of modern Greek history in many aspects. More specifically, during the eighteenth century, due to its traditional rivalry with the Ottoman Empire, Russia was connected, in the minds of the Greek-speaking populations, with the widespread expectation of the revival of an extended Orthodox Empire. Many Orthodox scholars were in favour of the expansionist plans of Catherine II and some of them visited Saint Petersburg in order to put their services at the disposal of the Empress. Thus, we have 12 cases of scholars (among whom were some of the most important Greek-speaking scholars of the eighteenth century) who paid 22 visits to Russia and almost all of them engaged in a successful career there. An interesting observation is that the intellectual activity of these people was related exclusively to the secular or religious offices they obtained at the imperial court. On the other hand, it must be stressed that Russia was the only non-Greek-speaking political milieu where Greek-speaking scholars had successful careers as courtiers.

3. CONCLUSION: LINES

In a sense, this is an incomplete work. An attempt has been made to process a large amount of data stored in a database in order to draw some conclusions concerning the typology of the scientific, or more precisely, *intellectual* travels of the Greek-speaking scholars of the eighteenth century. Nevertheless, the collection and proper classification of these data make the study of the historical circumstances possible on more than one level. The present paper is a preliminary survey of the intellectual itineraries, aiming to outline a general scheme about the circulation of scientific and philosophical ideas in the Greek-speaking world of the period.

Who were the agents of the new ideas? The answer that follows from the above study indicates that those who undertook the task of reforming Greek intellectual life were a new generation of scholars who originated mainly from the south-western Balkans. The particular historical circumstances in these regions favoured the development of a current of intellectual migration that brought these people to the universities of Italy and Germany. The libraries and the reading-rooms of Venice, Padua, Vienna and Leipzig also hosted many people who sought broader cognitive horizons. Thus, a couple of lines can be drawn from the narrow geographic area of the commercial triangle and the Ionian Islands (the dark triangle on the map) towards Italy and the main educational centres of central Europe.

How did these people seek to redeem their educational investments? The phrasing of the question should not puzzle the reader. People who spent from

4 to 10 years in the European educational centres would not go back to the Greek-speaking regions of the Ottoman Empire to become badly paid provincial teachers. The production of a new philosophical and scientific discourse played a significant role in the legitimisation of the upgraded authority of this group. In many cases this programme was carried out through the translation of philosophical and scientific books or through the compilation of original works where the new attainments of European thought were assimilated. These works were published in the printing centres of Italy and central Europe and were then delivered to the schools of the Greek-speaking regions. Thus, when the young scholars returned to their homelands, they were considered the agents of a new trend in philosophical and educational matters. This allowed them to seek out positions in places where their qualifications would be better appreciated. They were appointed directors in the schools of the rich commercial communities of the south-western Balkans and contributed to the reformation of local intellectual life. In this respect, the lines that represent the travels of the scholars to central Europe for educational purposes can be seen to run in the inverse direction as well — this time for professional purposes.

In most cases, however, the narrow limits of the areas, which gave birth to the new generation of scholars, did not measure up to their ambitions. As a result, many of the scholars moved toward the courts of Eastern Europe in order to put their services at the disposal of local rulers or to gain highly respectable posts in the schools and hospitals of Constantinople, Bucharest and Iaşi. These itineraries inscribe further lines on the map, which connect — either directly or through the Greek-speaking regions of the south-western Balkans — the educational centres of central Europe with the established centres of political power in Eastern Europe.

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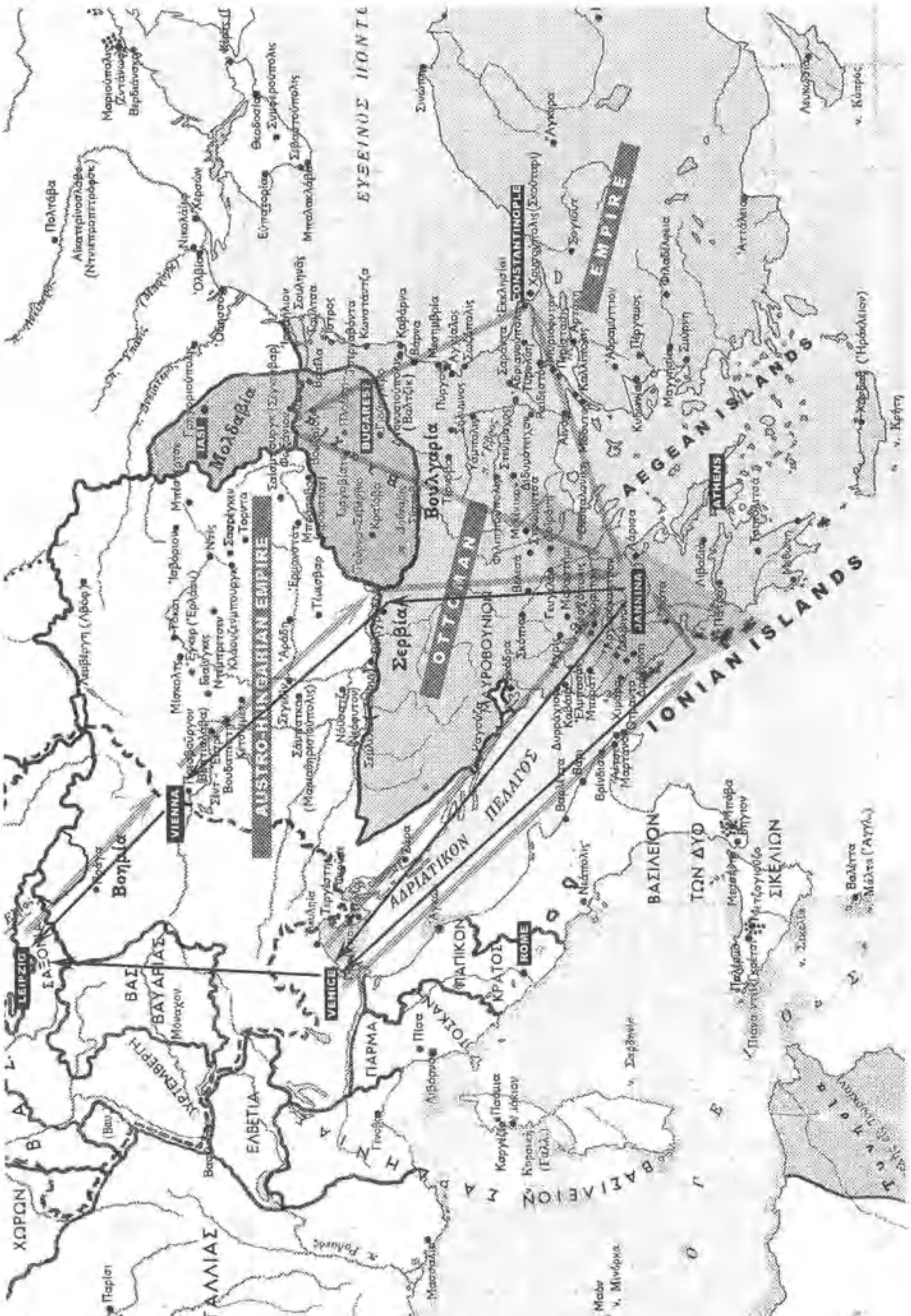
LEIPZIG
VIENNA
VENICE
ROME
ATHENS
CONSTANTINOPLE
BUCHAREST
AUSTRO-HUNGARIAN EMPIRE
OTTOMAN EMPIRE
IONIAN ISLANDS
AEGEAN ISLANDS
ΑΔΡΙΑΤΙΚΟΝ ΠΕΛΑΓΟΣ
ΕΥΞΕΙΝΟΣ ΠΟΝΤΟΣ
Σερβία
Βουλγαρία
Μολδαβία
Βοημία
ΕΛΒΕΤΙΑ
ΠΑΡΜΑ
ΒΑΣΙΛΕΙΟΝ ΤΩΝ ΔΥΟ ΣΙΚΕΛΙΩΝ

NOTES

1 [Collective], *Ιστορία του Ελληνικού Έθνους* (Athens: Εκδοτική Αθηνών, 1975), vol. XI, "Ο ελληνισμός υπό ξένη κυριαρχία (περίοδος 1669-1821). Τουρκοκρατία-Λατινοκρατία," p. 231 (in Greek; the translation is mine).

2 On this subject see K. Γαβρόγλου, M. Πατηνιώτης, "Η ρήξη που δεν έγινε: Επιστήμες και αρχαία ελληνική σκέψη στον ελλαδικό χώρο κατά το 18° αιώνα," *Σύγχρονα Θέματα*, 64 (1997), 88-92; D. Dialetis, K. Gavroglu, M. Patiniotis, "Sciences in the Greek-speaking Regions during the seventeenth and eighteenth Centuries. The process of appropriation and the dynamics of reception and resistance" in K. Gavroglu, ed., *The Sciences in the European Periphery During the Enlightenment* (Dordrecht: Kluwer Academic Publishers, 1999), pp. 41-71; K. Gavroglu, M. Patiniotis, "Patterns of Appropriation in the Greek Intellectual Life of the eighteenth Century: A Case Study on The Notion of Time" in Abhay Ashtekar, Robert Cohen, Don Howard, Juergen Renn, Sahotra Sarkar, Abner Shimony, eds., *Revisiting the Foundations of Relativistic Physics: Festschrift in Honor of John Stachel* (Dordrecht: Boston Studies in the Philosophy of Science, Kluwer Academic Publishers, forthcoming).

3 The determination of the timeframe is somewhat subjective: Basically, included in the study are scholars who were (or might be) productive during the period from 1700 through the mid-1820s — a crucial period for the maturing of the new Greek society, which we may call the "extended Greek eighteenth century." Most of my actors were born between 1660 and 1770, but also included are some scholars whose contribution to the intellectual fermentation of the period was significant, although their life spans exceeded the specific limits. The names of the scholars whose careers I examined, in chronological order according to their birth-dates, are the following (last name first): Sougdouris Georgios [Σουγδουρής Γεώργιος] (1640/1660-1725), Likinios Andreas [Λικίνιος Ανδρέας] (1650/1670-1715), Perdikaris Michael [Περδικάρης Μιχαήλ] (1650/1690-1719/1750), Anthrakitis Methodios [Ανθρακίτης Μεθόδιος] (1650-1736/1749), Pylarinos Iakovos [Πυλαρινός Ιάκωβος] (1659-1718), Notaras Chrysanthos [Νοταράς Χρύσανθος] (1660/1663-1731), Papa-Vasilopoulos Anastasios [Παπα-Βασιλόπουλος Αναστάσιος] (1660/1680-1720/1740), Meletios, bishop of Athens [Μελέτιος μητροπολίτης Αθηνών] (1661-1714), Prokopiou Dimitrios (Pamperis) [Προκοπίου Δημήτριος (ο Πάμπερις)] (1670/1700-1720/1760), Ypomenas Georgios [Υπομενάς Γεώργιος] (1680/1690-1745), Paraskevas Damianos [Παρασκευάς Δαμιανός] (1680/1700-1730/1760), Gordatos Konstantinos [Γορδάτος Κωνσταντίνος] (1680/1700-1740/1760), Argentis Efstratios [Αργέντης Ευστράτιος] (1680/1700-1750), Balanos Vasilopoulos [Μπαλάνος Βασιλόπουλος] (1690/1694-1760/1765), Katiforos Antonios [Κατήφορος Αντώνιος] (1696-1763), Litinos Agapios [Λίτινος Αγάπιος] (1700/1710-1800/1805), Charvouris Marinos [Χαρβούρης Μαρίνος] (1700/1720-1782), Charvouris Ioannis [Χαρβούρης Ιωάννης] (1700/1720-1801), Varkosis Nikolaos [Βάρκοσης Νικόλαος] (1700/1730-1782), Damodos Vikentios [Δαμοδός Βικέντιος] (1700-1754), Zerzoulis Nikolaos [Ζερζούλης Νικόλαος] (1706/1710-1772/1773), Konstantinou Georgios [Κωνσταντίνου Γεώργιος] (1710/1730-1786/1803), Fatzeas Georgios [Φατζέας Γεώργιος] (1710-1768/1780), Moschopoulos Antonios [Μοσχόπουλος Αντώνιος] (1713-1788), Voulgaris Evgenios [Βούλγαρης Ευγένιος] (1716-1806), Kontonis Ioannis [Κοντονής Ιωάννης] (1723-1761), Moisiodax Iosipos [Μοισιόδαξ Ιώσηπος] (1725-1800), Karaioannis Konstantinos

[Καραϊωάννης Κωνσταντίνος] (1730/1735-1800/1820), Mandakasis Thomas [Μανδακάσης Θωμάς] (1730/1740-1800/1820), Kyprianos, archimandrite [Κυπριανός αρχιμανδρίτης] (1730/1740-1802/1805), Adamis Ioannis [Αδάμης Ιωάννης] (1730-1800), Theotokis Nikiforos [Θεοτόκης Νικηφόρος] (1731-1800), Balanos Kosmas [Μπαλάνος Κοσμάς] (1731-1807/1808), Charvouris Markos [Χαρβούρης Μάρκος] (1731-1808), Tsoulatis Aggelos [Τσουλάτης Άγγελος] (1732-1798), Iliadis Manasis [Ηλιάδης Μανασής] (1733-1785), Pamplekis Christodoulos [Παμπλέκης Χριστόδουλος] (1733-1793), Makraeos Sergios [Μακραίος Σέργιος] (1734/1740-1819), Karakasis Dimitrios [Καρακάσης Δημήτριος] (1734-1800), Pezaros Ioannis [Πέζαρος Ιωάννης] (1740/1750-1806), Tzechanis Konstantinos [Τζεχάνης Κωνσταντίνος] (1740-1800), Skiadas Michael [Σκιαδάς Μιχαήλ] (1740-1802), Zaviras Georgios [Ζαβίρας Γεώργιος] (1744-1804), Doukas Konstantinos [Δούκας Κωνσταντίνος] (1745/1755-1815/1825), Asanis Spyridon [Ασάνης Σπυρίδων] (1749/1756-1833/1836), Kodrikas Panagiotis [Κοδρικάς Παναγιώτης] (1750/1755-1827), Kavras Zisis [Κάβρας Ζήσης] (1750/1770-1844), Polychronios of Thrace [Πολυχρόνιος ο Θραξ] (1752-1800/1830), Konstantas Gregorios [Κωνσταντάς Γρηγόριος] (1753/1758-1844), Vardalachos Konstantinos [Βαρδαλάχος Κωνσταντίνος] (1755-1830), Filippidis Daniel [Φιλιππίδης Δανιήλ] (1755-1832), Rigas Velestinlis [Ρήγας Βελεστινλής] (1757-1798), Darvaris Dimitrios [Δάρβαρις Δημήτριος] (1757-1833), Gazis Anthimos [Γαζής Άνθιμος] (1758-1828), Veniamin of Lesvos [Βενιαμίν Λέσβιος] (1759/1762-1824), Sparmiotis Ionas [Σπαρμιώτης Ιωνάς] (1760/1780-1830), Dougas Stefanos [Δούγκας Στέφανος] (1765/1770-1830), Govdelas Michael [Γοβδελάς Μιχαήλ] (1770/1790-1820/1860), Kommetas Stefanos [Κομμητάς Στέφανος] (1770-1830/1834), Christaris Michael [Χρησταρής Μιχαήλ] (1773-1831), Pyrros Dionysios [Πύρρος Διονύσιος] (1774/1777-1853), Stageiritis Athanasios [Σταγειρίτης Αθανάσιος] (1775/1785-1835/1845), Kyrillos, patriarch of Constantinople [Κύριλλος πατριάρχης Κωνσταντινουπόλεως] (1775-1821), Koumas Konstantinos [Κούμας Κωνσταντίνος] (1777-1836), Govdelas Dimitrios [Γοβδελάς Δημήτριος] (1780-1831), Kokkinakis Konstantinos [Κοκκινάκης Κωνσταντίνος] (1781-1831), Alexandridis Dimitrios [Αλεξανδρίδης Δημήτριος] (1784-1851).

[4] "Vague information" is always a problem for databases. In my study, this became more than obvious in the case of time: Very often I had to deal either with disagreements of the sources or with indefinite information like this: "Towards the end of the eighteenth century he visited Venice for a few years" or "He flourished in the first half of the eighteenth century." We tend to overlook the hazy character of such statements when we read a textbook or a primary source, but this same character becomes truly problematic when we try to put information in a strict order. In such cases I tried to define the proper "bandwidth," in order to maintain as much accuracy as possible. The result of this decision was a kind of quantum paradox: The same persons appeared to be simultaneously in different places. From a statistical point of view, however, these overlaps did not affect the results of my study, since the accumulation of information cancels the circumstantial character of such approximations.

[5] Based on the map published in *Ιστορία του Ελληνικού Έθνους, op. cit.* (1), 232-233. Courtesy of Ekdotiki Athinon.

[6] This scholar is Iosipos Misiodax, who originated in Chernavoda, Wallachia.

[7] On this subject see O. Cicanci, "Le rôle de Vienne dans les rapports économiques et culturels du Sud-Est européen avec le Centre de l'Europe," *Revue des Études sud-est européenes,* 24 (1986), 3-16 and especially the thorough study of Traian Stoianovich on

the territorial expansion of "The conquering Balkan Orthodox merchant," *Journal of Economic History,* 20 (1960), 234-313.

8 Ariadna Camariano-Cioran has specifically studied the migration of Epirotes to the Romanian countries. See Ar. Camariano-Cioran, *Contributions à l'histoire des relations Gréco-Roumaines. L'Empire et les pays Roumains* (Jannina, 1984). On the penetration of Greek culture to these countries see the first chapter of her other significant study, *Les Academies Princieres de Bucarest et de Jassy et leur professeurs* (Thessaloniki: Institute for Balkan Studies, 1974).

9 One aspect of this situation is studied by Olga Kastiardi-Hering in her paper on "The cure of multilingualism." See Ό. Κατσιαρδή-Hering, "Εκπαίδευση στη Διασπορά. Προς μια παιδεία ελληνική ή προς 'θεραπεία' της πολυγλωσσίας;" in *Νεοελληνική Παιδεία και Κοινωνία. Πρακτικά Διεθνούς Συνεδρίου αφιερωμένου στη μνήμη του Κ.Θ. Δημαρά,* (Athens: Όμιλος μελέτης του ελληνικού Διαφωτισμού, 1995), 153-177. The predominance of the Greek language in commercial and intellectual transactions of the period brought about serious political debates which, starting from educational issues, came to affect discussions about the cultural profile of various Orthodox populations of the Balkans.

10 The presence of Venice in the Ionian Islands was consolidated during the second Turkish-Venetian war between 1499 and 1503. The island of Lefkas, which came under Venetian domination with the treaty of Karlowitz, in 1699, was the only exception. However, as early as 1669, the Venetian Republic was compelled to yield Crete to the Ottomans, and this event marked the beginning of the decline of its power in the broader area of the Eastern Mediterranean. With the treaty of Passarowitz in 1718, Venice lost all its acquisitions in the Balkans except for the Ionian Islands. The subtle balance of power in the international scene and the simultaneous decline of the Ottoman Empire allowed the weak Republic to maintain the Ionian Islands until 1797, when Napoleon's troops arrived on the islands. For a detailed review of the changes of Venetian domination in the Greek-speaking areas of the Balkans, see Αν. Παπαδία-Λάλα, "Οι Έλληνες και η βενετική πραγματικότητα: Ιδεολογική και κοινωνική συγκρότηση" in Χρ. Α. Μαλτέζου, ed., *Όψεις της Ιστορίας του Βενετοκρατούμενου Ελληνισμού. Αρχειακά Τεκμήρια* (Athens: Ίδρυμα Ελληνικού Πολιτισμού, 1993), pp. 173-214, pp. 178-181.

11 Which cannot be grouped, however, since many Aegean islands changed hands between the Ottomans and the Venetians over the course of time. On the other hand, although it is clear that the Archipelago was a cultural crossroads rather than a culturally homogeneous region, both the islands and the western coast of Turkey are unified on the basis of a common characteristic that gives them a distinctive position in our study. As we shall see below, they comprised the main sphere of political influence of Fanariots and, in this capacity, a passage towards the centres of power of Constantinople.

12 With the exception of the visits paid to Peloponnese and Athens area, which appear to be a special case, from the point of view our study. 13 scholars paid 24 visits in the region, but more than half of those visits took place after 1813 and were motivated by political pursuits related to the Greek war of independence. In this sense, the intellectual travels to the Athens area and Peloponnese that actually come under the scope of my study are very few.

13 Παπαδία-Λάλα, *op. cit.* (10), pp. 182-183. The positive disposition towards the Venetians, however, was not a generic feature of those societies: the positive attitude was mostly associated with the higher social classes and the intellectuals who took advantage of the Venetian administration in order to promote their interests and improve their social

position (but they also put themselves in danger when the Ottomans took over). On the other hand, the attitude of the lower classes towards the Venetians was not always positive. Due to the despotic rule of many local governors, the poor people often favoured the advent of the Ottomans. This trend was encouraged by the (usually honest) declarations of the latter that they would secure religious tolerance and restore social justice (Παπαδία-Λάλα, *op. cit.* (10), pp. 183-184).

[14] Αγ. Πανοπούλου, "Οι Βενετοί και η ελληνική πραγματικότητα: Διοικητική, εκκλησιαστική, οικονομική οργάνωση" in Χρ. Α. Μαλτέζου, ed., *Όψεις της Ιστορίας του Βενετοκρατούμενου Ελληνισμού. Αρχειακά Τεκμήρια* (Athens: Ίδρυμα Ελληνικού Πολιτισμού, 1993), pp. 277-313, pp. 288-289 and 293.

[15] A potentially unknown word: Uniat means a trend within the bosom of the Eastern Orthodox Church aiming at union with the Roman Catholic Church. This trend — systematically encouraged by the various Catholic missions in the broader Balkan area — acknowledges the supremacy of the Roman pope in matters of faith, but maintains the Eastern liturgy, discipline, and rite.

[16] In 1670 the printing house of Glikis, in 1685 the printing house of Saros, and in 1755 the printing house of Theodosiou.

[17] Κ. Γ. Τσικνάκης, "Ο Ελληνισμός της Βενετίας (13ος-18ος αιώνας)" in Χρ. Α. Μαλτέζου, ed., *Όψεις της Ιστορίας του Βενετοκρατούμενου Ελληνισμού. Αρχειακά Τεκμήρια* (Athens: Ίδρυμα Ελληνικού Πολιτισμού, 1993), pp. 519-556, p. 546. See also the comprehensive study of G.Veloudis on the printing house of Glikis, *Das griechische Druck und Verlagshaus "Glikis" in Venedig (1670-1854)* (Wiesbaden, 1974).

[18] On the causes of migration see Stoianovich, *op. cit.* (7), esp. pp. 260-262.

[19] Κατσιαρδή-Hering, *op. cit.* (9).

[20] Stoianovich, *op. cit.* (7), 278; Σπ. Λουκάτος, "Ο πολιτικός βίος των Ελλήνων της Βιέννης κατά την Τουρκοκρατίαν και τα αυτοκρατορικά προς αυτούς προνόμια," *Δελτίον της Ιστορικής και Εθνολογικής Εταιρείας της Ελλάδος,* 15 (1961), 287-350 and 293-297; Cicanci, *op. cit.* (7), 5-6.

[21] Λουκάτος, *op. cit.* (20).

[22] The host of most of those scholars being the community of Ottoman subjects (Λουκάτος, *op. cit.* (20), 304).

[23] "Το εργαστήριον της νέας των Γραικών Φιλολογίας" ("The laboratory of the new philology of the Greeks"), as Korais (1748-1833), an important Greek savant and publisher of the early nineteenth century, commented in 1805. Details on this issue in K. Sp. Staikos, *Die in Wien Gedruckten Griechischen Bücher (1749-1800)* (Athens: Ίδρυμα Ελληνικού Πολιτισμού, 1995).

[24] The Greek school of Vienna was established in 1804 but it actually started working only 12 years later. Moreover, it was an elementary school aiming mostly at the offspring of Greek-speaking merchants who wished to acquire the necessary education in order to continue their fathers' enterprises. (Λουκάτος, *op. cit.* (20), 326-332). On the other hand, the University of Vienna, established in 1365, was a prestigious institution which, however, never drew the attention of Greek scholars. Notwithstanding their frequent visits to the city and their intense intellectual explorations, we have very little evidence that any of them studied systematically at the University.

[25] Cicanci, *op. cit.* (7), 16.

[26] See, for example, the reservations of Traian Stoianovich in *op. cit.* (7), 306-312.

[27] Stoianovich, *op. cit.* (7), 261-262.

[28] And, as seen above, of the equally Catholic University of Vienna.

[29] A telling example is the friendship between Evgenios Voulgaris (1716-1806) and Johann Andreas von Segner (1704-1777) during the former's stay at Leipzig. The contact between the two men led to the translation of Segner's *Elementa arithmeticae et geometriae* into Greek by Voulgaris himself.

[30] The remaining 11 visits in the first case, and 43 in the second, mainly concern internal travels of young people aiming to obtain elementary education in the Greek-speaking schools of the broader area. Several of these schools had quite an advanced curriculum, including philosophical and scientific lessons. Most of the scholars who studied privately in Venice, Vienna and the German cities had already been acquainted with philosophy and the sciences in such local schools. Another area that received quite a few visits for similar reasons was Athos, which belongs to the intermediate cases of our diagram above. The school of Athos became famous under the directorship of Evgenios Voulgaris, between 1753 and 1759. According to our statistics Athos received 11 visits paid by 11 scholars and the purpose of most of them was related to the function of the school — teaching or studies. What makes this limited number of visits important is that those 11 scholars were some of the most influential scholars of the Greek eighteenth century.

[31] In five cases, where the exact place of death was unknown, the last place visited has been used instead.

[32] In the Ottoman Empire it was often the case that the acquisition of wealth was easier than the consolidation and transfer of it to future generations.

[33] Stoianovich, *op. cit.* (7), 269-271.

BERNA KILINÇ

YİRMİSEKİZ MEHMED ÇELEBİ'S TRAVELOGUE AND THE WONDERS THAT MAKE A SCIENTIFIC CENTRE

"His curiosity is not limited only to flowers; it led him to all the sanctuaries of sciences. He saw the monastery of Saint-Denis, the Observatory, the school of medicine and surgery; he was even present at the Sorbonne on the 8th of July and was received by the doctors and the *bacheliers* in furs and ceremonial cloths."[1] This entry from the Parisian monthly *Le Nouveau Mercure* (the June and July 1721 issues) described Yirmisekiz Mehmed Çelebi, the Ottoman special envoy to France, whose embassy report contains one of the earliest Ottoman accounts of European arts and sciences. Although he had been sent to the court of Louis XV on a diplomatic mission, it is no accident that Mehmed Çelebi's report contained numerous observations on the state of arts and sciences, for he was also enjoined by the grand-vizier "to visit the fortresses, factories and the works of French civilization generally and report on those capable of application."[2] Mehmed Çelebi's long itinerary for his short trip in 1720-1 encompassed many such sites, from mirror workshops, the Opera, the palaces and gardens of Saint-Cloud, Meudon, Versailles, Marly and Chantilly, to the new learned institutions of early modern Europe, the botanic gardens and the Paris Observatory. Documenting an encounter between two cultures, Mehmed Çelebi's report bears witness to the formation of a scientific centre in Paris, one of the most vigorous in Europe at the time. It is at the same time a valuable source for the historian who seeks to understand scientific travels, and the related issue of how science travels.

With a view to delineating the modes of interaction between the centres and peripheries of epistemic cultures, I examine in this essay some aspects of

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the two cultures Mehmed Çelebi travelled through which both enabled and disabled his appreciation of sciences and technology. I use "epistemic culture" in a broad manner to cover a variety of ways philosophers and sociologists of science have identified the collectivity of scientific activity—disciplinary matrices, research traditions, thought collectives and the like. Abstracting from the individuals and the intellectual products which nourish scientific activity, practice oriented accounts of science raise the question of what scientific travels can accomplish. Socialization into an epistemic culture usually takes place through prolonged contact, by the shared experience of education and training, and by the securing of these ties through professional affiliations and values. Can this collectivity be accessed by an individual during her ephemeral existence in the places in which scientific research is carried out? How can an epistemic culture become a site of travel?

One answer to these questions is suggested in Bruno Latour's account of the nature of a scientific centre. According to Latour, a scientific centre evolves out of a continuous information flow from the world at large. Information is retrieved in the form of material traces, be they notes, specimens, or antiquities, wrenched out of their local habitats. Centres are where these collections are accumulated and assembled into universal representations, usually in the form of comprehensive scientific theories.[3] Numerous observations in Mehmed Çelebi's report bear on this collection activity. I draw upon Latour's account and generalize from Mehmed Çelebi's experience in order to suggest that one way in which an epistemic culture can become a site of travel is through its material existence. To this end, I investigate what Mehmed Çelebi absorbed during his stay and what he brought back with him. Given his standing as a statesman rather than a scholar, a question of a counterfactual nature will be also raised: What could Mehmed Çelebi have brought back in order to launch a scientific centre in Istanbul? Would the transmission of material goods have sufficed to create an epistemic culture in the Ottoman realm akin to those in France?

Material transportation does not suffice, for scientific centres are characterized no less by their material riches than by the representations they generate. Representations cannot be transported with the same ease—students, and not just any middlemen, zigzag through the centres and peripheries of scientific cultures. Whether artistic or scientific, their appreciation is culture bound. More precisely, styles of representation can create boundaries within or without others—such as national, religious or professional boundaries—which shape individual expression and receptivity. A salient component of Mehmed Çelebi's aesthetic appreciation of French cultural displays had to do with realism, with mimetic likeness in the case of art works, verisimilitude in the case of scientific or technological reproductions. That aesthetic value disrupts a facile generalization one is tempted to make regarding the cultural boundaries that separate those participating in the predominantly aniconic aesthetics of the Ottoman-Muslim realm from those engaged in the aesthetics of realism prevalent in Europe. Mehmed Çelebi's travelogue indicates that such a boundary, if it exists at all, does not seem to be rigid. An examination of this artistic-cum-scientific sensibility complements the first part of the paper, by attending to the selective pressures which regulate the activity of collection.

1. MEHMED ÇELEBİ'S MISSION

The embassy in Paris is an indicator of the changing course of Ottoman-European relations at the beginning of the eighteenth century. Ottoman military aspirations having been checked in two key events of the seventeenth century—the failed siege of Vienna in 1683, and the Karlowitz peace treaty in 1699—the Ottoman ruling elite began seeking diplomatic rapprochement with some of the European states. Mehmed Çelebi's mission was conceived in a relatively peaceful climate, in an epoch of recovery from the wars of the previous century, at least as far as the western frontiers of the Ottoman Empire were concerned. Characterized by some historians as the culmination of urban and courtly culture, the period from 1718 to 1730 has been called the "Tulip Period"—because of the fad for tulips—coterminous with the reign of Ahmed III's grand-vizier, Nevşehirli İbrahim Paşa. Partly due to the latter's patronage, the cultural life of the capital Istanbul was marked in this period by the advent of new forms of pleasure pursuits and secularist aspirations. With the late sixteenth century Ottoman downturn and the gradual reversal of the balance of power with European states, many historians trace the beginning of Ottoman westernising trends to this period, trends involving the acknowledgment and the emulation of some aspects of the social organization of powerful European states. The impact of Mehmed Çelebi's travelogue, disseminated both by his manuscript and by oral communication, is judged to be significant in this development.[4]

Yirmisekiz Mehmed Çelebi (c.1670-1732) was a statesman with a military background, promoted to the rank of "chief accountant" in 1719 at the time he was appointed as an ambassador to France. The son of a colonel in the army (Gürcü Süleyman Ağa), he is believed to have attended the school for pages of the imperial palace, after which he became a member of the 28th regiment of the Janissaries, the imperial army, whence the appellation "yirmisekiz," meaning "twenty-eight," prefixed to his name. He was considered to be a cultivated man, composing poetry with the pseudonym of Feyzi, but the venues of his formal education are not known.[5]

The official reason for dispatching an embassy, an institution that was not conceived by the Ottomans in permanent terms until the end of the eighteenth century, was to authorize the French government to repair the Church of the Holy Sepulchre in Jerusalem. A few other items on the official agenda notwithstanding, it is suspected that some ulterior motives may have been the real grounds for the grand-vizier İbrahim Paşa's decision to send an envoy, the chief one being the search for an ally against Austria. Perhaps no less important a motive was to gain first-hand observations on the social and cultural life of a mighty European state, the distance of which lessened the likelihood of imminent hostilities with the Ottoman state. The extent to which this motive also bears on scientific activity will be evaluated in the conclusion.

In the first quarter of the eighteenth century Paris was one of the major scientific centres of Europe. The establishment of the French Academy of Sciences in 1666 and the Paris Observatory in 1669, both under the patronage of Louis XIV, were turning points in the organization of scientific research around problems and projects carried out by the intensified effort of mathematicians, natural historians and natural philosophers.[6] On the agenda of the latter were problems such as determining longitude at sea, drawing the cartography of France, the construction of the air-pump, the reflecting telescope, optimum design of gun-carriages, and issues related to the constitution of light, hydraulics and mechanics. Under the supervision of the Italian astronomer Gian Domenico Cassini, observatory research focused on the codification of the motions of the moon and of Jupiter's satellites, and the measurement of a degree of the meridian near Paris. At the turn of the eighteenth century, the Academy also assumed a role in certifying new inventions. The result was the deposition of various instruments and plans, such as those for finding a ship's longitude at sea or for removing the salt from seawater. With state sponsorship of very costly instruments, the Paris Observatory was considered to be the European centre of excellence in its field.

Mehmed Çelebi started from Istanbul on 7 October 1720, to return a year later, on 8 October 1721. Accompanying him was his son, Said Efendi, also a statesman at that time, and a retinue of about one hundred men. They reached Paris after a long trip on sea and land, lasting about six months, part of which—39 days—was spent in quarantine at Maguelone. Transportation for the trip, including the sailboats, was provided by the French government.

Mehmed Çelebi spent only five months in Paris, from 8 March 1721 to 7 September 1721.[7]

2. THE LAND OF WONDERS

Upon his return Mehmed Çelebi completed his mission by submitting to the court of Ahmed III an embassy report—called "sefaretname" in Ottoman Turkish. An edited version of his original report to the court of Ahmed III, Mehmed Çelebi's manuscript, to be referred to from now on as *Sefaretname*, was later produced for circulation among the Ottoman elite.[8] *Sefaretname* is a strange mixture of official report and travelogue, a subspecies of a diary, written for the most part in chronological order. One of its peculiarities is the absence of the first-person singular voice, except for a few occasions.[9] Mostly the narrator writes in the first-person plural, which may sometimes refer to Mehmed Çelebi and his retinue (or a part thereof), but often simply to Mehmed Çelebi, the single person. Literary analysts of scientific texts are familiar with this use of the first-person plural. Even when the author of a text is a single person, the use of the plural conveys a sense of objectivity deriving from the anonymity of the agent. Facts or judgments reported from a first-person plural stance are more likely to be considered true, because they appear not to be the exclusive opinion of an esoteric community, but to be publicly observable and possibly replicable.

A similar effect is achieved by Mehmed Çelebi's systematic suppression of the first-person singular in his narration, but that effect was not necessarily conceived for the above reasons. The first-person plural stance was typical of Ottoman embassy reports.[10] Mehmed Çelebi is one of the earliest exponents of this type of writing, perhaps constituting a precedent for the following generations of statesmen.[11] However, not all aspects of his narrative conform to the conventions of this genre. Embassy reports, whether they were special ones focusing on a particular deal or of a more general nature like Mehmed Çelebi's, which contained a jumble of impressions, were usually written in an impersonal and sober tone, with a maximum of factual information and a minimum of personal expression. They completed the diplomatic mission with an efficient summary, registering important names, dates and the like, with little or no disclosure of personal emotions. Mehmed Çelebi's text stands out in this genre for its presentation of personal affect. Of course, given the absence of the first-person authorial voice in the text, one should be cautious about attributing these emotions to Mehmed Çelebi alone. However, in order not to lose sight of the spontaneity of experiential presence breaking through the official collective agent's vantage point, I will leave that caution aside, and refer to Mehmed Çelebi as the author of the text and the individual bearer of the emotions.

The emotion that dominated Mehmed Çelebi's account was wonder, oscillating between the two extremes with which its invocation can be associated. These are, on the one hand, wondrous, extraordinary and pleasurable, thus deserving reverence and approbation; and on the other hand, strange, weird and uncanny, which may lead to bewilderment if not to fear. Often expressing despair that "he had witnessed so many wondrous and strange things that he cannot relate them all," Mehmed Çelebi frequently used Ottoman adjectives in this context—*acaip*, *tuhaf*, *garip*—that qualify the object of wonder, and have these two sets of connotations.[12] The church organ, the phenomenon of ebb and flow, or the glitter of women shining in valuable jewellery and ostentatious gowns at the opera, constitute only a sample of the objects or events arousing Mehmed Çelebi's feelings. These were sometimes natural things, such as the giant pearl he had earlier heard about (which allegedly never stood still on a flat mirror, because it was such a perfect sphere), but often artificial objects, like the garden fountains of unusual scale and lavishness, embodying fine workmanship and organized labour.[13]

Occupying the middle ground between the natural and the artificial, one set of wonderful things had to do with gardens: Mehmed Çelebi was often intoxicated by the beauty of the gardens he was escorted to, praising at length the spectacle of the vast, highly geometric landscape design, with intricately planted plots adorned by garden pavilions, water cascades and fountains. The visual gratification, and more generally the sensory pleasure he derived from the French gardens, even more splendid and joyful during the time of his stay from spring to autumn, was probably in step with the new aesthetic disposition of the Tulip Period towards garden culture.[14] Another set of wonders had to do with the aesthetics of realism, and will be discussed in the next section. I shall first examine some salient features of Mehmed Çelebi's engagement with wonder.

The first has to do with Mehmed Çelebi's ability to express the rare things he had seen. Mehmed Çelebi frequently deplored the inadequacy of language to communicate the things he had witnessed, as when he noted the beauty of Versailles, or the strangeness of some fauna and flora. The many plants, animals or minerals he had encountered had no counterparts in his experience.[15] That is perhaps why there is no extensive detailing, but only passing mention, of the cabinets of curiosities he was shown. That several of his hosts proudly guided him to such cabinets is certain. *Le Mercure* of August 1721 reported, approvingly, how the minister from the Orient had displayed a European taste, visiting "all the places that are sought by an enlightened curiosity," the chief among them being the cabinets of curiosities and selected libraries. According to the report, Mehmed Çelebi visited Pajot d'Ozembray, the general director of the postal service and an honorary member of the Academy of Sciences, who showed him his cabinet, containing "a prodigious number of curiosities, pertaining to all parts of physics and natural history." A precursor of two modern institutions, the museum and the laboratory, such cabinets were also places for displaying strange phenomena and processes. On this particular visit, Mehmed Çelebi was honoured by the performance of chemical experiments that involved "the mixing of liquids which produced fermentation and colour changes." He, in turn, pleased his hosts by expressing the full satisfaction he had derived from this exhibition. Also on display were assorted specimens of phosphorus, the different illuminations of which took Mehmed Çelebi pleasantly by surprise. Mehmed Çelebi was also reported to have carefully inspected several models of machinery, and a vast number of illustrations of plants and animals, as well as wax models of anatomical parts.[16]

Mehmed Çelebi's report does not contain any information on these encounters. A cabinet he visited, belonging to the regent Philippe d'Orleans, struck him as filled with such rarities that he was simply unable to describe them.[17] Having grown up in the Spartan interiors of Ottoman households, and being unaccustomed to the kind of consumerism underlying the French passion for possessions, Mehmed Çelebi probably found it strange that such displays, somewhat decorative in function, and bespeaking the magnificence of their patrons, the aristocrats and the bourgeois gentlemen, were among their most cherished belongings.[18] Mehmed Çelebi did not realize that such cabinets of natural and artificial curiosities also played a crucial role in the evolution of new scientific sensibilities in early modern Europe. Chief among them was a new brand of empiricism, which could countenance the power of strange particulars to undermine or reshuffle received systems of taxonomical beliefs.[19]

Mehmed Çelebi did not dwell on the cabinets of curiosities, partly because the items therein defied description. Yet, struck by the opulence and the power of the country he visited, he augmented several of his observations by an approximate quantification of this wealth. *Sefaretname* is replete with estimations of size and number: the number of labourers at the royal manufacturers of the Gobelin tapestries and the Saint-Gobain mirrors; the number of beds and attendants at the veterans' hospital at the Invalides, the number and sizes of the fountains at Versailles; the number of candles used to illuminate the opera hall or the garden festivities. Mehmed Çelebi even noted the number of steps in the stairways, about one hundred and twenty five, at the famous machine drawing water from the Seine.[20] He attempted a rough comparison of the populations of Istanbul and Paris, adjusting his first impression that Paris was more crowded by taking into account the wider participation there of women in public life.[21] Apparently he gave up with his approximation methods at the pharmaceutical complex of the King's garden, noting that the many samples of roots, minerals and the like in the collection were simply uncountable.[22] Similarly at the botanical garden, the collection of trees and plants appeared beyond the pale of finite numbers.[23] The power and the wealth of the country he was visiting struck him not only through the mirabilia of arts and collections, but also through numbers—numbers indicating craftsmanship, labour and social organization responsible for these displays of magnificence. Mehmed Çelebi's tract provides statistics of this organization, when the term is understood in its original sense as having to do with information useful for the state, and not necessarily with precise and exhaustive counts.[24] As an accountant, Mehmed Çelebi was perfectly fit to be a statistician for the early modern Ottoman state.

What also struck Mehmed Çelebi about these innumerably large collections was the variety of distant lands the items were transported from. In the pharmacological building of the King's garden, he noted, "there was nothing missing of all the possible drugs produced in the world." The French had "collected so many land and marine wonders among trees, minerals and salts" that it was impossible to count them.[25] Similarly, he noted at the botanical garden that they had brought every possible plant the medical books mentioned, even those growing in Persia, Uzbek lands, China, India and especially in the New World. He thus intimated the wider experience of nature made possible by these collections.

3. THE POWER OF REPRESENTATION

One aspect of Mehmed Çelebi's fascination with the novelties he had witnessed concerned what can be broadly called the power of representation. An appreciation of the mimetic qualities of various crafts constituted an important dimension of Mehmed Çelebi's estimation not only of artworks but at the same time of scientific products. One of the first set of objects he was thus struck by were the relief maps of the major fortresses of the country—described as totalling one hundred and twenty, each one as large as a sofa, and apparently very costly.[26] Appreciating the three-dimensionality of those maps, Mehmed Çelebi admired the way one could behold a view of the hills and the plains around a fortress down to the very details of trees and meadows, the direction of water streams, the bridges and the houses with their windows. Viewing a map was like strolling around the very surroundings it depicted.[27] Simply by examining these maps, one could easily attain a sufficient degree of knowledge about the surroundings of each fortress. The maps produced a virtual reality especially well suited, in Mehmed Çelebi's eyes, to military decision-making.

Mehmed Çelebi was equally captivated by the tapestry collection at the royal manufacturers of the Gobelin in Paris—he estimated that more than one hundred items were displayed on the walls during his visit. Mehmed Çelebi was stunned by the realism of the designs, calling attention to "flowers embroidered as if they were alive within a glass jar." He added that "the eyes, the eyelids and eyebrows, especially the hair and the beard in the portrayal of people were so well done that neither Mani nor Behzad were capable of such artistry working on rice paper."[28] Besides the physiognomic features conveyed in these tapestries, Mehmed Çelebi was struck by the lifelikeness of the emotions woven into this medium, noting that sadness, fear, pain or crying were depicted in such a manner that they could be immediately grasped as such by a viewer.[29]

Another art form that deeply astonished Mehmed Çelebi for its evocative and realistic qualities was the opera, the essence of which was, in his formulation, "the depiction of a story in three dimensions."[30] Two aspects of the opera (performed by the Royal Academy of Music in the hall of the Palais-Royal) were particularly astounding: the stage decors and the acting. Mehmed Çelebi reported that each scene appeared all of a sudden in a setting recreating a real life location: a palace, a garden, or a church. Mehmed Çelebi was stupefied by the reproduction of lightning and thunder, so like their natural counterparts. The cast of performers invoked feelings of love in such a convincing manner that, according to Mehmed Çelebi one's heart would crush in pain with empathy. At another performance, accompanying the King at the grand hall of the Louvre, Mehmed Çelebi praised the stage decor again, especially the emulation of the sun by a golden centrepiece which reflected candles lit around it like sunshine.[31]

Mehmed Çelebi did not confine his praise of wondrous instances of convincing representation to works of art. More precisely, he did not reserve mimetic quality as a criterion exclusively for the appreciation of art works; he equally praised technological novelties and scientific products for their excellence at producing verisimilitude. At the King's garden (the future Museum of Natural History), he admired the anatomical displays of animals as well as humans. Some, he noted, like the pieces of an elephant skeleton, were displayed with the help of wires in an erect position, as if the animal were on its feet. He praised the care with which wax models of human bodies were prepared, exhibiting the veins, the nerves, the fat and the flesh. He pointed out that even the colours of the veins and the nerves were like their real counterparts.[32] Touring the garden further, Mehmed Çelebi marvelled at the way the climates of the New World were recreated in glass walled quarters for the cultivation of plants brought from those lands. In winter, he reported, workers heated those places with so much care and skill as to imitate exactly the conditions of the New World.[33]

A variety of mediums, from tapestries and greenhouses to scientific instruments, could conjure up realities in their specific manners. At the Paris Observatory Mehmed Çelebi saw a great number of scientific instruments, and was able to classify them into those for "watching the stars or the phases of the moon" and those for practical hydraulics and statics, but he admitted failure at describing innumerable others since they were so unique. The first observatory in Istanbul had been established in 1574, but was pulled down soon afterwards in 1595 due to the opposition of the clergy.[34] This must have been Mehmed Çelebi's first visit to an observatory.[35] Could a man of general education, such as Mehmed Çelebi, appreciate the point of concentrating so much scientific labour and capital on detailed observation of the skies? Mehmed Çelebi seems to have done so. With a utilitarian point of view, Mehmed Çelebi noted how some of the astronomical instruments could rapidly turn ignorant men into scholars. They had this pedagogical value because they "made visible what could be only imagined."[36] Mehmed Çelebi dwelled particularly on one instrument for representing the solar and the lunar eclipses. He was amazed that this mechanical model could be used to predict not only the times but also the shape of the occultations of future eclipses, just by tracing the motion of a small "coin-like" piece attached to something like a "watch hand." Apparently he did not perceive an immediate likeness between the instrument and the reality it purported to model.[37]

There is no indication in the *Sefaretname* whether Mehmed Çelebi was familiar with the revolution in early modern astronomy, whether, for instance, he knew of the rivalry between the earth-centred and the sun-centred models of the universe.[38] With the evidence at hand, we cannot determine whether Mehmed Çelebi's bewilderment over the mechanical model he described was due to his commitment to a geostatic model of the universe, or whether he had any exchange on the point with the head of the observatory, Jacques Cassini. Before the full establishment of the Newtonian theory of gravitation, along with the concepts of space and time it promoted, there were rival paradigms rendering the mobility of celestial objects either illusionary or relative or real depending on different philosophical theories of space and time. Although Newton's groundbreaking work, *Philosophiae Naturalis Principia Mathematica,* appeared in 1687, his reception on the continent was slow, with serious opposition from the Cartesians in France continuing well into the 1730s.[39] Both Jacques Cassini and his father, Gian Domenico Cassini, the first director of the observatory, were firm followers of the Cartesian mechanical philosophy, and had serious reservations about the heliostatic system of the Copernicans.[40] It is therefore another matter for speculation whether Mehmed Çelebi would have been told in the observatory that the mechanical model in question indeed provided a truthful representation of the motions in the solar system.

Mehmed Çelebi's perplexity over the scale model of the solar system gave way to admiration for instrumental ingenuity when he was shown the models for predicting the positions of the satellites of Jupiter. Possibly the latter scale model of a planet appeared more realistic to Mehmed Çelebi than the former one, involving as it did the somewhat counterintuitive idea of the motion of the earth. He was convinced of the truth of what he was told and partially shown, that the satellites of Jupiter revolved once on their axes while Jupiter was completing one revolution on its axis—a fact he thought was remarkable, and showed what God was capable of designing.[41]

At the Paris Observatory, Mehmed Çelebi made observations with the telescope. He had used at least a rudimentary form of the instrument, probably a spyglass, during his long sea journey aboard French sailboats—his very depiction of the telescope involves naval imagery.[42] He did not at all doubt that the images he saw through the telescope were veridical. Viewing the moon, he thought it was plausible that the moon's surface was rugged like the earth's, and that there were valleys and deserts, as he could infer from the distribution of shadows. His immediate consent to the revelations of the telescope was probably not simply an affirmation of what the astronomers at the observatory told him. For instance, he reported that he had not detected any water or trees on the lunar surface, though many French scholars, he was told, had proclaimed their existence.[43] More than a century after Galileo made his first observations of the skies with a telescope, the reliability of telescopic observations was already well entrenched among European scholars. Galileo and his contemporaries, however, had to quiet much opposition and many qualms about the veracity of instrumentally mediated experience of the heavens.[44] What is surprising is that Mehmed Çelebi had no such qualms; nor did he seem to be wanting in the skills of observation with the aid of this instrument. That is not to say that his depiction of the lunar surface would not have appeared distasteful to his scholarly hosts. He noted: "We witnessed that its surface looked exactly like the appearance of a loaf of bread with spongy interiors sliced into two."[45] There is no indication in Mehmed Çelebi's report of difficulties in communication (with the help of his interpreter) with the astronomers or other learned men he had met. We cannot assume that there was frictionless communication between the Ottoman and his European hosts. Yet Mehmed Çelebi's travelogue indicates that there was a surprising resonance between his ordinary experience and the experience constituted by the new techniques of observation.

Mehmed Çelebi grew up in a cultural milieu which usually avoided figural imagery in public settings. But whether his artistic expectations completely diverged from those of his French hosts cannot be established with certainty. Despite the disapproval of orthodox Islamic tradition for mimetic representation after the eighth century, aniconism was not universal in the Muslim realm. Portraiture, with an emphasis on the aesthetic importance of verisimilitude, was a thriving art form at the Timurid court in the fourteenth century, and it had a following among the Ottoman court artists as well.[46] To this must be added the various graphic illustrations in scholarly manuscripts, for instance, those in Katip Çelebi's *Cihannuma* alluded to above. Even though Mehmed Çelebi was silent on the portrait galleries he had seen, or the sculptures he must have viewed, he did not observe any strict allegiance to Islamic censorship on mimetic figural representations. While out of respect for this censorship the minor King Louis XV did not present his portrait to Mehmed Çelebi, thereby breaking the custom for gift exchange with diplomatic envoys, Mehmed Çelebi for his part had no qualms about posing for the French artists painting his portrait.[47] Some forms of European visual culture were probably more readily accessible to Mehmed Çelebi, but this did not prevent him from developing an appreciation for descriptive realism which was applicable to tapestries, acting and instrumental representations alike.

Mehmed Çelebi's sensitivity to realism, perhaps heightened by his prior experience of other conventions of lifelikeness, indicates, if not a shared element between the two cultures, at least fluidity in the boundaries separating them. His conversion to the value of realism, if earlier nonexistent, might have been as rapid as his grasp of describing distances in miles.[48] The realism at issue here is not tantamount to photographic accuracy—which would be a grossly anachronistic expectation—but to a set of more or less variable standards for "lifelikeness." It refers to a quality of artworks and scientific representations which would lead a historical agent to exclaim, as Mehmed Çelebi often did, how very similar a representation is to its real counterpart. This assessment of similarity cannot be assumed to be a universal of human cultures.[49] However, in the case of scientific products, standards of similarity and realism may have been more cross-cultural than has been suspected by recent sociological accounts of epistemic cultures.

4. THE SCIENTIFIC REVOLUTION AT A DISTANCE

That Mehmed Çelebi could so readily socialize in the learned circles of France was not simply due to his agreeable character or gentlemanly manners. The intellectual circles he navigated through were receptive and responsive. The gifts he was presented with included not only traditional intellectual works, like a special edition of the works of Aristotle, but also the latest corrections to the star catalogue of the Turkic astronomer Ulugh Beg, already computed by the late D. Cassini, but not yet published at the time of Mehmed Çelebi's visit to the Observatory.[50] Unwittingly, Mehmed Çelebi was travelling not only to France but also to the invisible dominion, in existence roughly between the years 1660 and 1789, cherished by contemporary European intellectuals as the Republic of Letters. Sharing at least in principle the values of cosmopolitanism and universalism in scientific matters, that is, aiming to rid academic life of national or confessional rivalries, members of this imaginary republic enjoyed supranational privileges and facilities in scientific travels. Although the leading scientific institutions of the seventeenth and eighteenth centuries were national academies, they actively sought foreign members, exchanged their proceedings, and began organizing collaborative investigations. For instance, the Dutch physicist Christiaan Huygens was invited to head the newly established Paris Academy of Sciences in the 1660s, and the Italian astronomer D. Cassini was installed as the head of the observatory in Paris. Before the French revolution, prior to the emergence of the nation state as the emblem of cultural identity, international affiliations among the intellectuals of the eighteenth century created several networks of scholarly participation.[51] The ideals of the Republic of Letters did not always mesh with the reality of intellectual interactions, but they did shape its general course.[52] J. Cassini's hospitality to his Ottoman guests, who were so fascinated by the Observatory that they visited it twice, suggests the possibility that the Republic of Letters was also open to the Ottomans, typically construed as the archenemy of the European states. This cosmopolitanism was not mentioned in Mehmed Çelebi's report, probably because a similar inclusiveness in the Ottoman identity made it unremarkable: a combination of Muslim, Christian and Jewish ethnic groups making up the Ottoman empire, divisions were mostly religious, and in certain contexts not so divisive either.

What Mehmed Çelebi overlooked or failed to report to the Court was the expansion of scientific activity the Republic of Letters had witnessed since the seventeenth century. Marked by a set of events signalling the advent of modern scientific practices, eighteenth century France was witnessing the Scientific Revolution.[53] The new sciences of the period were usually shaped by mechanistic points of view, even though the ideals of mathematization and experimentalism could ground them in different ways. While content and method alone cannot uniformly delineate the changes taking place in the sciences—in the course of which philosophical positions as diverse as those of Francis Bacon, René Descartes, the hermeticists and the neo-Platonists had followers—the social and cultural aspects of the changes were more uniform across several European states. The reformation in the sciences was mobilized in the seventeenth century by the newly founded scientific academies, usually in opposition to the university establishment. Beginning in Italy, the academic movement spread rapidly to England, France, Germany and other European countries. Run mostly by gentlemen rather than by clergy or university schoolmen, academies aimed at producing new knowledge rather than preserving, or transmitting with commentaries, the old learning. The reformed sciences of the period were also aligned more closely with utilitarian goals, seeking new technologies and solutions to civic problems, in contrast to the abstract scholarly or religious concerns of the universities. A by-product of this extended activity was that in many areas of inquiry, scientific studies were not easily accessible to the mere dilettante and the layman.[54]

Despite his standing as a non-participant observer in academic circles, Mehmed Çelebi could have registered a rough prosopography or statistics of these changes, for instance, of the French Academy of Sciences. However, except for what he implied about the labour and organization involved in the vast botanical, medical and zoological collections, the only note he made in this regard was about the fortunes the French government had poured into the Paris Observatory.[55] Mehmed Çelebi did note, however, that contemporary astronomers, equipped with these new specialized tools of inquiry, had discovered numerous new astronomical phenomena. He must have been aware of a growing gap between the new modes of understanding the heavens and the traditional ones—the ancients, he noted, did not know anything about these novelties. Yet there is no indication in the *Sefaretname* that Mehmed Çelebi was familiar with the revolution in early modern astronomy. In that transformation, it was not only the Ptolemaic geocentric and geostatic model that was contested; also at issue was the essential divide between terrestrial and celestial phenomena, against which telescopic observations had produced overwhelming evidence. It cannot be ascertained whether Mehmed Çelebi was aware of the scope of the transformations in astronomy brought about by the telescope. He mentioned, without much ado, that the position and motion of Jupiter with its satellites had been discovered with the advent of the telescope, without dwelling on the disconcerting implications of the discovery of other satellite systems in the universe besides the earth and the moon.[56]

From Mehmed Çelebi's point of view, there was nothing specifically French or European about the sciences or technologies he had witnessed. They were, to be sure, fascinating phenomena, but nowhere did Mehmed Çelebi mention any essential differences in the scholarly practices of the east and the west. The fact that he did not single out the sciences as the motor behind French economic or military power is understandable—modern historians still debate whether the sciences of the period had any direct impact on the production of economically useful technology. Yet Mehmed Çelebi could have testified to the utilitarian employment of the sciences, for instance, the role of the observatory in precision time-keeping, or the use of geometry in landscape design. Unless those would-be-considered self-evident pieces of information to his audience back home, his report missed some crucial features of the European sciences.

One reason why Mehmed Çelebi might have overlooked the reformation in sciences that was taking place in Europe may have to do with the perception of "scientific" activity in the Ottoman tradition. The word "ilim" used in Ottoman for scholarly knowledge was more inclusive than what the Latin word "scientia" denoted in the past or what the modern English word "science" does now. Closer to the German word "Wissenschaft," "ilim" has the connotation of "learning" or "scholarship." An Ottoman dictionary lists over a hundred branches of "ilim," ranging from theology, medicine, and geometry to rhetoric, rhymes, and gardening. While Mehmed Çelebi's tract can be seen as reflecting a general appreciation of "ilim" as practised by the French—witness their excellence in gardening, in tapestry, in architecture, etc. — because the concept "ilim" was not so conducive to unified accounts of sciences, the same tract might not duly record the progress the French had achieved in natural philosophy, the evolution of which lay at the core of the Scientific Revolution.

5. CONCLUSION: THE MEMORABILIA OF A TRAVEL

What might the souvenirs of the Scientific Revolution be? Herbs, animal specimens, cabinets of curiosities; and a voluminous library containing the works of Bacon, Descartes, Galileo, Kepler, and Newton and many others? Could a transfusion of these marvels to Istanbul have launched a scientific revolution in the Ottoman Empire or created a scientific centre at Istanbul? Any positive answer to this question has to grapple with the complexity of the phenomena making up the Scientific Revolution. As noted above, the heterogeneity of the contents and methods of this transformation makes it difficult to find a unified characterization of the constellation of epistemic cultures making up the Scientific Revolution. It becomes correspondingly difficult to imagine what would have been needed to transport the Revolution.

So far as we know, Mehmed Çelebi did not bring back any collections or specimens from the various botanical gardens, animal menageries or cabinets of natural and artificial rarities he had visited. He returned home with several gifts, including some fine watches and clocks, but the latter were nothing new to the Istanbul urban elite.[57] One consequence of his report was the fondness it created for certain material goods and luxury items among the Ottoman ruling class.[58] After having convened with Mehmed Çelebi, the grand-vizier commissioned a middleman to acquire numerous artefacts from France, including about a thousand engravings of the palaces, towns and gardens. The list contained, besides several household items, a number of lenses, spyglasses (or telescopes), microscopes and a wax anatomical display of a human head.[59] We do not know the uses to which these instruments were put. What can be ascertained is that there was no continuous flow of such goods from abroad, until the first European style educational institutions were established in the nineteenth century. The Ottoman realm of the period was connected neither with the material networks nor with the intellectual networks of European scientific circles on a regular basis.

That is not surprising, because Mehmed Çelebi did not lead a delegation of learned men, intent on making systematic observations for well-defined or urgent purposes, e.g. in mineralogy or medicine. In his retinue of about one hundred men, with the exception of his son who was also a state employee, only the physician and the Muslim minister would have had any training in the arts or sciences; most of the others in the entourage were guards and servants. While an interest in practical arts and sciences may have played a role in the designing of the embassy, there is no indication in Mehmed Çelebi's report of a conviction that the sciences, practical or theoretical, were factors useful to military power and commercial success. Mehmed Çelebi did not associate the technological advances of France that he was so impressed by with its scientific progress.[60]

While Mehmed Çelebi's travel account may have contributed to the development of European fashions among the grandees, the extent of its impact on the development of scientific activities in the empire should not be overrated, in the absence of documents establishing how much value the Ottomans accorded science and technology in the period. Even though it might have taken only a few intellectuals to drastically alter the course of scientific activity in a centralized bureaucracy like the Ottoman state, neither Mehmed Çelebi nor his son made any great impact.[61] They could not be said to have directly contributed to the launching of a scientific centre in Istanbul via ties to the European epistemic cultures.

Like all authoritarian states, the Ottoman state was fully vigilant on matters of belief and its expression. Mehmed Çelebi's report was first given to the state and then was edited for circulation. The major impact Mehmed Çelebi's trip had in this respect was its contribution to the establishment of the first Ottoman script printing press in the country. One of the two founders of this major undertaking in 1727 was Mehmed Çelebi's son, Said Efendi, who had also been a member of the retinue sent to Paris. While Mehmed Çelebi could have used his influence to procure the grantee for the printing press from Sultan Ahmed III, his direct involvement in the enterprise is not documented. What is known, however, is that his Parisian acquaintance Saint-Simon recollected having encountered Mehmed Çelebi whose intentions flourished while he was still in Paris: "He was a particular friend of the grand-vizier, and would urge him on his return to establish in Istanbul a printing-press."[62] Rather than imported printed books, it was the means of reproducing them cheaply that seems to have captivated Mehmed Çelebi and his son during their trip. A prerequisite of a scientific centre is a wide readership, as the European example after 1454 illustrates. However, since it was not so economically or culturally propitious, the Ottoman printing press did not catalyse intellectual events for at least a century afterwards. Readership did not expand until the nineteenth century, after new reform movements began changing the boundaries of cultural participation.

Mehmed Çelebi's travel did not initiate a travel route to the west. There was not any significant increase in the number of travellers to the west of Ottoman lands in the eighteenth century. Before the first student delegations were sent in the nineteenth century, there were only a handful of travellers and travel accounts.[63] Apart from the warring atmosphere of the previous centuries, an important factor mitigating against long journeys among the non-working population who could afford them was the instability of their social status, because it was not for the most part inheritable by birth. In the absence of an aristocracy, there being no association of nobility with "blood," Ottoman social life produced a form of gentry, especially through the system of *devshirme*, whereby children, mostly teenagers from Christian tribute, were recruited and educated by the state and later given high positions in the state administration.[64] This loyal but uprooted group usually owed its position to the Ottoman court. In general, the Ottoman elite depended on the favours of the palace to preserve their status, and long travels abroad could diminish their domestic power.[65]

Mehmed Çelebi's travelogue suggests one further effect travels to scientific centres such as Paris might have had on the religiously minded Ottoman travellers. Mehmed Çelebi did not underscore the relation between science and technology, but he admired the technological wonders he had seen, without any exception. While the most immediate implication of the French technology concerned its appropriation for Ottoman political and military ends, Mehmed Çelebi's tract points to another significance of technological power, albeit only tangentially. Technological achievements, especially large-scale ones, called attention to the extent to which human beings could counter natural forces and tame their environment for useful or pleasurable ends. The Canal du Midi, whose ingeniously designed system of locks was described by Mehmed Çelebi with admiration, connected the Mediterranean to the Atlantic Ocean, thereby circumventing the need for a lengthy and troublesome voyage through Gibraltar. The waterworks at Marly, the machine that drew water from the Seine to an incredible height, created the open courts of the Palace through which Mehmed Çelebi so delighted to stroll. In the greenhouses with artificial heating systems, tropical climates could be recreated in the midst of Paris. And even though Mehmed Çelebi did not enjoy having to stay in quarantine at Maguelone, he knew that was another action against the course of nature, against the recent outbursts of plague. Did not these interventions in nature have implications for divine omnipotence? Did not the appreciation of the latter diminish in proportion to the practical mastery of nature humans were capable of?

Theology per se did not enter Mehmed Çelebi's text, and yet his writing is punctuated with routine prayers (in the beginning and the end), and frequent invocations of God—"God willing" the voyage would be saved from several troubles; "God permitting," and conferring good fortune, the various parts of the trip could be undertaken; "the all powerful God" could design such delicate and beautiful astronomical or natural phenomena.

Much of this summoning of God belongs to the style of prose writing in this period, and can be discounted as indicative of a particular sort of religious belief. Yet a general aspect of Mehmed Çelebi's religious commitment can be inferred from this style, namely his belief in the proximity of God. The Muslim God did not lie at a remove, unconcerned with the particulars of daily affairs. Rather he was an all controlling master, always to be glorified, and summoned for help. He created the universe with all its wonders, and sustained it from moment to moment.

It is this proximity of God that may have been challenged by Mehmed Çelebi's experience in France. Upon visiting the castle of Marly, enchanted by the marvellously intricate architecture of sculptured trees, Mehmed Çelebi recalled the lines "*this world is the prison of the believer and the paradise of the unbeliever.*" He reported that the meaning of this aphorism, attributed to the prophet Mohamed, became transparent to him at that moment.[66] Mehmed Çelebi did not spell out that revelation explicitly. One can surmise that the garden's worldly temptations may have prompted him to remind himself, and the pious in general, of their rewards in the afterlife, if only they could forsake those temptations in this world. But waxing poetic on the splendour and the pleasures of the garden, Mehmed Çelebi seems to have approved of the worldly gains of the unbeliever even if it cost him other-worldly salvation. The French, recreating their environment as they willed, did not perhaps need constant divine monitoring or intervention. Human beings, empowered by technology, could imitate God by creating a paradise on earth. Whether Mehmed Çelebi saw this as a challenge to divine omnipotence, and as a removal of divine proximity, are issues *Sefaretname* was silent on. The silence is more marked since the latter parts of Mehmed Çelebi's report invoked God less frequently.

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NOTES

Abbreviations:

Sefaretname- B. Akyavaş, *Yirmisekiz Çelebi Mehmed Efendi'nin Fransa Sefâretnâmesi* (Ankara: Türk Kültürünü Araştırma Enstitüsü, 1993).

[1] Excerpts from "Le Nouveau Mercure," included in G. Veinstein, ed. *Le paradis des infidèles* (Paris: Librairie François Maspero, 1981), p. 199.

[2] The quotation is attributed to the Ottoman grand-vizier Nevşehirli İbrahim Paşa. See N. Berkes, *The Development of Secularism in Turkey* (London: Hurst & Com., 1998, facsimile ed. of 1964), p. 33.

[3] See B. Latour, *Science in Action. How to follow Scientists and Engineers through Society* (Cambridge, MA: Harvard University Press, 1987).

[4] New historiography in Ottoman studies questions both the character of this periodization and the extent to which westernisation, especially in art and architecture, was a dominant trend in this era. Settling this larger issue does not play a crucial role for the theme of this essay. On modern Ottoman historiography, see S. Hamadeh, *The City's Pleasures: Architectural Sensibility in Eighteenth-Century Istanbul* (Boston, M.I.T.: unpublished thesis, 1999) and E. Eldem, "18. Yüzyıl ve Değişim," *Cogito*, 19 (1999), 189-199.

[5] For biographical information, see the introduction to Veinstein, *op. cit.* (1), and the *Encyclopaedia of Islam* (New edition, 1991), s.v. "Mehmed Yirmisekiz," also written by Veinstein.

[6] The English word "science," from the Latin "scientia," corresponded at the period to systematic knowledge based on necessary first principles. Less ambitious in aim were "natural history," concerned with the identification and the classification of the kinds of things existing in nature, and "natural philosophy," dealing with the causes of natural phenomena. The fields of physics, chemistry, physiology and the like evolved from the latter category by specialization. Since the word "scientist" is only a nineteenth century coinage, anachronism would be avoided by using the expressions "natural historian" or "natural philosopher" for the practitioners of these inquiries in this period. For the sake of convenience, however, the words "sciences" and "scientific" will be used to refer to the activities involving all of the above categories.

[7] For the travel route, see F.M. Göçek, *East Encounters West: France and the Ottoman Empire in the Eighteenth Century* (Oxford: Oxford University Press, 1987), p. 19. Göçek provides a detailed analysis of the cultural differences which can be inferred from Mehmed Çelebi's narrative, from table manners and courtly socialization to the idea of entertainment, but she does not dwell on contemporary epistemic cultures.

[8] While the original report Mehmed Çelebi submitted to the court has not been found, four copies of a later draft dating from 1722-23 are preserved in the Ottoman archives. See F. R. Unat, *Osmanlı Sefirleri ve Sefaretnameleri* (Ankara: Türk Tarih Kurumu Basımevi, 1984), p. 57. Mehmed Çelebi's account was published in 1757 in French, *Relation de l'ambassade de Mehmet Effendi à la cour de France en 1721*, which is the basis of the recent edition of Veinstein's *op. cit.* (1). The translation into modern Turkish used throughout this essay, that of B. Akyavaş, *Yirmisekiz Çelebi Mehmed Efendi'nin Fransa Sefâretnâmesi* (Ankara: Türk Kültürünü Araştırma Enstitüsü, 1993) is based on the 1866 Ottoman printed version, *Sefaretname-i Fransa* (Istanbul: Matbaa-i İlmiyye-i Osmaniye).

[9] Mehmed Çelebi reverted to the first-person singular when he quoted himself; on a few other occasions too, he used the first-person singular, probably inadvertently. See *Sefaretname*, pp. 14, 22, 25, 38, 40, 46, 47, 53, and 56.

[10] The autobiographical form of literature, writing in the first-person singular, was not that common in contemporary Ottoman prose literature, but not entirely absent either. See C. Kafadar, "Self and Others: the diary of a dervish in seventeenth century Istanbul and first-person narratives in Ottoman literature," *Studia Islamica* 69 (1989), 121-150.

[11] See Unat, *op. cit.* (8), for an inventory of the embassy reports, and some excerpts.

[12] *Sefaretname*, p. 42. The words "garip," for strange, and "garb," which means "west," have the same Arabic root g-r-b. The history of this linguistic evolution is yet to be investigated. See Hamadeh, *op. cit.* (4), p. 270.

[13] For the various items listed here, see *Sefaretname*, pp. 29, 32, 29, 30, 34.

[14] That is not to say that the Ottomans cultivated the "bastion style" formal gardening developed by the French. For the cultural and social make-up of the contemporary Ottoman taste for public and private gardens, see Hamadeh, *op. cit.* (4).

[15] Mehmed Çelebi was awed by the sight of what he thought to be some very wonderful and strange plants and flowers; he could neither describe nor classify them. He ventured to describe one such strange animal brought from the New World at the private garden of Ecouen. Its nails were like those of a deer, body as big as a cow, fur like a sheep's, neck and ears like a horse's, yet with a head, mouth, nose and eyes like a deer's (*Sefaretname*, p. 54). The animal was probably a llama from the Andes.

[16] For the excerpts from Le Mercure, see Veinstein, *op. cit.* (1), pp. 198-9. The same report indicates that Mehmed Çelebi reciprocated this invitation by calling d'Ozembray and certain Geoffroy brothers, reported to be members of both the Paris and London Academies of Sciences, to dine in his quarters. The d'Ozembray in this report must be Louis-Léon Pajot d'Onsenbray. See R. Hahn, *The Anatomy of a Scientific Institution: The Paris Academy of Sciences, 1666-1803* (Berkeley: University of California Press, 1971). See also the memoirs of Saint-Simon on the pleasant impression Mehmed Çelebi made on Parisians, by kindly gratifying their wish to display the items they took pride in. Saint-Simon, *Mémoires*, Vol. 6 (Pleiade, ed. by G. Truc), pp. 732-3.

[17] *Sefaretname*, p. 34.

[18] For the contrast between the austerity and the modesty of the contemporary Ottoman interior decoration with its ostentatious and flashy French counterparts, see Göçek, *op. cit.* (7).

[19] For a history of these collections and their roles in shaping natural history and philosophy, see L. Daston , K. Park, *Wonders and the Order of Nature, 1150-1750* (New York: Zone Books, 1998).

[20] For these pieces of information, see *Sefaretname*, pp. 43, 28, 36, 32, 54, 39.

[21] *Sefaretname*, pp. 43-5.

[22] *Sefaretname*, p. 41.

[23] *Sefaretname*, p. 42.

[24] See I. Hacking, *The Emergence of Probability* (Cambridge: Cambridge University Press, 1975) for a history of statistics.

[25] *Sefaretname*, p. 41.

[26] These city models or city plans in relief were kept in the Tuileries at the time of Mehmed Çelebi's visit, and were later moved to the Musée de l'Armée. See Veinstein, *op. cit.* (1), p. 114.

[27] *Sefaretname*, p. 31.

[28] *Sefaretname*, p. 42. Mani and Behzad were masters of painting who flourished respectively in China and Persia. In the Ottoman commentaries on art, they were frequently mentioned as exemplary of eastern artistic excellence. See Hamadeh, *op. cit.* (4), p. 271.

[29] The depiction of emotional affect was not within the purview of the prevailing traditions in physiognomy in the Ottoman realm, which also influenced traditions of portrait painting. The science of physiognomy was primarily concerned with the portrayal of personality and with the art of reading the invisible character from the visible appearances. The immediacy of emotional expression in portraiture was probably a novel experience for Mehmed Çelebi. On the relation between physiognomy and Ottoman art, see G. Necipoğlu, "The serial portraits of Ottoman sultans in comparative perspective" in Selmin Kangal, ed., *The Sultan's Portrait: Picturing the House of Sultan* (Istanbul: İşbank, 2000).

[30] *Sefaretname*, p. 32. The Ottoman word for three-dimensionality, mücessem, also stands for form or corporeality, and has the connotation of lifelikeness. It is the same term Mehmed Çelebi used to describe the relief maps.

[31] *Sefaretname*, p. 34.

[32] *Sefaretname*, p. 41.

[33] *Sefaretname*, p. 42.

[34] See A. Sayılı, *The Observatory in Islam* (Ankara: Türk Tarih Kurumu Basımevi, 1960).

[35] He reported that being unable to take in so many strange and wondrous items at one time, he visited the Paris Observatory twice. *Sefaretname*, p. 50.

[36] *Sefaretname*, p. 49.

[37] *Ibid.*, p. 49. Veinstein surmises this instrument to be the one constructed by the Danish astronomer Ole Roemer in 1680. Veinstein, *op. cit.* (1), p. 149.

[38] A survey of the Ottoman scholarly texts of the period indicates that while some of these contentious positions were reported, they were not seen as cause for upheaval. The controversy was mentioned in a few Ottoman works produced in the 17th century, for instance, in the partial translation of Noel Durret's *Novae Motuum Caelestium Ephemerides Richeliane* (1641) by Tezkireci Köse İbrahim Efendi in 1660-4, and in Janszoon Blaeu's *Atlas Major*, translated in 1685 by Abdullah el-Hanefi el-Dimaski. For these translations, see E. İhsanoğlu, *Büyük Cihad'dan Frenk fodulluğuna* (Istanbul: İletişim Yayınları, 1996). Mehmed Çelebi was familiar with another work, Katib Çelebi's translation of the 1621 *Atlas Minor* of Mercator and Hondius in the 1650s, which did present the controversy using graphical illustrations (*Sefaretname*, p. 17). However, the credibility of Katib Çelebi's translation or of the original work (Mehmed Çelebi was aware it was a translation) must have been put into question when Mehmed Çelebi wanted to verify a fact it reported: At a certain location in Charenton, voices would be echoed back and forth as many as thirteen times. Mehmed Çelebi and his retinue found no-one in this town on their travel route who knew of this "strange" fact (*Sefaretname*, p. 17).

[39] See G. Henry, *Newton on the Continent* (Ithaca and London: Cornell University Press, 1981).

[40] The father Cassini, perhaps out of religious affiliation—he was of Jesuit orders— remained anti-Copernican until he died in 1712. See *Dictionary of Scientific Biography*, s.v. "Gian Domenico Cassini."

[41] *Sefaretname*, p. 50. In the original manuscript in Ottoman, Mehmed Çelebi drew miniature diagrams to illustrate the positions of the satellites he had seen. *Ibid.*, p. 141.

[42] *Sefaretname*, p. 3. Mehmed Çelebi used the same word, dürbün, to refer to both instruments.

[43] *Sefaretname*, pp. 49-50.

44 See S. Shapin, *The Scientific Revolution* (Chicago: The University of Chicago Press, 1996) for some of these qualms.

45 *Sefaretname*, p. 50.

46 For Ottoman traditions in painting, see Necipoğlu, *op. cit.* (29).

47 Mehmed Çelebi posed for various artists, including the painter Coypel. See G. İrepoğlu "Innovation and Change," in Selmin Kangal, ed., *The Sultan's Portrait: Picturing the House of Sultan* (Istanbul: İşbank, 2000).

48 Complaining at first of the incommensurability of the mile system with the "hour" system of the Ottomans, and having described distances in his trip to Paris in terms of hours and days, to describe his return trip Mehmed Çelebi began all of a sudden using miles rather than hours. For this conversion, contrast *Sefaretname*, pp. 14-15, 56-57.

49 See E.H. Gombrich, *Art and Illusion* (London: Phaidon Press, 1962) and *The Story of Art* (New York: Phaidon Press, 1966) for a start.

50 *Sefaretname*, p. 51. Ulugh Beg (1394-1449), whose real name was Muhammad Taragay, was a Timurid governor and patron of mathematics and astronomy in Central Asia. Together with several scholars, including Ali Kushcu, Ulugh Beg established an observatory in Samarkand, and produced the ephemerides that were used for many centuries after his death.

51 For the collapse of the cosmopolitanism of the eighteenth century, see L. Daston, "Nationalism and Scientific Neutrality under Napoleon," in T. Fraengsmyr, ed., *Solomon's House Revisited* (U.S.A. Science History Publications, 1990).

52 For an account of the Republic of Letters, see L. Daston, "The Ideal and Reality of the Republic of Letters in the Enlightenment," *Science in Context*, 4 (2) (1991), 367-386.

53 Recently, however, historians have begun to question not only the periodization of the Scientific Revolution—in the late sixteenth to early eighteenth centuries—but even the existence of a single major revolution that can be localized in space and time. An exponent of this view, Shapin, nonetheless does not deny that "the seventeenth century witnessed some large-scale attempts to change belief, and ways of securing belief, about the natural world," *op. cit.* (44), p. 5. My observations in this section are based on the view that, without loss of their specificity as indicated in my discussion, a cluster of events beginning in the seventeenth century and continuing well into the eighteenth century can be referred to as the Scientific Revolution.

54 See Shapin, *op. cit.* (44) and A.R. Hall, *The Revolution in Science, 1500-1750* (London and New York: Longman, revision of the 2nd ed. in 1662) for accounts of the changing practices in sciences.

55 State sponsorship of large-scale academic undertakings distinguished France from the rest of Europe in this period. In Britain, for instance, instruments were private possessions, and therefore less costly and less powerful. See Hall, *op. cit.* (54) and Hahn, *op. cit.* (16).

56 *Sefaretname*, p. 50.

57 See Göçek, *op. cit.* (7) for the items Mehmed Çelebi carried back. See O. Kurz, *European Clocks and Watches in the Near East* (Leiden: Brill, 1975) for the production and trade of watches in the Ottoman Empire.

58 That the *Sefaretname* bore the marks of a material culture, and inspired a novel sense of appreciation of material goods, was also noted by the French ambassador in Istanbul, Jean-Louis d'Usson Marquis de Bonnac (1672-1738), who was personally acquainted with Mehmed Çelebi. Reading Mehmed Çelebi's initial report, Bonnac remarked "he well noted many of the things he saw and described almost all with much exactitude ... but it is surprising that he has never said anything either on the subject of his embassy, or on the

spirit of the nation, nor on the characteristics of the diverse persons with whom he had dealt. For all intents and purposes, his account is of material things." (Quoted in Göçek, *op. cit.* (7), p. 65. For the original, see also Veinstein, *op. cit.* (1), pp. 234-6).

[59] See Veinstein, *op. cit.* (1), pp. 48-9, for the extended shopping list.

[60] Only much later was there a clear recognition of the utility of European sciences. The nineteenth century Ottoman intelligentsia known as Young Turks journeyed to Europe in search of models of statecraft and engineering, and were by and large convinced that European sciences marked the culmination of human civilization. The students who travelled to Europe in the first part of the twentieth century aimed in general to absorb and transmit the culture of modernism, at the same time firmly believing in the universality of that culture.

[61] After the insurrection of 1730, Mehmed Çelebi could no longer enjoy courtly patronage in Istanbul, and was sent to Cyprus as a governor. His son did serve the state for a long time afterwards, becoming an ambassador in his turn to France and Sweden, and rising to the position of grand-vizier in 1756, but only for a short time. His intellectual activity did not extend beyond writing a medical dictionary and a collection of poetry.

[62] Veinstein, *op. cit.* (1), p. 226.

[63] It was only in 1792 that Selim III's government began establishing resident Ottoman embassies in the major European cities—in London in 1793, Vienna, Berlin, and Paris in 1796. The first significant Ottoman mission of students, about 150 of them, were sent to various European cities in 1827 during the reign of Mahmud II. Prior to that, numerous Christian Ottoman subjects went to study to European, and especially to Italian universities, and a few of them remained there. See B. Lewis, *The Muslim Discovery of Europe* (New York and London: Norton & Company, 1982), and K. Kreiser, "Türkische Studenten in Europa" in von Gerhard Höpp, ed., *Fremde Erfahrungen. Asiaten und Afrikaner in Deutschland, Österreich und in der Schweiz bis 1945* (Berlin: Verlag Das Arabische Buch, 1996).

[64] C. Kafadar, "The Ottomans and Europe" in T. Brady et al, eds., *Handbook of European History 1400-1600*, I. (New York: Leiden, 1994).

[65] This view is advanced in S. Faroqhi, *Osmanlı Kültürü ve Gündelik Yaşam* (Istanbul: Tarih Vakfı Yurt Yayınları, 1998; trans. of Kunst und alltagsleben im Osmanischen Reich, Munich: C.H.Beck'sche Verlagsbuchhandlung, 1995).

[66] *Sefaretname*, p. 38.

RHODRI HAYWARD

EMMANUEL MENDES DA COSTA (1717-1791)

A Case Study in Scientific Reputation

The issue of testimony has become a central problem in the history of science. As Steven Shapin has made clear, all aspects of scientific activity are dependent upon certain levels of trust and faith in the words and arguments of others. Scientific practice is thus reliant upon the identification and maintenance of trustworthy informants. This is a situation which becomes more difficult when the transfer of knowledge moves from the face to face encounters of the college or the academy to a new dependence on the testimony of strangers travelling or corresponding from the European periphery. The complex strategies involved in the attainment, maintenance and recovery of trust will be examined through a study of the career of the Portuguese émigré scientist, Emmanuel Mendes da Costa. Mendes da Costa moved from being an intellectual outsider to become a renowned conchologist and antiquarian holding a wide network of correspondents and the clerkship of the Royal Society. In 1767 however the credible reputation which Mendes da Costa had so assiduously cultivated was torn apart when he was found guilty of perpetrating a massive fraud against the Royal Society. Despite his dismissal and eventual imprisonment, Mendes da Costa continued to participate in the Republic of Letters. This paper will examine the strategies which Mendes da Costa deployed in order to recover his position in a network of trust and scientific correspondence.

Science and travel maintained an uneasy relationship in early modern England. Travel was foundational to the emergent enterprise of natural philosophy yet at the same it threatened to undermine the implicit networks of trust and integrity that sustained the new experimental knowledge. This paper will explore this essential tension through an examination of the life of Emmanuel Mendes da Costa (1717-1791), an émigré Jewish geologist and conchologist who was born into the nomadic population of Portuguese Sephardim that fled the Inquisition.[1] In his own life, Mendes da Costa was to illustrate how the traveller's complementary strategies of accumulation and exoticism could establish a scientific authority with an innate strength which persisted even after the familiar supports of trust and reputation had been withdrawn.

Ana Simões, Ana Carneiro, Maria Paula Diogo (eds.), Travels of Learning. A Geography of Science in Europe. (101-114)

Although Mendes da Costa may have been born a refugee, within the Jewish diaspora he remained connected to families of considerable wealth and influence. His father Abraham da Costa (1683-1780) had amassed a minor fortune trading in bills of exchange in London, Rouen and Amsterdam.[2] His maternal uncle, [Anthony] Moses da Costa was a director of the Bank of England.[3] His cousin, Kitty da Villa Real was one of the richest women in England although she quickly became alienated from the Mendes da Costa family after breaking off her betrothal to Emmanuel's brother, Philip [Jacob].[4] Mendes da Costa was thus neither a citizen nor a traveller. He was at once a scion of the Anglo-Sephardic community based around the London synagogue of Bevis Marks, yet he remained in permanent exile in his host nation of Great Britain.[5] In the paper that follows, I will argue that it is this ambiguous identity, caught between the roles of citizen and traveller, which allowed Mendes da Costa to establish and maintain his scientific career in eighteenth-century England.

1. TRAVELLERS, ALIENS AND THE GREAT INSTAURATION

The testimony of foreigners and travellers had been foundational to the emergence of the new science. The Baconian ideal of the New Atlantis, in which the knowledge of all nations would be recorded and scrutinised within a single academy, was reflected in a number of schemes adopted by the Royal Society from its first inception.[6] In 1660, the first year of the society's existence, committees were established to promote correspondence with philosophers, scholars and learned academies across Europe.[7] As part of this strategy, merchants, diplomats and sailors were recruited as investigators into the natural phenomena and experimental labour of foreign lands. This arrangement was quickly formalised with prescriptive questionnaires such as Lawrence Rooke's *Directions for Seamen bound for Far Voyages* (1662, repr.1666) or Sir John Woodward's *Brief Instructions for Making Observations in all Parts of the World* (1696) being circulated amongst travellers by the initial members of the society.[8]

Within these various schemes for gathering foreign intelligence, the Royal Society repeatedly portrayed knowledge as a commodity which could be traded and accumulated to one's own advantage. As the first secretary of the Royal Society, Thomas Sprat (1635-1713), made clear — the cultivation of travellers and foreign correspondents would lead to a rapid process of intellectual enrichment:

> For by this means, they will be able to settle a *constant Intelligence* throughout all *civil Nations*, and make the *Royal Society* the general Bank and Freeport of the World: A policy which whether it would hold good in the *Trade of England*, I know not, but sure it will in *Philosophy*. We are to overcome the Mysteries of all the Works of Nature; and not only prosecute such as are confin'd to one Kingdom, or beat upon one Shore.[9]

As Sprat explained, such a scheme would allow the Royal Society to transcend the limitations not only of geography but also of race and national character. He pictured the "perfect Philosopher" as a European Union of international attributes, combining the "industry and inquisitiveness" of the Dutch, French, Scotch and English with the cool judgements and wary rationalism of the Italian and Spanish. International co-operation opened up the possibility of incarnating these disparate traits within one corporate individual. Such traits, claimed Sprat, are:

> scarce ever to be found in one single Man; seldom in the same Countrymen. It must then be supplied as it may by a *publick Council,* wherein the various dispositions of all these nations may be blended together. To this purpose the *Royal Society* has made no scruple to receive all inquisitive strangers of all Countries into its number.[10]

Travel and correspondence were thus conceptualised as key elements in a kind of "cognitive mercantilism": a process, in which the accumulation of knowledge and experience became a royal road to the achievement of intellectual authority.[11] The Royal Society was described by its apologists such as Thomas Sprat and Joseph Glanvill, as a great army which through its extensive connections was able to transcend the individual limitations of space and time. Glanvill (1636-1680) believed that the material technology of the compass and printing press had instigated an intellectual revolution in which knowledge of all the earth could be secured within one small location.[12]

This process of accumulation, as Bruno Latour has noted, introduces a generalised asymmetry into the distribution of knowledge and power. It constructs within the very fluid and dynamic Republic of Letters, specific "centres of calculation" which become the authoritative arbiters of truth.[13] Such centres, as Latour has made clear, may have appeared to others as the actual sources of knowledge and enlightenment, yet such images were illusory. The New Atlantis, celebrated in the work of Glanvill and Sprat, had only been made possible by the combined and articulated efforts of travellers and traders scattered across the globe.

2. THE TROUBLE WITH TRAVELLERS

If travelling sustained the emergent enterprise of modern science it also threatened to undermine it. As Steve Shapin has argued, there was a general awareness in early modern England of the fragility of testimony and in particular of the testimony of travellers.[14] As solitary witnesses reporting from distant locations, travellers could, in Daniel Carey's words, "lie by authority – availing themselves of the distance between their observations and the confirmation of additional witnesses."[15] Although the Royal Society might have celebrated its new methodology of multiple and sceptical witnessing within the closed space of the laboratory, the vast part of its accumulated observations remained dependent on repeated acts of faith in the veracity of travellers' tales.[16] The high cost of travel, both in time and resources, and its attendant dangers and hazards meant that the extension of natural knowledge beyond the philosophers immediate was predicated upon the honesty and industry of itinerant informants. As Steve Shapin has argued: "[I]t is difficult to imagine what early natural history would look like without the component contributed by travellers, navigators, merchant-traders, soldiers and adventurers."[17]

This cognitive dependence on travellers' tales rendered the Royal Society vulnerable. From its very beginning, lampooning critics repeatedly depicted the gullible virtuosi deceived by unscrupulous travellers. In the 1670's, Henry Stubbe (1632-1678), a fierce critic of the Royal Society claimed that the virtuosi's reliance on the "narratives picked up from *negligent, or inaccurate Merchants* and *Seamen*" proved that Sprat and Glanvill's claims of a new Instauration were little more than idle boasts.[18] Almost a century later, Mendes da Costa's erstwhile friend and confidante, John Hill (1714-1775) would repeat this accusation, depicting in his novel, *The Adventures of George Edwards, a Creole* (1751) the repeated deceits inflicted upon a scientific academy by a group of impostors.[19]

In the absence of any communal or objective criteria for judging travellers' reports, the Royal Society was forced to revert to a much older set of codes and procedures for assessing the veracity of testimony. Steven Shapin has shown in great detail, how gentlemanly codes of virtue and ethical conduct were imported wholesale into the scientific practice of the early Royal Society. Witnesses were thus subjected to trial by reputation: their accounts were assessed according to the known character, relationships, social status, demeanour and nationality of the informant. Such a method would quickly lend weight to reports from those closely associated with the core membership of the society, yet it also created a whole set of problems for travellers on the social periphery who were attempting to build new relationships with the dominant scientific establishment.

This was the position faced by Emmanuel Mendes da Costa in 1743; yet in the space of twenty years he was to transform his reputation and his identity. He moved from being an unknown Jewish refugee connected to a rich if fairly disreputable family to become one of the country's leading geologists, its foremost authority on sea shells and the secretary of the Royal Society.

3. THE RISE OF EMMANUEL MENDES DA COSTA

Despite the significance of Mendes da Costa's scientific contributions and the scandal of his professional career, his life has never been explored by professional biographers. Although he gains brief mentions in histories of the Anglo-Jewry and eighteenth century geology and a cryptic entry in the 1908 edition of the *Dictionary of National Biography*, the full pattern of his life and ideas has, until recently, awaited its proper reconstruction.[20] This biographical lacuna is surprising, since as we shall see, Mendes da Costa was assiduous in maintaining records of his family, his triumphs and his friendships, producing manuscript pedigrees and "Notes on literati and collectors" which were posthumously published in the *Gentleman's Magazine*.[21] His own correspondence books, now held in the manuscripts department of the British Library, run to eleven volumes and contain almost 2500 scrupulously annotated letters.[22]

From the published sources the bare bones of Mendes da Costa's scientific biography can be reconstructed. In his early twenties, Mendes da Costa was introduced to the Aurelian Society, a club of butterfly hunters that met in the Swan Tavern in Cornhill.[23] By 1746 he had been elected a corresponding member of the Spalding Society which under the direction of Maurice Johnson had pursued an eclectic agenda of natural historical and antiquarian research, and on the 26th of November, 1747 he was honoured with election to the Royal Society.[24] Nominated by the Society President, Martin Folkes and seconded by Brian Fairfax, Henry Baker, James Parsons, Peter Collinson and James Theobald, Mendes da Costa was recommended as "a Gentleman well skilled in the Philosophical Learning and Natural Knowledge particularly in what relates to the Mineral and Fossil parts of Creation; as one exceedingly diligent in his enquiries and one who by applying himself with great assiduity to the study of Natural History is likely to be a useful Member of the Royal Society and a zealous promoter of natural knowledge, for the advancement of which the same was founded."[25]

Mendes da Costa's gradual incorporation into the emergent scientific establishment can be attributed to a number of strategies. His first and most obvious means of introduction remained the extended Sephardic community based around the temple at Bevis Marks. Jacob de Castro Sarmento (1692-1792), Joseph Salvador (1716-1786), Joseph de Castro (1704-1789) and Solomon da Costa Athias were already well integrated into the medical and antiquarian communities.[26] Moreover Mendes da Costa made further close links with the awkward but influential Ashkenazi physician, Meyer Löw Schomberg through Schomberg's son, Ralph.[27] Meyer Löw Schomberg had developed a lucrative practice amongst the London aristocracy and been elected to the Royal Society, whilst at the same time entertaining a bitter feud with his Jewish co-religionists.[28] Despite the obvious alienation and occasional hostility which the Jewish community faced in mid eighteenth-century London they were sufficiently well integrated and well connected to sustain an individual's reputation and provide evidence of good character.[29] As David Lux and Hal Cook have shown in their use of Mark Granovetter's work on the "strength of weak ties," such extended communities were crucial in their provision of a network of distant and apparently unbiased acquaintances. Unlike close friends and kin, such weak acquaintances would each reinforce and sustain the known reputation and public identity of a named individual whilst avoiding any accusation of partiality or partisanship.[30]

Once such a network had been established, it quickly developed its own momentum, with invitations and introductions leading to the networks ever increasing growth and extension. Moreover this process of introduction and acquaintanceship could itself be further reinforced through participation in travel and expeditions.[31] Mendes da Costa though, was not a happy traveller. In his letters he frequently bemoans the sufferings he had to endure on his journeys around Britain and Holland – cursing poor horses, reckless carriage drivers and unsanitary and uncomfortable inns. Yet his early travels around the Peak District of Derbyshire in 1747 and the western counties of England in the 1750s provided him with a network of local correspondents and informants as well as a growing fossil collection which increased his own authority and reputation. By 1761, Mendes da Costa could inform Ralph Schomberg that his "collection of Fossils is reckoned equal if not superior, to any one in England."[32]

The expedition was thus foundational to Mendes da Costa's scientific identity. As he noted in a letter to Thomas Pennant in May 1752:

> I know I profited more in six months journey into Derbyshire and Cornwall by visiting caverns and mines than I did by study for the ten years before the time I first commenced a fossilist.[33]

Through the combined acts of travel, introduction and collection, Mendes da Costa was transformed. He moved from being a mere visitor to natural attractions to become instead a new site – an attraction in himself, which demanded the attention of his fellow scientific tourists and travellers.[34]

Travel thus allowed Mendes da Costa new sources to sustain his scientific reputation and identity. His extensive networks of distant associates granted him a certain familiarity and authority within the protean scientific culture of eighteenth-century Europe.[35] Moreover the fragility of his connection to the core of the scientific establishment lent his reputation a certain impartiality. As Steve Shapin has argued (drawing upon the work of Georg Simmel) outsider figures such as the European Jews could be seen as crucial scientific actors since they were not allied to any committed faction or social institution.[36] Mendes da Costa encouraged such an interpretation. By maintaining his correspondence widely, even between sworn enemies (such as Schomberg and Jacob de Castro Sarmento) he was able to cultivate a necessary air of scientific neutrality.[37]

Mendes da Costa's Jewish identity played one further significant role in the establishment of his scientific authority. Despite his Dutch birth and London upbringing, he was able to portray himself as a mediator between the contemporary scholastic cultures of natural history and antiquarianism and the ancient history of the Jews. He collected Hebraic manuscripts, soliciting further references from archivists in the London Chancery and the British Museum.[38] He was quick to correct published mistakes in Hebrew translation and offer his services to authors for future reference. Perhaps the most notable example of this procedure came when Mendes da Costa took charge of a project to make contact with the fabled community of Chinese Jews. This project had been initiated by the Oxford theologian, Benjamin Kennicot (1718-1783), who believed that this community represented one of the ten lost tribes of Israel.[39] Kennicot hoped that the community would have preserved an uncorrupted version of the Old Testament which would provide a renewed and secure basis for Biblical authority. Mendes da Costa placed himself as an intermediary, organising entreaties from the London synagogue in 1752 and forwarding them to Chinese and Russian travellers. Through his Jewish identity, Mendes da Costa was able to transform himself, becoming an "obligatory passage point" (to use a Latourian phrase) between the English cultures of theology and antiquarianism and the globally scattered Jewish Diaspora, both rumoured and actual.[40] Moreover in his insistence that so much of early British history was bound up in the records of the medieval Jews he became a crucial link in English attempts to recover the basis of their own national identity.

We can thus see how Mendes da Costa's outsider status was transformed: it moved from being a cause of alienation to become a source of authority. This transformation moreover, had a rapid effect. In January 1763, Mendes da Costa put himself forward for the position of clerk and keeper of the Royal Society.[41] His candidature was supported by the Society's secretary, Thomas Birch (1705-1766) and William Stukeley (1687-1765) who wielded a huge amount of influence amongst the society's antiquarian members.[42] His election was almost unanimous.

Esconced as clerk and keeper of the Royal Society, Mendes da Costa appeared to have reached the summit of his career. He had moved from being an immigrant outsider within British culture to become a key figure within the nation's scientific establishment. Yet within four years his career was in ruins. For reasons unknown, Mendes da Costa, once elected, embarked on the wholesale fraud of both the society and its fellows. He instituted a bogus membership scheme, selling life-time subscriptions at 25 guineas a head which he entered as one guinea annual fees in the returns. It was alleged that Mendes da Costa had made over £1500 from his new scheme.[43]

In December 1767, the fraud was discovered and Mendes da Costa was ejected from his office and lodgings in disgrace. The £1000 bond of his securitors, Joseph Salvador and Samuel Felton was confiscated and they in turn seized Mendes da Costa's collections and library as compensation.[44] The sale of these items in May 1768 failed to raise enough to recoup his bonds and six months later, Mendes da Costa was imprisoned for five years at the King's Bench in London.

One would have expected this national disgrace and imprisonment to provide the conclusion to da Costa's scientific career. Certainly if one follows Steve Shapin's argument that scientific culture is dependent upon the establishment of gentlemanly codes of trust and honour, then Mendes da Costa should have disappeared from the intellectual map. He had proved himself an unworthy correspondent, a liar and a thief, yet his scientific career continued unabated. Despite the fact that he had defrauded some of the most eminent natural philosophers in the country, Mendes da Costa maintained his scientific authority even to the extent of giving lectures from his prison cell.[45] In January 1772, he wrote to his friend Francis Nichols, describing his reduced circumstances and outlining his attempts to maintain his scholarly career:

> The almighty who has afflicted me with the confinement has through his mercies granted me the cell of reason and I apply myself as much as ever assiduously to my studies.
> I am capacitated to wear away the hours of affliction and idleness usually attendant on such places by the patronage of several eminent physicians and other gentlemen, as Dr MacKenzie, Dr Hunter, [*Dr Fothergill*] Mr Forster and I have read some Lectures on the Fossil Kingdom with Applause and success.
> ...I have a very handsome and commodious apartment in the State House, with a small library, my papers and a collection of natural history...[46]

By 1770, Mendes da Costa had given some 140 lectures and prepared new editions of Cronstedt's *Essay towards a System of Mineralogy* (1770) and Dru Drury's *Illustrations of Natural History* (1770-82).[47]

After his release on 8 October 1772, Da Costa revived his correspondence with many of his old informants. His old creditor, Joseph Salvador forgave his debts and sent him informative accounts of American natural history. The West Country naturalists, Richard Pulteney (1730-1801) and William Borlase (1695-1772), maintained their faith in him, trusting him with the loan of new books and specimens to further his research.[48] Others campaigned for his employment at the University of Oxford.[49] Yet the resumption of Mendes da Costa's scientific career was not simply based upon sentimentality or nostalgia. Instead, once he was released from prison he went on to win new audiences, through the publication of some of his most famous works. In 1776 his *Elements of Conchology* appeared, followed in 1778 by his *British Conchology*.[50] These two publications secured his reputation as Britain's foremost expert in this deeply fashionable field.[51] By 1783, Da Costa was in a position to revise and correct Sir Joseph Banks' (the then President of the Royal Society) account of his 1772 voyage to Iceland.[52] The idea that a disgraced foreigner who had defrauded the Royal Society could then go on to correct the writings of that selfsame society's President, obviously sits unhappily with Shapin's theory of the foundational role of trust and reputation in science.

In conclusion, I want to argue that the case of Mendes da Costa provides us with an opportunity to rethink the role of trust and travel in the history of science. Whilst an initial examination of Mendes da Costa's life provides a very obvious confirmation of Shapin's schema, the continuation of his scientific career after his public disgrace and humiliation, demands the development of a more complex or textured theoretical interpretation. Mendes da Costa's biography returns our attention to the way that travel was not simply a component strategy in the extending the powers of the major centres of scientific calculation, rather it also had a transformative effect on the powers of the individual. As Lorraine Daston has noted, travel (rather than trustworthiness *pace* Shapin) could be seen as the foundational act in the establishment of scientific objectivity. As she wrote in 1991:

> The yearning for distance, both literal and metaphorical, has a special role to play in the scientific sector of the Republic of Letters. What began in the eighteenth century as a quest for impartiality to others became in the nineteenth century a quest for objectivity even in relationship to oneself...The internalisation of the impartial critic implied that the faceless anonymity of foreigners or posterity now paradoxically extended to oneself: only by treating one's own discoveries and ideas as those of complete stranger could the standards of impartial self-criticism be upheld.[53]

In Mendes da Costa's own life we can see how travel, collecting and correspondence conspired together to turn the individual into a "centre of calculation" in his own right. Mendes da Costa could maintain his position within the Republic of Letters because there was no one there to replace him. Through his scrupulous recording of his travels and his correspondence and his cataloguing of his collections (and the collections of others), Mendes da Costa emulated the selfsame processes that had allowed the Royal Society and other academies to rise as centres within the Republic of Letters.[54] His assiduous networks and records meant that his knowledge escaped its local ambit and instead became a key point which held in place the knowledge and work of others. This perhaps was the constitutive function of scientific travel as opposed to tourism. Journeys which were recorded and friendships which were maintained escaped the transitory hold of memory and experience and instead became durable resources which could be fielded across personal disputes and international arguments.[55] As Mendes da Costa shows, by investing one's experience of travel into the durable material of correspondence and collections, travellers from the periphery could become a centre in themselves.

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NOTES

Abbreviations: B.L. – British Library

[1] On the origins of this community, see R. D. Barnett, *The Circumcision Register of Isaac and Abraham de Paiba, 1715-75, [Bevis Marks Records Part IV]* (London: The Spanish and Portuguese Jewish Congregation and the Jewish Historical Society of England, 1991): introduction.

[2] [Emmanuel Mendes da Costa], "Pedigree of the Family of the Mendes da Costa," *Gentlemen's Magazine*, 82 (1812) 21-24. See also the family trees of the Dutch and English in Da Costas, printed in Isidore Singer et. al. (eds.), *The Jewish Encyclopedia* 4 (New York: Funk & Wagnalls, 1925), pp. 289-90.

[3] Isidore Harris, "Costa, Anthony da" in Isidore Singer et. al. (eds.), *op. cit.* (2), p. 289.

[4] M. J. Landa, "Kitty Villa Real, the Da Costas and Samson Gideon," *Transactions of the Jewish Historical Society of England*, 13 (1936), 271-279; David Katz, *The Jews in the History of England, 1485-1850* (Oxford: Clarendon Press, 1994), pp. 224-226.

[5] Paul Goodman, *Bevis Marks in History: A Survey of the External Influences of the Congregation* (London: Humphrey Milford, 1935); Albert M. Hyamson, *The Sephardim of England: a history of the Spanish and Portuguese Jewish community, 1492-1951* (London: Methuen, 1951).

[6] Charles Webster, *The Great Instauration: Science, Medicine and Reform, 1626-1660*, (Oxford: Peter Lang, 2002, 2nd ed.).

[7] Thomas Birch, *The History of the Royal Society of London etc.* (London: A. Millar, 1756-57), pp. 23-29; pp. 402-407.

[8] Michael Hunter, *Establishing the New Science* (Woodbridge: Boydell, 1989), ch. 3; Daniel Carey, "Compiling Nature's History: Travellers and Travel Narratives in the Early Royal Society," *Annals of Science*, 54 (1997), 269-292, 272-274; C. A. Ronan, "Laurence Rooke (1622-1662)," *Notes and Records of the Royal Society*, 15 (1960), 113-118.; V. A. Eyles, "John Woodward, F.R.S., F.R.C.P., M.D., (1665-1728): a bio-bibliographical account of his life and work," *Journal of the Society for the Bibliography of Natural History*, 5 (1971), 399-427.

[9] Thomas Sprat, *The History of the Royal Society of London* (London, 1667), p. 64. On Sprat and his work, see Paul B. Wood, "Methodology and Apologetics: Thomas Sprat's History of the Royal Society," *British Journal of the History of Science*, 13 (1980), 1-26.

[10] Sprat, *op. cit.* (9), p. 64.

[11] Bruno Latour, *Science in Action* (Cambridge, MA: Harvard U. P., 1987), p. 220.

[12] Joseph Glanvill, *Plus Ultra or the progress and advancement of knowledge since the days of Aristotle* (London: James Collins, 1668), pp. 76-80.

[13] Bruno Latour, *op. cit.* (11), ch. 6.

[14] Steven Shapin, *A Social History of Truth: Civility and Science in Seventeenth-Century England* (Chicago: University of Chicago Press, 1994); Charles J. Withers, "Geography, Natural History and the Eighteenth-Century Enlightenment," *History Workshop Journal*, 39 (1995), 136-163.

[15] Carey, *op. cit.* (8), p. 220; Charles J. Withers, "Reporting, Mapping, Trusting: Making Geographical Knowledge in the Late Seventeenth Century," *Isis*, 90 (1999), 497-521, 503.

[16] Adi Ophir, Steven Shapin, "The Place of Knowledge: A Methodological Survey," *Science*

in Context, 4 (1991), 3-21; Steven Shapin, Simon Schaffer, *Leviathan and the air-pump: Hobbes, Boyle, and the experimental life* (Princeton, N.J.: Princeton University Press, 1985).

[17] Shapin, *op. cit.* (14), p. 245.

[18] Shapin, *op. cit.* (14), pp. 294-95. For Stubbe, see J. R. Jacob, *Henry Stubbe, Radical Protestantism and the Early Enlightenment* (Cambridge: Cambridge University Press, 1983).

[19] John Hill, *The Adventures of Mr George Edwards, a Creole* (London: T. Osborne, 1751). By 1755, da Costa had fallen out with Hill, claiming that his satires were "fit only for pastry cooks and cheese mongers to wrap their wares in". B.L Add[itional] Mss. 35,230.f.17. For Hill, see George Rousseau, *The Letters and Papers of Sir John Hill (1714-1775)* (New York: AMS Press, 1982).

[20] The fine biographical article on Mendes da Costa by George Rousseau, David Haydock ("The Jew of Crane Court: Emmanuel Mendes da Costa (171-91), Natural History and Natural Excess," *History of Science*, 38 (2000), 129-170) only appeared after the initial draft of this paper had been completed. Rousseau and Haydock's paper provides an exhaustive and authoritative account of da Costa's life and career coupled with a psychoanalytic explanation of his criminal failings. Whilst acknowledging the sheer scholarship of Rousseau and Haydock's work, this paper rejects the asymmetrical explanation which attempts to psycho-pathologise dishonest activity whilst failing to question the mechanics of ordinary scientific behaviour. For the classic account of the principle of symmetry, see David Bloor, *Knowledge and Social Imagery* (London: Routledge, Kegan, Paul, 1976).

[21] [Emmanuel Mendes da Costa], "Pedigree of the Family of the Mendes da Costa," *Gentlemen's Magazine*, 82 (1812), 21-24; "Notices and Anecdotes of Literati, Collectors etc.," *Gentlemen's Magazine,* 82 (1812), 204-7, 513-17.

[22] B.L. Add. Mss. 28,534- 28,544. Other papers are held in the Pulteney correspondence at the Natural History Museum; Derby Irongate Central Library; the Royal Society; the Linnaean Society and the Mocatta Library at the University of London. See Rhodri Hayward, *Catalogue of Portuguese Scientific Manuscripts in the United Kingdom* (Lisboa: Project Prometheus, 1996, unpublished); Rousseau, Haydock, *op.cit.* (20).

[23] David Allen, *The Naturalist in Great Britain: A Social History* (Princeton: Princeton U. P., 1994), pp. 11-12.

[24] On the history of the Spalding Society, see W. Moore, *The Gentlemen's Society of Spalding: its origin and progress* (London, 1851); H. J. J. Winter, "Scientific associations of the Spalding Gentleman's Society, 1710-50," *Archives internationales d'histoire des sciences* (1950), 77-88; Dorothy Owen, S. Woodward, *The Minute Books of Spalding Gentleman's Society*, 1712-1755 (Lincoln: Lincoln Records Society, 1981). On the Royal Society in the eighteenth century, see David Miller, "In the valley of darkness: reflections on the Royal Society in the eighteenth century," *History of Science*, 27 (1989), 155-166; George Rousseau, David Haydock, "Voices calling for reform: The Royal Society in the mid-eighteenth century," *History of Science*, 37 (1999), 377-406.

[25] A copy of this proposal was kept by Mendes da Costa. B.L. Add. MS. 28, 536.f.135.

[26] On Castro de Sarmento, see Richard D. Barnett, "Dr Jacob de Castro Sarmento and Sephardim in Medical Practice in Eighteenth Century London," *Transactions of the Jewish Historical Society of England*, 27 (1982), 84-114. On Joseph Salvador, see M. Woolf, "Joseph Salvador, 1716-86," *Transactions of the Jewish Historical Society of England*, 21 (1968), 104-137.

[27] On Schomberg, see C. R. Samuel, "Dr Meyer Schomberg's Attack on the Jews of London, 1746," *Transactions of the Jewish Historical Society of England*, 20 (1964), 83-111.

[28] See the letters held at B.L. Add. Mss. 28,542. ff. 157-64.

[29] On the casual persecution of the Jews in eighteenth century London, see Thomas Perry, *Public Opinion, Propaganda and Politics in Eighteenth-Century England: A Study of the Jew Bill of 1753* (Cambridge, MA: Harvard U. P., 1962); Katz, *op. cit.* (4), ch. 6; Todd M. Endlemann, *The Jews of Georgian England, 1814-1830: Tradition and Change in a Liberal Society* (Philadelphia: Jewish Publication Society of the United States, 1979), ch. 2.

[30] David S. Lux, Harold J. Cook, "Closed Circles or Open Networks? Communicating at a Distance during the Scientific Revolution," *History of Science*, 36 (1998), 179-211, 181-183.

[31] David Allen, "Natural History in Britain in the Eighteenth Century," *Archives of Natural History*, 20 (1993), 333-347, 333-335.

[32] This letter is reprinted in John Nichols, *Illustrations of the Literary History of the Eighteenth Century* 4 (London: Printed for John Nichols, 1812), p. 166.

[33] Quoted in Rousseau, Haydock, *op. cit.* (20), 131.

[34] On this process, see Paula Findlen, *Possessing Nature: Museums, Collecting, and Scientific Culture in Early Modern Italy* (Berkeley: University of California Press, 1994), ch. 7.

[35] Lux, Cook, *op. cit.* (30).

[36] Shapin, *op. cit.* (14), pp. 39-41. Cf. Anne Goldgar's remarks on the role of Huguenot refugees in the promotion of the Republic of Letters, *Impolite Learning: Conduct and Community in the Republic of Letters* (New Haven: Yale University Press, 1995).

[37] On this conflict, see Samuel, *op. cit.* (27); Royal Society Manuscripts: MM. 4. 58-59.

[38] Cf. his manuscript book: "A Book of Res Judaciae & Belles Letres or Humanities &c. &c.," B.L. Add. Mss. 29, 867.

[39] On Kennicot and this episode, see David Katz, "The Chinese Jews and the Problem of Biblical Authority in Eighteenth and Nineteenth Century England," *English Historical Review*, 105, (1990), 893-919. Cf. B.L. Add. Mss, 4303.ff. 178.

[40] On the idea of the "obligatory passage point," see M. Callon, "Some elements in the sociology of translation: domestication of scallops and the fishermen of St. Brieuc Bay," in J. Law (ed.), *Power, Action and Belief: A New Sociology of Knowledge* (London: Routledge and Kegan Paul, 1986); Latour, *op. cit.* (11), pp. 150f.

[41] See his letter to Birch, held at B.L. Add. Mss 4443. f. 134.

[42] Nicholls, *op. cit* (32), p. 540.

[43] See notes by James Parsons and Henry Baker, held at Royal Society, MM. 3. 13.

[44] For details of the sale, [Mendes da Costa], "Notes and Anecdotes of Literati etc," *op. cit.* (21); Rousseau, Haydock, *op. cit.* (24).

[45] For one published example of this fraud, see his correspondence with Joseph Priestley (14 June 1766) (Nichols, *op. cit.* (32), pp. 541-542).

[46] B.L. Add. Mss. 28, 540.f.129/147 partial repr. in Nichols, *op. cit.* (32), p. 760.

[47] Alex Cronstedt, *An Essay towards a System of Mineralogy ... Translated, from the original Swedish, with notes, by G. von Engestrom. To which is added, a Treatise on the Pocket-Laboratory, containing an easy method ... for trying mineral bodies, written by the translator. The whole revised and corrected, with some additional notes, by E. Mendes da Costa* (London: Edward & Charles Dilly, 1770); Dru Drury, *Illustrations of Natural History* (London, 1770-81). On Drury see C. H. Brock, "Dru Drury's *Illustrations of*

Natural History and the type specimens of *Golianthus golianthus Drury*," *Journal of the Society for the Bibliography of Natural History,* 8 (1977), 259-265.

[48] For the goodwill, extended by Pulteney and Borlase, B.L. Add. Mss. 35, 230. f. 29; British Museum (Natural History) MSS: Pul. A. 7, 11. On Pulteney, see Robert H. Jeffers, "Richard Pulteney and his Correspondents," *Proceedings of the Linnaean Society* (1959), 15-26. On Borlase see P. A. S. Pool, *William Borlase* (Truro: Royal Institution of Cornwall, 1986).

[49] See for instance, Josh Platt, B. L. Add. Mss, 28, 540. f. 258, 303.

[50] Emmanuel Mendes da Costa, *Elements of Conchology. Or, An introduction to the knowledge of shells* (London: B. White., 1776); Emmanuel Mendes da Costa, *Historia naturalis Testaceorum Britanniæ, or the British Conchology* (London, 1778). On the publication of the *Conchology*, see P. J. Whitehead, "Emmanuel Mendes da Costa (1717-1791) and the *Conchology, or natural history of shells,*" *Bulletin of the British Museum (Natural History) - Historical Series* 6, (1977), 1-24.

[51] Roy Porter, *The Making of English Geology* (Cambridge: Cambridge University Press, 1977), 99; Allen, *op. cit.* (23), 24f.

[52] Joseph Banks, *Letters on Iceland: containing observations on the natural history of the country, antiquities, manners and customs of the inhabitants, &c. &c. Made, during a voyage undertaken in the year 1772, by Sir Joseph Banks, P.R.S. assisted by Dr. Solander, F.R.S. Dr. J. Lind, F.R.S. and several other literary and ingenious gentlemen / written by Uno von Troil; with notes and additions by the translator. The whole revised and corrected by E. Mendes da Costa* (London: J. Robson and W. Richardson, 1783). On Banks (1743-1820) see John Gascoigne, *Science in the Service of Empire* (Cambridge: Cambridge University Press, 1998).

[53] Lorraine Daston, "The Ideal and Reality of the Republic of Letters in the Enlightenment," *Science in Context*, 4 (1991), 367-386, 383.

[54] On Mendes da Costa's attempt to escape the ravages of time through the preservation of his correspondence, see Rousseau, Haydock, *op. cit.* (20), 136-137. On the transformative role of the written record, see Jack Goody, *The domestication of the savage mind* (Cambridge: Cambridge University Press, 1977); Paul Connerton, *How societies remember* (Cambridge: Cambridge University Press, 1994).

[55] For an example of Da Costa's involvement in international disputes, see his unsuccessful rearguard attempt against the introduction of Linnaean classification. Porter, *op.cit.* (51).

BRIAN DOLAN

EMBODIED SKILLS AND TRAVELLING SAVANTS

Experimental Chemistry in Eighteenth-Century Sweden and England

1. ANALYSING THE LANDSCAPE

Blowpipe analysis was pioneered in Sweden in the eighteenth century. The blowpipe has secured a place in chemical hagiography by being an instrument with which Swedish chemists such as Axel Cronstedt and Carl Scheele isolated a number of elements including nickel, manganese, molybdenum, and tungsten. Other chemists, such as Gustaf von Engeström, Torbern Bergman, and Jacob Berzelius, were well-known authors of chemical treatises which espoused the utility of blowpipe analysis. This instrument was valued because of the simplicity of the apparatus and its portability. It was small (capable of fitting into a pencil case) and inexpensive. In design, it was a thin, curved metal tube, through which a practitioner would blow air in order to concentrate a candle flame onto a mineral specimen. The intense reducing flame caused rapid decomposition of the mineral, and, with the use of chemical reagents, the chemical constituents of the specimen could often be determined. Analysis could be performed on small mineral samples to provide instant results in the field.[1] Economic, social, and political conditions in Sweden aided the development of this form of chemical analysis. Training in blowpipe analysis was an important dimension in the education of Swedish civil servants, who conducted on-site analyses to determine the location and nature of metals for the increasingly important mining industry.

Sweden's achievements in chemical and mineralogical analysis were widely recognised in Britain by the late eighteenth century. As early as 1770, an edition of an English text on blowpipe analysis written by Cronstedt and enlarged by Engeström drew attention to these practices.[2] While scattered references to blowpipe analysis by British authors can be found during the first few years of the nineteenth century, it was not until the 1810s that this form of experimentation became popular among British chemical practitioners. Many articles relating to blowpipe analysis were published in natural philosophical journals, discussing new experimental results, new

Ana Simões, Ana Carneiro, Maria Paula Diogo (eds.), Travels of Learning. A Geography of Science in Europe. (115-141)

designs for the blowpipe, and suggesting improved ways of conducting analysis. Blowpipes became widely advertised in the market for philosophical instruments and public lectures incorporated demonstrations of their uses. One enthusiastic reviewer of "chemical achievements" in 1816, who referred to the immense interest in blowpipe analysis and its uses for the application of chemical theory to classification systems, went so far as to claim that these steps led to the reconfiguration of classification systems and effected a "very considerable revolution in the theory of that science."[3]

Revolution or no revolution, the blowpipe did appear rather suddenly in significant numbers in Britain's analytical community with widely discussed and debated results.[4] Why so sudden—and why in the 1810s? The beginning of the nineteenth century was a critical moment for British chemistry—antiphlogiston debates were settling down, a number of new chemical societies were established, and Humphry Davy had just announced the results of his pioneering electrochemical experiments to the patrons of the new Royal Institution and the Royal Society.[5] Natural philosophical attention was concentrated on what further chemical revolutions might occur through new developments in instrumentation and experimentation, and in the 1810s blowpipe analysis attracted much attention. But why was such a well-known form of analysis not developed more readily in Britain prior to the 1810s? There exists a curious lacuna, particularly if we take as an "introduction" of blowpipe analysis to chemistry and mineralogy in Britain to be Engeström's 1770 publication. The familiarity with the accomplishments of, and the debt British practitioners owed to, their eighteenth-century Swedish predecessors in developing blowpipe analysis was widely acknowledged in their contemporary accounts. Theory was known, but practice, save a few isolated examples, delayed. Why?

In the 1810s, London instrument dealers such as John Newman, Friedrich Accum, and John Mawe, sold an array of affordable blowpipe apparatus, while authors, including Mawe and Arthur Aikin, wrote manuals describing the use of the instrument.[6] In Britain by the 1820s, blowpipe kits were standard equipment for chemists, mineralogists, and geologists. In 1827 the chemist and author of popular textbooks, John Joseph Griffin, collected "scattered intelligence" from the previous decade and published an updated essay on the use of the blowpipe.[7] Historians of science Brian Gee, William Brock, and Ian Inkster have suggested that the familiarity with blowpipe analysis among the chemical community was the result of the translations of Swedish texts being introduced to the short-lived Askesian Society (1799) and the British Mineralogical Society (1799-1806).[8] Yet pointing to the appearance of books translated from Swedish as cause for the development of chemical practices in Britain is inadequate.[9] The aim of this article is to explore some additional issues involved in understanding the transfer of the practices of blowpipe analysis from Sweden to Britain from Engeström's 1770 publication until the publication of subsequent manuals by British authors in the 1810s and after.

At one level, crossing national boundaries draws attention to the different bureaucratic structures in which scientific practices develop. But more detailed examination reveals further subtle conditions which affected the ways in which scientific knowledge "travelled" from one place to another. To this end it is useful to examine the relationship between scientific knowledge presented in texts and the skills of experimentation that transfer face to face. Publications on blowpipe analysis were descriptions of experimental practices linked to particular contexts. Even when examining the use of an instrument celebrated for its simplicity, it is useful to look beyond textual translations to the activities of travellers who acquired new skills and knowledge which they later used to effect changes in their own local contexts.

As we will see in the following account, blowpipes were simple in design but difficult to use. A significant amount of skill was necessary to conduct analyses correctly. In Sweden, attention was given to, and patronage from the state received for, instituting training regimes which facilitated face-to-face, practical training in blowpipe analysis for chemists and mineralogists. This system was observed by three British travellers to Sweden in the late eighteenth and early nineteenth century: Smithson Tennant, Edward Daniel Clarke, and Thomas Thomson. Upon their return to Britain, these travellers pursued an ambitious programme to reform the educational practices in chemistry and mineralogy, and each carried back to Britain a particular interest in blowpipe analysis. Many acknowledged that the books and articles which discussed the uses of this instrument were inadequate guides for teaching others the practical skills involved in this useful form of chemical analysis. Thus, looking at travellers' moments of "hands-on" training helps us to get a sense of the wider issues involved in the transfer of this form of experimentation from Sweden to Britain.

2. TRAINING AND ANALYSIS IN SWEDEN

Chemists in the eighteenth century worked within a framework which distinguished between "dry" methods of chemical analysis, which focused on reactions to heat, and "wet" (or "solution") methods of analysis.[10] Fire was the central component in dry methods of analysis, the uses of which were promoted by the development of different kinds of furnaces (often the centrepiece to alchemists' or chemists' laboratories) and blowpipes. The ability to intensify and concentrate flames broadened the range of chemical reactions, and created new means to define "chemical elements" which contributed to mineral classification.[11] These classification systems distinguished between so-called "species" of minerals.[12] In addition to perceived external characteristics, the practice of melting minerals to determine their chemical composition became essential to classification systems.[13] The first order of classification was the characteristic of fusibility—determining if the mineral could be melted, a quick test with the blowpipe. If the mineral *was* fusible, a larger sample would typically be placed in a furnace for further tests to determine its chemical composition. Chemical analysis of minerals with furnaces was common practice by the late eighteenth century, yet not without its problems. It was clumsy and time consuming. Precise temperatures were difficult to judge and maintain, hours were needed for the specimen to burn, and only once the furnace was opened—was the end result visible.

Before it was developed as an instrument for the chemical analysis of minerals, the blowpipe was a familiar tool for prospectors, smelters, and artisan glass-blowers. However, William Campbell has noted that seventeenth-century natural philosophers including Robert Boyle and Robert Hooke found a "small crooked pipe of metal or glass, such as tradesmen for its use call a blow-pipe," useful for assaying purposes.[14] Traces of the use of the instrument in mineralogy also stem back to the seventeenth century, when natural philosophers directed blowpipe flames onto mineral samples to reduce them to their simple metallic constituent. This test was designed to meet the practical demand of estimating the amount of metal which could be obtained from an ore, an important analysis for prospectors tending to the increasingly important mining industry both on the Continent and in Britain. Continental theories of mineralogy and chemistry, especially in Sweden and Germany, gave new meaning to heat analysis, mineral classification, and the value of blowpipe analysis for the mining industry.[15]

Compared to the "portable laboratories" (which consisted of small furnaces) designed by London instrument makers and natural philosophers in the eighteenth century, blowpipe equipment used in Sweden proved more efficient.[16] Because of their portability, blowpipes could be conveniently taken to the mines where on-site analyses could take place, thus realising the advantage of *in situ* observations during field experiments. During analysis, a pea-sized mineral sample was used, carefully ground to powder, making experiments on precious metals more economical and instantaneous. Unlike using furnaces, the blowpipe allowed the analyst to see chemical reactions as they occurred, rather than just the end result. Hence, flame and smoke colour and brightness, smell, reactions when cooling, weight, even sound in certain instances all became signs signifying the mineral's chemical constituents.

The first order in mineral classification systems which the blowpipe quickly determined was combustibility. In the eighteenth century, a substance's ability to burn was thought to be a characteristic marked by the presence of phlogiston in the substance. While phlogiston itself could not be isolated during combustion, weight differences recorded with a precision balance indicated degrees of combustibility, which provided for a two-component theory of classification. Combustible earths could be distinguished experimentally and classified based on measurements of the degree of phlogiston released, as well as different appearances in the reaction of the specimen to heat analysis. Further, the "affinity" which held the component parts together could likewise be measured through degrees of combustibility, which worked by quantifying weight differences in minerals' constituent ingredients. Blowpipe analysis thus involved skilful qualitative analysis (interpreting empirical signs of the combusting mineral) as well as quantitative measurements (such as using the balance), thus resembling the analytical spirit of precise and disciplined measurement which later became associated with the theory of definite proportions.[17]

While the benefits of blowpipe analysis were in its economy, portability, and efficiency, much was demanded of the analyst. Associated equipment ranging from the chemical reagents to the candlewick needed careful preparation. Special training was required in order to link the empirical signs—such as flame coloration—to substances present in the mineral sample. For a number of specimens, however, different chemical fluxes and reagents were used in the analysis which increased the complexity of the visual language of colours displayed.[18] "Reading" the signs of the reaction was not all that was taught. In order to get the expected responses from the mineral, a particular style was necessary in using the instrument. As the Swedish doyen of late eighteenth-century blowpipe analysis, Jacob Berzelius, wrote, "the variations in the sort of flame required in experiments with the blowpipe, depend on such slight changes in the position of the beak [tip of blowpipe], that it is impossible to accomplish them with precision by the mere action of the mouth."[19] Successful analyses often hinged on the ability of the practitioner to create a consistent reducing flame when blowing into a candle flame. Thus not only were the reactions of the burning mineral to be observed, but careful control in managing the yellow, orange, or blue parts of the flame was necessary. Nor was it as simple as merely blowing through the pipe. Most experiments could be conducted within a few minutes, but during this time the practitioner was required to maintain a steady flow of air through the instrument—a notoriously difficult task. Advice on how to accomplish this included filling one's cheeks with air, slowly releasing it, and simultaneously inhaling through the nose. Determined students frequently confessed to light-headedness, muscle aches, and fatigue when conducting experiments.

Skilful operation required specific training in observation and technique; one had to acquire "the knack," as was reported in Rees' *Cyclopaedia.*[20] It was the "skill in its application" and the "sufficient knowledge of the phenomena presented," as Berzelius further remarked, that Swedish miners gradually acquired through training at the mining academies, and what university students went on to use for the development of their classification systems. It is significant that all Swedish pioneers of chemical and mineralogical analysis were at some time connected to either the chemical labs at Uppsala University or the Board of Mines.

The chemical laboratory at Uppsala was in operation by 1754 and used by the first professor of chemistry Johan Gottschalk Wallerius.[21] Wallerius worked with Daniel Tilas, a supervisor at the Board of Mines who worked with Cronstedt, who also studied at Uppsala. Wallerius' successor, Bergman, extended Cronstedt's blowpipe experiments and was quickly recognised as a leading blowpipe analyst.[22] Engeström learned blowpipe analysis from Cronstedt at the Swedish Mint, and afterwards both of them found employment at the Board of Mines. Two people working with Bergman, Carl Scheele and Johan Gottlieb Gahn, went on to become luminaries in Swedish chemistry and obtained positions elsewhere; in 1775 Scheele became an apothecary in Köping and, in 1784, Gahn became an assessor for the Board of Mines at Falun, the oldest and most productive mine in Sweden. Berzelius studied in Uppsala under Johan Afzelius and was trained in the proper use of the blowpipe by Gahn. In his autobiographical notes, Berzelius drew a vivid picture of his experiences with Gahn. "It was surprising to see the speed and accuracy with which he could identify minerals and how traces of metals, which otherwise would certainly have escaped the eyes of the analyst, could be detected and identified," he noted while collecting minerals with Gahn in Falun in 1814.

> Gahn, who at this time had attained an age of seventy years, followed the work with youthful vivacity. I learned his method of handling the blowpipe, with which he had acquired unusual skill, enhanced by the

> microchemical methods he had developed. Henceforth the blowpipe became an altogether indispensable tool for the analytic chemist as well as for the mineralogist. A number of simple chemical instruments, moreover, had been devised by Gahn for his own use but had never been described and therefore were not known.[23]

Berzelius' encounter with Gahn was not unusual. He noted that

> Gahn always travelled with his blowpipe, and the continual use which he made of it, led him to make several improvements in its application; ... He most readily and carefully instructed those who were desirous of information on the subject, but he never appears to have thought of publishing an account of his labours, nor has it been done by others.[24]

Gahn's position with the Board of Mines made his abilities at training others in blowpipe analysis important to the Swedish economy, linked as it was to the palaeoindustrial exploitation of mines.[25] Between the development of laboratory practices, the elaboration of classification systems based on blowpipe analysis, and the training regime instituted under the direction of the Board of Mines and Uppsala University, blowpipe analysis – recognised for both theoretical and practical uses – received heavy patronage.

From Cronstedt and Engeström in the 1760s to Gahn and Bergman in the 1780s to Afzelius and Berzelius in the 1800s, a direct pedagogical heritage is traceable in which the skills of blowpipe analysis, face-to-face demonstrations, and training for dexterity and acute observation, were passed on through generations of analytical chemists and mineralogists.[26] The sites of the Swedish laboratory and assaying chamber (spaces with blurred boundaries in Sweden) were regarded as perhaps the most important places in the production of knowledge, for it was here that all miners were obliged to undergo training, including blowpipe analysis, before travelling to mines all over Sweden.

Late eighteenth-century chemical analysis of minerals in Sweden was recognised by natural philosophers elsewhere. Not only did Swedish analysts travel with their blowpipes (at home and abroad), but accounts of their achievements and their classification schemes were published in foreign journals and books. Nevertheless, the practice remained a particularly Swedish enterprise. This was not because the published accounts of their analytical practices were disguised to protect national secrets, but because the craft skills involved with this form of experimental practice could not be transferred through the textual medium. The development of blowpipe analysis in Britain in the early decades of the nineteenth century – long after textual accounts of blowpipe analysis in Sweden were available in London – can be linked to Sweden via the travels of certain Britons trained there.

3. TRAVELLERS TRAINED

In 1782, the young Smithson Tennant inherited his father's estate in Yorkshire, providing him with enough income to leave his Edinburgh medical studies and migrate to Christ's College, Cambridge, where he entered with the privileged status of Fellow Commoner.[27] With very few academic obligations, Tennant took to the casual pursuit of the extra-curricular subjects of botany and chemistry. His interests in chemistry were first sparked by the Professor of Chemistry in Edinburgh, Joseph Black, most well-known for his work on gases in which he isolated "fixed air" (carbon dioxide). Desirous of exploring the wider intellectual geography of chemistry, Tennant took further advantage of his new wealth and embarked on a trip to Sweden, where he hoped to meet the famous Uppsala chemists. When he arrived in Stockholm at the end of July 1784, however, he learned that Bergman had recently died. Further, his meeting with Scheele the following month was hampered by language. The only way they could communicate was through an intermediary: Tennant spoke English or Latin, Scheele Swedish or German.[28] Despite these trying circumstances, Tennant's travels through Sweden were not in vain. Carrying Engeström's 1770 edition of Cronstedt's *An Essay Toward a System of Mineralogy*, along with Engeström's *Guide aux Mines*, Tennant went to visit Engeström himself, who was a central administrator at the Board of Mines in Stockholm. Besides touring chemical labs, Tennant also met Gahn, with whom he spent a week learning – in Gahn's preferred "hands on" method – the skills of blowpipe analysis.

Tennant returned to Cambridge in late 1784 with newfound enthusiasm for practical chemistry and blowpipe analysis (Tennant designed his own blowpipe after returning to England; see illustration 1). He was one of the founding members of the short-lived Askesian Society and in 1813 became professor of chemistry at Cambridge. Soon, his experiments and portable chemical apparatus attracted the interest of a number of students, in particular William Hyde Wollaston, who proved keen to take up research in blowpipe analysis. Wollaston had attended the lectures of the Jacksonian Professor of Natural and Experimental Philosophy and Chemistry, Isaac Milner, before Milner was driven from the University for his radical

Unitarian beliefs. According to Wollaston, Milner was a "first-rate Showman," who kept students entertained by staging experimental explosions and dramatic chemical reactions. For professors whose income often depended on the enrolment of students, entertaining often proved more useful than lecturing.[29] In 1792 Francis Wollaston, William's brother, succeeded Milner and seems to have stuck to the syllabus a bit more closely. The syllabus included a description of chemical apparatus, including various types of furnaces, blowpipes, and lenses; it discussed the various degrees of heat necessary for the fusion of substances, processes for separating the ingredients of compound bodies, as well as doctrines of chemical affinity. The course was then further divided into an investigation of the three kingdoms of nature with discussion on the natural history and practical uses of chemical substances.[30] Despite being extra-curricular, the activities of even a small group (in a thinly populated university) suggest that experimental practices in chemistry were an increasingly stimulated subject in Cambridge.

As Henry Warburton, a fellow Cantabrigian and Secretary of the Geological Society of London later remarked, when Tennant returned from Sweden he had "strengthened in [William] Wollaston that passion for the science [of chemistry] which Milner had kindled."[31] It was from Tennant that Wollaston became interested in small-scale chemical analysis, a method for which Wollaston later went on to champion, and which was a technique which had commonly been associated with blowpipe analysis.[32] Even Berzelius, after having travelled to England in 1812, informed Gahn about Wollaston's "astonishing ability" to work with small quantities of materials. Commenting on Wollaston's scrupulous detection of nickel in meteoric iron, he noted:

> The whole of his apparatus for these experiments in some bottles with stoppers, drawn out to a point so that they reach down into the liquid and collect one drop, which is the quantity he needs to extract. In these he keeps the commonest acids, alkalis and a few reagents. The solutions are made on a narrow glass strip, and he uses a small lamp for his blow-pipe and evaporation experiments on the piece of glass. Everything stands on a small wooden board with a handle, and is taken out or put away all together.[33]

Tennant and Wollaston together pursued a line of chemical inquiry using blowpipe analysis. Through researches with Tennant on crude platinum, Wollaston was able to develop platinum crucibles for blowpipe experiments, helping to reduce the risk of contamination of the analysis previously performed with weaker crucibles.[34] Wollaston not only pursued his own line of inquiry in chemical mineralogy, but, by 1806, had designed his own portable blowpipe.[35] Nor were their researches isolated. After becoming professor of chemistry in 1813, Tennant corresponded with Berzelius, discussing the results of his, Wollaston's, and others' experiments at Cambridge and London.[36]

Wollaston's and Tennant's collaboration in blowpipe analysis took place within a community experiencing rapid changes in common concepts and practices in chemistry. By the late 1780s, the "new chemistry" of anti-phlogiston was promulgated by many across Europe. Even though blowpipe analysis grew from theoretical principles based on phlogiston chemistry, its usefulness as a methodological practice transferred easily to the chemistry of oxygen. In short, the effects of mineral combustion with the blowpipe flame could be explained either by the old or new chemistry. Many mineral analysts, whether using the blowpipe or the furnace, could have embraced the new chemistry. As Anders Lundgren has pointed out, in Sweden, where concerns over the practical identification of mineral substances were predominate, the signs of the chemical reaction—whether caused by the removal of phlogiston or the addition of oxygen—revealed information about the specimen's constituent ore.[37] The theoretical underpinnings of the chemical revolution that separated the "phlogistonists" from the anti-phlogistonists did not necessarily affect the experimental practices in chemical mineralogy and the use of instruments of fire to identify simple substances and construct mineral classification systems. Thus, in Cambridge in the 1790s, the phlogistonist geologist and mineralogist John Hailstone could replicate the anti-phlogistonist Martin Klaproth's experiments on the analysis of Baryta with the central concern being that the furnace was constructed properly.[38] By the beginning of the nineteenth century, mineral analysis with the blowpipe could well embrace Lavoisian chemistry. Lavoisier himself seems to have employed traditional blowpipe experiments to develop his mineral classification scheme, which showed how the blowpipe, the effects of the chemical reaction, and the use of the precision balance could work towards a rational analysis of mineral composition.[39]

The culture of chemistry in Cambridge in the 1790s grew to encourage new forms of experimental practices and the use of new types of instruments, and to accommodate debates about the nature of chemical reactions. From this atmosphere in 1799, Edward Daniel Clarke, a Fellow from Jesus College and a former student of Milner's, set out on an exploration of Europe as a "travelling tutor" to a young gentleman named

John Marten Cripps. Their first destination was Sweden. Clarke was a seasoned traveller by this time, having spent much of the decade supervising other patrician students on fashionable trips to the Continent. This was the first time, however, that Clarke would see Scandinavia, a land little explored by British travellers but of great interest, not least due to Tennant's recent sojourn. Following in Tennant's footsteps, Clarke went well prepared. He read up Linnaeus' *Flora Lapponica,* Pontoppidan's *Natural History of Norway,* and Engeström's *Guide du Voyage,* all purchased specially for the journey.[40] From the outset, natural history was central to their interests and both eagerly collected mineral, botanical, and insect specimens.[41]

Clarke was an indefatigable traveller with an ambitious itinerary. Moving swiftly through Copenhagen and Stockholm, through "land of wood and iron," the travellers headed for Uppsala, having already made arrangements with Adam Afzelius, assistant to the professor of botany at the University and brother of John Afzelius, professor of chemistry. With their horses, servants, translators, and wagons loaded with trunks and specimens, they approached the University.

> Its appearance, in approach to it, is really noble: we descended a hill towards it, calling to mind the names of Celsius, Linnaeus, Wallerius, Cronstedt, Bergmann, Hasselquist, Fabricius, Zoega, and a long list of their disciples and successors, which has contributed to render this University illustrious; the many enterprising young travellers it has sent forth to almost every region of the earth; the discoveries they have made, and the works of which they are the authors. For since the days of Aristotle and Theophrastus, the light of Natural History has become dim, until it beamed, like a star, from the North; and this was the point of its emanation.[42]

Clarke and Cripps remained in Uppsala for about a week, absorbed in the glory of the past. Uppsala was where the "northern star" had shone, reminiscent of the image of *Svecia*, the allegorical guardian of the Board of Mines, sitting on her throne with the North Star beaming over her crown.[43] The light illuminated the activities of the chemists and natural historians in the eighteenth century whose work was celebrated around the world. Clarke reflected on the history of Uppsala, "once the metropolis of all Sweden," and commented that comfort was to be found in the thought that the university "may never be without a Wallerius, a Hasselquist, a Thunberg, or a Berzelius."[44]

With letters of introduction from Hailstone, the vice-chancellor of Cambridge University, and assorted English diplomats, Clarke and Cripps were shown around the famous Botanic Garden. They saw the cottage where Linnaeus had once lived, and visited the chemical laboratories where Wallerius and Bergman had worked. Finally, "having expressed an earnest wish to be present at some of the public lectures," they joined the students and attended the lectures of Thunberg, who succeeded Linnaeus in the botanical chair, and John Afzelius's chemical lectures. The latter lectures were particularly impressive, thought Clarke:

> Around the chemical lecture room was arranged the Professor's collection of minerals, - perhaps more worthy of notice than anything else in Uppsala; ... It was classed according to the methodical distribution of Cronstedt, and has been in the possession of the University ever since the middle of the eighteenth century. The celebrated Bergmann added considerably to the collection, which may be considered as one of the most complete in Europe; especially in specimens from the Swedish mines, which have long produced the most remarkable minerals in the world. ... One small cabinet contained models of mining apparatus; pumps, furnaces, &c. There is no country that has afforded better proofs of the importance of mineralogical studies to the welfare of a nation, than Sweden.[45]

Encountering a mineral collection based on Cronstedt's methods, who, as Clarke went on to note, "laid the true foundation of the science, by making chemical composition of minerals the foundation of the species into which they are divided," was to have a significant impact on the view that Clarke maintained of the organisation of the mineral kingdom and of mineralogical investigations. But Clarke's mineralogical training did not stop in Uppsala.

With Engeström's *Guide aux Mines* in hand, Clarke and Cripps journeyed up to the Great Copper mine in Falun to meet (the now anti-phlogistonist) Gahn, who was head of the research school. Gahn was occupied in extending the experimental research into the chemical composition of minerals begun by his mentor Cronstedt, as well as training students in blowpipe analysis, including Berzelius, who was still working with Gahn at that time. During his few weeks with Gahn, Clarke also received training in the use of the blowpipe. Soon he was an enthusiast not only for mineral collecting, but mineral analysis. Throughout the remainder of their journey, Clarke was equipped with a blowpipe and conducted a number of on-the-spot experiments. Appropriately, as a vignette to a chapter in his *Travels,* Clarke reproduced a picture of his travelling "mineralogical apparatus," including a blowpipe, hammer, and phials for fluxes and reagents.[46]

Clarke returned to Cambridge after his three-year journey with Cripps in 1802. Shortly after, Clarke was granted permission from the vice-chancellor of the university to unpack his collection (which totalled seventy-six boxes) and advertise "lectures" which related to his travelling experiences. Clarke occupied one of the lecture rooms next to the chemical laboratories in the Cambridge Botanic Garden. This became Clarke's "museum." The room was set up as a dazzling display of artefacts from exotic locations, a successful allurement to undergraduates. Clarke's "delivery was a masterpiece of didactic eloquence," recollected one student. "From every stone, as he handled it and described its qualities—from the diamond, through a world of crystals, quartz, lime-stones, granites, &c. down to the common pebble which the boys pelt with in the streets, would spring some pieces of pleasantry."[47] Clarke presented a unique natural history of each mineral, combining narration of where he had collected the specimen, an account of how various natural philosophers classified the mineral, as well as reflections on how ancient authors had described it. Included was his own classification scheme, based on blowpipe analysis.[48] So popular were Clarke's lectures that in 1808 the University Senate awarded him a specially-created position of Professor of Mineralogy.

A few years after Clarke settled down into his new professorial position in Cambridge, another British traveller visited Sweden, the Edinburgh-trained historian and chemist Thomas Thomson. From the beginning of the nineteenth century, Thomson, also a student of Joseph Black, was active in promoting chemistry. In 1802 the first edition of his popular *System of Chemistry* appeared and, between 1800 and 1811, he was a private chemistry tutor for Edinburgh students, to whom he offered unique training in practical laboratory classes.[49] In 1812, having just finished teaching, as well as writing his *History of the Royal Society,* Thomson decided to visit Sweden with the ostensible aim to "take a mineralogical survey of that Country ...to view as nearly as possible the state of chemistry in Sweden, and to make myself acquainted with the discoveries made in that science by the Swedes during the last ten years."[50]

It had been ten years since Clarke visited Sweden, but Clarke's account of his experiences there would not be published until 1819. Thomson was familiar with late eighteenth-century "guide-books" to Sweden and had similar natural philosophical interests as Clarke. Indeed, the account of his journey looks almost as if the two travelled together.[51] Like Clarke, Thomson had included hagiographic accounts of the great eighteenth-century chemists: Scheele, Cronstedt, and Bergman, praising their achievements in the chemical analysis of minerals. These chemists, reflected Thomson, "contributed prodigiously to the great revolution which chemistry underwent; invented many new methods of analysis, and left admirable models of research to their successors," such as Berzelius, who Thomson described as pushing ahead the frontiers of chemistry.[52]

In Stockholm, Thomson spent several days visiting various mineralogical collections and touring the Royal Academy of Sciences. When he arrived in Uppsala, Thomson met John Afzelius, the professor of chemistry, who showed him Bergman's laboratory and the mineral collection of the University. Continuing further north, collecting specimens along the way, Thomson visited Falun, where he met the sixty-eight year old Gahn, "an excellent mechanic, who has supplied himself with accurate philosophical instruments of every kind."[53] With Gahn, Thomson examined an admirable cabinet of minerals in Falun's "Mining Company," performed blowpipe analysis, and discussed recent experiments by Gahn and Berzelius.[54]

The trip was profitable for Thomson. Shortly after returning from Sweden – even before his mineral collection arrived back in Britain – Thomson wrote his *Travels,* which were published in 1813. That same year he became the editor of *Annals of Philosophy.* As editor of the journal, Thomson aimed to reform the image that British science was parochial and inferior compared to the rest of Europe; the articles, reviews, and summaries of annual achievements were meant to acknowledge and embrace European methods of inquiry and work to synthesise British and continental developments in natural philosophy.[55] Throughout the 1810s, Thomson's reputation as a successful textbook writer grew with successive, improved editions of his *System of Chemistry.* The decade of his achievements was crowned with his election to the position of Regius Professor of Chemistry at the University of Glasgow in 1818.

The 1810s also became the decade of the popularisation of the blowpipe in Britain. One of the most enthusiastic proponents of blowpipe analysis and ardent experimentalists was Clarke. From his lecture-room demonstrations to late-night laboratory experiments, the blowpipe was the core of Clarke's concentration. Nothing escaped the intense heat of the blowpipe, and with virtually every analysis he claimed a remarkable discovery. He was outspoken about the uses and benefits of blowpipe analysis, spreading the word in the local Cambridge newspaper which reported on his more spectacular experiments and in the many articles he wrote in the *Annals of Philosophy.*

In fact, Thomson's *Annals* – one of the main natural philosophical journals of the period – became the vehicle for a profusion of articles relating to blowpipe analysis. In general, this reflected the desire of a number of practitioners to try blowpipe analysis, to relate the results of their experiments, and often to draw attention to particular difficulties they encountered in their investigations. The activities of natural philosophical instrument makers, who redesigned and marketed a variety of blowpipe kits and "manuals" for their use, reveal a similar story. For chemists such as Friedrich Accum or Arthur Aikin, mineralogists like John Mawe, or instrument makers such as John Newman, the market in the 1810s for "portable labs" and travelling blowpipe kits could provide a lucrative source of income.[56] The relevance of Tennant's, Clarke's, and Thomson's travels to Sweden, and their explicit commitment to learning local practices for chemical analysis, is that their efforts to promote that method of experimental inquiry upon their return to Britain make them central to increased interest in their own local communities. The three travellers, who each endorsed blowpipe analysis through their teaching programmes and subsequent publications, were clearly linked to the propagation of this form of experimental practice. The transfer of blowpipe analysis from Sweden to Britain (as marked by the developments in Britain in the 1810s) is understood better through an examination of the activities of these travellers than the distribution of texts. As the following section suggests, the degree of skill involved in the practices of blowpipe analysis complicated its acceptance.

4. SKILL TRANSFER: DISCIPLINE OR DESIGN?

Many of the manuals relating to blowpipe practice, stemming back to Engeström's 1770 publication, confessed to the difficulties in rendering through text the subtleties involved in conducting accurate analyses, such as describing changes in flame colour, adjustments in breathing patterns, or other signs involved in the chemical reaction. In many accounts on the use of the blowpipe, authors included a disclaimer regarding the efficacy of their descriptions, and appealed to the necessity of direct training. Such was the appeal made by Berzelius, who was a tough critic of experimental practice: "As in other practical sciences, books alone are "weak masters" to make adepts in this; but they who had seen Cronstedt or Von Engeström at work, learned to work like them, and transmitted their skill to their successors."[57] For Berzelius, face-to-face transfer of skill could not be replaced by textual guides. In Berzelius' account of the history of the chemical and mineralogical sciences, people without contact to the masters were unlikely to advance in the field. Berzelius suggested that this was an important reason why Engeström's book was not well received in England:

> The work attracted the general attention of chemists and mineralogists to the use of the instrument, who, however, derived at first little other advantage from it, than as a means of ascertaining the fusibility of bodies, and occasionally their solubility in glass borax; for the want of that skill in its application, which can only be derived from patients [sic] and practice, together with a sufficient knowledge of the phenomena presented by the various fluxes for the bodies experimented on, prevented a just estimate being formed of its value, whilst the difficulties attending its use were abundantly evident; and hence, everywhere but in Sweden, the art of the blowpipe made but little progress.[58]

For some natural philosophers, the attempt to provide a widely accessible and reliable method of analysis, which would ideally provide an unproblematic classification scheme with the use of the blowpipe, could not rely upon textual guides. As an alternative to the problem of providing textual instructions, craftsmen and instrument makers worked to remove such complications altogether by designing an instrument that embodied analytical skills in its design. For example, in the 1780s Bergman experimented with a spirit lamp, slowly heated to release a constant flow of air. Another attempt was made by Bengt Geijer, also in the 1780s, who used displacement of water in two tanks to force air through the blowpipe. Such attempts, however, met with critical responses from some blowpipe practitioners who argued that, just as attempting to replace face-to-face training with texts, these designs reduced the effectiveness of analysis. Results were less subtle and more prone to error. Similar attempts to transfer the skill from the practitioner to the instrument were made in Britain.

Two articles appeared in the first few years of the 1800s suggesting how the blowpipe could be adapted and attached to a "gasometer" in order to produce intense heat for fusion.[59] Both devices were mechanically operated with bellows or pumps; the double barrel blowpipes were designed neither for subtle variations in air-flow nor portability. Two additional attempts to design a refined instrument with controlled flame appeared shortly after in *Nicholson's Journal.* A correspondent who signed as "N. N." noted that the blowpipe could prove useful to the chemist and mineralogist, but lamented the difficulties involved in attempting to follow the instructions for its use by Bergman or Engeström. Furthermore, he noted the inconvenience of having only one hand free while the other held the instrument. He proposed a device similar in design to one of Bergman's, where a heated container filled with alcohol forced vapour through the small pipe. He claimed, however, that the instrument was useful for fusion or soldering, and that "glass-blowers have long sold a little implement" similar in purpose.[60] Shortly afterwards, George Bellas Greenough described a blowpipe which operated on the principle of water displacement which was in use at the Royal Mineralogical Collection in Naples. In neither instance was the instrument's uses for mineralogical *analysis* referred to, just its convenience for fusion or soldering. It was clear that despite its versatile uses in Sweden for mineral classification, little had changed from Boyle's observation that blowpipes were "tradesmen's tools" in England. Blowpipes were devices useful for an artisan's craft of glass-blowing; if part of laboratory apparatus, they were more likely used for sealing flasks than as instruments of analysis.

In Britain, the transformation from a craft tool to a philosophical instrument – a status reached by the 1810s – was clearly not easy.[61] The "knack" one needed in order to perform successful blowpipe analysis made it difficult to train others, particularly with the lack of institutionalised positions for practical training in science. While mining in Britain had, throughout the eighteenth century, transmitted complex craft skills through generations by means of apprenticeships, a School of Mines was not opened up until 1851, in London.[62] As opposed to Sweden, where such institutional and government patronage promoted the union between practical mining and scientific theory, the uses of chemistry in mineralogy and the mining industry were not promoted in Britain until well into the nineteenth century.[63] Nevertheless, various attempts were made to legitimise blowpipe analysis which involved trying to replicate and standardise new experimental results reached using the blowpipe. It is interesting to observe who proffered suggestions for ways of making the use of the instrument easier.

In 1813 a letter appeared in the *Transactions for the Society for the Encouragement of Arts* by John Tilley, a craftsman sensitive to the subtle manners of using a blowpipe. "Being a travelling fancy glass-blower," he wrote, "I work with a machine which I have contrived for my own use, and which I have been advised, by a great number of respectable gentlemen, to lay before the Society of Arts, &C."[64] His "Hydro-pneumatic" blowpipe consisted of a tin box, approximately one square foot, fitted with handles. The box was internally separated into two compartments, each partially filled with water. Tilley claimed he could control the airflow by blowing through tube which caused a displacement of water, which in turn forced a controlled and steady stream of air through the pipe. "The whole apparatus," he went on to note, "including lamp and case, weighs only three pounds and a half."[65]

The benefits of this blowpipe were conveyed in an appended note to Tilley's letter, which was reprinted in the *Philosophical Magazine* in 1814:

> The usual manner of producing a stream of air for blowing glass, is by means of a small pair of double-acting bellows, fixed beneath a table, and worked by the operator's foot; ...The defect of the bellows are [*sic*], that the stream of air is not perfectly regular, which causes a wavering of the flame, so that it does not fall steadily upon the object which is heated.[66]

Tilley's blowpipe corrected this problem, and he deemed it suitable for artists and natural philosophers alike. The important feature of portability was retained with Tilley's blowpipe, and the emphasis on a continual, controlled flame acknowledged a central concern in its use. The instrument attracted immediate attention and the Society of Arts awarded it a Gold Medal for its unique design.[67]

Another structural change to the blowpipe came with the suggestion in 1816 from Henry Brooke, in a letter published in Thomson's *Annals of Philosophy*. Brooke was the first to replace the mouth tube with an air pump.[68] His design retained the metal box (he used copper) but removed the principle of water displacement. Instead, air was pumped and compressed into the sealed copper box. Extending from the front of the box was the air pipe, through which air was released; the flow was controlled by a stop-cock. This design rendered the instrument completely mechanical.

In the same year, John Newman, the instrument maker for the Royal Institution, published an article in their journal describing his structural change to the blowpipe. Newman modified Brooke's blowpipe by attaching a bladder to the air pump. Aware of Humphry Davy's researches on electrical decomposition of water and the combustibility of hydrogen, Newman filled the bladder with a mixture of oxygen and hydrogen gas, which was then pumped into the copper box. The mixed gases were burned, thus creating a flame without requiring an external source (candle, spirit lamp, etc.). Burning the oxy-hydrogen gas created a flame of greater intensity and higher temperature than previously produced, which effectively eliminated the characteristic of "infusibility" as the first order of a mineralogical classification system. This development had major implications for experimental results produced with Newman's blowpipe, also known as the "gas blowpipe."

By this time, changes in the design of the blowpipe produced new kinds of results one obtained when different quantities of gases were used in the experiment, thus re configuring the criteria of experiment. The use of very powerful flames eliminated the subtleties of experiment and important details about the chemical constituents of minerals. It had also altered what were originally considered the virtues of the instrument, including its portability, simplicity, and low cost. Some, like Berzelius, rejected changes in the design of the blowpipe, arguing the impracticality of trying to transfer human skill to a mechanical device. As Berzelius reminded his readers, correct use of the traditional, hand-held blowpipe involved a great deal of sensitivity in controlling air flow. The inventors of "pretended improvements" such as bellows, he complained, "have demonstrated by their very contrivances that they did not know how to use the blowpipe."[69]

While the heat from the new gas blowpipe pushed back the frontiers of analysis, an element of skill involved with the analysis was not lost. After the development of the gas blowpipe, Clarke quickly became known as *the* fervent analyst with this new instrument – so much so that philosophical shops began to advertise "Clarke's blowpipe" rather than "gas blowpipes" (illustration 7). With it, Clarke started a research programme which involved analysing everything from diamonds to rose petals, work which culminated in the publication of his *The Gas Blow-Pipe*, where he argued that the instrument was essential for every chemist and mineralogist.[70]

Some remained sceptical, such as Davy, who resisted Clarke's claim that with the blowpipe he was able to reduce refractory earths to their metallic constituents, something Davy claimed only he was able to do with his esteemed galvanic battery.[71] Clarke supposed that the reason for resistance was because others found difficulty in performing analyses and replicating his experiments in attempting to verify his results. In any sort of blowpipe analysis, varying the intensity of the flame, adjusting the proportion of the oxygen and hydrogen mixture, interpreting the colours involved in the reaction correctly, and knowing when to stop the analysis, continued to be difficulties for even the most skilled of analysts. Clarke's persistence, combined with crucial support and patronage he gained from Thomas Thomson (who encouraged Clarke to publish the results of his work in *Annals of Philosophy*), convinced many others of the benefits of blowpipe analysis.

I have drawn attention to the various means of mechanising blowpipe practice and the difficulties in replicating the experiments to point out the contemporaneous concern over the skill involved in using the instrument.

Once a sense of the amount of labour and training that was demanded of the analyst is obtained, one realises the difficulties involved in providing textual accounts of experimental practices. This helps broaden our conception of what contexts are necessary to consider when thinking about how scientific practices (and subsequent experimental results) "travel" to other places – particularly to places, such as Britain, with different bureaucratic, institutional, and pedagogical structures to support such activities.

5. CONCLUSION

The development of blowpipe analysis in the 1810s – changes in the structural designs of the instrument and the dissemination of the results obtained with it – was boosted by the interests and enthusiasm of certain individuals with special knowledge and training in the correct use of the instrument. If we consider the local community of Cambridge University, we see that two travellers – Tennant and Clarke – who acquired certain experimental skills while visiting Sweden, were crucial to the promotion of this form of chemical analysis. It is possible to trace others, like Wollaston, who then carried their skills elsewhere, and helped inform and perhaps influence the work of people around them. Clarke's enduring commitment to blowpipe analysis affected a number of practitioners, among them John Kidd, the professor of chemistry at Oxford. Kidd watched Clarke perform blowpipe experiments in Cambridge and later, in defence of science teaching at the ancient universities, cited the development of blowpipe analysis in Cambridge as a significant improvement in chemistry. After Clarke died, the excitement over accessibility and practice in chemical instrumentation at Cambridge was expressed by Erasmus Darwin, when he first arrived as a student in 1822. An early letter he wrote to his brother, Charles, offers an insight into what many of Clarke's students would no doubt have felt:

> There is a shop here with every sort of thing, it quite made my mouth water to *see* all the jars & stopcocks & all sorts of things, graduated tubes, blow pipes, cubic inch measures, test tubes & ye Lord knows what besides. ...I have also found out another very nice little man. He was 14 years assistant to ye late Dr Clarke, ye great mineralogist. I have bought 2 or 3 little stones from him; ... He sells things very cheap & so if you will mention any stones I can probably get them.[72]

By the 1820s, blowpipe analysis was part and parcel of chemical, mineralogical, and geological practice. The blowpipe was no longer constrained by disciplinary boundaries. It also continued to travel; Charles Darwin conducted blowpipe analyses while on the voyage of the *Beagle,* and Charles Lyell purchased a blowpipe in London in preparation for his travels in 1822.[73]

Thomson's support of Clarke and the coverage of blowpipe analysis in the pages of his *Annals* further propagated interest in this form of instrumentation. With the further development of blowpipe kits, such as those popularised by John Joseph Griffin in the 1820s, and the integration of blowpipe instruction at places such as the Surrey Institution, blowpipe analysis gradually became a routine part of chemical and mineralogical education. Although blowpipe analysis was significantly displaced by the invention of the Bunsen burner and spectral analysis in the 1850s, blowpipe practices continued to be taught in many chemistry classes into the twentieth century. Despite the existence of a number of texts on blowpipe analysis, including at least one reprint in 1984, few people can claim to have the skill necessary to perform blowpipe experiments properly.[74]

What is clear is that the transfer of blowpipe analysis from Sweden to Britain involved complicated steps. This article has examined certain conditions which made the development of practices of blowpipe analysis not just acceptable but popular. This account suggests ways that historians of science can refine conceptions of the diffusion of scientific knowledge. What we have traditionally called "science" does not travel; people who practice science do. All that is involved with experimental practices can not always be bound between hard covers and forwarded to different areas of the world. The production of scientific knowledge took place within a complex culture of communication and support which affected the way people behaved — the way natural philosophers worked to make sense of the world in which they lived and travelled.

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NOTES

[1] For a survey of the literature on the history of the blowpipe, see Brian Dolan, "Blowpipe," in A. Hessenbruch, ed. *Reader's Guide to the History of Science* (London: Fitzroy Dearborn, 2001), 87-88; useful studies which should be mentioned include U. Burchard, "The History and Apparatus of Blowpipe Analysis," *The Mineralogical Record*, 25 (1994) 251-277; W.B. Jensen, "The Development of Blowpipe Analysis," in J.T. Stock and M.V. Orna, eds., *The History and Preservation of Chemical Instrumentation* (D. Reidell Publishing Company, 1986), pp. 123-149; and W.A. Campbell, "The Development of Qualitative Analysis 1750-1850: The Use of the Blowpipe," The *University of Newcastle Upon Tyne Philosophical Society*, 2 (1971-2), 17-24.

[2] G. von Engeström, *Description and Use of a Mineralogical Pocket Laboratory, and especially the use of the Blowpipe in Mineralogy* (London, 1770), added as an addendum to his translation of A.F. Cronstedt, *Försök till Mineralogie eller Mineral-Rikets upställning* (1758).

[3] [Thomas Thomson] "Improvements in Physical Science during the Year 1816," *Annals of Philosophy*, 9 (1817), 6-13, 8.

[4] Jan Golinski, *Science as Public Culture: Chemistry and Enlightenment in Britain, 1760-1820* (Cambridge: Cambridge University Press, 1992), particularly chap. 6, for good discussion of analytical community, although he simplifies debates over blowpipe results.

[5] Ian Inkster, "Science and Society in the Metropolis: A Preliminary Examination of the Social and Institutional Context of the Askesian Society of London, 1796-1807," *Annals of Science*, 34 (1977), 1-32; G. Averley, "The Social Chemists": English Chemical Societies in the Eighteenth and Early Nineteenth Century," *Ambix*, 33 (1986), 99-128.

[6] For an account of the market for chemical apparatus and attempts to write chemical textbooks in the early nineteenth century , see Brian Dolan, "The Language of Experiment in Chemical Textbooks: Some examples from early-nineteenth-century Britain," in A. Lundgren and B. Bensaude-Vincent, eds., *Communicating Chemistry: Textbooks and their Audiences, 1789-1939* (Canton, MA: Science History Publications, 2000), pp. 141-164.

[7] J.J. Griffin, *Practical Treatise on the Use of the Blowpipe in Chemical and Mineral Analysis* (Glasgow, 1827), p. iii.

[8] B. Gee and W. Brock, "The Case of John Joseph Griffin: From Artisan-Chemist and Author-Instructor to Business-Leader," *Ambix*, 38 (1991), 29-62, 39; Inskster, *op.cit.* (5).

[9] It is worth noting, as Gee and Brock also pointed out, that Griffin's interests in blowpipe analysis probably grew from his personal acquaintance with Aikin, who was one of the original members of the Askesian Society. In this respect it is significant that Smithson Tennant was also one of the founding members of the Askesian Society; Gee and Brock, *op. cit.* (8), 39.

[10] For distinctions between dry and wet analysis, see W.A. Campbell, "Analytical Chemistry," in C.A. Russell, ed., *Recent Developments in the History of Chemistry* (London: Royal Society of Chemistry, 1985), pp. 176-190, pp. 178-179; A.G. Debus, "Fire Analysis and the Elements in the Sixteenth and the Seventeenth Centuries," *Annals of Science*, 23 (1967), 127-147; A.G. Debus, "Solution Analyses prior to Roberty Boyle," *Chymia*, 8 (1962), 41-61.

[11] F.L. Holmes, "Analysis by fire and solvent extractions: the metamorphosis of a tradition," *Isis*, 62 (1971), 129-148; R. Siegfried and B.J. Dobbs, "Composition: A neglected aspect of the chemical revolution," *Annals of Science*, 24 (1968), 275-293; H. Cassebaum and

G.B Kauffman, "The Analytical Concept of a Chemical Element in the Work of Bergman and Scheele," *Annals of Science*, 33 (1976), 447-456.

[12] R. Hooykaas, "The species concept in 18th century mineralogy", *Archives Internationales d'Histoire des Sciences*, 5th year (1952), 45-55; D.R. Oldroyd, "Mineralogy and the "Chemical Revolution," *Centaurus*, 19 (1975), 54-71.

[13] R. Laudan, *From Mineralogy to Geology: The Foundations of a Science, 1650-1830* (Chicago: University of Chicago Press, 1987), for discussion of external characteristics and crystallography.

[14] Hooke quoted in Campbell, *op. cit.* (1), p. 17; also F. Greenaway, *Chemistry: 1: Chemical Laboratories and Apparatus to 1850* (London, 1966); G. Turner, *Nineteenth-Century Scientific Instruments* (London: Philip Wilson Publishers Ltd., 1983); M. Dumas, *Scientific Instruments of the 17th and 18th Centuries* (New York: Praeger, 1972), for chronological catalogue of blowpipes.

[15] T.M. Porter, "The Promotion of Mining and the Advancement of Science: the Chemical Revolution of Mineralogy," *Annals of Science*, 38 (1981), 543-570; B. Earl, *Cornish Mining: The Techniques of Metal Mining in the West of England, Past and Present* (Cornwall: D. Bradford Barton Ltd., 1968), for examples in Britain; Frangsmyr, "Science in Sweden;" see Gee and Brock, *op. cit.* (8) for discussion of later significance of continental theory for British chemistry and mineralogy, 39-41.

[16] For example, in 1731 two well-known London natural philosophers published a book describing a "portable laboratory" for various chemical analyses. They described small, portable furnaces, the uses of which extended from testing mineral composition of minerals at mines to providing a means for families to brew their own alcohol. See P. Shaw and F. Hauksbee, *An Essay for Introducing a Portable Laboratory: By Means where all of the Chemical Operations are Commodiously Perform'd, for the Purpose of Philosophy, Medicine, Metallurgy, and a Family* (London, 1731) for broader conception of portable labs, which include blowpipe kits, see W.A. Smeaton, "The Portable Chemical Laboratories of Guyton de Morveau, Cronstedt and Gottling," *Ambix*, 13 (1966), 84-91.

[17] D.R. Oldroyd, "Some Phlogistic Mineralogical Schemes, Illustrative of the Evolution of the Concept of "Earth" in the 17th and 18th Centuries," *Annals of Science*, 31 (1974), 269-305; A. Lundgren, "The Changing Role of Numbers in 18th-Century Chemistry," in T. Frangsmyr, J. Heilbron, and R. Rider, eds., *The Quantifying Spirit in the 18th Century* (Berkeley and Oxford: University of California Press, 1990), 245-266, for suggestive comments about bringing the quantifying spirit to blowpipe analysis.

[18] See Campbell, *op. cit.* (1) for chart of simple colour scheme in blowpipe analysis, p. 23.

[19] J.J. Berzelius, *The Use of the Blowpipe in Chemical Analysis, and in the Examination of Minerals* trans. J.G. Children (London, 1822), p. 13.

[20] A. Rees, *The Cyclopaedia; or Universal Dictionary of Arts, Sciences, and Literature*, 39 vols (London, 1819), "Blow-pipe" (probably written by Arthur Aikin, vol. IV, no pagination, published in 1805).

[21] S. Lindroth, *A History of Uppsala University, 1477-1977* (Stockholm: Almqvist & Wiksell, 1976).

[22] M. Beretta, "T.O. Bergman and the Definition of Chemistry," *Lychnos*, (1988), 37-67, pp. 37-38.

[23] Qtd. in J. Jorpes, *Jac. Berzelius: His Life and Work*, trans. B. Steele (Stockholm: Almqvist & Wiksell, 1966), pp.87-88.

[24] Berzelius, *op. cit.* (19), p. 5; a translation of a paper penned by Gahn did appear: see [J.G. Gahn], "On the Blow-pipe;" for more information on Gahn, see Jan Trofast, *Johan Gottlieb Gahn* (Lund: Wallin & Dalholm, 1994).

[25] S. Lindqvist, *Technology on Trial: The Introduction of Steam Power Technology into Sweden, 1715-1736* (Uppsala: Almqvist & Wiksell, 1984), pp. 95-107 for discussion of the work of the Board of Mines.

[26] Some might wonder why Anton von Svab, who was assessor to the Mining Academy at Stockholm in the 1730s, is not added to this list; Gee and Brock *op. cit.* (8), for example, cite Svab as the first in Sweden to use the blowpipe in chemical mineralogy, but Campbell *op. cit.* (1) suggests that this was a mistaken claim which originated with a reference by Linnaeus; Burchard *op. cit.* (1) observed that a reference by Bergman to "Swab" as the first to use the blowpipe was not to Anton, but to Andreas, who died before alleged blowpipe experiments took place, which may have further confused the point. It should also be noted that Jensen *op. cit.* (1) recognised the importance of examining communities of chemists amongst whom skilled techniques could be transmitted, but preferred to trace a chronology of blowpipe literature.

[27] D. McDonald, "Smithson Tennant, F.R.S. (1761-1815)," *Notes and Records of the Royal Society of London*, 17 (1962), 77-94.

[28] S. Tennant, "Journey to Stockholm 1784," diary transcribed by Henry Warburton, Cambridge University Library, MSS ADD 7736, entries for 28 July and 26 August.

[29] William Wollaston's account of Milner in Cambridge University Library, MSS ADD 7736, Box 2, Envelope B, ff. 2-3; for income and entertainment, see J. Golinski, "Utility and Audience in Eighteenth-Century Chemistry: Case Studies of William Cullen and Joseph Priestley," *British Journal for the History of Science*, 21 (1988), 1-31.

[30] I. Milner, *A Plan of a Course of Chemical Lectures* (Cambridge, 1788); F.J.H. Wollaston, *A Plan of a Course of Chemical Lectures* (Cambridge, 1794); Cambridge University Library has an annotated copy of Wollaston's syllabus: class-mark 7360.d.ll.

[31] Cambridge University Library, MSS ADD 7736, Box 2, Envelope B, f. 2, "Biographical Sketch of Tennant."

[32] B. Gee, "Amusement Chests and Portable Laboratories: Practical Alternatives to the Regular Laboratory" in F.A.J.L. James, *The Development of the Laboratory: Essays on the Place of Experiment in Industrial Civilization* (London: Macmillan Press, 1989), pp. 37-58, mistakenly claims that Wollaston travelled to Sweden, whereas Tennant was the traveller, p. 46.

[33] Berzelius qtd. in D. Goodman, "William Hyde Wollaston and His Influence on Early Nineteenth-Century Science" (Ph.D. Thesis, Oxford University, 1965), p. 129.

[34] Goodman, *op.cit.* (33), pp. 128-132.

[35] Wollaston's experiments in his notebook, Cambridge University Library , MSS ADD 7736, Box 2; Wollaston, "Description of a Portable Blow-Pipe."

[36] For Tennant -Berzelius correspondence, see manuscripts in Royal Academy of Sciences, Stockholm, Saml. 3, ff. 96-101.

[37] A. Lundgren, "The New Chemistry in Sweden: The Debate that Wasn't," *Osiris*, 2nd series, 4 (1988), 146-168, p. 165; E.M. Melhado, *Jacob Berzelius: The Emergence of His Chemical System* (Stockholm: Almqvist & Wiksell, 1980), p. 130.

[38] For brief discussion about Hailstone's experiments, see B. Dolan, *Governing Matters: The Values of an English Education in the Earth Sciences* (Cambridge University, unpublished PhD thesis, 1995), pp. 165-166; Hailstone's experiments described in correspondence at West Sussex Record Office, Hawkins Papers.

[39] A.L. Lavoisier, "De l'action du feu animé par l'air vital sur les substances minerals les plus réfractaires," *Œuvres de Lavoisier,* 6 vols (Paris, 1864-1893), Vol. III, pp. 451-502; Oldroyd, *op. cit.* (12), pp. 60-61; E.L. Gonzalez, "Bochard de Saron and the Oxyhydrogen Blowpipe," *Bulletin for the History of Chemistry* 4 (1989), 11-15, T. Levere, "Lavoisier: Language, Instruments, and the Chemical Revolution," in T. Levere and W. Shea, eds., *Nature, Experiment, and the Sciences* (Dordrecht & London: Kluwer Academic Publishers, 1990), 207-223; Jan Golinski, "The Nicety of Experiment: Precision of Measurement and Precision of Reasoning in Late Eighteenth-Century Chemistry," in M. Norton Wise, ed., *The Values of Precision* (Princeton: Princeton University Press, 1994), for the processes of persuasion used by the anti-phlogistonists to argue the accuracy of the instruments used to "prove" the new chemistry .

[40]E.D. Clarke, *Travels in Various Countries of Europe, Asia, and Africa*, 6 vols (London: Cadell and Davies, 1810-1823), references in Vol. V.

[41] For more thorough discussion of Clarke's travels, within the context of the cultures of scientific travel in the late eighteenth-century, see B. Dolan, *Exploring European Frontiers: British Travellers in the Age of Enlightenment* (Basingstoke: Macmillan, 2000).

[42] Clarke, *op. cit.* (40), Vol. V, p. 171; see also H. Sandblad, "Edward D. Clarke och Giuseppe Acerbi, upptacktsresande i Norden 1798-1800," *Lychnos* (1979-80), 155-205.

[43] For Svecia, see Lindqvist *op. cit.* (25), p. 104.

[44] Clarke, *op. cit.* (40), Vol. V, p. 88.

[45] Clarke, *op. cit.* (40), Vol. V, pp. 178-179.

[46] Clarke, *op. cit.* (40), Vol. IV, p. 594.

[47] J.M.F. Wright, *Alma Mater: or, Seven Years at the University of Cambridge*, 2 vols (London: Black, Young & Young, 1827), Vol. II, pp. 30-31.

[48] E.D. Clarke, *A Methodical Distribution of the Mineral Kingdom* (Lewes, 1806); E.D. Clarke, *A Syllabus of Lectures in Mineralogy* (Cambridge, 1807).

[49] J.B. Morrell, "Thomas Thomson: Professor of Chemistry and University Reformer," *British Journal for the History of Science*, 4 (1969), 245-265, 246.

[50] T. Thomson, *Travels through Sweden, during the autumn of 1812* (London, 1813), p. 1.

[51] Historians interested in travellers must exercise caution when using published accounts of journeys as if they were field-notes. Published accounts, sometimes written years after the journey took place, were often embellished to meet the demands of an audience eager for new information or exciting narratives. Also, authors often swapped travel-notes and letters in order to reconstruct the journey. What may appear a spontaneous quip about local customs in the published narrative, for example, may have been thought of when relaying stories of the journey at dinner parties back home. The case of Thomson and Clarke is an example. Much of Thomson's observations of Swedish mines and reflections on the "state of chemistry," published in 1813, appear verbatim in Clarke's account, published in 1819. In fact, this was not unusual, and for this reason consulting as many contemporary accounts as possible helps capture the spirit of the genre of travel literature published in a particular era. Many travel writers "borrowed" text from other authors, but usually claimed the uniqueness of their books lay in their *additional* observations. Published travel accounts can generally be relied on as records of where people went, when they arrived, and who they met. Particulars, such as what they thought about individuals or what they gathered along the way, are best cross-referenced with

correspondence (often published in *Life and Letters,* as in Clarke's case) or manuscript diaries, when extant.

[52] Thomson, *op. cit.* (50), p. 173.

[53] Thomson, *op. cit.* (50), p. 222.

[54] Thomson, *op. cit.* (50), pp. 224-227.

[55] Morrell, *op. cit.* (49), p. 247.

[56] For more on the "pedagogical market place," Dolan, *op. cit.* (6).

[57] Berzelius, *op. cit.* (19), p.3; for another discussion of skill in laboratory practice compared to textual accounts, see H.O. Sibum, "Reworking the Mechanical Value of Heat: Instruments of Precision and Gestures of Accuracy in Early Victorian England," *Studies in History and Philosophy of Science*, 26 (1995), 73-96.

[58] Berzelius, *op. cit.* (19), p.3.

[59] A. Tilloch, "Account of some interesting Experiments, performed at the London Philosophical Society," *Philosophical Magazine*, 8 (1800), 21-29, 262-266, 322-326; R. Hare, "Memoir on the Supply and Application of the Blowpipe," *Philosophical Magazine*, 14 (1802), 238-245, 298-306.

[60] "N. N.", "Description of a cheap and simple Apparatus or Blow-pipe, in which the flame of Oil or Tallow is impelled by Vapour of Alcohol," *Journal of Natural Philosophy, Chemistry, and the Arts,* 3 (1802), 1-3, 2.

[61] For the wider transition in the discipline of chemistry as a whole, see L. Roberts, "Filling the Space of Possibilities: Eighteenth-Century Chemistry's Transition from Art to Science," *Science in Context*, 6 (1993), 511-533.

[62] J.R. Harris, "Skills, Coal and British Industry in the Eighteenth Century," *History*, 61 (1976), 167-82; H. Torrens, "Some Thoughts on the Complex and Forgotten History of Mineral Exploration," *DUGS Journal*, 17 (1996), 1-12, although Torrens does mention that in 1818 a short-lived "School of Mines" was run by James Ryan in Montgomeryshire: p. 5; Ross, a late-eighteenth-century writer on blowpipe analysis, expressed his dissatisfaction with The City Guilds of London Institute and the Royal School of Mines, for their lack of interest in teaching blowpipe analysis earlier in the century; W.A. Ross, *The Blowpipe in Chemistry, Mineralogy and Geology* (London, 1889), p. x; as a side-note, however, by the 1840s Durham University was training engineers in blowpipe analysis; see Durham chemistry papers (I would like to thank Professor David Knight for this reference).

[63] Porter, *op. cit.* (15).

[64] J. Tilley, "Description of a Hydro-pneumatic Blow-pipe for the Use of Chemists, Enamellers, Assayers, and Glass-Blowers," *Philosophical Magazine*, 43 (1814), 280-284, p. 280; this article is a reprint of the letter in the *Transactions.*

[65] Tilley, *op. cit.* (64), 281.

[66] Tilley, *op. cit.* (64), 284.

[67] For the Society of Arts award system and its role in the promotion of scientific instrumentation in the early nineteenth century, see J.A. Bennett, "Instrument Makers and the "Decline of Science in England": the effects of institutional change on the elite makers of the early nineteenth century," in P.R. de Clercq, ed., *Nineteenth-Century Scientific Instruments and their Makers* (Amsterdam: Rodopi, 1985), pp. 13- 27, pp. 21-22.

[68] H. Brooke, "Description of a new Blow-Pipe," *Annals of Philosophy*, 7 (1816), 367.

[69] Qtd. in Campbell, *op. cit.* (1), p. 21.

[70] E.D. Clarke, *The Gas Blow-Pipe, or Art of Fusion by Burning Gaseous Constituents of Water* (London: Cadell and Davies, 1819), a catalogue of the results of his experiments, together with brief history and discussion of the use of the instrument.

[71] For more on this debate and a comparison of the development of analysis with blowpipes and galvanic batteries in early nineteenth-century England, see B. Dolan, "Blowpipes & Batteries: Humphry Davy, Edward Daniel Clarke, and Experimental Chemistry in Georgian Britain," *Ambix*, 45 (1998), 137-162.

[72] E. Darwin to C. Darwin, 25 October 1822, printed in F. Burkhardt and S. Smith, eds, *The Correspondence of Charles Darwin*, 10 vols (Cambridge: Cambridge University Press, 1985-present), Vol. I, pp. 1-2.

[73] J.A. Secord, "The Discovery of a Vocation: Darwin's early geology," *British Journal for the History of Science*, 24 (1991), 133-157; L. Wilson, *Charles Lyell: the years to 1841: the revolution in geology* (New Haven and London: Yale University Press, 1972), p. 111.

[74] The 1984 publication is J. Landauer, *Blowpipe Analysis*, trans. James Taylor (London, 189; reprint, New York, 1984); for a more thorough bibliography of texts relating to blowpipe analysis, mainly from the period covered in this article, see the appendix to B. Dolan, "Transferring Skill: Blowpipe Analysis in Sweden and England, 1750-1850," in B. Dolan, ed., *Science Unbound: Geography, Space & Discipline* (Umeå: Umeå Universitet Skrifter, 1998), pp. 92-125.

ANTONIO GARCÍA BELMAR AND JOSÉ RAMÓN BERTOMEU SÁNCHEZ

CONSTRUCTING THE CENTRE FROM THE PERIPHERY

Spanish Travellers to France at the time of the Chemical Revolution

1. INTRODUCTION

During recent decades, scientific activity in the Spanish Enlightenment has attracted the attention of many historians of science. The policies of enlightened governments have been regarded as an important step in the process of modernisation of eighteenth-century Spanish society. At the beginning of that century, a new Bourbon dynasty was established in Spain and its policies have been regarded – mainly by conservative historians – as an attempt to introduce "foreign" ideas and practices into Spain. These policies have also been considered as a major effort to "modernise" a supposedly traditionalist country isolated from the rest of Europe and under the control of the powerful Catholic Church. Due to this caricatured image, enlightened Spanish governments have been very appealing for a group of politicians and historians who actively participated in the recent so-called "Spanish transition" from dictatorship to democracy, as they considered themselves engaged in a process of modernisation very similar to that initiated by their eighteenth-century forerunners. This trend reached its apex during the commemorations of the bicentennial of Carlos III, the most outstanding representative of Spanish enlightened despotism. One of the most important parts of the so-called modernisation process, then and now, was science. According to this view, the isolated Spain scarcely participated in the Scientific Revolution of the sixteenth and seventeenth centuries and enlightened governments tried to solve this problem by implementing three main policies: (a) Reforming the recalcitrant universities, which were anchored in old scholastic ways of teaching, or, to avoid opposition, founding new scientific establishments in which new science could be taught and cultivated; (b) Appointing foreign scientists in some of the new institutions, so that they could introduce new ideas into Spain and train

Ana Simões, Ana Carneiro, Maria Paula Diogo (eds.), Travels of Learning. A Geography of Science in Europe. (143-188)

disciples; (c) Sending young students – *pensionados* [1]– abroad in order to improve their scientific background in the most famous European academic centres. Scientific trips are therefore considered a key part of Spanish enlightened policies and are mentioned in almost every study concerning eighteenth-century Spanish science.[2]

Taking into account the history of chemistry, this image of the Spanish Enlightenment fits perfectly the nineteenth-century narratives of "chemist-historians" who regarded the late eighteenth century as the period in which chemistry emerged as a scientific discipline. This "revolution-foundation" of chemistry took place almost at the same time as the arrival of the *pensionados* in Paris, the most prominent centre of chemistry, where Antoine Lavoisier was developing and propounding his theories on chemical combustion.[3] In this context, the quick and painless reception of the new chemistry in Spain has been related to the *pensionados*' trips, and historians have been interested in finding out when and where Spanish travellers met the famous French chemists who created the new ideas. The diffusionist image has been reinforced by the supposed lack of a substantial chemical tradition before these trips took place. According to this thesis, there were no powerful supporters of phlogiston theory in Spain as there were, for instance, in Germany or Britain, so that Spanish *pensionados* could easily introduce new ideas without major resistance. As a result, little attention has been paid to issues such as the reasons and interests that attracted historical actors to chemistry, the processes of appropriation of new teaching and research practices, or the context of reception in which new ideas and practices were accommodated.[4]

The abandonment of the diffusionist approach and the new images of the chemical revolution offer a renovated historiographical framework through which the *pensionados*' trips should be analysed. New historical studies have portrayed eighteenth-century chemistry as a consolidated discipline in several European countries, including investigative programmes and well-established theoretical concepts, experimental practices and instruments.[5] The image of a revolution-foundation has been abandoned and new historical actors and geographical contexts have entered the picture. Although many different approaches coexisted, the chemical revolution is no longer regarded as an achievement of a small group of British and French chemists but as a larger and more complex process involving other European countries and scenarios. The image of diffusion from a creative centre to a passive periphery can hardly be supported after studies such as those focusing on new chemical nomenclature which have been portrayed as the final outcome of a process of negotiation among a large network of European chemists.[6]

In tune with this approach, the context of reception has gained importance in studies on the chemical revolution. Increasing attention has been paid to issues such as the structure of national chemical communities and the different professional groups who were interested in chemistry and their reaction against (or for) new ideas.[7] The vehicles and mechanism that materially supported the exchange of ideas and practices inside the European network of chemists have also been a topic of study. As in other areas of historical research, the non-verbal process of learning has been regarded as an important vehicle of transmission of new ideas for late eighteenth-century-chemistry, an experimental science which involved emerging and undefined concepts as well as practical work in the laboratory; a type of knowledge and practice mainly transmitted by listening to and talking to other chemists or seeing and manipulating in the laboratory, rather than through scientific texts. These personal contacts transmitted not only scientific concepts and practices but also institutional models and values about science. Due to this range of historical problems, scientific trips have gained space in historians' research agendas. Studies on scientific trips during the chemical revolution have been focused on exchanges between Britain and France, particularly those related to the transmission of pneumatic chemistry from Britain to the Continent.[8] There are also studies on individual travellers who played a significant role in the transmission of the new chemistry to a particular national context.[9]

Unfortunately, studies about other travellers are few in number and limited almost entirely to departure and arrival dates and personal contacts. In some cases, the scant number of relevant sources available transforms historical inquiry into a troublesome and time-consuming activity. In consonance with some recent works,[10] our study has adopted a quantitative and comparative approach, aiming to identify general trends as well as significant and representative singular cases to be studied in detail. In order to increase the number of historical actors under study and the information available on them, we have used a variety of archival sources related to both their scientific and technical activity as students, teachers, researchers or even spies, and their status as foreigners and exiles. The data base supporting our study contains information about eighty biographies of Spanish people who for a variety of reasons travelled around Europe between 1770 and 1830 and who were involved in different activities related to chemistry, ranging from attendance at chemistry courses, publication of memoirs, papers or books on chemistry, or some chemical subject, to a professional career in chemistry.[11]

The first outcome has been a preliminary periodisation which is based on the changing characteristics of departure and arrival contexts related to the trips, the purposes and aims of travellers and their sponsor institutions, and their activities before, during and after travelling abroad. This periodisation will be discussed in the first section of this paper. In the second part, we analyse the institutions that supported these trips, their reasons for and interests in acting in this way and the arguments chemists employed to obtain their financial support. Finally, the third part focuses on the spaces of sociability and networks in which the travellers were temporally integrated during their travels as well as the strategies that they followed to appropriate the theoretical and practical knowledge they were seeking.

2. ROUTES AND PERIODS OF SPANISH SCIENTIFIC TRAVELS FOR THE STUDY OF CHEMISTRY

France was the country most frequently visited by Spanish scientific travellers, particularly those interested in areas such as chemistry, for which France became a major scientific centre during the eighteenth century. Apart from sharing a long common border, Spain and France enhanced their political and cultural relationships during the Enlightenment thanks to the common Bourbon dynasty which ruled both countries after the Spanish War of Succession. Paris, where the most important French scientific institutions were situated, was the most frequently visited city, although the University of Montpellier also attracted many Catalan medical students during the eighteenth century thanks to the particular relationship between the two geographical areas. The other important group of travellers related to chemistry was formed by students who attended lectures on mining and metallurgy at the Central European schools of Freiberg and Schemnitz. Some of them visited other countries with relevant mining activities, such as Sweden. Britain was an important destination for those interested in areas such as medicine, nautical science, astronomy, optics and scientific instrumentation techniques, and became a major refuge for liberal exiles during the first third of the nineteenth century. Trips to other countries were related more to particular circumstances than to general trends. For instance, by the middle of the eighteenth century the Italian peninsula became a haven for Jesuit scientists expelled by Carlos III's government.

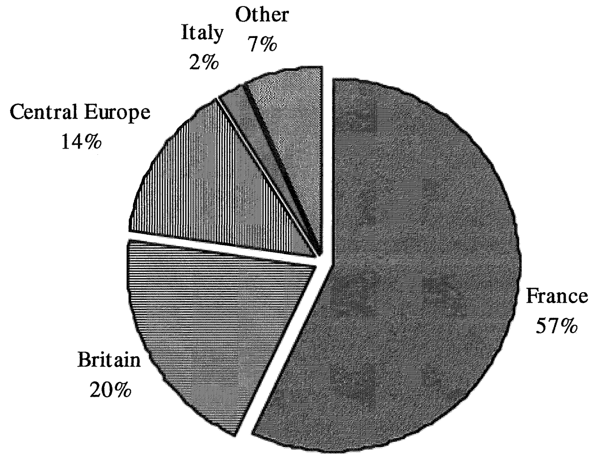

Figure 1. Destinations of Spanish scientific travellers, 1770-1833[12]

During the period studied, substantial changes occurred not only in the goals of the institutions promoting the trips, but also in the main features of the European institutions frequented by Spanish travellers and in the scenario that travellers had to face back in Spain. Taking into account these changing features, three main periods can be distinguished. Although many other earlier scientific trips might be mentioned, the first period actually started in 1770 when the first substantial group of travellers arrived in Paris, around the "crucial year" in which Lavoisier developed an investigative programme which led him to abandon former theories on combustion and to adopt the quantitative chemical method with which he is generally associated.[13] The first *pensionados*, however, hardly knew anything about Lavoisier's research because the first important public exposition of his emerging ideas was not published until 1777. Moreover, these first travellers were probably more interested in topics related to mining and metallurgy than in theoretical and methodological problems of chemistry. Most of them were members of the Basque Economic Society (*Sociedad Bascongada de Amigos del País*), the first and most famous of a large group of similar societies that appeared all over Spain during the 1780s and 1790s, aiming to influence Spanish agriculture and industry. The number of trips reaches its peak during the late 1780s thanks to the royal support of Carlos III's enlightened government and some institutions related to medicine and surgery such as the School of Surgery of Cádiz. As a result, a large number of Spanish *pensionados* were able to attend chemistry lectures and meet chemists such as Antoine Fourcroy, who, at that time, was committed to a campaign in defence of the new chemistry using various media such as textbooks, journals, lectures, dramatic experiments made at prestigious scientific institutions and private meetings in salons such as Mme. Lavoisier's.[14]

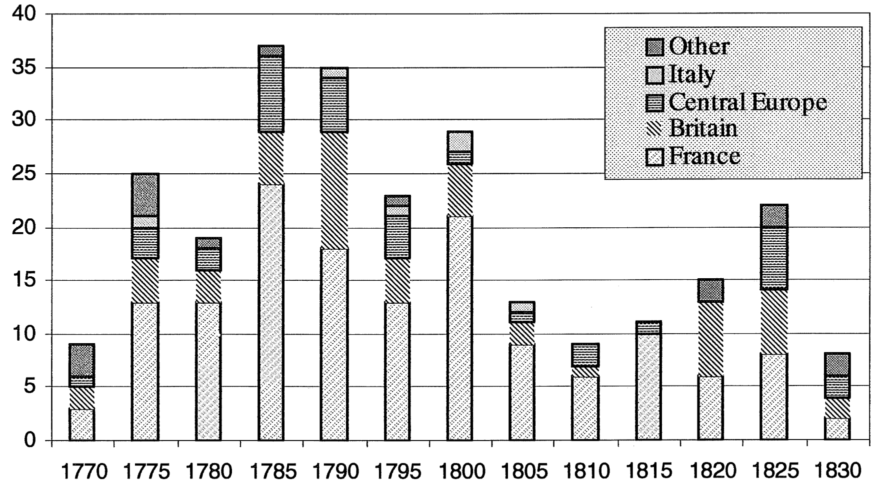

Figure 2. Spanish Scientific Travels, 1780-1833

Scientific travels were seriously affected by the Spanish government's panic-stricken reaction to the French Revolution. The Count of Floridablanca, the enlightened Minister whom Carlos III imposed on his son Carlos IV, reinforced control at French-Spanish borders, banned revolutionary propaganda and implemented book censorship and control – even the *Journal de physique* was banned by a Royal Order in 1791. In 1790, Floridablanca forbade Spaniards to be educated in a foreign country and, finally, trips were completely suspended during the Spanish war against the French Republic in 1793.[15] Spanish residents in Paris were requested to return to Spain and those who decided to remain in France, such as the engineer José María Lanz (1762-1837), were punished and removed from their posts.[16]

The second period began at the end of the war in 1796. After several important setbacks involving Spanish arms against French troops, Manuel Godoy, the most influential person in Carlos IV's court, changed sides and joined the French against Britain. As a minor consequence, but important in our narrative, trips to France were again reinstated, although the number of trips was not substantial until the first years of the nineteenth century. The Peninsular War (1808-1814) created an extremely adverse context for scientific trips. Although the government of Napoleon's brother, José I, attempted to maintain enlightened policies and support the trips of *pensionados* in France, war expenses exhausted royal resources and prevented the development of many of the *afrancesados*' projects.[17]

The third and last period of our study starts in 1814, after the defeat of the Napoleonic army and the return of Fernando VII, who created an absolutist government and persecuted liberals and *afrancesados*, including many important scientists. Domingo García Fernández, Josep Garriga i Buach and Francisco Angulo spent several years in France. Another important flux of Spanish exiles to France and, mainly, to Britain happened in 1823. After several unsuccessful uprisings, Spanish liberals staged a successful revolution in 1820 and forced Fernando VII to reinstate the Constitution of 1812. The European Coalition of Absolutist countries, the so-called Holy Alliance, became alarmed, and France undertook a military intervention in Spain with the aim of restoring Fernando VII to absolute power. The Spanish absolutist King, backed by French arms, revoked the constitution in 1823, and the ruthless repression that followed forced many liberal scientists to spend part of their lives in exile. Many of them, such as Juan Manuel de Aréjula and Andrés Alcón Calduch, were old *pensionados*.[18]

The social and political changes associated with the crisis of the Old Regime strongly shaped the scenario in which scientific trips took place. The first important group of travellers arrived in Paris in the 1770s. Supported by the enlightened atmosphere of Carlos III's years, they found a favourable context on their return to Spain. Thanks to this situation, most of them were appointed to scientific and teaching institutions, so that they could teach or develop the knowledge they had acquired in France. The crisis of the Spanish Enlightenment made the completion of the whole process more difficult. The *pensionados* of the second period, who travelled at the beginning of the nineteenth century, found in France a more sophisticated group of scientific and teaching institutions related to chemistry but, in contrast, when they returned to their country, their careers were interrupted by the military and political crisis which agitated Spanish society during the first third of the nineteenth century. Some of them were politically persecuted for their collaboration with the *afrancesados* or liberal governments, and in some cases, they were compelled to leave the country, constituting thus the third group of travellers identified in our study. This third group included mostly exiles or the sons of exiles, and even though some institutions, such as the Museum of Natural History, sponsored scientific trips, most of these displaced persons were not officially part of scientific projects or policies. As a result, they hardly contributed at all to reviving Spanish scientific activity.

3. REASONS AND INTERESTS

The trips of the *pensionados* involved significant human and material effort, mainly for the institutions who supported them and for the individuals who made them. The government and the industrial or teaching institutions had to obtain financial and political support, arrange housing and subsistence, gain access to foreign training centres and foster the development of institutions that could integrate the travellers after their trip abroad. Which institutions or political powers supported them and what did they expect to attain with these trips? As their biographies show, the *pensionados* were required to make a considerable personal effort, which included not only learning new languages and dealing with new customs and manners but also accepting the risks associated with travelling along unsafe routes and the troubles related to wars or social and political disorders, which were quite common in European countries during the late eighteenth and early nineteenth centuries. They also embarked on uncertain and problematic academic careers, which did not secure them a permanent position that would enable them to develop their scientific research or even to earn a living. In this context, one might wonder why the principal actors of such trips regarded such investments and efforts as justified.

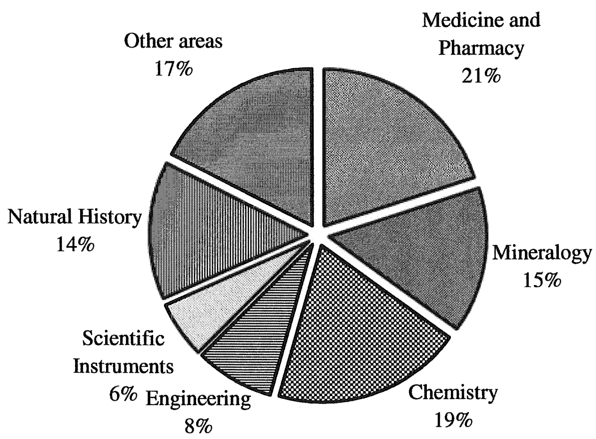

Figure 3. Trips and disciplines, 1770-1830

To answer these questions we must analyse the rhetoric that connected the complex network of interests — not always explicit neither public — motivating these trips and the main reasons that supporters invoked. In the case of chemistry, academic lectures and inaugural speeches frequently included a defence of the usefulness of this discipline, which had gained manpower, political support and institutional acceptance in Spain by the end of the eighteenth century. However, before becoming an institutionalised science, several topics related to chemistry were studied and taught in different venues, including pharmaceutical workshops, medical faculties or metallurgical and mining centres. Hence, during the first two periods under study, the trips were largely supported by groups or institutions related to these academic or technological traditions.

3.1 The practice of chemistry in eighteenth-century Spain and the promotion of scientific trips

The first group of institutions that supported chemical travellers were related to medicine, surgery and pharmacy, chemistry being a traditional auxiliary topic in the scientific background of these occupations and professions. A second support network was formed by the mineralogical and metallurgical centres that sponsored the first chemical travels at the beginning of the 1770s. In close relationship to this second network, a third group of trips was supported by civil or governmental institutions aiming to improve industry and agriculture by diffusing knowledge of what was later called "chemistry applied to the arts and manufactures." There were also some travellers who came from military institutions, mainly related to artillery. Each group had particular aims related to chemistry, and, as a consequence, different interests and expectations about the missions and activities of the travellers they supported.

3.1.1 Medical uses of chemistry

The old debate about medical applications of chemistry was revived during late eighteenth and early nineteenth centuries. Pneumatic chemistry, modern analytical methods and new explanations of combustion and respiration raised great expectations for medical applications of chemistry, transforming the relationships between the two disciplines. This situation was attractive for many Spanish chemistry students with medical or pharmaceutical degrees, one of the main groups of Spanish travellers to Paris during the late eighteenth-century. Many of them got in touch with one of the most outstanding supporters of medical chemistry, Antoine Fourcroy (1755-1809).

Juan Manuel de Aréjula (1755-1830), who was given a grant by the School of Surgery of Cádiz to train as a naval surgeon, was one of these. Attracted by the new chemistry, during his stay in Paris in the 1780s, he contacted Antoine Fourcroy and attended his lectures. When Aréjula returned to Spain, he was appointed professor of chemistry in Cádiz. In his opening address, focused on medical applications of chemistry, he endorsed chemistry as a useful tool for the advancement of medicine. Like other authors, he discussed in separate paragraphs the applications of chemistry to anatomy, physiology, hygiene, pathology, *materia medica* and pharmacy. As an example of the uses of chemistry in medicine, he discussed his ideas on intermittent fevers and their cure, based on chemistry. In other parts of his talk, he emphasised the advantages of elemental analysis and the new theory of respiration as well as other achievements of eighteenth-century chemistry such as the theory of affinities, which he considered of great importance for the preparation and administration of medical drugs. He was very optimistic about medical uses of chemistry and did not consider any limitations in this area, not even for physiology and pathology, whose relation to chemistry was, in those years, a controversial topic. In this sense, Aréjula is a good example of the group of physicians and surgeons who saw the changes related to the "chemical revolution" as a great hope for the advancement of the theory and practice of medicine.

This confidence in the medical applications of chemistry was, in many cases, related more to the great popularity achieved by the new chemistry than to its actual success in solving medical problems. At the end of the eighteenth-century, many authors cautioned against the excessive use of chemistry in medicine; among them was Antoine Fourcroy, the author of numerous works on medical chemistry, including a scientific journal in this field. However, he criticised various hasty applications of chemistry to medicine, arguing that wrong uses of chemistry in this area could be very dangerous. In one of his papers, Fourcroy described the strong reactions his lectures elicited at the Medical Faculty of Paris:

> Young people enthusiastically follow my course on animal chemistry at the school of medicine. Their desire to learn is extraordinary; I am aware that the twenty lessons I impart on this very new area in chemistry give a great impulse to this branch of nature studies, but I control it as much as I can; I do not want to accelerate it, for fear of breaking that beautiful machine in my hands.[19]

Aréjula, who attended Fourcroy's chemistry lectures, was perhaps among these exalted students. Other *pensionados*, like Francesc Carbonell i Bravo (1761-1837), adopted more moderate positions. After studying at the Montpellier Faculty of Medicine, where he attended Chaptal's chemistry courses, Carbonell wrote a doctoral dissertation on the uses and abuses of chemistry in medicine, in which he defended the difference between "inorganic" and "organic" bodies both in reactions studied in the chemistry laboratory, and those taking place inside the human body under the influence of the vital force. A large part of his dissertation focused on a critical discussion of Baumès' nosological ideas and their therapeutic consequences.[20] Carbonell argued that all chemical nosology was "defective" (*improvida*) and all chemical therapeutics were "vicious" (*vitiosa*), but he praised chemical applications to hygiene (analysis of air, water or food, for instance) and *materia medica*, the part of the art of healing where chemical applications were more fruitful. As far as physiology was concerned, Carbonell thought that chemistry as well as physics and mechanics– should focus on studying the "perfection of the instruments" (substances) which participated in life functions but not on explaining the causes of these processes that were developed under the influence of vital forces. Finally, Carbonell concluded that "valid applications of chemistry to medicine" were very useful but their abuse could be pernicious.[21]

One of Carbonell's most talented pupils in Barcelona was Mateu Orfila i Rotger (1787-1853), who pursued a brilliant career in Paris during the 1810s. He published several papers on medical chemistry and became the most famous toxicologist of the first half of the nineteenth-century in France. He was also the author of one of the most often reprinted textbooks on medical chemistry, in which he briefly discussed the uses of chemistry in medicine. According to Orfila, it was difficult to deny the utility of chemistry in determining the characteristics of drugs or in medico-legal research concerning cases of poisoning. He admitted however that other applications were the subject of debate among physicians:

> But what are the dangers of an excessive application of this science to medicine? Medical-chemists [médecins-chimistes], it will be argued, paying no attention to vital forces, only see in the exercise of the various functions of animal organisation, phenomena analogous to those observed in their laboratories; they heedlessly compare the properties of inanimate bodies with those of living bodies and establish theories in physiology which are purely chemical and false, and which are overturned by the slightest observation.[22]

Orfila argued that these criticisms had to be directed only to "inattentive and little-enlightened observers" and not to "savants" who "incessantly interrogate nature" through "experiments and observations" and who prefer "new and well-established facts" to "premature and unfounded explanations." According to Orfila, such research would lead to "the future perfection of physiology." In agreement with his teachers Fourcroy and Carbonell, Orfila was not against chemical research in physiology but he did not agree with hurried and careless conclusions. However, recognising the existence of the controversy, Orfila wrote in the introduction to his book that he only offered medical applications of chemistry whose benefits were not contested, such as those related to therapeutics and legal medicine. Regarding "physiological applications," he declared that his book included only the results of chemical experiments related to physiology because this part of science was not advanced enough to be "reduced to general principles."[23]

The three authors just mentioned are representative of different opinions and practices in the realm of medical chemistry. In spite of their divergence, their views offer enough evidence about the interest in chemistry shown by Spanish physicians, surgeons and pharmacists. This is the context in which training trips to Paris were promoted by institutions related to the art of healing, such as the Cádiz School of Surgery.[24] In contrast, Spanish medical faculties did not support any training trips, so the travelling expenses of physicians were usually financed privately. One example is Ignacio María Ruiz de Luzuriaga (1763-1822), a physician linked to the Basque Society, who travelled to several places in France and Britain during the 1780s. He attended Pierre-Joseph Macquer's (1718-1784) and Fourcroy's chemistry lectures as well as lessons on other medicine-related topics at the Parisian Medical Faculty, the School of Surgery and the Collège du Roi.[25] In 1784, he published a memoir in the French journal *Observations sur la physique* on "the decomposition of atmospheric air by lead." This paper is another example of the miscellaneous chemical topics that attracted the attention of Spanish physicians. Luzuriaga was interested in lead's properties because of the so-called "colique des Peintres" (painter's colic), a disease related to lead materials. In his paper, he recognised that he had not achieved any conclusive result on the matter. However, he confessed that this research had led him to a more interesting field: the new developments in pneumatic chemistry. He performed several chemical experiments in order to study how several bodies – among them, lead – "deprive air of its phlogiston."[26] After remaining for several years in Paris, he travelled to Britain and attended William Cullen's lectures (1710-1790), obtaining an M.D. degree from the University of

Edinburgh.[27] Eventually, Luzuriaga obtained royal support, and stayed in Madrid for several years after his return from Britain.[28]

The most important group of Spanish physicians who travelled to France in the eighteenth century went to Montpellier Faculty of Medicine rather than to Paris. The trips were encouraged by the strong cultural and economic relations between Languedoc and the Catalan area. Moreover, the council of Girona supported the "College of Girona," an institution founded in the Middle Ages which supported young students who wanted to study medicine in Montpellier. Some medical students, such as Josep Garriga i Buach and Francesc Carbonell i Bravo, attended Chaptal's chemistry lectures and, under his influence, were introduced to chemistry applied to the arts. Many of the *pensionados* of the late eighteenth and early nineteenth-century who came from a medical background were interested in this area and some of them, like Carbonell and Garriga, published papers or books on both medical and industrial chemistry.[29]

3.1.2 Chemistry applied to the arts

During the eighteenth century, chemistry underwent important changes in academic status and its relationship to other disciplines. Paradoxically, its consolidation as an academic discipline could not easily accommodate its old association with technological activities. The medieval opposition between *scientia* and *ars* implied a serious conflict for chemistry: if such a dichotomy was accepted, then for chemistry to be considered a science and to be accepted in learned societies, a substantial practical part of chemistry related to craft and industry had to be removed, namely all areas related to activities such as mining, metallurgy, dyeing, glassware, etc. By the middle of the eighteenth century, the Swedish chemist Johann Gottschalk Wallerius developed a new approach which avoided the problematic dichotomy of *scientia* vs. *ars* and brought into existence the modern division of pure and applied chemistry. As Cristoph Meinel has pointed out, the new distinction fitted comfortably into the enlightened conception of science and its potential for useful applications.[30]

This utilitarian image of chemistry was very attractive for Spanish enlightened governments, which aimed at developing agriculture and industry. This rhetoric was also in consonance with the main goals of the so-called *Sociedades Económicas de Amigos del País*, associations of enlightened clergy, wealthy aristocrats and businessmen who also struggled to improve industry and agriculture by supplementing the education of craftsmen with public courses, including chemistry lessons.[31] As a result, chemistry became a central area in the educational activities of these groups.

Due to the scarcity of experienced chemists in Spain, the *Sociedades Económicas* were compelled to hire foreign – mainly French – professors to support training trips to other countries, – also mainly to France. The most famous Society was established in Bergara, in the Basque region, an area which had an important metallurgical industry. Thanks to the support of the Naval Ministry, interested in new foundry techniques, the Basque Society established a chair of chemistry in 1777 and appointed two young French chemists for this post: first Louis Proust (1754-1826) and then François Chabaneau (1754-1842). At the same time, the Basque Society supported several trips by its members and its members' young sons. Most of them travelled to Paris, where they followed a propaedeutic scientific instruction course preceding the studies and missions they were expected to accomplish in Central Europe in mining academies and mining sites or in the Swedish steel industries.[32]

Like the Basque Society, other *Sociedades Económicas de Amigos del País* attempted to offer chemistry lectures, although only a small group succeeded in doing so. During the late 1780s, the Society of Valencia asked the government to found a chair of chemistry applied to the arts. The chair was finally established in the Faculty of Medicine and lectures included applications of chemistry to the arts, industry and mining.[33] The *Sociedad Económica Aragonesa*, which was established in Zaragoza, also succeeded in presenting public chemistry lectures at the end of the eighteenth-century. The chair was closed during the Peninsular War, but reopened later on and remained active until the 1840s. Some former Spanish travellers to Paris occupied this chemistry chair.[34] Other Societies, such as those established in Granada, Oviedo, Santander, Seville and Valladolid, supported similar projects but were quite unsuccessful.

Another important professorship was established in Barcelona at the beginning of the nineteenth century. This chair, supported by the *Junta de Comerç* (Trade Board), was founded in 1805 and occupied by Carbonell, a chemist who had studied in Montpellier and who wrote and translated several texts, including Chaptal's books, about chemistry applied to the arts and medicine. The *Junta de Comerç* supported several young students' trips to Paris, among them Orfila's. He was sent to Madrid in 1807 in order to study under Louis Proust's tutelage but, when he reached Madrid, Proust had returned to Paris, so Orfila decided to follow him and travelled to the French capital. There, he registered at the Medical Faculty and started attending public chemistry lectures, getting in close touch with Nicolas Vauquelin (1763-1829), who supported him during the difficult period of the Peninsular War, when Orfila was arrested by the French police and Vauquelin managed to get him out of prison. Although the Spanish government offered him an important post in Madrid, Orfila never returned to Spain and embarked on a meteoric academic career, becoming dean of the Paris Medical Faculty between 1831 and 1848.[35]

The *Junta de Comerç* also supported other students' travels, and when the activity of other Societies decreased during the first third of the nineteenth century, it became perhaps the most outstanding institution promoting these trips. The group of students related to the *Junta de Comerç* included Carlos Ardit (1777-1821), who was commissioned to report on dyeing technology in several parts of France and Switzerland. Orfila guided him during his stay in Paris, accepting him in his private chemistry lectures and introducing him to the staff of a large calico-printing factory in Jouy, near Paris, run by Christophe-Phillipe Oberkampf (1738-1815)[36] Another student of the professorship of Chemistry was Esteban Desprats (b. 1788), who studied in the Paris Medical Faculty[37] and attended Thenard's chemistry lectures at the *Collège de France* between 1816 and 1820.[38] Josep Roura (1787-1860), Carbonell's successor in the chemistry chair of Barcelona, also spent several brief periods studying in Paris during the late 1820s.[39]

Trips related to chemistry applied to the arts were also supported by the enlightened Spanish Government. As mentioned above, the Naval Office collaborated with the Basque Society by supporting Elhuyar's travels, aiming to modernise military cannon technology. Other *pensionados* were funded by the government to gather information related to artillery. Tomás de Morla (1752-1820), who wrote a famous treatise on artillery, travelled to several European countries with the captain of artillery José Guillelm. In 1788, they posted the Government several plans of industrial machinery and José Guillelm was requested to spend several months in the Netherlands to study the gunpowder industry.[40] The government also funded several trips to Central European mining academies and commissioned these *pensionados* to obtain information about mining and metallurgic technology. For instance, in 1791, three Spanish *pensionados*, who were attending lessons at the Freiberg School of Mines, were requested by the Government to visit mines and describe "every machine that might be interesting, especially the furnaces and lead foundry techniques [...] from Carinthia" (now in Austria). They were also to travel to Hungary and visit its mines and foundries, collecting information about procedures and industrial costs and products. The instructions specified that they were to write a structured report of their observations when back in Freiberg, at the same time as they attended the courses at the School of Mines. After the courses had finished, they were requested to travel again around the Saxony and Bohemian regions and "thoroughly scrutinise their mines and foundries, mainly those of copper and tin."[41]

The Spanish government supported other trips related to industry and some of these travellers became very influential chemists. Among them was Domingo García Fernández (1759-1826), who later translated Berthollet's *Élémens de l'Art de la Teinture*. When García Fernández received governmental support, he had already visited Paris on a private trip, and attended lectures at the School of Pharmacy[42] and the Medical Faculty.[43] In 1783, he was commissioned to study chemistry applied to the arts in Paris and to observe and report on the dyestuff procedures and technology of the famous *Manufacture des Gobelins*.[44] Some years later, he was appointed professor of a chair of chemistry applied to the arts in Madrid and was again sent to Paris with the mission of improving his background in this field and buying the necessary scientific instruments for the new professorship.[45] The Spanish Government also asked García Fernández to observe and report on several French industries:

> … to learn the recent progress in chemistry, to purchase instruments that cannot be made here [in Spain], and, above all, to gain detailed knowledge about what is performed at the Mint Houses of Paris and Bordeaux regarding smelting, refining, extracting techniques, methods of assaying and recasting our coins, trying to acquire Plans, or Models of the most useful Furnaces and Machines, and extensive knowledge about the mechanism of works, expenses, prescribed precautions aiming to decrease waste and lessening [in production], and everything that deserves to be noted and notified.[46]

During the early nineteenth century, Carlos IV's government still encouraged trips related to chemistry applied to the arts. The most outstanding result of this policy was the first Spanish book on this subject, published in Paris by two *pensionados*: Josep Garriga i Buach and José María San Cristóbal.

Garriga had studied medicine in Montpellier at the end of the eighteenth century and, in 1803 he was funded by the Spanish government to study dyeing technology.[47] In Paris, Garriga published several papers and reviews in influential French journals such as *Annales de Chimie* and *La Décade Philosophique*.[48] Between 1804 and 1805, Garriga and San Cristóbal published two volumes of their *Curso de Química General aplicada a las artes*, which were presented to the First Class of the *Institut de France* by Guyton de Morveau. This French chemist also wrote a very favourable review, in which he stressed that the book included the most recent developments in chemistry and praised its descriptions of scientific instruments.[49] The authors used instruments belonging to the laboratories of Alexander Charles (1746-1823) and Vauquelin, and the plates were prepared by a Spanish engraver, Manuel Esquivel de Sotomayor (b. 1777), also sponsored by the Crown to study in Paris during this period. In spite of the favourable reviews of the book, the last two volumes were never published, and neither were San Cristóbal's subsequent translation of Jean Baptiste Vitalis's book or his own textbook on dyes. Garriga kept working on dyes and wrote an important report on indigo dyes, which was positively reviewed by Gay-Lussac, Vauquelin and Berthollet at a meeting at the Institut de France in 1807.[50] Garriga was at a promising moment of his scientific life when he returned to Spain and was appointed director of dyes at a large textile factory in Segovia. However, his collaboration with the government of José Napoléon I in Spain ruined his career and he never published another substantial work on this subject. San Cristóbal escaped political persecution because he remained in Paris, but his attempts to obtain a position in Spain were unsuccessful. In 1819, he was supported by the Spanish Museum of Natural History to establish a professorship of dyeing in Madrid but again political instability frustrated San Cristóbal's mission, which, as we shall see, included reporting on several relevant French industries.[51]

3.2 Building a disciplinary identity for chemistry in Spain

The above examples show that medicine and surgery, mining and metallurgy, artillery and industry were the motivating factors behind trips related to chemistry during the eighteenth century. Hardly any of the trips mentioned have as its main purpose the training of future chemists. This is not surprising because in Spain chemistry was not generally recognised as an academic discipline, with its own teaching and research institutions, as it was in many European countries during the eighteenth century. Chemistry started to gain a larger institutional space in Spain during the last third of the eighteenth century. At that time, chemistry lectures were sponsored by the Spanish Government and other social institutions such as the *Sociedades Económicas de Amigos del País* and the *Junta de Comerç*. Moreover, chemistry was becoming more important in the curricula of Medical Faculties and Schools of Surgery and, as in other European countries, chemistry was beginning to be regarded as a part of the education of enlightened gentlemen, so that an increasing number of wealthy and leisured people attended chemistry lectures together with students of pharmacy and medicine or craftsmen.

At the end of the eighteenth century, the government supported a Royal Chair of Chemistry, held by Pedro Gutiérrez Bueno (1745-1822), one of the small group of important Spanish chemists who never travelled abroad during this period.[52] Infante Don Antonio Pascual de Borbón (1755-1817), the King's brother, created his own laboratory and carried out small chemical experiments, which eventually became a public chemistry course in Madrid during the 1810s.[53] In order to fill the Royal chairs created in different Spanish cities, the Spanish monarchy hired foreign chemists, such as Louis Proust and François Chabaneau, and also sponsored scientific trips to France to train future chemistry professors. The most ambitious project in this area was the Practical School of Chemistry, which was founded in Madrid at the beginning of the nineteenth century under the directorship of Louis Proust. According to the plan of the School, six students of Proust's chemistry chair were selected to undergo advanced chemistry training in France.[54] The selected students had to spend a year studying chemistry in Paris, after which they would be appointed to one of the chemistry chairs established in various Spain cities:

> As soon as a Disciple is regarded as capable of holding a professorship, he will be appointed to one of the available chairs [...] in the Provinces and he will immediately be sent to Paris for only a year, where he will meet the most famous lecturers and note their way of teaching; he will visit the establishments related to natural history, chemistry and mineralogy, etc; he will fortify and perfect his knowledge by comparing strategies of different teachers, their systems, their schools, etc.; and, at the same time, under the supervision of the [Spanish] Ambassador, he will purchase the necessary books and instruments for the School [of Chemistry] to which he was affiliated [in Spain].[55]

Regrettably, neither complete alumni register nor reports or exams from this institution are available – this documentation probably disappeared during the Spanish Civil War – so historians have scant evidence about the activity of the Practical School of Chemistry. Nevertheless, several documents recently found in different archives prove that, at least, a few students were trained at the Practical School and completed their studies in France. Although the plan was never completely implemented due to the Peninsular War and the subsequent political instability, many of the students found a position in industry or teaching institutions related to chemistry.[56] For instance, Gabriel Fernández Taboada (1776-1841), after studying Latin grammar and philosophy in Orense, moved to Madrid aiming to become a pharmacist. In the Spanish capital, Taboada studied chemistry and also mathematics and experimental physics. After attending Proust's lectures for four years, he was selected as one of the six disciples of the recently created Practical School of Chemistry. Once he passed the first year of practical training, he was requested, firstly, to give public chemistry lessons at the Royal School of Chemistry, and, afterwards, to spend a year in Paris improving his knowledge of chemistry. Fernández Taboada died between 1804 and 1805. During his sojourn in Paris, Taboada published a paper in the *Journal de physique*, in which he referred to himself as an "élève de Proust" and described various chemical experiments with mercury compounds.[57] After returning to Spain, he was appointed professor of chemistry at the Nobles' Seminar in Santander (*Seminario de Nobles de la Montaña*). He moved to this city in 1807 but he was unable to give his lectures because the chemistry laboratory was never built. Taboada probably delivered lectures on other scientific topics until the Napoleonic troops entered Santander. He asked José Napoléon I's new government for another position in "one of the areas related to chemistry," such as "saltpetre, gunpowder, dyes, saltworks or glass factories," "the chemistry laboratory in Madrid" or the "Mint." This is a fair list of the available posts for chemistry students in Paris at the beginning of the nineteenth century. As it turned out, Taboada never occupied any of the above-mentioned positions. He finally got a position at the School of Pharmacy in Santiago, where he arrived in 1811 after fleeing from the French troops in Santander.[58]

Another pupil of the Practical School of Chemistry was Esteban Brunete (*fl.* 1804-1817), who after being tested by Proust and gaining his approval, was appointed professor of chemistry in Zaragoza in 1804. According to the plan of the School, he received a grant of 12,000 *reales* a year to travel to Paris, where he stayed in 1805 seeking to improve his chemical background. In September of 1807, Brunete travelled to Zaragoza to take charge of the chemistry chair of the *Sociedad Económica Aragonesa.* A laboratory was established, several books were bought for the chair and even the Royal Cabinet of Natural History sent several boxes with duplicated mineralogical specimens to Zaragoza. In spite of these efforts, the Peninsular War frustrated Brunete's lectures. In July 1808, a government order transformed the school into military barracks. At the end of the war, Brunete left Zaragoza for good and was appointed director of the Royal Glass Factory at the Granja de San Ildefonso, not far from Madrid.[59]

Many other pupils of Proust's, as well as *pensionados*, faced further problems in gaining a permanent position related to chemistry, and some of them were even persecuted for their collaboration with the Napoleonic Government during the Peninsular War. This was what happened to Josep Garriga i Buach, who was commissioned by the government of Carlos IV to study dyes with José María de San Cristóbal. Paradoxically, political persecution was the reason behind some trips to Paris, so much so that many Spanish students attending famous chemistry lectures in the French capital were, in fact, political exiles. Just a couple of trips made during the 1810s were supported by the Spanish Government: such was the case of José María de San Cristóbal and Andrés Alcón Calduch, which will be contrasted later in the paper. Both trips were related to a new institution, the Museum of Natural

History of Madrid, in which the Spanish government attempted to create two chairs of chemistry. The chair of general chemistry was given to Andrés Alcón, another former student of Proust's, who was sent to France in 1819 with the main purpose of improving his knowledge of chemistry, contacting other professors, seeing and discussing their didactic methods with them and buying the required scientific instruments for his future lectures. As in other cases, political instability frustrated this ambitious plan and, due to his collaboration with the liberal government during the early 1820s, Andrés Alcón was forced into exile in London for several years.[60]

But in contrast with eighteenth-century trips, Alcón and Proust's other students were sent to study chemistry and not medicine, pharmacy, surgery, mineralogy or mining. At the beginning of the nineteenth century, chemistry in Spain had gained academic and social recognition and public lectures were introduced and supported by the government, which, in consequence, needed trained professors. As had been done in other areas, the Government sponsored scientific trips to Paris, probably the most important centre of learning and research in chemistry, in which well-known professors lectured to large audiences of national or foreign students at consolidated scientific institutions. Spanish students attended these lectures, learnt theoretical and sometimes practical chemical knowledge and also formed a disciplinary image of chemistry, which included persuasive rhetoric about the usefulness of the discipline, its relationships with other academic areas and its methods of teaching and research. By appropriating these elements, they gained a common background which probably gave rise to an *esprit de corps* between them. At least, this is what some of their critics pointed out. In the introductory paragraphs to the plan of the Practical School of Chemistry, there were some remarks on this question:

> Experience has shown that grants awarded to learn chemistry in foreign countries often used to produce the opposite effect to that intended by the Government, because those who obtained them lost much of their enthusiasm and fondness for learning, regarding themselves as having the right to be appointed more readily than others, so that, for this reason, they impaired the hopes of those who really wanted to learn.[61]

Pedro Gutiérrez Bueno, one of the few Spanish chemists who never travelled abroad, remarked in his curriculum that "without any other help but his own constant application" he was able to teach "a science which many others had studied in Paris, at the expense of the State, and which many of them never managed to teach."[62] Other critical voices against the *pensionados* circulated in popular journals such as *Variedades de Ciencias, Literatura y Artes.* In 1803, an anonymous journalist compared the policy of sending *pensionados* abroad with the young student who "pretends to be wise without the fatigue that instruction costs imply." He asserted that the Enlightenment government's policy had hardly been fruitful but he qualified it as "laudable" and "necessary" in order to obtain, later on, "the just reward for such useful tasks."[63]

The criticism was not unfounded. It is not a coincidence that the three critical texts mentioned appeared at the beginning of the nineteenth-century. At that time, the crisis in the Royal Treasury, which got worse during the following years, made it very difficult for the Government to give grants for scientific trips. Moreover, because of political persecution and social and economic instability, long-term projects related to the missions of *pensionados* were doomed to failure. Trips also lost a substantial source of support due to the decline of some institutions which promoted trips during the late eighteenth century, notably the *Sociedades Económicas de Amigos del País*. Consequently, during the first decades of the nineteenth century, most of the trips were induced by political persecution and the rest they were privately supported at the traveller's own cost and, importantly, trips were not integrated into a general policy aiming, for instance, to improve industry or to establish chairs of chemistry. Whatever their reasons, support, and purposes, travellers of this period found in Paris a more consolidated discipline of chemistry, including regular teaching methods, respected and prestigious professors and impressive teaching and research institutions.

4. SPACES OF SOCIABILITY AND LEARNING PRACTICES

The Spanish *pensionados*' trips to France coincided with a significant transformation of public spaces for the teaching and diffusion of science, which took place in the late eighteenth-century and gained momentum during the French Revolution and Empire. The new teaching and research spaces transformed certain cities into learning sites which attracted scientific travellers from various places in Europe and America. From the point of view of chemistry, the most important centre was Paris, where foreign and local students could choose from a variety of important old and new scientific institutions (Académie des Sciences, Jardin du Roi, Ecole des Mines, Ecole Polytechnique, etc.), as well as a large variety of private courses which covered a broad range of subjects. The increase of public and private teaching institutions introduced a rich diversity of learning practices, especially in areas such as chemistry, where both theoretical knowledge and practical skills in chemistry were important features of one's education. Chemical knowledge was transmitted and appropriated in very different ways in institutions such as the *Collège de France*, faculties of sciences, private laboratories, apothecaries and craft workshops or factories and nascent industrial complexes. The career routes and activities of *pensionados* offer an interesting perspective from which to explore these diverse forms of sociability associated with the learning of chemistry and related areas at the end of the eighteenth-century.

4.1 Networks of pensionados *as structures for the reception and control of newly arrived students*

Although some Spanish travellers were able to plan their itineraries and activities according to their own personal interests, most of them were strongly affected by the social and institutional framework of which they were part. Their activities were shaped by institutional and individual relations between the centres of origin in Spain and the reception centres in France. In some cases, the Spanish diplomatic embassy in Paris helped them to enter French academic circles or provided financial support. Moreover, the *pensionados* developed their own networks so that veteran *pensionados* gave logistic support to the newly arrived students, facilitating their accommodation in the new city or their admission to teaching or research institutions. These networks were, in some cases, means of controlling and evaluating the students' activities. For instance, students coming from the School of Surgery of Cádiz were organised in small groups, in which the most experienced student acted as leader, supervising and reporting the activities of his fellows.[64] This was the role played by Juan Manuel de Aréjula1830) when he was sent to Paris between 1787 and 1789, as the leader of a group of surgical students that included Miguel Arricruz (1761-1825) and Francisco Flores Moreno (*fl.* 1787-1822).[65] A similar group was headed by Agustín de Betancourt (1758-1824), who was in charge of several *pensionados* from the Spanish School of Engineering, including José María Lanz and Joaquín Abaitúa Barrientos (b.*ca.* 1769), among others.[66]

Experienced *pensionados* supervised the training of new students. For instance, in the late 1770s the School of Mines of Almadén supported several students who were learning mining and metallurgical techniques in the Schools of Mines of Freiberg and Schemnitz. Before moving to these cities, students were required to spend some months in Paris, in order to improve their scientific background, mainly in areas such as chemistry. This stage of training was supervised and evaluated by trained *pensionados* already settled in Paris. Among the mining students sent to Paris by the School of Mines of Almadén were Andrés Manuel del Río (1765-1849), Fernando Casado de Torres (d. 1829) and José Ricarte (*fl.* 1792). After evaluating their scientific background and studies, Fausto de Elhuyar1833), who had been appointed to supervise the group, reported to the Minister José Gálvez that the three new *pensionados* had to stay in Paris for an extended period in order to reach a good level of expertise in chemistry and mechanics.[67] Afterwards, Ricarte and del Río helped the new *pensionados*, Manuel de Angulo (b. *ca.* 1760), Juan López de Peñalver (*fl.* 1788-1835) and José Miaja Pingarrón (*fl.* 1788-1825), with some logistical problems, such as obtaining a temporary residence permit or introducing them to professors of the Academy of Mines.[68]

Political networks were also important for some Spanish travellers, especially for those who were forced into exile due to their ideological affinities or political activities during the rule of the absolutist King Fernando VII (1814-1833). Most of the exiles arrived in France after the Peninsular War or the brief liberal period (1820-1823) and the French police maintained regular surveillance over their activities and movements inside France. As a result, an enormous number of files with police reports accumulated. Some of them are still held in the French National Archives, offering interesting but still underused sources of historical analysis. In these files, there is substantial information about the political networks of the travellers, the lectures they attended and their political leanings.[69]

4.2 Chemistry in old and new learning venues

In spite of these constraints, *pensionados* and exiles had a broad range of possibilities open to them when looking for chemistry training. The plurality and transformation of chemistry teaching venues in Paris revealed degrees of freedom which prevented absolute control of their activities, offering them different choices in their academic careers. Their choices were, therefore, shaped by their interests and the characteristics of the various public and private lectures on chemistry in Paris. The institutional reforms carried out in France during the Revolution and throughout the Empire were crucial in defining the main features of the organisation of science in the country during the nineteenth century. The changes were especially important in the case of chemistry. Lectures were introduced in the new secondary schools (*lycées*) as well as in the new higher teaching institutions such as the Faculties of Sciences, the *Ecole Normale Supérieure* or the *Ecole Polytechnique*. Other institutions such as the Faculties of Medicine were reformed, so that chemistry lectures gained importance in the medical curriculum; and, last but not least, the apothecaries' apprenticeship was transformed with the new Schools of Pharmacies, in which chemistry chairs were also established.[70]

These changes did not have the same dramatic consequences in areas such as mathematics or astronomy – included in the *Collèges* of the *Ancien Régime* and in the University syllabus – when compared to other less institutionalised areas such as chemistry, which had previously been almost non-existent in secondary education and little studied in the Universities. The new institutions opened new venues for the diffusion and practice of chemistry, in parallel with private laboratories or apothecary workshops. The new institutions did not, however, eliminate private lectures and, in some cases, they even encouraged them. During the first decades of their existence, Faculties of Sciences focused their activity on delivering exams and granting degrees but not on training. As a result, preparatory courses for the *baccalaureat-ès-sciences* exam flourished in private academies in Paris, mainly after this degree became compulsory in order to be accepted by a Faculty of Medicine. In a similar way, the Schools of Pharmacy did not replace the old apothecary apprenticeship, which was still important in the mid-nineteenth century.

In fact, some of the most famous new institutions, such as the *Ecole Polytechnique* and the *Ecole Normale*, played a minor role in the learning paths of *pensionados* and Spanish exiles. There is just one case where we have evidence of studies in these institutions: Alcón Calduch, whose trip was funded by the Spanish Museum of Natural History, was admitted to the *Ecole Polytechnique* thanks to the support of the Spanish ambassador. In his report, Calduch mentioned that he was "the only foreign person who was allowed to enter the school."[71] Being a military institution, the access to the *Ecole Polytechnique* was difficult for foreigners, even if some of them, such as Calduch, succeeded in being admitted.[72] There is also a small number of Spanish travellers in the alumni registers of the Faculty of Sciences. These trips were not supported by training programmes implemented by Spanish teaching institutions and governmental offices but the result of personal circumstances, generally related to politics. That is the case of José Luis Casaseca (1800-1869), son of a Spanish exiled *afrancesado* who arrived in Paris just after the end of the Peninsular War and the fall of José Bonaparte's government. As a result, Casaseca obtained an excellent scientific education at the Parisian *Lycée Henry IV*, and afterwards attended lectures at the Faculty of Sciences, obtaining the sciences doctoral degree.[73]

As we have said before, during the eighteenth century a substantial number of Spanish students attended lectures and were awarded medical degrees at French universities, mainly in Paris and Montpellier. Catalan students took advantage of the grants given by the Girona council, which supported the *College of Girona* at Montpellier. There were also Spanish students attending the courses of the Faculty of Medicine in Paris. During the Revolution and throughout the Empire, chemistry gained importance in medical curricula and prominent chemists such as Fourcroy and Vauquelin lectured on chemistry at the Paris Medical Faculty, making this institution more attractive for Spanish *pensionados* interested in chemistry. At the beginning of the nineteenth-century, Josep Garriga i Buach, who had studied medicine in Montpellier, attended some lessons at the Parisian Faculty of Medicine together with other Spanish travellers such as Luzuriaga, a member of a family of prestigious Basque physicians who studied at the Faculty of Medicine, the Schools of Surgery and the *Collège Royal* in Paris.[74] Among the Spanish medical students interested in chemistry, the most famous was Mateu Orfila, who registered as a student at the Paris Medical Faculty in 1807. At least twenty Spanish students were registered in the alumni register of the Paris Medical Faculty during the 1810s and 1820s.[75]

Despite the importance of these institutions, Spanish travellers preferred to attend chemistry lectures at other locales. They mostly frequented the *Collège de France* and the *Muséum d'Histoire Naturelle*, where lectures were public and not part of a larger official curriculum, so they could be followed as independent courses. From the last decades of the eighteenth century, chemistry lectures at the *Collège de France* attracted a heterogeneous audience which included mostly medical and pharmacy students, but also artisans, gentlemen and enlightened wealthy notables ("gens du monde"), fascinated by chemical demonstrations. Spanish students regarded these lessons as an accessible way to complete their chemistry background. They were looking for both practical and theoretical lectures in which chemistry was presented as an organised and systematic body of knowledge. Their presence dates from the 1780s, just after the creation of the first professorship of chemistry, held by Jean Darcet (1725-1801). Several *pensionados* from the Basque Economic Society studied with Darcet), such as Jerónimo Más, who travelled to Paris in order to set up a course of chemistry in Bergara and acquire scientific instruments for his lessons. Jerónimo Más performed several experiments on "the composition and decomposition of water" with Léfevre de Guineau (1751-1829), professor of experimental physics, and Jérôme Dizé (b. 1765), Darcet)'s assistant at the laboratory of the *Collège de France* since 1784. In this way, the Spanish teacher performed this famous water experiment himself, employed by Lavoisier's followers to disseminate his new ideas on combustion. After the French Revolution, which introduced minor changes in the *Collège de France*, Spanish travellers continued to fill its lecture hall, representing for some years almost half of the audience.[76]

Apothecary workshops continued to play an important role in the teaching of chemistry during the first decades of the nineteenth century. Although it is difficult to gather historical evidence on this type of training, Spanish students do not seem to have chosen a course of training which compelled them to practice pharmacy with a *maître* for several years. This training option was only followed by some exiles who found sanctuary in France. Thanks to police reports, we know that in 1809 Francisco Evangelista, who studied medicine in the city of his birth, Salamanca, and was taken prisoner in France during the Peninsular War, was taken on as an apprentice in the pharmacy of Mr. Landreau, in Angoulême, where he stayed until 1814. Like other provincial pharmacy students, he moved to Paris to complete his training and attended various courses on chemistry and botany, some of them at the *Muséum d'Histoire Naturelle*. Finally, in 1816, he was "reçu Maître en Pharmacie." Some years later, Evangelista attended Orfila's chemistry courses and became his *préparateur*.[77]

Orfila's private lectures became very popular during the 1810s. He started delivering private lectures on physics and chemistry during his years as a medical student in Paris in a laboratory equipped by a wealthy friend.[78] The war between France and Spain deprived Orfila of his grant and encouraged him to organise new private scientific courses which were to become his main source of income.[79] During the winter of 1812, Orfila taught chemistry to a group of forty students. The following year he moved to a new laboratory, where he went on lecturing on chemistry and other subjects, such as legal medicine, botany and anatomy, for more than three years.[80] He also applied for a post as a teacher of physics and chemistry in one of the Parisian *Lycées* but, despite being supported by Vauquelin, Haüy and Thenard, he was not accepted.[81] In 1817, he replaced Louis Jacques Thènard (1777-1857) as lecturer in the chemistry at the *Athénée* of Paris and published his *Elémens de chimie médicale*, aimed at the "medical and pharmaceutical students" attending his private lectures on chemistry.[82] Orfila's lectures soon became an attractive destination for Spanish *pensionados* such as Evangelista and Carlos Ardit.[83]

Private scientific lectures were, in fact, very common in Paris and perhaps one of the main things that attracted students from other parts of France, Europe and America. The teachers were among the most famous chemists of the time. Fourcroy announced in the *Décade Philosophique* his "Experimental Course on Chemical Philosophy," delivered in 20 sessions.[84]

The young Thenard, teacher of many Spanish *pensionados*, offered preparatory courses to the *Ecole Polytechnique* for 20 francs per month and claimed to train his students in "chemical manipulations" of substances, their use "in the arts" and "mineral, vegetable and animal" analysis.[85] Many courses were conducted by young students, pharmacists or physicians such as Orfila, who realised that the enormous student community of Paris was a potential clientele for his courses. And, like Orfila, many chemistry teachers delivered their lectures to medical students of the Paris Faculty of Medicine. In 1818, a students guide to the Faculty of Medicine in Paris recommended courses at institutions such as the *Ecole de Pharmacie* and the *Collège de France* as well as private courses in anatomy, physiology, medicine, surgery, etc. given by teachers such as Jean Marjolin (1780-1850), Nicolas Adelon (1782-1862) and François Magendie (1783-1857). The guide also recommended private chemistry courses taught by Vauquelin, Orfila and Laurent Sallé.[86] In the *Almanach général de médecine* of 1827, a great number of private courses were reported, including courses on medical chemistry given by Marie Guillaume Devergie (1798-1879), chemistry applied to the arts by Henry François Gaultier de Claubry (1792-1878) and general chemistry by George Sérullas (1774-1832).[87] These private courses were encouraged by members of the Parisian Faculty of Medicine to such an extent that spaces in the faculty building were reserved for the classes. According to Orfila, dean of the Faculty, this system fostered pedagogical innovation:

> I strongly support this system, which complements the syllabus to be taught by the Faculty during the year and stimulates a useful competitive spirit among teachers who will always be wary of allowing themselves to be overshadowed by young rivals; in short, within the bounds of reason, this is the principle of academic freedom so often insisted upon.[88]

In his book on American students in Paris during the nineteenth century, John Warner showed that private instruction became a valued core of their training in medicine, especially in areas such as clinical instruction, in which they wanted to learn practical skills and obtain their own sensory experience at the patients' bedside. In some cases, a small group of students arranged with an *interne* to admit them to his wards and, in return for a fee, the *interne* pointed out interesting cases, allowed the students to examine patients and answered questions.[89] There is evidence that Spanish chemistry students also preferred these private courses, perhaps because of their brief duration –which fitted better with their temporary sojourn in Paris – and the chances they offered for access to chemical manipulations. In some cases, like American medical students, they were employed in public teaching institutions and laboratories, and thanks to arrangements with *préparateurs* or *adjoints*, they gained access to places that were not attended by regular students. A good example is Antonio Benito, a Spanish lawyer who collaborated with José Napoleon's government and, as a result, was compelled to seek exile in Paris in 1814. He decided to study "chemistry and mineralogy" and attended Sage's lectures at the Mint House, but he soon realised that these lectures were out of date. Seeking to improve his chemical knowledge in "a brief period of time," he convinced himself that private lessons were necessary and he contacted the young chemist Gaultier de Claubry), who had joined Thenard in his courses at the Faculty of Sciences.[90] Benito took two or three lessons a week for a year, paying Gaultier the laboratory running costs plus four francs per lesson. According to Benito, Gaultier used for his lessons Thenard's chemistry laboratory – probably at the *Collège de France* – which private students could use even after the end of courses. Benito also had access to some of the instruments belonging to the "rich cabinet of Physics" considered as "indispensable [...] at least for the first lessons in chemistry."[91]

Many other Spanish travellers probably took private courses such as those already mentioned, but the evidence is scarce. The main problem faced when following private courses is the scant number of historical sources which can be employed to analyse their contents, didactic practices or even the number of students and their profiles. We find a similar problem for other important chemistry learning places attended by Spanish travellers: craft workshops and factories where *pensionados* tried to improve their knowledge of "chemistry applied to arts and industry."

4.3 Industrial Espionage and Technological Transfer

As mentioned above, a significant number of travellers were required to learn technological processes related to dyes, metallurgy or mining. In this case, the learning scenarios were completely different from public lectures at the famous teaching institutions of Paris. To begin with, relevant workshops and factories were scattered all over French territory. Travellers interested in dyeing technology, such as José María de San Cristóbal or José Garriga i Buach, could not expect to obtain this knowledge during a brief stay in Paris or by reading the main chemistry textbooks and journals. They were compelled to travel from one dyeing centre to another, negotiating with dyers their admittance to their workshops to observe procedures and routines. San Cristóbal and Garriga, as well as other *pensionados*, also attended public lectures in Paris, so they were faced with very different ways of appropriating chemical knowledge. In order to compare these extreme situations, let us focus on two trips that were supported in 1819 by the same Spanish institution: the Museum of Natural History in Madrid.

The first traveller was Andrés Alcón Calduch (1782-1850), son of a chemistry demonstrator at the University of Valencia, who studied with Louis Proust at the beginning of the nineteenth-century. After obtaining his degree in pharmacy, he was appointed chemistry professor at the School of Pharmacy of Madrid in 1815 and, three years later, he held the new chair of chemistry at the Natural History Museum of Madrid. During the first years in his new position, Alcón focused on the organisation of the laboratory and the acquisition of chemicals and teaching instruments. As a part of these activities, he was sent to Paris in 1819, where he visited chemical factories, "chemistry and physics laboratories and cabinets" and the School of Mines. According to Alcón's report, he used to approach professors before the beginning of their lectures that they could give him an advance idea about lesson contents and methods. Among the chemists and teachers he contacted were some of the most famous French chemists, such as "Vauquelin, Thenard, Deyeux, Laugier, Gay-Lussac, Biot, Haüy, Brongniard, Say, Clement-Desormes, Thouin, Bertholet and others...."[92] Through this intense social activity, Alcón succeeded in attending the assemblies of the *Institut de France* and the classrooms of the *Ecole Polytechnique.*[93] By the end of 1819, Alcón Calduch also attended chemistry lectures at the Faculty of Sciences, the Faculty of Medicine and the *Collège de France* as well as some courses of physics.[94] In his report, Alcón also pointed out that social relationships allowed him to have access to the private laboratories of some important chemists. He used this information, as well as informal talks with professors, to organise his future chair of chemistry and the teaching laboratory at the Natural History Museum of Madrid. Moving in this academic arena of public knowledge, Alcón, a young Spanish chemistry teacher, would find it easy to access very different venues, ranging from chemistry lectures and scientific discussions held in the *Institut de France* to private spaces such as personal laboratories.

His colleague, José María de San Cristóbal, who also obtained a grant from the Museum of Natural History, had a very different experience. In September 1819, he travelled to France to learn dyeing technology, so that, when back in Spain, he could lecture on "the most elaborate procedures of this important art and disseminate the scientific principles on which it is founded."[95] San Cristóbal visited several chemical plants in Bordeaux, Limoges, Orléans, Rouen and Louviers. In Louviers, an important city in the textile industry, San Cristóbal succeeded in "attending one of the best dyeing workshops every day," in which, besides practising regular dyeing procedures, he was able to perform "a series of experiments" with dyes.[96] San Cristóbal remarked that the art of dyeing "can be learned just in the workshops (*obradores*)" but it was difficult to be accepted in these secret places and even more complicated to collect useful information, that is, "to observe craft operations, to be informed about different procedures and to practise."[97] In a report, San Cristóbal described the strategies he employed to overcome these obstacles:

> To travel from one place to another, verifying beforehand the names of the principal patrons of manufactures, seeking for some recommendations that, in most cases, are useless; spending much time on gaining the trust of the most accessible workers, before penetrating what we shall call the sanctuary of the arts and conferring with its ministers [...]. [Besides these problems] one must add giving tips to workmen and what is extremely useful – or to be perfectly honest, absolutely necessary – making arrangements with master craftsmen so that they will allow us to observe, ask and act freely, otherwise it is impossible to achieve one's goal.[98]

Simultaneously, San Cristóbal prepared a translation of a textbook on dyes which was written by a professor of chemistry applied to the arts in Rouen, Jean-Baptiste Vitalis (d. 1832). He enriched the translation with "instructions about textile bleaching" and other additions, owing to his friendship with Vitalis.[99] San Cristóbal visited several factories in the North of France and, in Sedan, made an agreement with a craftsman who, in exchange for a fee of 12,000 *reales* (half of San Cristóbal's annual salary), promised to unveil to him "the secret of his precious procedures" and to allow him to work in his workshop. But political instability in Spain frustrated San Cristóbal's projected chair of dyeing "grounded not on uncertain recipes, nor only on tradition, but founded on the scientific principles of chemistry."[100] San Cristóbal claimed that such a chair would perhaps never be created in Spain, considering that seldom "does a chemist become a craftsman or a craftsman becomes a chemist."[101] Like his colleague Alcón Calduch, San Cristóbal was probably ostracised by the subsequent Spanish absolutist governments.[102]

In contrast to Alcón Calduch's experience, San Cristóbal's struggles to collect craft information about dyes seemed more a mission of industrial espionage than an academic trip. However, the use of the term "espionage" might be ambiguous and veil our understanding of San Cristóbal's experiences in the complicated area of chemistry applied to arts and factories. In fact, as well as other chemists interested in this area, such as Jean Antoine Chaptal, San Cristóbal was trying to gather craft information, which was strictly controlled by traditional rules of transmission and learning, and to make it public through public lectures and textbooks. In this way, he was developing one of Chaptal's main objectives for the enhancement of chemistry applied to the arts:

> Before chemistry was restored to general principles, the many operations of industry, factories and workshops were, so to speak, the prerogative of a few nations and the property of a small number of individuals; the greatest secrecy wrapped each process in a veil of mystery; formulas and procedures were handed down from generation to generation. Chemistry has unveiled it all: it has turned the realm of arts into the heritage of us all; and, in a short period of time, we have seen how all the people who have cultivated this science have improved the establishments of their neighbours. Preparations of lead, copper and mercury; works on iron; the manufacture of acids; dressing of cloths; printing of colour on textiles; the composition of glass, earthenware and china, etc.; all these things have been brought out into the open, and are common property today.[103]

Like San Cristóbal, many other *pensionados* travelled to France for this purpose during the first decades of the nineteenth-century. Josep Garriga i Buach, co-author with San Cristóbal of a textbook on chemistry applied to the arts, visited several factories in France, collecting information about indigo dyes, their manufacture and operation. He finally reported his results at a public session of the Paris Academy of Sciences in 1807. Vauquelin, Gay-Lussac and Bertholet, referees of Garriga's memoir, remarked on the great obstacles that Garriga had to overcome in order to learn the "operations of the art of dyeing" and to practise them "in different workshops and in different parts of France."[104] Could one employ the term "industrial espionage" to describe an activity whose details were openly described by its author in the main scientific institution of the country in which the mission was carried out?

Other trips of Spanish *pensionados* fit better into the term "industrial espionage." Perhaps the most representative one was that of Eugenio Izquierdo (*fl.* 1770-1814) who stayed in Paris during the 1770s and 1780s studying chemistry and natural history thanks to royal financial support. Izquierdo, who was appointed first vice-director and afterwards director of the Royal Cabinet of Natural History, was a freemason who assisted several *pensionados* from the Basque Economic Society to find accommodation in Paris and who probably introduced them to Freemasonry.[105] Izquierdo was, in fact, carrying out several missions of industrial espionage and he was in touch with several French spies in Britain. In 1785, he made a deal with the French spy Le Turc in order to introduce a new English stocking loom in Spain.[106] Le Turc succeeded in transporting the machine and several specialised workers to France, where he left them with Francisco Angulo, future vice-director of the Spanish Royal Cabinet and professor of chemistry, who was apparently living at Izquierdo's house in Paris at that time.[107] In spite of the problems between the French and Spanish spies, Izquierdo purchased the new loom and ordered twelve more of the same type. According to Le Turc, Izquierdo had a free hand to send looms of several types to Spain. Izquierdo had been appointed Director of the Rocheguyon Company, a group of aristocratic or wealthy partners, including the Duc de Rochefoucauld, the Duchesse d'Anville and the financier Lecouteulx.[108] Izquierdo also collaborated with Le Camus de Limary, another French spy who introduced English copper sheathing in France. Izquierdo provided additional capital for Le Camus's firm and he also described to Le Camus the latest progress on Watt's steam-engine. According to Le Camus, Izquierdo had been to Cornwall, where he had "observed and admired" Watt's engines.[109] At the same time, between 1786 and 1788, Izquierdo co-operated in several tasks related to the establishment of a chemical laboratory in Madrid.[110] These activities and his post as director of the Royal Cabinet helped him to hide his espionage activities, but eventually they were discovered. In 1798, the French Republican Government arrested Izquierdo after intercepting some compromising letters. In a report addressed to the Spanish Government, the Spanish Ambassador in Paris, Nicolás de Azara, remarked that Izquierdo was an appropriate agent for a espionage mission in France because he was able to use his fame and contacts inside the French academic community. Azara also mentioned that a prominent member of the French Government accused Izquierdo of having used "science to serve politics."[111]

The use of scientific missions to hide industrial espionage was a practice that we found in other cases, for instance, in the Elhuyar brothers' trips. During the 1770s, Fausto (1755-1833) 1833) and Juan José de Elhuyar (1754-1796) spent several years in Paris, where they attended lectures given by Hillaire Marin Rouelle (1718-1779) at the *Jardin du Roi*. They also contacted Jean D'Arcet (1725-1805), professor of chemistry at the *Collège de France*, as well as other Basque *pensionados*. Just after returning to Bergara, Juan José de Elhuyar was entrusted with a mission supported by the Spanish Navy Department in conjunction with the Basque Society. He received two documents with two sets of instructions, one open ("instrucción ostensible"), the other secret ("instrucción secreta").[112] The open instructions pictured Elhuyar's mission as a purely scientific trip supported by a private institution, the Basque Society. According to these instructions, Elhuyar not only had to attend lectures in Paris and Freiberg but also had to contact a prominent German iron smelter, with whom he had to "engage in a close personal relationship in order to find out his achievements." He was also requested to visit ironworks and foundry furnaces and report on "everything" he saw.[113] The secret instructions required him to focus his activities on the manufacture of military cannons, including a final trip to Scotland. He was to consult various French scientists in Paris and then study at the School of Mines in Freiberg, where he was to collect information about cannon foundries in Saxon and Sweden. Finally he also had to learn German so that he could act as if he were a good German foundry worker whose activities in Britain would be above suspicion. In Britain, he joined Ignacio de Montalvo (*fl.* 1787-1781), a Bergara silver-smith acting as an industrial spy, who succeeded in entering the famous Scottish Carron ironworks, seeking technological information related to naval cannons. José Elhuyar never met Montalvo in Carron, but he travelled to Central Europe, attended the lectures given by Abraham Gottlob Werner at the Freiberg School of Mines, and visited Torbern Olaf Bergmann in Uppsala.[114] This latter encounter was very significant for Elhuyar's career, for it led him later on to the discovery of wolfram (tungsten).[115] A failed espionage venture that ended up producing the most celebrated scientific achievement of the Spanish *pensionados*!

This example clearly reflects the interplay of academic or scientific trips and secret missions of industrial espionage, especially in the case of disciplines such as applied chemistry, mineralogy, metallurgy and mining. The disciplinary borders and structure of chemistry were in the process of negotiation during the eighteenth-century as was its relation to other disciplines (medicine and pharmacy, for instance) and industrial arts. As a result, chemistry travellers crossed not only geographical and political borders but also cultural frontiers between scientific and technological traditions with very different norms and values about what was considered as private or public information, training and expertise. During the same trip, they had probably visited academic institutions, freely attended public chemistry lectures and bribed craftsmen to gain access to their workshops. In each of these situations they came across very different values regarding the transmission of knowledge and practices of teaching and learning. In other cases, the scientific façade of the trip was an excellent strategy to veil secret – and more important – espionage motives. In this sense, expressions such as "purely scientific interests," "technologically oriented" or "industrial espionage" may be misleading labels, which obscure rather than clarify our historical understanding of the *pensionados*' activities.

5. CONCLUSIONS

Spanish *pensionados* and exiles offer us a broad range of cases through which to study how science was appropriated from one geographical context to another. Their names are scarcely mentioned in important narratives concerning the history of chemistry and, apart from a few cases, their lives are hardly attractive for hagiographic purposes. Although some *pensionados* are usually mentioned by early twentieth-century Spanish chemist-historians and they played a major role in recent historiography on the Spanish Enlightenment, many of their biographies have not yet been studied in depth. In this study, we have offered some conclusions from a collective study of a large sample of travellers who spent many months or years studying chemistry in Europe during the late eighteenth and early nineteenth centuries. The reasons and interests underlying their trips changed during the three periods under study as well as their places of destination and itineraries.

During the last third of the eighteenth century, travellers were supported by government institutions or economic societies which aimed to revitalise and implement chemical knowledge, as a means of developing medical theory and practice as well as many industrial arts. Therefore, the main institutions which backed travellers were surgical schools, on the one hand, and economic societies and the government, on the other. The main aim was not chemical theory per se but its applications to medicine and industry. These goals undoubtedly shaped the way in which the "chemical revolution" was perceived and appropriated in Spain. When they returned to Spain, many travellers joined teaching institutions or were appointed to key positions in royal factories or Trade Boards. Thus, they could spread their newly gained knowledge, values and skills through chemical lectures, textbooks, journals and institutional reforms.

Many elements of the second group of travellers, especially those who visited Paris during the first years of the nineteenth century, were supported by the Spanish government to study chemistry in order to became chemistry teachers on the return to Spain. However, the economic and political crisis and the unfavourable context of the Napoleonic wars severely hampered their careers as well as governmental plans. In addition, political persecution against Napoleonic and liberal government supporters led many scientists to be ostracised or sent to exile in France and England. Many exiles attended chemical courses in Paris and a small group even followed important scientific careers in France, but they encountered great difficulties when they attempted to return to Spain to secure positions in academic establishments. In consequence, despite their advanced training and expertise in chemistry, their trips did not have any impact on Spanish society as they hardly published any textbooks or papers in Spanish journals or participated in any teaching institutions.

The travellers visited many different places and they put forward diverse strategies to gain the theoretical and practical knowledge they were looking for. Some of them attended scientific and teaching institutions and got in touch with many famous French chemists. The most visited scientific centre in this period was the *Collège de France*, which offered many advantages to Spanish visitors thanks to the open character of its lectures. Other travellers attended chemistry lectures by private tutors, who allowed them to obtain practical training in their laboratories. Our study clearly shows that private chemistry courses played an outstanding role during this period, and many young chemists, such as Mateu Orfila, were able to start and maintain a scientific career in chemistry. Finally, other groups of travellers, who were mainly interested in technological aspects, visited not only public and private teaching institutions but also industrial factories and craft workshops. In this case, they faced coercive rules regarding the transfer of technological information and their trips turned out to be real spying missions. It should be kept in mind, however, that there was a continuous spectrum of activities ranging from tours apparently seeking the appropriation of scientific knowledge to expeditions of blatant spying. In fact, there are many intermediate cases ranging from travellers with a mixed agenda, with both scientific and industrial goals, to travellers who used their scientific background to hide political or industrial spying missions.

The plurality of motivations, activities and training strategies illustrated by this sample of scientists and travellers is no doubt a reflection of the diversity of contexts in which chemistry was practised and taught throughout the period under study. Scientific trips constitute an excellent topic for the analysis of different forms of production, circulation and appropriation of scientific and technological knowledge during a period in which new instruments and forms of communication appeared, dramatically transforming scientific activity.

The trips of Spanish *pensionados* also offer us an occasion to reflect on the use of the categories of centre and periphery in studies on the transmission of science. The idea of an outside space providing scientific and technical knowledge appears in our study as a diffuse and controversial category that is both historically and historiographically constructed. For our historical actors this outside space was not identified with particular centres. We find rather a plurality of places – cities, schools, factories and industrial sites – linked by a diversity of lines drawn by the *pensionados*' and exiles' itineraries. Places and itineraries had, moreover, different meanings according to travellers' interests. Paris, a city that might be considered as a centre, actually appears in travellers' narratives and activities with very different meanings, running from the main destination for medical students interested in chemistry to just a first step on trips motivated by other aims such as mining and metallurgy. Paris, or any other destination, turned into a centre only in our actors' minds according to their professional expectations, scientific interests and even political ideas. As we have shown, scientific relations with foreign countries, and especially with France, were rhetorically transformed into an object of political and ideological controversy. Territories and people from the other side of the Pyrenees became the main source of progress and modernity for travellers and their supporters and a dangerous focus of strange perverting ideas and mores for their more radical detractors. This polarised and Manichaean image of international scientific relations was reinforced and elaborated by several generations of historians who identified themselves with the political and scientific situation lived by our historical actors. All of them contributed to shaping the idea of a central source of knowledge that spread like an oil slick through an immaculate periphery. These categories should remain, therefore, as historical constructs rather than historiographical tools.

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NOTES

Abbreviations:
Archivo Histórico Nacional, Madrid (AHN)
Archivo General de Simancas, Simancas (AGS)
Archivo del Palacio Real, Madrid (APR)
Archivo del Museo de Ciencias Naturales, Madrid (AMCN)
Archives du Collège de France, Paris (ACF)
Archives Nationales de France, Paris (ANF)

[1] The word *pensionado* was employed to refer to travellers who were supported by Royal Governments or private institutions.

[2] For an introduction to the history of science during the Spanish Enlightenment, see M. Selles; J.L. Peset; A. Lafuente, *Carlos III y la ciencia de la Ilustración* (Madrid: Alianza Editorial, 1987), and J. Fernández Pérez; I. González Tascón, eds., *Ciencia, técnica y estado en la España Ilustrada* (Zaragoza: MEC, 1990). About scientific trips, see A.

Lafuente, "Las políticas y los métodos de internacionalización de la ciencia española durante el siglo XVIII," *Revista de Occidente* (1988), 229-42; M. Valera; M. López Sánchez; C. López Fernández, "Científicos españoles en el Reino Unido (1750-1830)," *Asclepio,* 50 (1) (1998), 49-68, and A. García Belmar; J.R. Bertomeu Sánchez, "Viajes a Francia para el estudio de la química, 1770-1833," *Asclepio*, 53 (1) (2001), 95-135.

[3] For a discussion of some images related to the chemical revolution, see B. Bensaude-Vincent, "Between History and Memory: Centennial and Bicentennial Images of Lavoisier," *Isis*, 87 (1996), 481-499. A survey of recent trends in A. Donovan (ed), "The Chemical Revolution: Essays in Reinterpretation," *Osiris*, 4 (1988), 1-236 and P. Bret, "Trois décennies d'études lavoisiennes. Supplément aux bibliographies de Duveen," *Revue d'histoire des sciences*, 48 (1/2) (1995), 169-197.

[4] On the chemical revolution in Spain, see R. Gago's works, which include references to former historical research by Spanish "chemist-historians" such as Bonet i Bonfill, Rodríguez Carracido and Moles Ormella. See R. Gago, "La enseñanza de la química en Madrid a finales del siglo XVIII," *Dynamis*, 4 (1984), 277-300; *id.* "The New Chemistry in Spain," *Osiris*, 4 (1988), 169-192 and *id.* "Cultivo y enseñanza de la química en la España de principios del siglo XIX." In: J.M. Sánchez Ron, ed., *Ciencia y sociedad en España* (Madrid: El Arquero, 1988), pp. 129-143.

[5] F.L. Holmes, *Eighteenth Century Chemistry as an Investigative Enterprise* (Berkeley: University of California, 1989).

[6] B. Bensaude-Vincent,; F. Abbri, *Lavoisier in the European Context. Negotiating a New Language for Chemistry* (Canton: Watson Publishing International, 1995).

[7] K. Hufbauer, *The formation of the German chemical community, 1720-1795* (Berkeley: Univ. of California Press, 1982); F. Abbri, "Chemistry turned outside down: Aspects of the Italian debate on Lavoisier's theory." In: F. Abbri; F. Crispini (eds.), *Atti del III° Convegno Nazionale di Storia e Fondamenti della Chimica* (Cosenza: Brenner, 1991), 101-111; and M. Beretta, "Gli scienziati italiani e la rivoluzione chimica," *Nuncius*, 4 (2) (1989), 119-146.

[8] Good examples are papers such as H. Guerlac, "The Continental Reputation of Stephan Hales", *Archives Internationales d'Histoire des Sciences*, 4 (1951), 393-404. These and other works have paid attention to travellers such as João Jacinto de Magalhães (1722-1790). See I. Malaquias; M. Fernandes Thomaz, "Scientific Communication in the 18th century: The case of John Hyacinth de Magellan," *Physis*, 31 (1994), 817-834.

[9] One of the most studied cases is that of Martinus van Marum, who established several contacts with a number of Parisian scientists, and especially Lavoisier, during his trip in 1785. See T.H. Levere, "Martinus Van Marum (1750-1837): The introduction of Lavoisier´s Chemistry into the Low Countries," *Janus*, 53 (1966), 115-134 and H.A.M. Snelders, "The New Chemistry in Netherlands," *Osiris*, 4 (1988), 121-146. For other studies showing the role of individual travels in the transmission of the chemical revolution see, for instance, A. Lundgren, "The New Chemistry in Sweden," *Osiris*, 4 (1988), 146-169, in which the travels of Pehr Afzelius, co-author of the Swedish translation of the new nomenclature, are studied. See also A.S. Jacobsen, "A.W. Hauch's Role in the Introduction of Antiphlogistic Chemistry into Denmark," Ambix, 47 (2) (2000), 71-95.

[10] Due to the similarities with our study, studies on Portuguese "estrangeirados" are particularly valuable for a comparative view. See A. Simoes; A. Carneiro; M.P. Diogo, "Constructing knowledge: Eighteenth-century Portugal and the new sciences," in K.

Gavroglu (ed.) *Sciences in the European periphery during the Enlightenment* (Dordrecht: Kluwer, 1999), 1-40; M.P. Diogo; A. Carneiro; A. Simões, "Sources for the History of Science in Portugal: one possible option," *Cronos*, 3 (1) (2000), 115-141, and other papers quoted therein. See also their chapter on this volume.

[11] For a detailed description of the sources and methodology, see A. García Belmar, *op. cit.* (2).

[12] All graphs have been made using available biographical information from different sources. In order to avoid possible bias in Graph I, II and III, authors with only archival information have been excluded. For the case of trips around different places, each country visited has been individually considered.

[13] H. Guerlac, *Lavoisier - The crucial Year. The Background and Origin of his First Experiments on Combustion, in 1772* (Ithaca, Cornell University Press: 1961) and F.L. Holmes, *Antoine Lavoisier - The Next Crucial Year* (Princeton: Univ. Press, 1997).

[14] See C.E. Perrin, "The Triumph of the Antiphlogistians," in *The Analytic Spirit. Essays in the History of Science in Honor of Henry Guerlac* (Ithaca and London: Cornell University Press, 1981), pp. 40-64 and B. Bensaude-Vincent, *Lavoisier. Mémoires d'une révolution* (Paris: Flammarion, 1993).

[15] AHN, *Consejos*, file 1289. Letter by the Conde de Floridablanca addressed to the Consejo de Castilla. "El Rey ha determinado que ninguno de sus vasallos salga a educarse a países extranjeros sin motivo ni permiso de S.M."

[16] On these subjects, see M.S. Oliver, *Los españoles en la revolución francesa* (Madrid: Renacimiento, 1914); R. Herr., *España y la revolución del siglo XVIII* (Madrid: Aguilar, 1988); J.R. Aymes, ed., *España y la revolución francesa* (Barcelona: Crítica, 1989) and J.R. Aymes, "Españoles en Francia (1789-1823): Contactos ideológicos a través de la deportación y el exilio," *Trienio*, 10 (1987), 3-26.

[17] The *afrancesados* were a small but influential group of Spaniards who collaborated with José Bonaparte's government. They attempted to adapt many French scientific institutions to the Spanish context and, in some cases, they developed old Enlightened projects. On these projects see J.R. Bertomeu Sánchez, *La actividad científica en España bajo el reinado de Jose I (1808-1813)* (Valencia: Universitat de Valencia, 1995) and J.R. Bertomeu Sánchez, A. García Belmar, "Tres proyectos de creación de instituciones científicas durante el reinado de José I: Un estudio sobre la transmisión de la ciencia en el marco de la Guerra de la Independencia," in J.A. Armillas, ed., *La Guerra de la Independencia. Estudios* (Zaragoza:. Diputación, 2001), vol. I, pp. 301-325.

[18] On Spanish liberal exiles, see V. Lorens, *Liberales y Románticos*. Una emigración española en Inglaterra (Madrid: Castalia, 1979), and R. Sánchez Mantero, *Los liberales en el exilio* (Madrid: Rialp, 1975). For a general view of Spanish scientific trips to Britain, see Valera, *op. cit.* (2).

[19] "Les jeunes gens suivent avec ardeur mon cours sur la chimie animale à l'Ecole de médecine. Rien n'égale leur envie d'apprendre; les vingt leçons que je fais sur cette partie si neuve de la chimie, donnent, je le vois, un grand mouvement à cette branche de l'étude de la nature; mais je le modère le plus que je le puis; je ne veux pas trop l'accélérer, de crainte de briser cette belle machine entre mes mains. "Cf. A. Fourcroy, "Extrait d'une lettre du citoyen ... , au citoyen Van Mons, au sujet de celle de M. Humboldt," *Annales de Chimie*, 22 (1797), 77-80. Antoine Fourcroy was the editor of La Médecine éclairée par les sciences physique ... between 1791 and 1792, a journal translated soon afterwards into Spanish with the title Diario de los nuevos descubrimientos de todas las Ciencias Físicas, que tienen alguna relación con las diferentes partes del arte de curar... (Madrid: Sancha,

1792), 2 vols. On the medical aspects of the chemical revolution, see F.L. Holmes, "The chemical revolution and the art of healing," Caduceus, 11 (2) (1995), 103-126. On the consequences of this debate in Spain, see J.R. Bertomeu Sánchez; A. García Belmar, "Los libros de texto de química destinados a estudiantes de medicina y cirugía en España (1788-1845)", *Dynamis*, 20 (2000), pp. 457-489.

[20] Jean-Baptiste-Thimothée Baumès (1756-1828), professor of the Faculty of Medicine of Montpellier, proposed a nosological system based on the new chemistry. His five main classes of diseases were: "calorinèses," "oxigenèses," "hydrogenèses," "azotenèses" and "phosphorenèses." See J.B.T. Baumès, *Fondements de la science méthodique des maladies, pour servir de suite à l'Essai d'un système chimique de la science de l'homme...* (Montpellier: 1801-1802) vol. I, pp. 174-180. On Baumès, see Holmes , *op. cit.* (19), pp. 118-12

[21] F. Carbonell i Bravo, *De Chemiae ad Medicinam applicationis usu et abusu* (Monspelii: Apud G. Izar et A. Ricard, an IX). On Carbonell, see A. Nieto Galán, *Ciència a Catalunya a l'inici del segle XIX: teoria i aplicacions tècniques a l'escola de Química de Barcelona sota la direcció de Francesc Carbonell i Bravo (1805-1822)* (Barcelona: PhD, 1994). Carbonell published an important textbook on pharmacy and translated several papers by Fourcroy about the relation between chemistry and pharmacy. Cf. F. Carbonell i Bravo, *Pharmaciae elementa chemiae recentioris fundamentis innixa...* (Barcelona: J.F. Piferrer, 1796) (4th ed. 1824). French translations: Paris, Méquignon l'aîné, 1803; 3rd ed. 1821. Carbonell's translation of Fourcroy's Discourse was published in Madrid by Repullés in 1804.

[22] M.J.B. Orfila, *Elémens de chimie médicale* (Paris: Crochard, 1817) vol. I, p. ii.

[23] Ibid. "cette partie de la science nous ayant paru trop peu avancée pour pouvoir la réduire à des principes généraux."

[24] On these institutions, see M. Astrain Gallart, *Barberos, Cirujanos y Gente de Mar.* La sanidad naval y la profesión quirúrgica en la España ilustrada (Madrid: Ministerio de Defensa, 1996).

[25] The alumni register of Paris Medical Faculty (Bibliothèque Faculté de Médecine, Paris, Ms. 25, 131-154) offers evidence that Luzuriaga attended courses by Jean Baptiste Langlois and Jean Louis Marie Solier de la Romillais. At the Collège du Roi, Luzuriaga attended lectures by Joseph Roulin (1708-1784) in 1782 (ACF, A-XIV/8). More information in A. Chinchilla, *Anales históricos de la medicina en general y biográfico-bibliográficos de la española en particular* (Valencia: Imprenta de López y Cia., 1841-46), vol. IV, 357-59

[26] Observations sur la physique..., 25 (1794), 252-261.

[27] On this point, see J. Riera, "Los estudios en el Reino Unido de Ignacio María Ruiz de Luzuriaga, documentos y epistolario 1785-1787," *Cuadernos de Historia de la Medicina española*, 14 (1975), 269-301.

[28] AHN. Hacienda, libro 6463, f. 341, and lib. 6467, f. 296 v.

[29] On the Collège de Girone, see L. Dulieu, *La médecine en Montpellier* (Montpellier: 1986), vol. III (1) pp. 219-226. On Garriga, see A. García Belmar; J.R.Bertomeu Sánchez, "El Curso de química general aplicada a las artes (1804-1805) de San Cristóbal y Garriga". In: J.L. Barona Vilar et al., eds., *Las ciencias en la Ilustración* (Valencia: Universitat de València, 2002) (forthcoming).

[30] C. Meinel, "Theory or practice? The eighteenth century debate on the scientific status of chemistry," *Ambix*, 30 (1983), 121-132.

[31] For an introductory study about the Economic Societies and Sciences, see J. Fernández Pérez, "Las sociedades económicas de Amigos del País," in M. Selles; J.L. Peset; A. Lafuente, eds., *Carlos III y la ciencia de la Ilustración* (Madrid: Alianza Editorial, 1988), pp. 129-140. See also the references cited therein.

[32] On this chair, see Gago, R.; I. Pellón, *La cátedra de química del Seminario de Bergara* (Bergara, 1994), which includes additional bibliography.

[33] See R. Gago et al., "El plan del rector Blasco (1786) y la renovación de las disciplinas científicas en la Universidad de Valencia: la química y la enseñanza clínica," *Estudis*, 6 (1977), 157-170; A. Ten Ros, "La ciencia experimental en la Universidad española de la Ilustración. El laboratorio químico de la Universidad de Valencia: 1787-1807," *Asclepio*, 28 (1985), 287-312; A. García Belmar; J.R. Bertomeu Sánchez, "El laboratorio químico de la Universidad de Valencia a través de sus gastos," in H. Capel; J.M. López Piñero; J. Pardo, eds., *Ciencia e Ideología en la ciudad* (València: Generalitat Valenciana, 1992), vol. I, pp. 123-132.

[34] See A.G. Rocasolano, "La escuela Química de Zaragoza," *Universidad*, 13 (1936), 254-287; I. Aramendia, "La cátedra de química de la Real Sociedad Aragonesa de Amigos del País," *Llull*, 20 (1997), 739-746; P.G. Echeandía, *Función pública de abertura de las cátedras de Botánica y Química, que celebró la Real Sociedad Aragonesa* (Zaragoza: Institución "Fernando el Católico" - Real Sociedad Económica Aragonesa, 1997).

[35] For biographical information about Mateu Orfila, see A. Fayol, *La vie et l'oeuvre d'Orfila* (Paris: Albin Michel, 1930); J. Hernández Mora, "Orfila, El hombre, la vocación, la obra," *Revista de Mallorca*, 49 (1953), 1-121; and S. Loreén, *José Buenaventura Orfila. Estudio crítico-biográfico de su obra e influencia* (Zaragoza: C.S.I.C., 1961). On his chemical research and teaching, see J.R. Bertomeu Sánchez; A. García Belmar, "Mateu Orfila (1787-1853) y las clasificaciones químicas," *Cronos*, 2 (1) (1999), 3-46. and J.R. Bertomeu Sánchez; A. García Belmar, "Mateu Orfila's Elémens de chimie médicale and the Debate about the Medical Applications of Chemistry in Early Nineteenth Century France," *Ambix*, 47 (2000),1-25.

[36] On Ardit and his travels and publications, see A. Nieto-Galán, *op. cit.* (21), pp. 189-203 and A. Nieto-Galán, Coulouring Textiles. *A History of Natural Dyestuffs in Industrial Europe* (Dordrecht: Kluwer, 2001), p. 126.

[37] ANF, AJ16, 6426-6428. According to the register, he studied medicine between 1816 and 1820.

[38] ACF, Paris, A-XIV/20. He attended Jacques Thenard's lectures during 1818. More data about Desprats in A. Gil Novales, et al., *Diccionario biográfico del trienio liberal* (Madrid: Ediciones el Orto, 1991), p. 178·

[39] See M.D. Martínez No, "Les pensions culturals de la Junta de Comerç i la figura de Josep Roura i Estrada (1797-1860)," *Pedralbes. Revista de Historia Moderna*, 8 (2) (1988), 335-347. There is an interesting French police report on the activities of Roura in France during the 1820s. Cf. ACF, Paris, F7 /12062 (2243). More information about other pensionados coming from the Junta de Comerç, see M.S. Oliver, *Los Españoles en la Revolución Francesa* (Madrid-Buenos Aires: Renacimiento, 1914).

[40] See AHN, Hacienda, book 6463, f. 103v.; Ibid., book 6464, f. 207-207v.; Ibid. book 6467, f. 266v.-267; Ibid. book 6468, f. 58v.-59 and 599-600.

[41] Ibid., book 10.832, f. 169v.-170, April, 8th, 1791. More information in García Belmar, *op. cit.* (2).

[42] Bibliothèque Interuniversitaire de Pharmacie, Paris, register 81.

[43] Bibliothèque Faculté de Médecine, Paris, Ms. 25, 131-154.

[44] Gago, *op cit.* (4), 282-283.

[45] AHN, libro 10828, f. 241-242, July 7th, 1787 and book 6463, f. 294, September 28th, 1787. See Gago *op cit.* (4).

[46] "tomar conocimiento de los adelantamientos que ha tenido la química, encargar los instrumentos que no pueden hacerse aquí, y, sobre todo, a instruirse menudamente de lo que se practica en las Casas de la Moneda de París y Bordeaux en lo relativo a fundición, afinación, apartado, métodos de ensayos y refundición de nuestras monedas, procurando adquirir Planos, o modelos de los Hornos y Máquinas más útiles, y un completo conocimiento del mecanismo de las Labores, gastos que ocasionan, precauciones que se observan para evitar desperdicios y mermas y todo lo demás que fuera digno de notar y advertir." Cf. AHN, Hacienda, book 10828, f. 241-242, July 7th, 1787.

[47] AHN, Hacienda, book 6479, f. 230v., May 5th, 1803. On Garriga, see García Belmar, *op. cit.* (29).

[48] "Lettre de Garriga, médecin, etc. Aux redacteurs des Annales de Chimie," *Annales de Chimie*, 48 (an XII), 104-107; La Décade Philosophique, 31, an XII (4e trim.) (1804), pp. 193-198, and *Journal Général de Médecine*, XVII, an XII, pp. 437-446

[49] *Annales de Chimie*, 53 (an XIII), pp. 115-118. Other favourable reviews were published in *Décade Philosophique*, an XIII (IIIè trim.), pp. 70-71; an XIV (Ie trim.), pp. 385-387; and *Journal générale de médecine*, XXI, 341-342 ; XXIV, 239; 446-451.

[50] Archives de l'Académie des Sciences de Paris, *Mémoire sur les cuves d'indigo par M Garriga, médecin de l'université de Montpellier et pensionné de S.M.C.*, Lu le 21 septembre 1807, 36 p. The report of the French chemists was published by L. N. Vauquelin; J.L. Gay-Lussac; C. Berthollet, "Rapport d'un memoire sur les cuves d'indigo de M. Garriga, docteur en médecine, et pensionnaire du Roi d'Espagne, par MM...," *Annales de Chimie*, 65 (1808), 99-106 and *Mémoires presentes a l'Institute des Sciences, lettres et arts, par divers savants, et lus dans ses assemblées. Sciences mathématiques et physiques* (Paris: Baudin, 1811), vol. II, pp. 634-636.

[51] On this project, see García Belmar, *op. cit.* (29).

[52] On this chair, see J.R. Bertomeu Sánchez; A. García Belmar, "Pedro Gutiérrez Bueno (1745-1822) y las relaciones entre la química y la farmacia durante el último tercio del siglo XVIII", *Hispania*, 61 (2) (2001), pp. 539-562.

[53] Many authors praised Don Antonio's support to science. See P. Gutiérrez Bueno, *Manual del arte de vidriería para uso de los fabricantes de vidrio, cristales, piedras preciosas artificiales y esmaltes*. (Madrid: Villalpando, 1799 and G. Bañares, Filosofía Farmacéutica (Madrid: 1814), vol. I, pp. i-ii.

[54] Plan de la Escuela práctica de química establecida en Madrid, y aprobado por S.M. en 13 de enero de 1803, which has been published by X. A. Fraga Vazquez, "El Plan de la Real Escuela Práctica de Química de Madrid (1803), una alternativa institucional para la incorporación de la Química en el Estado español," *Llull*, 18 (34) (1995), 35-65.

[55] *Ibid.* "Luego que un Discípulo se halle capaz de desempeñar el empleo de Profesor será nombrado para tal o cual cátedra según la mayor o menor urgencia que haya en las Provincias y enviado inmediatamente a París por espacio de sólo un año, donde verá los Profesores más célebres, notará su modo de enseñar, los establecimientos de Historia natural, de química y mineralogía, etc; acabará de fortificar y perfeccionar sus conocimientos comparando unos con otros los profesores, sus sistemas, escuelas, etc.; y comprará al mismo tiempo, bajo la dirección del Embajador, las obras e instrumentos que sean indispensables para la Escuela que ha de dirigir a su regreso."

[56] On these students, see García Belmar, *op. cit.* (2).

[57] "Recherches sur quelques combinations du mercure; par M. Taboada, élève de Proust," *Journal de Physique, de chimie et d'histoire naturelle*, LX (an XIII), 378-390.

58 AGS, Gracia y Justicia, File 1090. Report by Gabriel Fernández de Taboada, April 18th, 1809. APR, Gobierno Intruso, Book 2209, f. 45 v. (534). More information on Fernández Taboada in R. Roldán Guerrero, *Diccionario biográfico y bibliográfico de autores farmacéuticos españoles* (Madrid: Gráficas Valera, 1958-76), vol. II, p. 216; A. Meijide Pardo, *El científico Fernández Taboada* (1776-1841) (A Coruña: Sem. de Estudos Galegos, 1988); Fraga Vázquez, op. cit. (54) and R. Sisto Edreira,; X.A. Fraga Vázquez, "A recepcion da ciencia moderna na Universidad de Santiago, 1772-1845. A incorporación da Física e da Química e o labor dos colexios prácticos," *Ingenium*, 5 (1996), 23-58.

[59] AGS, file 1089, Report by the "Real Sociedad Económica de Amigos del País," Zaragoza, May 16th, 1809; AMHN, Química, box 001, file 6. Oposiciones, May 21th, 1818. More information in M. Tomeo Lacrue, *Biografía científica de la Unviversidad de Zaragoza*, (Zaragoza, 1962), 113-114 and García Belmar, *op cit.* (2).

[60] See Valera, *op. cit.* (2).

[61] "La experiencia ha acreditado que las dotaciones señaladas para estudiar química en las naciones extranjeras suelen producir un efecto casi siempre muy contrario al que se promete el Gobierno porque al paso que amortiguan el ardor y afición al estudio en aquéllos que las consiguen, creyéndose con bastante derecho para obtener los empleos a menos costa que los demás perjudican por esto mismo las esperanzas de aquéllos que se proponen estudiar de veras." *Cf. Plan de la Escuela* práctica .... In Fraga Vázquez, *op.cit.* (54), 59.

[62] "Relación de los Exercicios literarios, méritos y servicios de D. Pedro Gutiérrez Bueno..." (early nineteenth century). In APR, box 490, exp.26, p.5. See Bertomeu Sánchez, *op. cit.* (52).

[63] "Sobre el orden que se debe seguir en el fomento de las ciencias naturales y las artes," *Variedades de Ciencias Literaturas y Artes*, I, 1803, pp. 212-226·

[64]·On this point, see J. Riera, *Cirugía española ilustrada y su comunicación con Europa* (Valladolid: Publicaciones, 1976); D. Ferrer, *Historia del Colegio de Cirugía de la Armada de Cádiz* (Cádiz: 1961) and Astrain Gallart, *op. cit.* (24). We are grateful to Mikel Astrain for substantial information about this issue.

[65]·AHN, book 6463, f. 202, 14.07.1787. On Aréjula see R. Gago *et al.*, "Juan Manuel de Aréjula (1755-1830) y la introducción en España de la nueva nomenclatura química," *Cuadernos de Historia de la Medicina Española*, 13 (1974), 273-295 and Bertomeu Sánchez, *op. cit.* (19).

[66] On this School see A. Rumeu De Armas, *Ciencia y tecnología en la España Ilustrada. La Escuela de Caminos y Canales* (Madrid: Turner, 1980).

[67]· AHN, *Hacienda*, book 6468, f. 76-76v. See also Palacios Remondo, J. *Los Delhuyar. La Rioja en América. Biografía de los hermanos Juan José y Fausto a través de fuentes y bibliografía* (Logroño: Gobierno de la Rioja, 1993), p. 331.

[68] Letter by Manuel Angulo, Schemnitz, July 4th, 1788. Reprinted in G. Puig y Larraz, Viajes de estudio por Europa..., *Boletín de la Sociedad Geográfica de Madrid*, 40 (1899), 168-169.

[69] On the liberal exiles in Paris, see R. Sánchez Mantero, *op. cit.* (18). On exile in England, see V. Lorens, *op. cit.* (18). On the exile of collaborators with the Napoleonic

Government, see P. Barbastro Gil, *Los afrancesados. Primera emigración política del siglo XIX español (1813-1820)* (Alicante: Instituto de Cultura "Juan Gil-Albert", 1993).

70 See R. Belhoste, "Les caractères généraux de l'enseignement secondaire scientifique de la fin de l'Ancien Régime à la première guerre mondiale," *Histoire de l'Education,* 41 (1989), 3-45; N. Hulin, *L'organisation de l'enseignement des sciences* (Paris: Comité des travaux historiques et scientifiques, 1989); C. Fournier-Balpe, *Histoire de l'enseignement de la physique dans l'enseignement secondaire en France au XIXe siècle (*Paris: Université de Paris XI, Thèse de Doctorat, 1994), and M. Gontard, *L'enseignement secondaire en France de la fin de l'Ancien Régime à la loi Falloux, 1750-1850 (*La Calade: Edisud, 1984), About the teaching of chemistry for medical and pharmaceutical students, see bibliography quoted in Bertomeu Sánchez, *op. cit.* (35). On technical, agricultural and military education, see F. B. Artz, *The development of Technical Education in France, 1500-1850* (Cambridge: University Press, 1966); A. Léon, *Histoire de l'éducation technique* (Paris: PUF, 1968); and T. Charmasson (ed.), *L'enseignement technique de la Révolution à nos jours* (Paris: I.N.R.P. and Economica, 1987). For legal aspects, see A. Beauchamps, *Recueil des lois et règlements de l'enseignement supérieur (1789-1914)* (Paris: Delalain, 1880-1915).

71 AMCN, *Química*, 001, file 8 (1), Letter by Alcón Calduch, Paris, January 1st, 1820.

72 A. Fourcy, *Histoire de la Ecole Polytechnique* (Paris: chez l'auteur, 1828; reprinted in Paris, Belin, 1987); M. Bradley, "Scientific education for a new society: the Ecole Polytechnique, 1795-1830," *History of education,* 1 (1976) , 11-24.

73 R. E. Misas Jiménez, "Un químico español del reinado de Fernando VII: José Luis Casaseca y Silván," *Llull*, 19 (36) (1996), 131-160; We are grateful to Dr. Misas Jiménez for his help on this topic. See also García Belmar, *op. cit.* (2).

74. He was registered on the courses of Jean Baptiste Langlois y Jean Louis Marie Solier de la Romillais at the Faculty of Medicine (*Bibliothèque Faculté de Médecine*, Paris (Ms. 25, 131-154)), as well as on the courses given by Joseph Roulin (1708-1784) at *Collège de France* in 1782 (ACF, Paris (A-XIV/8). According to Chinchilla, he studied with Macquer, Fourcroy, Antoine-Laurent Jussieu (1748-1836) and Louis Jean Marie Daubenton (1716-1800), as well as various teachers from the *Ecole de Chirurgie* of Paris (Chinchilla, *op. cit.* (26), vol. IV, pp. 357-59).

75 ANF, Paris, AJ16, files 6422-6430.

76 See J.R. Bertomeu Sánchez; A. García Belmar, "Alumnos españoles en los curso de química del *Collège de France* (1774-1833)," in *Actes de les III Trobades d'Història de la Ciència i de la Tècnica als Països Catalans* (Barcelona: SCHCT, 1995), pp. 407-418.

77 ANF, AJ16/1915. and *http://www. lamarck.net*, where he is registered on the courses for 1815.

78 Orfila described his first lectures in his autobiography published by M.G. Chapel D'Espinasoux, "La Jeunesse d'Orfila. Fragment d'une autobiographie inedite publié par ," *Revue Hebdomadaire*, 22-3 (1914), 615-34; 86-113.

79 Letter from Mateu Orfila to his mother, Paris, February 16th 1812. Printed in M.C. Bosch, "Contribució a l'epistolari d'Orfila," *Randa*, 30 (1988), 133-176.

80 Orfila's autobiography reproduced by M.G. Chapel D'Espinasoux, *op. cit.* (78). See also Orfila's letter to *Junta de Comerç* of Barcelona, Paris, November 29th, 1814 in *Arxiu de la Biblioteca de Catalunya,* Barcelona, *Junta de Comerç*, 21 bis 366.

81 The letters were printed by P. Lemay, "Contribution à la biographie d'Orfila," *Bull. Soc. Franç. Hist. Med.*, 25 (1931), 516-22.

[82] Orfila, *Elémens de chimie médical, op. cit.* (22), vol. I, p. II. Orfila's autobiography in Chapel d'Espinasoux, *op. cit.* (78). The *Athénée* of Paris replaced the Musée created by Jean-François Pilâtre of Rozier (1757-1785) in Paris, where important chemists such as Lavoisier, Fourcroy, Brogniart, Thenard, Chevreul, etc. gave classes. By mid-century, when Orfila wrote his autobiography, the institution no longer had the prestige it had enjoyed in the years when he gave his first chemistry courses. See C. Dejob, *De l'établissement connu sous le nom de Lycée et d'Athénée et de quelques établissements analogues* (Paris: Colin, 1889) and W.A. Smeaton, "The early years of the Lycée and the Lycée des Arts," *Annals of Sciences*, 11 (1955), 309-19; 349-55.

[83] Arxiu de la Biblioteca de Catalunya, *Junta de Comerç*, 21 bis 263, Letter by Carlos Ardit, Paris, November 25th, 1814.

[84] *Decade Philosophique*, 7 (an VII), pp. 443-444.

[85] *Annales de Chimie*, 34 (an VIII), p. 103. Quoted by J. Simon, *The Alchemy of Identity. Pharmacy and the Chemical Revolution, 1777-1809* (University of Pittsburgh: Ph.D. 1997), p. 190.

[86] J.P. Maygrier, *Guide de l'étudiant en médecine...* (Paris: Gabon, 1818). pp. 41-42 and p. 197.

[87] L. Hubert, *Almanach général de médecine pour la ville de Paris. 1827. Par ..., chef des bureaux de la Faculté, secrétaire du Jury médical* (Paris: Gabon et Cie, 1827), pp. 144-146.

[88] Cf. *Rapport de M. Orfila sur l'état de l'enseignement médical en France*, September 10th, 1837 in A. Beauchamps, *Recueil des lois et règlements de l'enseignement supérieur (1789-1914)* (Paris: Delalain, 1880-1915), vol. III, pp. 612-652. See Bertomeu Sánchez, *op. cit.* (35).

[89] J.H. Warner, *Against the Spirit of System* (Princenton: University Press, 1998), chap. III.

[90] Gaulthier translated W. Henry's textbook into French during these years and he also played a minor role in the transmission of Daltonian atomism in France. See A.J. Rocke, *Chemical Atomism in the Nineteenth Century. From Dalton to Cannizzaro* (Ohio State University Press: 1984), p. 69 and M.P. Crosland (1968), "The First Reception of Dalton's Atomic Theory in France," in D.S.L. Cardwell, ed., *John Dalton and the Progress of Science* (Manchester: Univ. Press, 1968), pp. 280-281.

[91] AMCN, *Química*, 001, file 4 (4), Antonio Benito, París, January 20th, 1816. On Benito's collaboration with José Napoleón I, see Mercader Riba, J. *José Bonaparte, Rey de España* (Madrid: CSIC, 1983), pp. 88-89.

[92] *Ibid. Química*, 001, file 7 (6). Report activities by Andrés Alcón, Paris, October 26th, 1819.

[93] It has been already mentioned that Alcón greatly valued his acceptance at the Ecole Polytechnique: "[It is] so remarkable taking into account that I am the only foreigner [...] who has been allowed to enter the school." Cf. AMCN, Madrid, *Química*, 001, file 7 (6) Report by Andrés Alcón, Paris, January 1st, 1820.

[94] *Ibid.*

[95] AMCN, *Química*, 001, file 7 (1). "con el objeto de instruirse más de propósito en la práctica de la tintorería, e introducir en España, por medio de un curso público las perfeccionadas maniobras de este arte importante, y difundir los principios científicos en que se fundan". On this case see F.J. Puerto Sarmiento, "La huella de Proust: el laboratorio de química del Museo de Historia Natural," *Asclepio*, 46 (1) (1994), 197-220, and García Belmar, *op. cit.* (2) and (29).

[96] *Ibid.*, Report by José María de San Cristóbal, Louviers, February 20th, 1820.

[97] *Ibid.*, Report by José María de San Cristóbal, Paris, April 18th, 1820.

[98] "Viajar de una parte a otra, [...] averiguar de antemano los nombres de los principales propietarios de manufacturas, [...] buscar para ellos algunas recomendaciones que las más veces son inútiles, de gastar mucho tiempo en ganar la confianza de los más accesibles, antes de penetrar en el santuario, digámoslo así, de las artes y conferir con sus ministros; a todo lo cual se agregan todas las trabas [que suponían el escaso valor de su pensión de 1000 reales mensuales que debían servir] para viajar [...] gratificar operarios y lo que es sobremanera útil o para decirlo con más verdad, del todo necesario hacer ajustes con los maestros que le dejen a uno ver, preguntar y hacer libremente, sin cuya condición es imposible lograr el objeto propuesto," (*Ibid.*, *Química* 001, carpeta 7 (1), Report by San Cristóbal to the Spanish Government, Paris, May 12th , 1820).

[99] AHN, *Estado*, file 5327 (23). Report by J.M. San Cristóbal, París, November 22th, 1824. The book was published by Vitalis in 1810 and was reissued. See Nieto-Galán, *op. cit.* (36) and García Belmar, *op. cit.* (29).

[100] *Ibid.* Quoted from a letter written by Marqués de Casa-Irujo, November 4th,1821.

[101] *Ibid.* Letter by Marqués de Casa-Irujo, Paris, May 25th, 1822, reporting about a letter from San Cristóbal.

[102] He was requested to send reports written by well known French monarchic notables but, even if he succeeded in obtaining these letters, his return to Spain probably never took place. See García Belmar, *op. cit.* (27).

[103] "Avant que la chimie eût ramené à des principes généraux les nombreuses opérations de l'industrie, les fabriques, les manufactures, étaient, pour ainsi dire, l'apanage de quelques nations et la propriété d'un petit nombre d'individus; le secret le plus absolu couvrait chaque procédé du voile du mystère; les formules et les pratiques se transmettaient en héritage de génération à génération. La chimie a tout dévoilé: elle a rendu le domaine des arts le patrimoine de tous; et, en peu de temps, on a vu tous les peuples, chez lesquels cette science a été cultivée, s'enrichir des établissements de leurs voisins. Les préparations de plomb, de cuivre, de mercure; les travaux sur le fer; la fabrication des acides; l'apprêt des étoffes; l'impression des couleurs sur toile; la composition des cristaux, des terres cuites et des porcelaines, etc.; tout cela a été tiré du secret, et forme aujourd'hui une propriété commune." Cf. J.A.C. *Chaptal Chimie appliquée aux arts* (Paris: Déterville, 1807), vol. I, xv, and vol. III, 5-7, about the role of the war in this process.

[104] L.N. Vauquelin; J.L. Gay-Lussac; C. Berthollet (1808), op. cit. (50) on p. 100. See García Belmar, op. cit. (27) for more information.

[105] E. Maffei; R. Rúa Figueroa, *Apuntes para una Biblioteca española de libros, folletos y artículos, impresos y manuscritos, relativos al conocimiento de las riquezas minerales y a las ciencias auxiliares* (Madrid: 1871-72), vol. I, p. 495; Gago, op. cit. (32), pp. 21 and 54. Many Portuguese "estrangeirados" also belonged to the Freemasons. See A. Carneiro; A. Simões; M.P. Diogo, "Enlightenment Science in Portugal: the Estrangeirados and their communication networks," *Social Studies of Science*, 30 (4) (2000), 591-619; M. P. Diogo; A. Carneiro; A. Simões, "The Portuguese naturalist Correia da Serra (1751-1823) and his impact on early nineteenth-century botany," *Journal of the History of Biology*, 34 (2) (2001), 353-393.

[106] J. R. Harris, *Industrial Espionage and Technology Transfer. Britain and France in the Eighteenth Century* (Aldershot: Ashgate, 1998), pp. 435-6.

[107] A. J. Barreiro, *El Museo Nacional de Ciencias Naturales* (Madrid: Museo de Ciencias Naturales, 1992) (1st ed. 1944), pp. 71-72 and Harris, *op. cit.* (106), p. 435, who mentioned "M. Angelo." Angulo collaborated with Guyton de Morveau and, in 1786, was

appointed vice-director of the Royal Cabinet with the order of teaching chemistry. He was also appointed Director of Mines at the end of 1786. Cf. AHN, Hacienda, book 10827, f. 495v., December 28th, 1786

108 Harris, *op. cit.* (106), pp. 436-347.

109 *Ibid.* pp. 208 and 309. According to Palacios Redondo, Le Camus was a member of the Basque Society Cf. Palacios Remondo, op. cit. (67), p. 133).

110 AMCN, *Química*, 001, several letters addressed at Izquierdo, 1786-1788.

111 A. Muriel, *Historia del Reinado de Carlos IV*. In: Biblioteca de Autores Españoles, vol. 115, p. 42-43. G. Puig y Larraz, "Viajes de estudio por Europa (Francia, Austria, Alemania central, Prussia, Holanda, Suecia, Noruega e Inglaterra) durante los años 1788-1795: cartas científicofamiliares de Manuel de Angulo...," *Boletín de la Sociedad Geográfica de Madrid*, 22-24 (40-42) (1898-99), pp. 154-155. More information about Izquierdo's activities in the correspondence published by I. Pellón; P. Román, *La Bascongada y el Ministerio de Marina. Espionaje, Ciencia y Tecnología en Bergara* (1777-1783) (Bergara: Real Soc. Bascongada, 1999).

112 The full text of both sets of instructions is reproduced in Palacios Remondo, *op. cit.* (67), 128-132.

113 Palacios Remondo, *op.cit.* (67), 131.

114 Elhuyar attended Bergman's lectures in 1782 and took some notes in French, which have been published by A. Fredga; S. Ryden, "Juan José de Elhuyars anteckningar efter Toberbn Bergmans föreläsningar 1782," *Lychnos*, 11 (1959), 161-208. We are grateful to Dr. Anders Lundgren for his help on this question.

115On Elhuyar's trip see A.P. Whitaker, "The Elhuyar mining missions and the Enlightenment," *Hispanic American Historical Review*, 31 (4) (1951), 557-585; Palacios Remondo, *op. cit.* (67), 112-11 and Gago, *op.cit* (32), pp. 25-32. For other "metallurgical travellers," see Harris, *op. cit.* (106), pp. 222-237, notably pp. 233-235 on the Carron ironworks.

AGUSTÍ NIETO-GALAN

UNDER THE BANNER OF CATALAN INDUSTRY

Scientific journeys and transfer of technology in nineteenth-century Barcelona.

1. INTRODUCTION

In 1851, in the official report on dyeing and calico-printing for the Great Exhibition, the French chemist Jean-François Persoz explicitly referred to Catalonia as an "intéressante contrée industrielle." He noted that the Catalans had developed their own methods of spreading technological knowledge and had acquired a reputation as "imitateurs des impressions."[1] This contemporary view is not far removed from the assessments of recent economic historians on the process of nineteenth-century industrialization in this peripheral Mediterranean area. Ramon Garrabou's study of the Catalan industrial engineers of that period underlines the fact that it was the ability to absorb and appropriate foreign technology, more than local technological creativity that was decisive in the region's industrial development.[2] In the same vein, referring to the first half of the nineteenth century at least, Jordi Maluquer sees Catalonia as a milieu innovateur, eager to receive new technology from abroad.[3]

In their recent re-assessments of traditional analytical models of the industrial revolution, economic historians and historians of technology have stressed the importance of particular regional patterns of industrialization.[4] In this context, local strategies, often linked to protectionist policies, were frequently complemented by attitudes of technological awareness, which encouraged efforts (both legal and illegal) to learn and copy foreign technological innovations through integration in international networks.[5]

The overall picture of the Catalan economy of the nineteenth century conforms very well to this general framework in which journeys to foreign countries were a major vehicle for technology transfer. Visits to France were pivotal strategies for a long time, and became almost a routine habit in the

Ana Simões, Ana Carneiro, Maria Paula Diogo (eds.), Travels of Learning. A Geography of Science in Europe. (189-212)

Catalan industrial culture. These visits helped to link the periphery to important nodes in the technological network of industrial growth, and through personal itineraries, they created subtle networks of knowledge transfer.

In the early 1800s,[6] the Barcelona *Junta de Comerç* (Trade Board)[7] was eager to build on the demographic, agricultural and industrial growth of the previous century and devoted great efforts to promoting regional progress.[8] Enjoying a substantial level of financial independence from the Spanish *Junta General de Comercio y Moneda*, it created a network of technical schools in the fields of navigation, business, design, mechanics, physics, chemistry, agriculture, botany, and mathematics in order to educate craftsmen and early industrial workers.[9] This network of schools had explicitly utilitarian objectives and most of the syllabus was based on contemporary scientific and technological developments abroad.[10] Surviving political instability and wars, the *Junta*'s project lasted until the mid-nineteenth century, when it became part of the new Spanish technical schools system.[11] There were many reasons for the project's success, but the permeability of the Catalan border to technological innovations from the north was certainly one. The innovative character of the process can only be understood through its presence in a broader international network, in which travelling played an important role.

Technological permeability – that is to say, the process by which new technology was transferred from northern Europe to the south – took other forms in the second half of the century. When the Schools of the *Junta* disappeared, other public and private institutions continued to encourage *pensionados* to travel abroad, and also appointed skilled foreigners to posts in Spain. Great efforts were made, for instance, to improve the art of dyeing and printing textiles, which was fundamental for the growth of the textile industry, especially for printed cottons, or *indiennes*. Textile innovations required chemical knowledge and close collaboration with the chemical industry. Other efforts were focused on developing machinery for the factory system, which by the mid-nineteenth century had become firmly established.[12]

Through a detailed analysis of a set of travellers and their travels, this paper attempts to sketch a typology: their objectives when they set out from the periphery, the international connections they made in the centre and the strategies of appropriation they used and the application of the new-found knowledge back in the periphery. A selected group of experts in dyes and machinery will provide the case studies for our purpose.

2. ARDIT, ROURA AND VALLHONESTA: DYESTUFFS AND CHEMICAL TRAVELS

The reception of foreign mechanical innovations, especially spinning machines, was rapid and enthusiastic. By the end of the eighteenth century, the Catalan version of the spinning jenny, called the *bergadana*, was already in use.[13] Nevertheless, there was a belief that Catalonia lacked the chemical expertise and artistic taste required to print calicoes with natural dyestuffs. The Barcelona *Junta de Comerç* decided to send a *pensionado* abroad to spy on the latest chemical and technical innovations.[14] A teacher at the School of Design, Carles Ardit (1777-1821),[15] was chosen to travel to Switzerland and France. The plan was:[16]

1. to observe ways of making and improving drawings of flowers and decorations.
2. to inquire how to make and improve engravings.
3. to report on procedures for printing flowers and other ornaments, which had given Swiss fabrics in particular a high reputation.
4. to learn the chemical composition of colours, mordants, dyeing vats, and other substances used in the dyeing and printing processes.
5. to examine all the operations in those industries, including bleaching.
6. to observe new machines for spinning, weaving, and printing, which are still unknown or little used in Catalonia.
7. to prepare three-monthly reports, to be sent to the Junta, concerning all the significant technical details observed.
8. to share his information on return to Barcelona after a two-year period, following the instructions of the Junta.

The *Junta* undertook to finance Ardit's travel and stay abroad. Ardit left Barcelona on 26 November 1814, and visited calico-printing firms in Nimes and Lyons. In Paris, Ardit learnt some basic chemistry from another Spanish *pensionado,* Mateu Orfila,[17] and visited Christophe-Philippe Oberkampf's factory in Jouy.[18] In August 1815, he travelled to Geneva, Neuchatel and several Swiss calico-printing factories. In December that year he went to Mulhouse, one of the key cities in the international network of dyers and printers, and he stayed in the region for a year and a half. In August 1817, he was back in Barcelona.

Fragments of Ardit's correspondence with the Barcelona *Junta de Comerç* have been preserved and make interesting reading.[19] He applied to the Spanish political authorities for the accreditation he would need to gain entry to industrial concerns in Switzerland.[20] In 1816, he wrote from Mulhouse, complaining about the war, the foreign languages, the bad weather, and again bemoaning his lack of personal recommendations that would have enabled him to visit the factories.[21] In 1817, during his long stay in Mulhouse, Ardit repeatedly asked the *Junta* for better diplomatic protection.[22]

Ardit sent some technical reports to the Barcelona Junta,[23] and all the information was compiled in his two-volume book, *Tratado teórico y práctico de la fabricación de pintados o indianas* (1819), which was intended for use by local Catalan calico-printers and dyers.[24] The book contained information on all the substances used in the dyeing processes, and on the techniques of drawing, mordants, and bleaching.[25] The machines that Ardit studied during his trip were also carefully described.[26] Before publication, Ardit had given the *Junta* five notebooks describing machines, formulae, and colouring matters from the factories he visited. He even gave public demonstrations to Catalan firms on the art of dyeing.[27]

Ardit received the help of Francesc Carbonell, the director of the *Junta*'s School of Chemistry, to produce a book that combined data on chemistry, design and mechanics, and also to publish an academic diary of his journey. Other materials that Ardit had compiled were published, between 1815 and 1821, as papers in the journal *Memorias de Agricultura y Artes,* promoted jointly by the Schools of Agriculture and Botany, Mechanics, and Chemistry.[28] In 1818, the new dyeing and printing techniques were also presented to the city in the Public Exercises of Chemistry, which were held under Carbonell's supervision.[29]

Although the nineteenth-century chemical industry was probably too weak to meet the numerous demands of the Catalan textile manufacturers,[30] a large number of firms were nonetheless involved in the making of mineral acids and mordants for dyeing. In 1824 Josep Roura (1797-1860),[31] Carbonell's successor as director of the School of Chemistry, set up an applied chemistry programme which covered gas lighting, the chemistry of wine, distillation, and white powder. In the 1830s and 1840s, the number of students attending his lectures rose spectacularly, and he gained a high reputation in the city. Sponsored by the *Junta*, Roura travelled frequently. In 1825, one year after being appointed director of the School of Chemistry, he went to France;[32] in 1826, he again travelled to France and then to Holland, and later, in 1834, to France again. The schedule for this last trip, as in the case of Carles Ardit's journey, was planned by the *Junta*'s governing body. The main focus was on dyeing and the wine industry, which were key areas in the Catalan economy. The *Junta* saw Roura as a professional industrial chemist, and entrusted him with the following tasks:[33]

1. To visit factories and to record the novelties in chemistry and metallurgy.
2. To study the new wine distillation techniques in Southern France.
3. To inquire about the procedures used in Sette and Marseilles to improve the taste and colour of wine.
4. To study the latest innovations in the art of dyeing and bleaching silk in Lyons.
5. To gather a collection of dyed wools and cottons in all colours and procedures.
6. If possible, to visit a range of firms in England: calico-printers, chemical factories, coal suppliers, steam engine workshops, train manufacturers, etc. [we know that this part of the trip was never accomplished].
7. To learn details of the making of sulphuric acid in Saxony.
8. To study the technical novelties of calico printing and bleaching factories of Tuy and Esonne.
9. To visit other chemical factories in Charanton and Choisy-le-Roy.
10. To study the nature of flax and linen fabrics and their bleaching treatments.
11. To obtain geological information on potential sources of coal and water.

Roura travelled from Barcelona to Paris, via Lyons, later visiting the porcelain manufacture at Sèvres. He stayed for some time in Paris to study the chemistry of wine. He copied an apparatus for the making of sparkling wine (*champagne*),[34] and made contact with various French scientific societies. He also contacted Julia de Fontenelle, who acted as the *Junta*'s representative in Paris and he sent new books on scientific matters to Catalonia.

Roura then travelled from Paris to Bordeaux, to learn more about oils, and visited Montpellier, Sette, and Perpignan. In Béziers he contacted expert wine and oil distillers. In Mèze he visited M. Privat, a wine expert, who had recently built an apparatus that could rapidly transform very young wines into old liqueurs.[35] Roura purchased a fine collection of books on chemistry, dyeing, printing textiles, geology, mineralogy, physics and agriculture. He also bought laboratory instruments, chemical reagents,[36] and other objects to be used later in teaching and research at the School of Chemistry: a hydraulic press, various samples of sparkling wine and drinks, a collection of minerals, and measuring instruments.

The result of the journey was the *Memoria sobre los vinos y su destilación y sobre los aceites* which Roura published in 1839.[37] The book was based on utilitarian criteria, but introduced new chemical analyses for wines, brandies and oils. It covered distillation techniques, fermentation, wine quality tests, and the chemical nature of oils. This updated the compilation of the technological system for wine production and continued a tradition from the late eighteenth century, when the Catalan wine industry experienced substantial growth influenced by the works of the French industrial chemist Jean-Antoine Chaptal and the Montpellier model.[38]

In the second half of the nineteenth century, foreign references remained crucial for the chemical industry. After Perkin's synthesis of mauve in 1856, the art of dyeing had entered the world of artificial colorants and was again arousing the interest of academic chemists and entrepreneurs. Ramón de Manjarrés (1827-1918) reported dyeing and printing novelties at the 1862 International Exhibition in London, such as aniline dyes and new commercial derivatives.[39] He held a chair in chemistry at the Escuela Industrial of Seville and in 1868 was appointed director of the Escola Industrial in Barcelona, becoming one of the leading figures in Catalonia's emerging chemical industry.

In 1861, another industrial engineer from the Barcelona School, Josep Vallhonesta (1835-1899) arrived in Paris as a chemistry *pensionado,* sponsored by the *Diputació Provincial de Barcelona*,[40] an enlightened, liberal nineteenth-century institution whose aim was to provide support for city councils. Vallhonesta was awarded the grant after writing a short paper on chemistry and making an industrial product in a public exam in the laboratory. The applicant had to hold a degree in industrial engineering, and would have to:[41]

1. spend two years abroad to study the progress of chemistry in its applications to industry.
2. study the latest innovations in dyeing and printing.
3. spend one year in Paris to attend lectures on industrial chemistry.
4. spend one year in several firms in Mulhouse to learn practical dyeing and printing.
5. obtain official letters of attendance from the heads of the teaching

institutions and private firms.

6. on his return to Catalonia, he was to remain for at least three more years

In Paris, Vallhonesta asked the Spanish Ambassador for a letter of recommendation to the French chemist Jean-François Persoz,[42] a highly influential figure in the world of dyeing and printing across Europe, and the professor of *Teinture et impréssion* at the *Conservatoire Nationale des Arts et Métiers*. He was also the author of the *Traité théorique et pratique de l'impression des tissus* (1846),[43] which contains a remarkable collection of more than 400 samples sent by calico-printers from all over Europe.[44]

At the end of 1861, Vallhonesta was formally admitted to the *Manufacture royale des Gobelins* by its director, Michel-Eugène Chevreul, a prominent figure in the Parisian scientific arena, who had taught Vallhonesta in his course at the Musée d'Histoire Naturelle. Chevreul agreed to send his Catalan visitor to Mulhouse.[45] Under Chevreul's supervision, the *atelier de teinture*, the laboratory, the amphitheatre, and the *Ecole de Teinture* strengthened the position of the *Gobelins* as a reference centre of dyeing and printing.[46]

Contrary to his original plans, Vallhonesta stayed almost three years at the *Gobelins*, from November 1861 to July 1864. He later worked in Paris with O. Briffaud, a silk dyer, and with Jean Béchard, a wool dyer. He was keen to make personal contact with dyeing and calico-printing firm owners, as well as with expert dyers and workers in a French network in which Paris and Mulhouse were the two main centres.[47] His fellowship was extended by the Barcelona *Diputació* on the condition that, on his return, he would teach some regular courses on the art of dyeing. Vallhonesta later became professor of industrial inorganic chemistry at the Escola Industrial in Barcelona. He was also asked to write his own books on the subject,[48] and to bring with him all the available collections of colours.[49]

Michel-Eugène Chevreul had attempted to establish a new nomenclature of colours in order to avoid the confusions of names related to geographical or personal origins, and to overcome the subjectivity of visual perception. In 1839, he published *De la Loi du contraste simultané des couleurs*, which contained a chromatic circle and a system of quantification of colours and their contrasts.[50] At the *Gobelins*, Vallhonesta's reference for colours and dyeing, Chevreul made a circle of 72 colours, with 14,420 shades.[51] This numerical systematization and the study of the visual effects of the juxtaposition of colours later had a profound influence on artists and painters.[52]

On returning to Catalonia at the end of his journey, Vallhonesta produced a collection of texts and material objects laying particular emphasis on their future utility. The collection included a report on the art of dyeing wool yarns with 210 of Chevreul's chromatic types; a set of colouring matters which he had prepared in Chevreul's laboratory; and a report on colour contrast, which was later distributed among local institutions, dyers, printers and libraries.[53] Vallhonesta introduced Chevreul's chromatic circles and his classification and theory of colour contrast in Barcelona.[54] Parts of his reports provided the raw material for his later book, *El arte del tintorero*,[55] which, according to the journal *Revista Tecnológico-Industrial*, became widely known in the Catalan industrial context: [56]

> Mr. Vallhonesta, who spent three years with the reputed M.E. Chevreul at the *Manufacture royale* des *Gobelins* in Paris....has shown his great skills in a subject that... today is one of the most difficult parts of the chemical science... Works of this kind can only be executed by those, who, like Vallhonesta, have a thorough knowledge of scientific principles, but have also applied them in industrial workshops.

Vallhonesta was also a prominent figure at the *Reial Acadèmia de Ciències i Arts* in Barcelona (RACAB).[57] His memoirs provide many examples of the appropriation strategies of the new dyeing techniques in a period in which, after William Perkin's discovery of mauve in 1856, new artificial dyestuffs competed with the traditional natural ones.[58] At the RACAB, Vallhonesta discussed the introduction of the new aniline colours in a language that was accessible to the Catalan dyers;[59] he also compared old and new colours (natural and artificial dyestuffs);[60] and he popularized Chevreul's law of contrast of colours as a new "scientific" tool for the classification and systematic use of dyes.[61] He even donated his own chromatic circle to the Barcelona Academy.

3. "MECHANICAL TRAVELS": THE CIRCULATION OF MACHINERY AND ITS ACTORS

The Catalan textile industry, in constant growth throughout the century, was quick to react to technological innovations in mechanization, particularly to those from Britain.[62] It was a two-way process. In 1789, John Wadle and Joseph Caldwell, two English skilled artisans, addressed the Catalan *Junta* in the following terms:[63]

> We propose, at first, to instruct people of this country to erect machines for carding, refining and spinning cotton, also to instruct them in the art of conducting the said machines to the utmost of our power to bring the said fabric to perfection, and we expect to receive for our support 30 Reales de Vellón each [...] for the term of 10 years, also for our gratification a fifth part share and interest of the machines that may be erected [...]

The region they chose for their new business activities was a dynamic one. By 1804, there were more than a hundred calico printing factories, 4,000 looms, and 100,000 workers in the Barcelona area.[64] In the same year, after a journey abroad, a calico printer named Jacint Ramon considered the possibility of utilizing steam for his textile machinery and asked the physician Francesc Santponç, director of the Section of Statics at the Barcelona Academy (RACAB) for scientific advice. After making a prototype of the Newcomen engine, and drawing on G.M.R. de Prony's *Nouvelle Architecture Hydraulique* as well as the technical information provided by Agustín de Betancourt's earlier espionage in England and in France,[65] Santponç designed an original double effect Watt's machine.[66] But Napoleon's invasion of Spain (1808-1814) interrupted the operations with the new machine, and the steam engine was not introduced in Catalonia until the 1830s.[67] In spite of this "failure," this example shows that the circulation of machinery from Britain and France to Catalonia through industrial journeys and espionage was a very rapid process.

In 1822, the Barcelona *Junta de Comerç* sent Domènec Cavaillé to France on a three-month journey to acquire (either legally or illegally) all the necessary information for the making of a new weaving device, the *jacquard*. Invented in early nineteenth-century France, this revolutionary machine allowed systematic reproduction of woven colour designs as an alternative to printed calicoes. Cavaillé was entrusted with the task of studying all the minor mechanical details: small parts of machines, transportation costs and working requirements. Because of the political upheavals of the time, his journey lasted for seven years, instead of the original three months. Although he was unable to fulfil his mission of establishing channels for the importation of jacquard machines to Catalonia in 1829, on his return to Barcelona, he provided the *Junta de Comerç* with details of new mechanical inventions, and offered to teach a course on applied mechanics. Cavaillé also played a mediating role between François Cros, from Montpellier, a leading figure in the introduction of the heavy chemical industry in Catalonia, and the *Junta*.[68]

In the same context, from 1815 onwards, the importation of foreign wool machinery to Catalan textile factories reached impressive levels. The process tended to start with the circulation of a particular machine from the centre to the periphery, followed by the circulation of experts with the technical knowledge required to operate it.[69] In the 1840s, wool entrepreneurs from Sabadell – a major industrial city near Barcelona – travelled to France and Belgium. In 1841, Pere Turull and Josep Sagret went to Rouen, Louviers, Paris and Lille, in France, and to Liege and Verviers, in Belgium. Between 1842 and 1845, as a result of their journey, new wool machinery was imported from Verviers, from the Cockerill factory near Liege, and Rouen. These journeys were funded by private companies and also targeted International Exhibitions, which offered ideal opportunities for seeing the latest innovations in the huge machinery halls that attracted millions of visitors.[70]

The sons of influential Catalan wool entrepreneurs used to stay long periods abroad as part of their technological and industrial education. Under the protection of family recommendations, which were able to establish personal relations in the international network of wool entrepreneurs, they stayed for two or three months at a time with different firms. Pere Turull, for example, often found temporary posts for young entrepreneurs in companies abroad. In the case of the wool industry, the high permeability also reached foreign skilled experts who were appointed to the Catalan firms, at least until the 1850s.[71]

Financed by his family, Joan Girona travelled to Switzerland and France between 1814 and 1829. Later, between 1830 and 1833 under the patronage of the Barcelona *Junta de Comerç*, he visited England. Girona began by learning clock mechanics and foreign languages at the Giourd firm in Neuchâtel and later spent nine months in Geneva. In Paris, under the protection of the marquis of Pontejos, he was allowed to enter the *Conservatoire Nationale des Arts et Métiers*. On his return to Catalonia he introduced new hydraulic presses and pumps as a private business.[72]

He set off for England in May 1830, having finally obtained the economic support of the *Junta*, but first spent some months in Lyons, Paris and Mulhouse to study a variety of spinning, weaving and printing mechanical processes. After three months in London spent learning English, he went to Birmingham, one of the leading industrial cities of the time, where he spent a year at two metallurgy workshops. This enabled him to send plans and drawings of blast furnaces and other mechanical devices to the *Junta*. Girona then travelled to Manchester to study the most recent spinning machines and finally visited Sheffield and Leeds. By July 1883 he was back in Barcelona with plans of machines, books, and scientific instruments.

Nevertheless, in terms of appropriation strategies in the peripheral context, Girona's story was not a complete success. He was a strong candidate for the chair of Mechanics and Hydrostatics at the School of the Barcelona *Junta*, but, for several reasons, he did not obtain the post. He eventually played only a modest role in the development of new mechanical devices. It appears that he did not give the Junta the plans and drawings acquired during his foreign experiences, perhaps out of disappointment at failing to gain the Chair. In spite (or because) of his impressive international education, he was unable to settle at home.[73]

In 1866, the Barcelona *Diputació Provincial* offered two grants, one for chemistry and one for mechanics, to study abroad. After passing a public exam with two tests – a theoretical paper on mechanics, and a practical problem – Josep Foulon was awarded the mechanics fellowship. In December 1865, the terms for the working plan had already been made public:[74]

1. A young mechanical engineer [in the event, Josep Foulon] obtained a three years stipend (*pensión*) of 12,000 *reales* per year to travel abroad.
2. He was to study new machinery, its theory and its practice.
3. He was to spend two years at the Cockerill firm in Seraing (Belgium), and one year in Manchester or any other place in England.
4. He was to write a report every four months, and, under the supervision of the local authorities, obtain official certificates of his visits to workshops and schools. A full, detailed report had to be written at the end of every year.
5. On his return to Catalonia, he had to stay for five years in order to make his results and new discoveries known.
6. If conditions 4 and 5 were not accomplished, he would lose his *pensión*.
7. The degree of Industrial Engineer was required.

Some of Foulon's letters to the *Diputació* offer interesting hints of his personal adventures and long-distance interaction with the local periphery. He arrived in Paris in August 1866 and stayed there waiting for the end of cholera epidemics in Liege and Seraing. Meanwhile, he visited the *Ecole Centrale des Arts et Manufactures*, the *Conservatoire Nationale des Arts et*

Métiers, the *Ecole Polytechnique*, together with some private workshops, and railway stations, where he studied steam engines.[75]

In November 1866, with a letter of recommendation from the Spanish Ambassador in Brussels, Foulon was welcomed as an official "visitor" by M. Savoine, the director of the prestigious Cockerill firm in Seraing. There he was able to copy details regarding raw materials, blast furnaces, puddling processes and steam engines.[76] Trying to go a step further, Foulon asked to be taken on as an "unpaid worker" in the boilers' section in order to gain experience of everyday life in the workshop. At the same time he aimed to study all the steam engine novelties in the region, and was granted permission to record information on Belgian railways, machines and workshops.[77] Using the works of Carnot, Clausius, Regnault, and Hirn as his theoretical basis, he also took part in the making of the "674 model" locomotive. He paid particular attention to the circulation of steam and described his findings in some of the reports he sent to the *Diputació*.[78] In the locomotive section, he learnt modelling and design practices of the new machines, and the small-scale tests and studies involved.[79]

Foulon's powerful diplomatic protection served him well in Seraing, when a group of Austrian engineers, also on official commission, were sacked in January 1868 for stealing designs and machines.[80] A letter dated April 1868 states that Foulon's personal contact was Joseph Clerfeyt, a high-ranking civil servant in the Belgian Government, who had also introduced other Spaniards into the country's industrial network.[81] In 1869, Foulon crossed the Channel with the intention of staying for three months as a visitor at John Penn and Son, an English firm that made steam engines for boats. But technical details were not easily available. The chief engineer forbade him to enter the design section, and so Foulon sought the protection of Mr. Gridley, a well-known independent engineer, and worked with him on making small steam engines (10 H.P.) for boats.[82]

At the end of his three year *pensionado*, Foulon was still eager to add to his experience of foreign practices. He formally asked the *Diputació* for permission to spend a year in Prussia to expand his knowledge of steam engine locomotives and to learn German, but the political changes in Spain after the Liberal Revolution of 1868 put an end to his hopes. There is some evidence that, unable to fulfil his German adventure, Foulon travelled to the United States, returning to Barcelona in 1871 hoping to popularize the practical knowledge he had acquired in the "leading countries of industrial progress."[83]

In the same period, other Catalan travellers were also involved in the search for the latest innovations in electric machinery. The dream of obtaining a new electric light spurred on the search for new sources of electricity, but neither the results of the Bunsen batteries for night lighting, nor other magneto-electric machines were deemed satisfactory. Equally, the designs of Siemens' and other firms were still too expensive to allow mass production of electric current.[84]

One of the most successful machines at the International Exhibition held in Vienna in 1873 was Graemme's dynamo, a highly innovative electricity generator.[85] It had illuminated the Houses of Parliament in London, and the Barcelona *Escola Industrial* declared its interest in importing and adapting the device for teaching purposes. The project was led by Tomás J. Dalmau and his private firm – later called *Sociedad Española de Electricidad* (SEE) – which had a high reputation in the city.[86]

On 16 April 1875, Tomás J. Dalmau set off for Paris to visit the workshops where Graemme's machine was made and to study its potential uses. He also planned to discuss the pros and cons of the new apparatus with several Parisian professors of physics. Aiming to cover both academic and industrial fronts, Dalmau contacted Alfred N. Breguet, the engineer director of the Breguet firm, as well as M.E. Sarreau, professor at the *Ecole Polytechnique* and an expert on powder techniques. Through the Parisian relative of a Catalan engineer, Sarreau agreed to introduce Dalmau to several professors at the Sorbonne and at the *Ecole Polytechnique*. They became crucial sources for the "scientific" explanation of the dynamo that Dalmau wanted to hear. He even met Mr. Graemme in person and asked him numerous technical questions.

Dalmau crossed the Channel to Britain, where the instrument maker L.P. Casella introduced him to British experts on electric machines, and their favourable opinion on Graemme's dynamo was unanimous. Back in Paris, Dalmau spoke to J. van Maledern, a renowned inventor of *magneto-electric* machines, who considered the new dynamo to be cheaper and smaller than others, but ran the risk of overheating. Nevertheless, after weighing up the opinions of all the experts Dalmau decided to buy a Graemme's dynamo (number 56) for the Barcelona *Escola Industrial,* for use in a range of electromagnetic experiments. Back in the periphery the engine was used by the Spanish Navy to illuminate the frigate Victoria in a very successful public display attended by the military and political authorities.[87]

4. CONCLUSION

All the journeys described here seem to provide a preliminary picture of technological permeability in nineteenth-century Catalonia. Public and private sectors differed in terms of organization and material support, but coincided fully in terms of their objectives and strategies. As the correspondence preserved in the archives shows, every single traveller experienced a unique adventure, full of anecdotes and personal contacts, but their journeys present many common features that exemplify the plans of an area on the periphery eager to establish contacts with the centre. Perhaps we can draw up an exploratory typology of the journeys that connected Catalonia and Barcelona in particular, with the main centres of industrial innovation in France, Belgium, England and Switzerland. The following features stand out:

a. *Institutional plans and detailed targets*. Many of those trips were carefully planned in advance. This is the case of the journeys funded by the Barcelona *Junta de Comerç* (Ardit, Roura, Girona), by the *Diputació* (Vallhonesta Foulon), and by the *Escola Industrial* (Dalmau). Their schemes involved a method for the selection of the candidate, a fixed period of travelling with a very well defined itinerary, regular ways of maintaining contact, and specific duties of the *pensionado* during and after the journey. There was not much room for improvisation.

b. *Centre-periphery correspondence*. The *pensionados* were usually asked to send reports home every three or four months, a requirement that helped not only to maintain the flow of new information, but also in a way to strengthen the traveller's commitment to the local institution at home. Through Ardit's letters and reports to the *Junta*, we discover, for example, his personal interest in copying printing machines and new methods of colouring calicoes. Equally, many reports describe the difficulties of transferring all the details of new machines and processes needed for their successful application in the periphery. Ardit's reports from Mulhouse were draft versions of his future *Tratado*. Vallhonesta's reports to the *Diputació* were also the basis of his later printed texts on the art of dyeing and on Chevreul's law of contrast of colours.

c. *Personal contacts in the centre*. Gaining access to relevant sites of technical innovation was not an easy task.[88] Mechanisms of technology transfer were based on trust and on personal negotiations in which the limits of secrecy were defined. The key to "opening up" the factories lay in cultivating one's social contacts and in breaking down political constraints.

In the case of Ardit, Vallhonesta, Foulon, and probably many others, it is interesting to see how the Spanish Ambassador or a high civil servant in the foreign country was vital to the introduction of the *pensionado* to local entrepreneurs. The acquisition of the status of "official visitor" allowed our travellers to enter, see, copy, ask questions, and gain acceptance inside the factory.

The academic prestige of figures from the periphery who had become established in the centre also helped the introduction of the new *pensionado* in the new milieu. This was for example the case of the chemist Mateu Orfila who helped to introduce Ardit to Oberkampf's calico-printing factory in Jouy. In Dalmau's case, personal contacts with engineers were very useful and enabled him to compare impressions of Graemme's dynamo. Often, it was the personal relationship of the *pensionado* with the chief engineer of a particular factory that allowed or denied him access to new designs, machines and procedures.

d. *Espionage and the fringes of illegality.* A careful examination of Ardit's correspondence with the *Junta* shows what a demanding mission it must have been to copy foreign machines and send designs to the home institution. Lack of authorization, and the risk of breaking foreign laws, were serious difficulties. Inside the factories, negotiations about the limits of copying and later transferring to the periphery were extremely complex. Foulon, for example, saw how visiting Austrian engineers were sacked at Cockerill for breaking a secrecy agreement, whereas in England, he himself had to negotiate hard with local engineers to gain acceptance as a visitor.[89] In fact, all those practices operated inside a multi-centred network with several nodes. Personal and institutional contacts were sometimes hierarchical,[90] but were very often established between peers eager to avoid conflict and to create a supportive context for their work.[91]

e. *Strategies of appropriation in the periphery.* An understanding of the role of travels in peripheral contexts in which science and technology have not been traditionally conceived as particularly innovative requires a study of the activities of our travellers on their return home. Strategies for building an international network of experts needed the existence of a context in which local practices could be validated by local experts. The latter were often travellers, and not all of them were able to readapt to life in public educational institutions or in private firms at home.

Thanks to these craftsman-oriented journeys a wide circulation of designs, books, scientific instruments, and machines was achieved.[92] In the case of Ardit, we know that some of the printing machines he had copied were reproduced and tested in Barcelona, but local calico printers hesitated for years before deciding to make investments in new mechanical printing. Roura was very keen to buy new instruments for his laboratory every time he went to Paris. The *Junta* also had its own contacts abroad which supplied it with new scientific books in the international markets. Dalmau himself bought a Graemme dynamo in Paris, later used at the *Escola Industrial* in Barcelona, and numerous private wool entrepreneurs personally bought textile machinery abroad. With the travellers' mediation, objects were copied, sketched, reproduced, and then evaluated in the local context.

The travellers were in fact the actors in complex processes of appropriation in which foreign knowledge was adapted to particular local needs through a range of strategies. Perhaps the most important of them were:

Books: Printed texts and documents were produced after Ardit's and Roura's journeys, and so their missions can be considered successes. The mere existence of Ardit's *Tratado* and Roura's *Memoria*, and even the numerous papers on the art of dyeing which were published at the *Memorias de Agricultura y Artes*, are examples of the appropriation of foreign knowledge from the international network into the Catalan local context. Vallhonesta was also very keen to produce a printed version of many of his reports from abroad, in particular, what he learnt directly from Chevreul on the classification of colours.

Usually, institutionally funded journeys required the *pensionado*'s commitment to write useful texts for local audiences once back in the periphery. They were asked to publish a synthesis of their experience abroad often for teaching purposes. Moreover, as in Vallhonesta's case, copies of books were widely distributed among political authorities, private firms, libraries, which acted as a reception network.

Courses, public lectures and public exams. Lecturing regular courses of chemistry applied to industry, or even performing public experiments in front of large local audiences were other channels for spreading foreign knowledge. Ardit's valuable information on dyeing and printing was disseminated through the public exercises of the School of Chemistry of the *Junta*, under the supervision of Francesc . In August 1818, some of his students passed public chemistry exams, which included a theoretical paper, some experiments, and a short discussion.[93] A summary of these public exams was published, and copies handed out to the audience. Vallhonesta's chemistry lectures at the *Escola Industrial*, were the vehicle through which much of his expertise on artificial dyestuffs reached a wider audience in the peripheral context. For his part, Foulon asked the *Diputació* for an extension of his fellowship, and undertook to offer a course in mechanics for workers in Barcelona.

Machines. After copying designs and testing small scale models abroad, what really mattered was the actual construction and application of a particular machine in the periphery. Santponç's appropriation of a Watt's double effect machine embodied some original changes with respect to the original British design. Moreover, the technological system of the early nineteenth-century Catalan industry did not follow British patterns exactly: the steam engine was mainly used as a source of hydraulic power for textile machinery. Private travellers made substantial contributions to the circulation of textile machinery from the centre to the periphery, but, as in the case of the steam engine, each firm decided how to use the new devices, according to the specific constraints of the local technological system. After Dalmau's journey, Graemme's dynamo was used in Barcelona for teaching purposes, to be later applied to industrial purposes.

Throughout the nineteenth century, travelling was, then, a vehicle for learning and transmitting skills from the centres of industrial innovation to the Catalan periphery. These journeys were vital elements of private and public policies that sought to encourage foreign innovations and promoted a technological permeability, which was repeatedly noted by contemporary witnesses and by later economic historians and historians of technology.

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NOTES

Abbreviations:

AGDB: Arxiu General de la Diputació de Barcelona
AGS: Archivo General de Simancas
AJC: Arxiu de la Junta de Comerç
BC: Biblioteca de Catalunya
CSH: Consejo Supremo de Hacienda (AGS)
JCM: Junta de Comercio y Moneda (AGS)
RACAB: Reial Acadèmia de Ciències i Arts de Barcelona

[1] J. F. Persoz, "Impressions et Teintures. Examen des produits en impressions et teintures qui figuraient à l'exposition universelle de 1851," in *Travaux de la Commission française sur*

l'industrie des nations (Paris: Imprimérie Royale 1854), Vol. V, pp. 1-74 (p. 58). Cited in R. Fox, A. Nieto-Galan, eds., *Natural dyestuffs and industrial culture in Europe, 1750–1880* (Canton MA: Science History Publications, 1999), pp. 101-102.

[2] R. Garrabou, *Enginyers industrials, modernització económica i burgesia a Catalunya (1850-inicis del segle XX)* (Barcelona: L'Avenç, 1982). See also: G. Lusa Monforte, A. Roca Rosell, "Doscientos años de técnica en Barcelona. La técnica científica académica," *Quaderns d'Història de l'Enginyeria*, 3 (1999), 101-130.

[3] J. Maluquer, "El desenvolupament regional i la teoria dels *milieux innovateurs*: innovació tecnològica i espionatge industrial a Catalunya als inicis del segle XIX," in A. Carreras, et. al., eds., *Doctor Jordi Nadal. La Industrialització i el Desenvolupament econòmic d'Espanya*. Collecció homenatges, 17. (Barcelona: Publicacions de la Universitat de Barcelona, 1999), 2 vols. II, 1080-1100.

[4] See, for example: S. Pollard, *Peaceful Conquest: The industrialization of Europe 1760-1970* (Oxford: Oxford University Press, 1981); N.J.G Pounds, *A historical geography of Europe 1800-1914* (Cambridge: Cambridge University Press, 1985).

[5] B. Latour, *Science in Action. How to follow scientists and engineers through society* (Milton Keynes: Open University, 1987).

[6] P. Vilar, *Catalunya dins l'Espanya moderna* (Barcelona: Edicions 62, 1987), 4 vols. (1st French edition, 1962); J. K. J. Thomson, *Els orígens de la industrialització a Catalunya. El cotó a Barcelona 1728-1832* (Barcelona: Edicions 62, 1994). Original English version, Cambridge University Press, 1992.

[7] For a recent overview of eighteenth-century scientific institutions in Catalonia, see: A. Nieto-Galan, A. Roca Rosell, "Scientific education and the crisis of the University in eighteenth-century Catalonia," to appear in M. Feingold, ed., *Universities and Science in modern Europe*. Special issue, *Archimedes*.

[8] A. Ruiz Pablo, *Historia de la Real Junta particular de Comercio de Barcelona 1760-1847* (Barcelona: Cámara de Comercio, 1919); J. Iglésies, *L'obra cultural de la Junta de Comerç (1760-1847)* (Barcelona: Dalmau, 1969).

[9] A.B. Gassó, *España con industria fuerte y rica* (Barcelona: A. Brusi, 1816).

[10] These were, for example, the cases of the chairs of Chemistry and Mechanics. For the School of Chemistry, see A. Nieto Galan, *Ciència a Catalunya a l'inici del segle XIX. Teoria i aplicacions tècniques a l'Escola de Química de Barcelona sota la direcció de Francesc Carbonell i Bravo (1805-1822)* (Barcelona: unpublished thesis, 1994).

[11] Lusa Monforte, Roca Rosell, *op. cit.* (2).

[12] J. Nadal, *El fracaso de la revolución industrial en España. 1814-1913* (Barcelona: Ariel, 1975). According to Carles Sudrià, *El fracaso* had been reprinted 12 times by 1992, and sold more than 50,000 copies: J. Nadal, *Moler, tejer y fundir. Estudios de historia industrial* (Barcelona: Ariel Historia, 1992).

[13] C. La Force, *The Development of the Spanish Textile Industry 1750-1800* (Berkeley: California University Press, 1965). In 1780 the "bergadanes" were introduced, copying the English "jenny" (James Hargreaves in 1767); in 1791, the "water-frame" (invented by Richard Arkwright in 1769, and used in England in 1785) was first used in Catalonia; in 1805, the "mule" (invented by Samuel Crompton in 1779) was used in Catalonia. For a recent analysis see: A. Sanchez, "Les bergadanes i les primeres màquines de filar," in J. Maluquer, ed., *Tècnics i Tecnologia en el desenvolupament de la Catalunya Contemporánea* (Barcelona: Enciclopèdia Catalana, 2000), pp. 296-299.

[14] On 12 July 1797 two reputed local calico printers and members of the Government body of the Catalan *Junta* wrote: "We have studied the situation of the industries of the country

and we have compared our calicos with foreign samples. We are clearly a long way behind, not only in terms of drawings and designs, but also in terms of the shades of the colours...it is extremely important that the *Junta* develop a policy to help the progress of one of our most important industries...Our current knowledge is due to the considerable effort of some private printers, who spend substantial sums of money to appoint skilled foreigners to teach the local artisans...it is extremely difficult to find a calico printer who could afford the expenses of sending a colourist abroad to improve his knowledge of the art of dyeing." A report by Joan Canaleta and Josep Gironella on the need to send some people abroad to learn the "art of colours," AJC. File 53, f. 29, 34. BC. Barcelona. Cited in Fox, Nieto-Galan, *op. cit.* (1), p. 112.

[15] AGS. CSH. JCM. File 263. Simancas. See also Fox, Nieto-Galan, *op. cit.* (1).

[16] "1. Debe examinar el modo de perfeccionar y facilitar el dibujo de flores y adornos para la fabricación.; 2. Debe indagar igualmente el modo y perfección del grabado; 3. Debe informarse también exactamente del modo con que se estampan las flores y demás adornos que tanto realce dan a aquellos pintados; 4. Igualmente debe aprender la composición de los colores, mordientes, baños y demás concerniente a la fabricación; 5. Examinara también todas las operaciones de aquellas fábricas tanto en el blanqueo, como en lo demás, desde la primera hasta la última; 6. Asimismo observara si para la fabricación así de hilados, como de tejidos y estampados se valen de algunas maquinas que aquí no estén en uso, o si las que ya son conocidas, están montadas con mas perfección y ventaja; 7. De todo lo que vaya adquiriendo, cada tres meses dará parte a la Junta para su gobierno; 8. Acabados los dos años debe regresar a esta ciudad, y enseñar todo cuanto haya adquirido en el modo y forma que la Real Junta determine; 9. La Real Junta señala a D. Carlos Ardit dos duros cada día empezando a correr desde el de la salida de esa ciudad para dos años solamente y a mas sesenta duros para el viaje," AJC. File 149, f. 34. BC. Barcelona.

[17] R. Huertas, *Orfila, saber y poder médico* (CSIC: Madrid, 1988); M. Orfila, *Éléments de Chimie Médicale* (Paris: Crochard, 1817), 2 vols.; J.R., Bertomeu Sánchez, A. García Belmar, "Mateu Orfila (1787-1853) y las clasificaciones químicas. Un estudio sobre los libros de texto de química durante la primera mitad del siglo XIX en Francia," *Cronos,* 2 (1999), 3-46.

[18] AJC. File 21bis, f. 363. BC. Barcelona; S.D. Chapman, S. Chassagne, *European Textile Printers in the Eighteenth Century. A Study of Peel and Oberkampf* (London: Heinemann, 1981); J. Brédif, *Classic Printed Textiles from France 1760-1843. Toiles de Jouy* (London: Thames and Hudson, 1989). French edition: Adam Biro, Paris.

[19] AJC. File 21bis, f. 194.

[20] AJC. File 21bis, f. 138. BC. Barcelona.

[21] "...el uso que tienen en estas fábricas de no admitir ningun obrero que a lo menos no sea por un año, y con mayor motivo conmigo que les soy sumamente suspecto." AJC. File 22, f. 582. BC. Barcelona.

[22] AJC. File 22, f. 1115. BC. Barcelona.

[23] AJC. File 22, f. 368-372. BC. Barcelona. J.F. Persoz, *Traité théorique et pratique de l'impression des tissus* (Paris: Victor Masson, 1846), 4 vols., I, p. xviii.

[24] "Our calico-printers have tried to imitate [foreign samples]; our dyers have sought the help of chemistry to improve their colours, but they have not been able to achieve the perfection of the others. It was necessary to examine the procedures of foreign workshops in situ, to copy their machines, to see their materials, to learn their formulae...," C. Ardit,

Tratado teórico práctico de la fabricación de pintados o indianas (Barcelona: Vda. de Agustín Roca, 1819), 2 vols., I, p. iii. (The translation into English is mine).

[25] Ardit, *op. cit.* (24), II, pp. 94-128.

[26] Ardit, *op. cit.* (24), I, p. 62.

[27] Maluquer, *op. cit.* (3), p. 1096.

[28] *Memorias de Agricultura y Artes que se publican de orden de la Real Junta de Gobierno del Comercio de Cataluña* (Barcelona, Brusi, 1815-1821); Maluquer, *op. cit.* (3), p. 1096.

[29] F. Carbonell, *Ejercicios públicos de Química que sostendran en la casa Lonja los alumnos de la Escuela gratuita de esta Ciencia establecida en la ciudad de Barcelona por la Real Junta de Comercio del Principado de Cataluña* (Barcelona: Antoni Brusi, 1818), pp. 40-41.

[30] J. Nadal, "La debilidad de la industria química española en el siglo XIX. Un problema de demanda," *Moneda y Crédito*, 176 (1986), 33-70.

[31] For the case of Josep Roura Estrada, the director of the Barcelona School of Chemistry after F. Carbonell, see: A. Nieto-Galan, "Searching an identity for chemistry in Spain: Medicine, Industry, University, the Liberal State and the new 'Professionals'" in D. Knight, H. Kragh, eds., *The making of the chemists in nineteenth-century Europe* (Cambridge: Cambridge University Press, 1998), pp. 177-190; J. Roura, *Memoria sobre los vinos y su destilación* (1839). Facsimile edition. (Barcelona: UPC, 1997). Introduction by G. Lusa and A. Roca Rosell.

[32] "adquisición de noticias y descubrimientos en el ramo de ciencias naturales y otras industrias." AJC. File 67. BC. Barcelona.

[33] "1. Los nuevos descubrimientos y adelantos que se hayan hecho en las artes químicas y mineralúrgicas. Para conseguirlos procurará introducirse en los principales establecimientos o fábricas de productos químicos y metalúrgicos; 2. La destilación de los vinos, siendo para esta Provincia uno de los más importantes ramos, procurará a su paso para le medio día de la Francia averiguar los adelantos que sobre el particular se hayan hecho, esto es, tanto en la perfección y modificación de los aparatos como en el modo de hacerlos operar para que produzcan buenos resultados; 3. Los procederes que siguen en Cette y Marsella para mejorar el color y sabor de los vinos llamarán también de un modo particular su atención; 4. A su paso para Lyon indagará los nuevos descubrimientos que se hayan hecho con los procederes de tintura y blanqueo con seda; lo propio hará con respecto a los materiales indígenas y exóticos que se hayan adoptado en este punto de química aplicada a las artes; 5. Si le es posible se procurará una colección completa de algodones y lanas adornadas con todos los colores que se fijan a dichas sustancias con los correspondientes procederes; 6. Si el tiempo se lo permite pasará a Inglaterra a fin de visitar algunos de sus principales establecimientos industriales, entre los que se hallan las fábricas de indianas, de ácido piroleñoso, de productos químicos, las explotaciones de carbón de piedra, los talleres de máquinas de vapor, los caminos de hierro, etc.,; 7. Uno de los principales puntos que tiene en vista en su viaje, es la fabricación de ácido sulfúrico glacial o de Sajonia, por considerar este renglón de grande interés para nuestro país por lo mucho que de dicho ácido consume. Parece que no se fabrica otro ácido en Francia ni en Inglaterra lo que tratará de averiguar; 8. Se impondrá de los adelantos que se haya hecho en las fábricas de blanqueo y de indianas de Tuy y de Esonne; 9. Visitará las fundiciones de Charanton y las de carbón vegetal, ácido piroleñoso y prioleñazo de plomo, cobre e hierro de Choisy-le-Roi; 10. Otro punto interesante llamará también su atención, siendo éste el de indagar el estado de los hilados y tejidos de cáñamo y lino para máquinas de blanqueo de otras substancias; 11. Se procurará todas las noticias y casos raros que se

hayan presentado en la perforación de terrenos en busca de carbón piedra y aguas ascendentes. "Objeto del viaje que en este año de 1834 D. José Roura se propone hacer al extranjero." AJC. File 104, f. 105, 126, 138;. BC. Barcelona. The text of the plan has been published in: Roura, *op. cit.* (31), Introduction by G. Lusa and A. Roca Rosell, pp. xiii-xvi.

[34] "Aparato que sirve para saturar el vino de ácido carbónico," in J. Roura, *Memoria sobre los vinos y su destilación y sobre los aceites* (Barcelona: Imprenta Oliveras y Gavarró, 1839). (further editions: 1857, 1883, 1887).

[35] D. Martinez, *Josep Roura: precursor de la química industrial catalana* (Barcelona: Associació-Col.legi d'Enginyers Industrials, 1993), pp. 43-50.

[36] AJC. File 104, f. 138. BC. Barcelona

[37] Roura, *op. cit.* (34).

[38] A. Nieto-Galan, "Un projet régional de chimie appliquée à la fin du XVIIIème siècle. Montpellier et son influence à l'Ecole de Barcelone: Jean-Antoine Chaptal et Francesc Carbonell," *Archives Internationales d'Historie des Sciences* 44 (1994), 23-64.

[39] R. Manjarrés, *Memoria sobre tintes y estampados y sobre los adelantos que en estos ramos se presentaron en la Exposición Universal de 1862* (Madrid: Imprenta Nacional, 1864), p. 26.

[40] R. Duran, *José Vallhonesta Vendrell y los colorantes artificiales en la Cataluña del siglo XIX.* (Bellaterra: unpublished master thesis, 2002).

[41] AGDB. File 1389.

[42] On the biography of Persoz, see: B. Bensaude-Vincent, Bernadette, R. Christophe, "Persoz, Jean-François (1805-1868) Professeur de teinture, impression et apprêts des tissus (1852-1868)," in C. Fontanon, A. Grélon, eds., *Les professeurs du conservatoire des arts et métiers* (Paris: CNAM, 1994), Vol II, pp. 389-398.

[43] Persoz, *op. cit.* (23).

[44] J.B. Dumas representing the Committee for chemical arts of the *Société d'encouragement pour l'industrie nationale*, stated in the first pages: "Ces echantillons, au nombre de plusieurs centaines, reproduissent les procedés de tous les pays; car l'Alsace, la Suisse, la Normandie, les environs de Paris, l'Angleterre et l'Ecosse ont rivalisé de liberalité envers l'auteur; les principales fabriques ont mis à sa disposition des pieces de leurs etoffes, qui découpées en échantillons, donnent à l'auteur des types inappreciables," J.B. Dumas, "Rapport au nom du comité des arts chimiques " in Persoz, *op. cit.* (23), I, Preface.

[45] A. Nieto-Galan, *Colouring textiles. A History of Natural Dyestuffs in Industrial Europe* (Dordrecht: Kluwer, 2001).

[46] Ch. Gastinel-Coural, "Chevreul à la Manufacture des Gobelins," in G. Roque, B. Bodo, F. Vienot, eds., *Michel-Eugène Chevreul. Un savant, des couleurs!* (Paris: Editions du Musée national d'histoire naturelle, 1997), pp. 67-80, p. 67. Cited in Nieto-Galan, *op. cit.* (45).

[47] AGDB. File 1389. Josep Vallhonesta's correspondence.

[48] J. Vallhonesta, *Colores derivados de la anilina: historia, fabricación y aplicación a la tintorería y otros varios ramos de la industria* (Madrid: Manuel Tello, 1874).

[49] AGDB. File 1389.

[50] M. E. Chevreul, *De la loi du contraste simultané des couleurs* (Paris: Chez Pitois-Lerraut et Cie., 1839).

[51] J. Gage, *Colour and Culture* (Singapore: Thames and Hudson, 1993); G. Roque, *Art et Science de la couleur.Chevreul et les peintres, de Delacroix à l'abstraction* (Nimes:

Jacqueline Chambon, 1997), pp. 38-45; Roque, Bodo, Vienot, eds., *op. cit.* (46), pp. 68-69; A. Rosenstiehl, *Traité de la couleur au point de vue physique, physiologique et esthétique, comprenant l'exposé de l'état actuel de l'harmonie des couleurs* (Paris: Dunod, 1913).

52 Gage, *op. cit.* (51), p. 175.

53 Strategies of appropriation are reflected in the plan for the diffusion of the 800 copies of his report: 50 copies to the author; 12 copies to the Ministerio de Gobernación; 12 copies to the *Ministerio de Fomento*; 3 copies to the *Gobierno Civil* de Barcelona; 2 copies to the *Biblioteca Nacional*; a copy to every Spanish library; a copy to all the present and former M.P's of the *Diputaciones Provinciales*; 30 copies to the Barcelona City Council; 2 copies to the *Junta de Agricultura, Industria y Comercio*; 2 copies to the RACAB; 2 copies to the *Sociedad económica barcelonesa de amigos del país*; 2 copies to the *Escuela Industrial* in Barcelona; 5 to the Barcelona *Associació d'Enginyers*; a copy to every dyeing, printing, paper painting firm; a copy for every Catalan town and city . AGDB. File 1389.

54 Chevreul, *op. cit.* (50); J. Vallhonesta, *Clasificación y contraste de colores según Chevreul. Primera memoria: Sistema de clasificación de los colores. Segunda memoria: Ley del contraste de los colores* (Barcelona: C. Verdaguer, 1873).

55 J. Vallhonesta, *El arte del tintorero* (Barcelona: Renaixensa, 1880).

56 *Revista Tecnológico-Industrial,* 1880. (The translation into English is mine). I thank Ricard Duran for this information.

57 A. Nieto-Galan, A. Roca-Rosell, eds., *La Reial Acadèmia de Ciències i Arts de Barcelona en els segles XVIII i XIX. Història, ciència i societat* (Barcelona: IEC-RACAB, 2000); "Spain did possess a significant provincial scientific society in the Real Academia de Ciencias Naturales y Artes of Barcelona....Like its French neighbours the Barcelona Academy was in these regards a provincial institution...it followed closely developments in Lavoisier Chemistry. The horizon of its interests was more limited to Catalan, and after 1790, it took up questions of industrial growth and development," J.E. Mcclellan, *Science Reorganized. Scientific Societies in the eighteenth century* (New York: Columbia University Press, 1985), p. 139.

58 A.S. Travis, *The Rainbow makers. The origins of the Synthetic Dyestuffs Industry in Western Europe* (London and Toronto: Lehigh Associated University Press, 1993); Nieto-Galan, *op. cit.* (45).

59 J. Vallhonesta, "Importancia de los colores de anilina en la industria de la tintura" (22-05-1870).

60 J. Vallhonesta, "Comparación entre los procedimientos de tintura con las materias colorantes antiguas y modernas" (28-05-1881).

61 J. Vallhonesta, "Sobre las leyes que rigen el contraste sucesivo de colores" (25-04-1887).

62 See for example: Sánchez, *op. cit.* (13).

63 AJC. File 73, f. 17,19. BC Barcelona.

64 La Force, *op. cit.* (13).

65 On Betancourt, see: A. Rumeu de Armas, *Ciencia y Tecnología en la España ilustrada. La Escuela de Caminos y Canales* (Madrid: Turner, 1980); I. González Tascon, J. Fernández Pérez, eds., *Betancourt, A.d., Memorias de las Reales Minas de Almadén* (1783) (Madrid, 1990).

66 On Watt's steam engines, see: R.L. Hills, *Power from Steam* (Cambridge: Cambridge University Press, 1989).

[67] J. Agustí Cullell, *Ciència i Tècnica a Catalunya en el segle XVIII. La introducció de la màquina de vapor* (Barcelona: Institut d'Estudis Catalans, 1983); C. Puig Pla, "L'establiment dels cursos de mecànica a l'Escola industrial de Barcelona (1851-52). Precedents, profesors i alumnes inicials," *Quaderns d'Història de l'Enginyeria,* 1 (1996), 127-196; A. Nieto-Galan Agustí, *La seducción de la máquina. Vapores, submarinos e inventores* (Madrid: Nivola, 2001).

[68] M. R. Fontanals, "La contribució de la família Cavaillé al progrés tecnològic," in Maluquer, *op. cit.* (13), pp. 176-179.

[69] J.M. Benaul, "La transferència de tecnologia en la industrialització llanera," in Maluquer, *op. cit.* (13), 192-203.

[70] R. Brain, *Going to the Fair. Readings in the culture of nineteenth-century exhibitions* (Cambridge: Whipple Museum of the History of Science, 1993).

[71] Benaul, *op. cit.* (69), p. 203.

[72] J. Nadal, J. Domènech, "Joan Girona i Agrafel, el 'maquinista' malaguanyat," in Maluquer, *op. cit.* (13), pp. 228-233.

[73] Nadal, Domènech, *op. cit.* (72).

[74] *Boletín Oficial de la Provincia de Barcelona*, 20, 24-01-1866, p.2.

[75] AGDB. File 1389. J. Foulon's correspondence (Seraing, 05-12-1866)

[76] "...he visitado los talleres con asiduidad,... pidiendo cifras y explicaciones que con la mayor galantería me han facilitado los jefes de las minas de hulla, de los altos hornos, hornos de pudelar y recocer el hierro, de cok, laminadores y martillos de vapor." AGDB. File 1389. J. Foulon's correspondence (Seraing, 05-12-1866).

[77] AGDB. File 1389. J. Foulon's correspondence (Liège, 25-07-1867).

[78] AGDB. File 1389. J. Foulon's correspondence (Seraing, 28-01-1868).

[79] AGDB. File 1389. J. Foulon's correspondence (Seraing, 27-04-1868).

[80] AGDB. File 1389. J. Foulon's correspondence (Seraing, 28-01-1868).

[81] AGDB. File 1389. J. Foulon's correspondence (Seraing, 18-04-1868).

[82] AGDB. File 1389. J. Foulon's correspondence (Greenwich, 3-04-1869).

[83]"...dedicarme a vulgarizar los conocimientos prácticos adquiridos durante mi residencia en los países que van al frente del progreso industrial." AGDB. File 1389.

[84] Th. P. Hughes, *Networks of Power. Electrification in Western Society, 1880-1930* (Baltimore, London: Johns Hopkins University Press, 1983).

[85] Garrabou, *op. cit.* (2), p. 166.

[86] J. Maluquer, "Los pioneros de la segunda revolución industrial en España: La Sociedad Española de Electricidad (1881-1894)," *Revista de Historia Industrial*, 2 (1992), 121-141. See also: B. Cuadros, T. J. Dalmau, R. Tapis, *Sociedad Española de Electricidad:cuatro palabras a los señores accionistas* (Barcelona: SEE, 1883). On dynamos see:, B. Paul, *Premiers principes d'électricité industrielle: piles, accumulateurs, dynamos, transformateurs* (Paris: Gauthier-Villars, 1910). 6è. édition.

[87] Dalmau's journey was described in detail in the journal: *El Porvenir de la Industria*, 2, 1876, 80-81; 99-100; 138-140. See also: Garrabou, *op. cit.* (2), p. 166.

[88] J. R. Bertomeu Sánchez, A. García Belmar, "Viajes a Francia para el estudio de la química, 1770 y 1833," *Asclepio,* 53 (2001), 95-139.

[89] J. R. Harris, *Industrial Espionage and Technology Transfer. Britain and France in the Eighteenth Century* (Aldershot: Ashgate, 1998); J. R. Harris, *Essays in Industry and Technology in the Eighteenth Century: England and France* (Hampshire: Variorum, 1992).

[90] N. Reingold, M. Rothenberg, eds., *Scientific Colonialism. A Cross-Cultural Comparison* (Washington: Smithsonian Institution Press, 1987), p. xii.

[91] M. Callon, ed., *La science et ses réseaux. Génèse et circulation des faits scientifiques* (Paris: Editions La Découverte, 1989).

[92] For the circulation of botanical information, see: M. L. Pratt, *Imperial Eyes. Travel writing and Transculturation* (London-New York: Routledge, 1992).

[93] Carbonell, *op. cit.* (29).

IRINA GOUZEVITCH AND DMITRI GOUZEVITCH

TRAVELLING INTERCHANGES BETWEEN THE RUSSIAN EMPIRE AND WESTERN EUROPE

The Travels of Engineers during the First Half of the Nineteenth Century

1. INTRODUCTION

This paper focuses on the interchange of engineers between the Russian Empire and Western Europe in the first half of the nineteenth century. First we analyse the rise of engineering travels in the reign of Alexander I and provide a typology based on the purposes these travels fulfilled: the hydraulic missions, the missions of resident engineers and the missions of legal reconnaissance. Second, we focus on the routines and innovations of engineering travels during the reign of Nicholas I. Third, we concentrate on the travels of French engineers to the Russian Empire, and finally the kind of literature which emerged associated with engineering travels and the pedagogy of technical training.

Engineering travels from the Russian Empire to Western Europe and from Western Europe to the Russian Empire are an old phenomenon. Inviting foreign specialists to the Russian service dates back to the fifteenth century. Ivan III, the first Russian national sovereign, initiated this policy and laid the foundations for the systematic importation of Western technologies and knowledge, especially in the field of military engineering and medicine. Peter I not only developed this practice, but extended it to other fields of activity such as shipbuilding, professional training and academic research and considerably increased the number of invitees. The foreign specialists were required, among many other duties, to teach in the newly created Russian engineering schools.[1]

Engineers who travelled from Western Europe belonged essentially to one of three groups. The first included engineers who went to the Russian Empire as invited or, at least, welcomed specialists, usually in the service of the Crown or, more rarely, of a private administration. The second included professional visitors who travelled to the Russian Empire as State commissioners: most often they were sent by some administrative body. The

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third group included political and economic emigrants and/or adventurers of all kinds whose expertise was finally recognised.

As far as the Russian Empire is concerned, educational travels turned out to play a major role in its engineering policy, whereas Russian specialists were not usually employed abroad. This double peculiarity arises historically from the peripheral location of the Russian Empire and from the specific path of "taking up" developments as a way to modernization.[2] The first official educational travels from the Russian Empire were for scientific purposes and date back to the beginning of the eighteenth century. They generally combined educational, scientific and intelligence aims. Russian students funded by the State had to attend European universities and technical institutions.

An important impetus was also given to assessing foreign technical developments through diplomatic and intelligence channels, efforts which expanded in the nineteenth century. The earliest of them – the Great Embassy (1697-98) – facilitated the first journey abroad of a sovereign of Moscovy.[3] Two kinds of activities were possible within this framework: official (legal reconnaissance) and illegal (espionage).

2. TRAVELS FROM THE RUSSIAN EMPIRE: THE RISE OF ENGINEERING TRAVELS IN THE REIGN OF ALEXANDER I (1801-1825)

At the beginning of the nineteenth century, Alexander's reforms gave a new impetus to the exchange policy. These reforms were characterized by the following features:

– A preference for the French system of engineering training and the invitation of French "polytechniciens" with the aim of setting up technical schools for higher education in the Russian Empire;[4]

– A practice, still maintained, of inviting foreign specialists as one of the main means of bringing about technological change;

– An increasing practice of sending Russian students for training abroad (especially in France and in Germany);

– A wider use of intelligence travels, both under their legal and semi-legal forms;

– The abandonment of the practice of inviting foreign specialists within the context of the Academy of Sciences and the institutionalization of two new statutes: those of corresponding and foreign members of the Academy of Sciences, and the creation of various scientific societies;

– A wider development of formal written communication associated with the bilinguism of the Russian nobility and the temporary decrease of censorship.

The reign of Alexander I was particularly favourable to the travels of young nobles (the "grand tour") who travelled abroad at their own expense, often heading to Western Europe with scientific and educational aims in mind.

The first Russian student who followed the courses of the Ecole Polytechnique in 1804 went to France under a private arrangement. His name was Petr Rahmanov and he was an engineer.[5] Between 1808 and 1828, only 18 fellow students were sent to different European institutions officially funded by the Ministry of Public Education in order to prepare for their future professorship in the Russian Empire.

In contrast, engineering administrations (e.g. the General Direction of Ways of Communication, Admiralty or Mining Department) showed themselves much more dynamic and generous in sending their officers abroad, though it is important to stress that they were professional engineers rather than students. This new dynamism was due to the very logic of modernization: as appointed State-employed messengers, they were given the mission of exploring and prospecting, which consisted mainly of gathering information about new technologies and the latest European achievements in the field of engineering sciences and training.

2.1. Hydraulic Missions

In the light of these facts, engineering travels, together with the establishment of institutions for higher education and professional organizations (engineering corps) of the early nineteenth century, emerge as fundamental to the institutionalization of the engineering profession in the Russian Empire. It is no accident that this kind of travel increased and varied. In addition to the old proven kinds of travel, some innovative forms were then tried. The *Table* at the end offers the chronology of engineering travels which took place during this transition period. Using them as examples we can better sense the spirit of innovation which laid the foundations of modern engineering communication in the country.

Two typical travel scholarship holders open our list. Needless to say these travel scholarship holders continued the old tradition of educational travelling, which was introduced by Peter I, abandoned by his direct successors and brought back into practice in the mid-eighteenth century. At the turn of the eighteenth century these travels were still common. They also retained their purely educational character. Indeed, S. Gur'ev in 1792, then L. Vaxel and I. Markov in 1802, aimed at studying "hydraulic works" in England. All three travellers were well-educated people with a good mathematical background, and they looked to improve their knowledge in hydraulics rather than seeking to be initiated in it.[6] In this way, training itself changed in nature.

Four years later, Vaxel went back to Great Britain, but this time as a member of the so-called *hydraulic mission*, an innovation of the 1800s introduced by the reform of the minister Petr Rumâncev. Far from being a real Russian invention, these missions mixed educational and reconnoitring purposes and were then widely adopted by other peripheral countries. Back in the mid-1780s, the Spanish government sent to Paris, to the Ecole des Ponts et Chaussées, its own *hydraulic team* composed of trainee engineers headed by Augustin Betancourt. They aimed to become more competent at building models and at gathering information about any interesting technical innovation in the field of mechanics and civil works.[7] In the Russian case, this specific mission was made easier thanks to the double function of Rumâncev within Alexander's government. As General Director of Waterways he understood better than anybody else the urgency of reforming transportation; as State Chancellor in charge of foreign affairs he could use the methods of diplomacy in the interest of this reform. By means of *hydraulic missions*, Russian engineering could benefit from the best European achievements in this domain and therefore such missions were sent to England and Scotland where hydraulic engineering had reached its highest standards. These travels lasted two years, from 1806 to 1808, and they included, besides Vaxel, two of his young colleagues, Dewitte and Janish, who both later became eminent Russian engineers.[8]

As noted above, the hydraulic mission was but one kind of educational travel. However, it had an important distinctive trait, which is highly significant to the history of engineering travel. In contrast to the training periods spent abroad typical of the previous period, apprenticeship was relegated to a secondary position, and the gathering of information and its subsequent analysis were given a prominent place.

2.2. The Missions of the Resident Engineers

From Vaxel's second trip abroad another type of mission originated, whose importance was enhanced a few decades later - the *mission of the resident engineer*. These missions differed from espionage in their strictly legal character. The instructions given to Vaxel in this regard were clear: "To this mission will be given the protection of the Russian Embassy (…) it should not undertake anything without the approval of the latter (...) but it should try (…), by only official means, to see everything (...), without causing troubles that could arise from the unhealthy curiosity, which can be considered indiscretion by English people."[9] However, the boundaries of legality were very easily overcome. If Vaxel succeeded in bringing to Russia all the documents he collected, the trainees of the Navy Administration did not have the same chance in 1807: all the plans they had collected during their mission – the outcome of many years of work – were confiscated by British Customs.[10]

As a resident, Vaxel was in charge of various tasks. Besides the education of young trainees, he had to buy books and models, to make descriptions and draw plans of various civil works such as bridges, docks, locks, channels and embankments. Special emphasis had to be placed upon the organisation of works and machine building, particularly regarding steam engines. Telford helped him a lot during this mission; in return for his services the Russian Emperor gave him a diamond ring.[11]

The attempt to send a similar mission to France was much less successful. Instead of the five persons initially planned, only two were finally sent in 1808: the head of the team A. Maûrov and the draughtsman Dusaev. Moreover, the latter could not resist the temptations of Paris: excessive drinking and gambling caused his dismissal.[12] As for Maûrov, he followed some courses at the Ecole Polytechnique and the Collège de France.[13] He then travelled widely across France and Holland. Later on, Vaxel and Maûrov were elected members of the Academy of Sciences of Saint-Petersburg.[14]

2.3. Missions of Legal Reconnaissance

In addition to these new engineering missions, some of Rumâncev's other initiatives contributed greatly to the reorganisation of the administration of ways of communication in the Russian Empire, notably those stemming from professional contacts he established in Erfurt with two eminent European engineers, Karl Wiebeking from Bavaria and Augustin Betancourt from Spain. Vaxel, Janish, Dewitte and Maûrov became officers of the newly created Corps of Engineers of Ways of Communication (CEWC, 1809); Betancourt, admitted to the Russian service, was entrusted with the general inspection of the Institute of this Corps (ICEWC, 1809/10);

Wiebeking engaged himself in welcoming Russian engineers and trainees in Bavaria.[15]

These far-reaching changes allowed, in turn, for a re-think of the very nature of engineering travels. A completely new kind emerged shortly after the Institute of Engineers of Ways of Communication was created: the *mission of legal scientific reconnaissance*. Professional training ceased to be its function, the sole concern of this mission being to collect professional information. The first engineer to travel for this purpose in 1810-12 was Jaroslav Potozky, an officer of the CEWC. For two years, Potozky travelled in Austria, Bavaria and some other German and Italian states, visiting the most important hydraulic works wherever he went. In 1811, he witnessed the demonstrations of Sömmering's electrolytic telegraph in Munich and was welcomed there by Wiebeking.[16]

The Napoleonic wars of 1812-15 very seriously affected the natural pace of this process. Paradoxically, the engineering travels were able to restart in the CEWC by the end of the decade thanks to the French "polytechniciens" who remained in Russian service after the restoration of the Bourbons. Potier in 1816-17, then Bazaine in 1819-20, visited their motherland as officers on leave, and they used this opportunity to renew their former professional contacts in France and to collect useful information which might be of interest to the Russian administration.

The missions of legal scientific reconnaissance came into particular prominence during the 1820s and 1830s. The most important are listed in the *Table* (Kauling and Menelas, England, 1824; Dolgorukov, Europe, 1826-27; Bazaine, Germany, France and England, 1828; Lamé, England, 1830; Kraft, Bohemia, 1835; Mel'nikov and Kerbedz, France and Belgium, 1837-38; Mel'nikov and Kraft, United States, 1839-40).

3. TRAVELS FROM THE RUSSIAN EMPIRE IN THE REIGN OF NICOLAS I: ROUTINES AND INNOVATIONS (1825-1856)

Generally speaking, the thirty-year reign of Nicholas I was a period of relative stability. In the field of engineering, be it administration or training, nothing fundamentally new happened, although some aspects of managing policy were refined. Thus, the number of foreign specialists invited to the Russian Empire as technical experts was reduced: Russia trained its own engineers in sufficient numbers to allow the Russian tsar to show his aversion towards "dangerous agitators," particularly of French origin. Some of the "polytechniciens" (e.g. Raucourt, Lamé and Clapeyron) were forced to abandon the Russian service. Russian students and trainees abroad, as well as intelligence travellers, grew in number. The travels of resident engineers promoted under the previous reign resulted in a network of resident engineers who stayed in Western Europe. They were either officially attached to diplomatic missions or embassies, or were representatives of various ministries. They were in charge of intelligence missions and sometimes acted as industrial spies.

The four-year stay of Pierre Dominique Bazaine in France (1835-38) is paradigmatic of the mission of a resident engineer. Bazaine was invited to the Russian Empire in 1809 with three other "polytechniciens" (Destrem, Potier and Fabre), as agreed by the Russian and the French emperors in Erfurt a year earlier. However, his career was soon interrupted owing to the campaign of 1812. As officers in Napoleon's army, the four men found themselves exiled in Eastern Siberia, where they stayed until 1815. Back in Saint-Petersburg after the "Hundred Days," they were recommended and unanimously accepted as members of the State Russian service, provided they abandoned the French service. It was not until five years later that Bazaine, while on leave in Paris, could secretly be re-integrated in the French service as well. When 15 years later he went to Paris as an official Russian resident engineer, his personal situation was all the more original: not only was he an officer of two States, but he occupied in each a very high hierarchical position, that of "inspecteur divisionnaire" (major-general) des Ponts et Chaussées in France, and that of lieutenant-general of the Corps of Engineers of Ways of Communication in the Russian Empire. Such an ambivalent situation greatly contributed to his discharge. He could, in fact, use the whole network of personal and professional contacts and acquaintances in France. Having his headquarters in Paris, Bazaine then travelled widely across Western Europe, collected technical documentation, bought and ordered books and models, and welcomed Russian trainees and visiting engineers. The results of his activities, materials and reports, were sent to five different Russian engineering administrations.[17]

Despite its original character, the case of Bazaine is indicative of some more general trends, especially of the renewed traditional practice of "vacuum cleaning."[18] This practice, which consisted of a regular importation of Western European knowledge essentially through the invitation of foreign specialists, had been promoted in Russia since the seventeenth century. However, during the 1820s and 1830s the brain drain gave way to the information drain. This information was often handled by the same foreign specialists who accepted invitations to work for the Russian Empire in West European countries.

One more peculiarity of Bazaine's mission is his institutional status in the Russian Empire. He stayed in France as an official representative of at least two Russian administrations, being at the same time on extended leave in relation to his main Crown service. This situation became possible due to the new administrative policy which, along with official State-supported travels, encouraged private travels of engineers with professional aims, be they on leave or retired. Accordingly, any State engineer who intended to go abroad privately could be commissioned to collect and send to the Russian Empire any interesting information about engineering, technology and science. In return for this service, they were rewarded with official accolades or a sum of money. The results of these missions were published in the *Journal of Ways of Communication.* As for retired engineers, the fact of being designated as correspondents allowed them to keep their ranks and uniform, and to receive a good pension. This initiative met a wide response among engineers.

French engineers in Russian service were the most active promoters and beneficiaries of this kind of travel because it allowed them to manage extended stays in their native country while proceeding with their professional duties. Among these correspondents were Wilhelm Traitteur (retired in the early 1830s); Jean Résimont (retired, France, 1836-37); Maurice Destrem (on leave, France, 1837), and Matvej Volkov (on leave, 1833, Western Europe). Both sides gained from this arrangement: engineers who for some reason found themselves out of service could in this way improve their financial situation and feel useful; as for the State, it benefited from the work of retired servicemen and was free from any moral charge in the event of indiscreet curiosity, among others.

4. TRAVELS TO THE RUSSIAN EMPIRE: THE MOVEMENT IN THE OPPOSITE DIRECTION

A movement in the opposite direction occurred simultaneously. In this section we will look at the role of the Russian Empire in attracting French engineers by means of three examples.

The first one concerns two French military engineers, d'Hincourt and Cathala, who travelled to the Russian Empire in 1826.[19] The documents concerning their mission are kept partly in Russia, partly in France. The Russian file includes correspondence between the administrations of both countries and deals essentially with the official arrangements concerning this trip aiming "to collect information pertaining to military achievements in Prussia, Russia and Denmark." The documents resulting from this mission are now part of the Memoirs and Reconnaissance Department of the Ministry of War, in Vincennes. The files include 17 letters "concerning travel in Russia" as well as several dispatches and reports, the whole containing detailed descriptions of the places visited with the evaluation of their military potential.

The fact that Cathala and Bazaine were schoolmates — both entered the Ecole Polytechnique in 1803 — suggests that the former could have benefited from the help and advice of the latter. It is worth recalling in this regard that France had available legal ways of obtaining information that Russia did not possess: the French specialists who entered the Russian service with the agreement of their government continued to be French officers. This situation was unthinkable for the Russians.

The case of the four French "polytechniciens" who were invited by Alexander I in 1810 should be seen from this new vantage point.[20] Traditionally considered as a gesture of friendship by Napoleon, this mission also had a strategic value because it offered the French government a wonderful opportunity to train, at the expense of the Russian Empire, well-informed technical experts on Russian affairs. As for Lamé and Clapeyron who went to the Russian Empire ten years later, their official mission was to regularly inform their French administration about Russia's achievements in engineering.[21]

The archives of the French Ministry of War contain one more impressive collection of reports, memoirs and notes written between 1833 and 1837 and describing Eastern and Southern Russia. These documents originated from two trips by the Count of Sainte-Aldegonde, a military attaché of the French Embassy in Saint-Petersburg. Very little is known about him except that he belonged to an ancient noble family, and that he was a major-general, probably trained as an engineer. In 1833-34, he visited the Urals, Altai and Siberia. This list of extant papers testifies to the range of his travel interests, especially on questions associated with mining and the metallurgical industry. Indeed, the Count seems to have been an expert in this field and his observations are sharp and realistic. It is no accident that three years later he was asked to follow and facilitate the works associated with the exploitation of the Donetz Basin. These works were ordered, organized and funded by Anatole Demidov, who entrusted a group of French engineers to carry them out under Frederic Le Play's direction.

After these travels, Saint-Aldegonde wrote a series of memoirs covering the various problems of the region he visited: the waterways to be built in the Russian Empire; the Donetz mineral field; the plan for an arms factory in

Lugan; the use of coal for firearms production; the project of the reorganization of the Mining Corps; and the evaluation of Russian military power. Written in stylish French, the whole offers a stereoscopic image of this underdeveloped region and can be legitimately considered as a scientific treatise complementary to that of Le Play. The very fact that Saint-Aldegonde took part in this trip is indicative of its ambivalent nature: although a private enterprise, the Donetz expedition was in fact sponsored by the French special services because of its strategic importance. At the same time, Saint-Aldegonde's memoirs give many complementary details concerning the first and rather obscure Russian period of Le Play, an eminent engineer and economist whose three famous trips to the Russian Empire constitute our third example.

The Russian Empire has a particular place in Frederic Le Play's life and career. His long adventure began in 1835-36, when in Napoleon III's salons he met Anatole Demidov, the richest owner of mines and metallurgical works in the Urals, and accepted his invitation to be scientific head of the exploratory expedition to Southern Russia. The next two years were devoted to the study of the Donetz region from the point of view of its mineral wealth and industrial potential. Four volumes authored by Demidov crowned this important scientific work.[22] The intricate relations between Le Play and his Russian employer are yet to be clarified. In 1844, Demidov invited Le Play to visit his works in the Urals, and finally, they signed a contract entrusting the engineer with the post of technical assistant and the task of reorganising Demidov's metallurgical works. The mission ended in 1853, the year Le Play visited the Russian Empire for the third and last time in order to evaluate the impact of his managerial efforts aimed at reorganising a gigantic enterprise (45,000 workers!). The reasons for his break-up with Demidov are still unclear. However, one can find some fragmentary accounts of Le Play's two last trips in the Russian Empire thanks to the letters he wrote to his wife. Later on, Albert Le Play edited and published his father's letters in the famous book titled *Voyages en Europe: 1829-1854*.[23] A good observer and experienced traveller, Frederic Le Play remains first of all an engineer: most of his attention was concentrated on local natural resources and on the state of the roads. French readers curious to know something about the Urals could find in Le Play's descriptions many interesting and picturesque details.

5. THE IMPORTANCE OF TRAVEL: PREPARATION, REPORTS AND REFLECTIONS

Two other aspects of Le Play's travels are of particular interest. The first deals with observations. His studies on the working class contributed greatly to the elaboration of his "méthode sociale" and of his doctrines on social reform, very much framed in his Roman Catholic beliefs. He influenced a social movement among employers which came to be known as "paternalism." The second aspect deals with his enormous experience as a traveller. With time, Le Play felt tempted to share it with his younger colleagues and pupils, and a more general reflection emerged by the 1870s deriving from his triple experience as economist, social expert and scientific traveller. It materialized in the "school of travels," a completely new teaching topic that aimed to make professional explorers experts in social problems. The "art of travelling" is one of many important topics Le Play developed in the preface to the book *Méthode sociale*.[24] According to him "travels are for the science of societies what chemical analysis is for the science of ores, and collection is for botany, and in more general terms what observation of facts is for all natural sciences."[25] His teaching at the "school of travel" included three degrees: the course on method, the course on doctrine and the course on critic. Its members were engaged in fundamental social research which consisted in direct study of social facts based upon a monographical method (monographies of families and monographies of societies) and upon regular inquiries. In this framework, "methodical" travel was considered as the main tool for both the investigation of society and the education of future reformers. Le Play's attempt to systematise guidelines for scientifically-organised travels of social experts, though not unique, is perhaps the best known.

From the 1840s, similar attempts were made in the Russian Empire. However, they did not arise from any engineering context but from the university milieu. We will look at two examples dealing with academic training, which illustrate early attempts at systematising guidelines for educationally- and scientifically-oriented travelling in such different fields as agronomy and pedagogy.

In 1838, M.G. Pavlov's article titled "Agronomic travels" was published in the specialist *Russkij zemledeletz* (The Russian Farmer). A professor at Moscow University, the author introduced and discussed the notion of scientifically-oriented educational agronomic travel.[26]

In the Russian Empire at least, agronomic travel was an early example of an institutionally promoted educational tour in Western Europe. It was considered to be part of the academic syllabus in this field and related in particular to university professors. A good collection of travel documents provides evidence of the state of the sciences in many European countries. It also provides many interesting observations concerning various aspects of the scientific, economic and social life of the countries visited. It is worth noting that to date this source has not been fully explored.

Let us consider from this point of view Â. Linovskij's Western-European agronomic tour.[27] Linovskij was Pavlov's pupil and tried to organise a trip to Germany, France, Belgium, Switzerland, Austria, Italy and England in accordance with the guidelines of his former teacher. He carefully outlined a programme, checked the itineraries approved by the Minister of Public Education and made a preliminary study of the situation of the countries to be visited. All these aspects exemplified the travelling a young candidate for a professorial position in 1841-1844 had to undertake. Before leaving, Linovskij signed a contract appointing him an officer of the Ministry for at least 12 years. During his trip, which lasted more than three years, Linovskij visited France twice, going first to its Northern regions (Alsace, Champagne, Nancy, Paris) and then travelling southwards (Marseille, Avignon, Lyon, Châlons, Paris). His travel notes, titled "Notes de voyage à travers la France du magistré Linovski," were published in four consecutive issues of the journal *Moskovskijé vedomosti,* in 1843. Generally, Linovskij's writings on France form a considerable part of his scientific and literary legacy. Among the subjects that particularly interested him were the French economy, agriculture, trade and industry; agricultural training and popularisation in France; agricultural societies and meetings; and recent French works in the field of the natural sciences associated with agronomy and agricultural techniques.

Some of his accounts are particularly interesting due to their detailed character. Among them one finds descriptions of various industries (e.g. the silk-mills in Lyon faithfully portraying both the weavers and their work and life styles), educational institutions (e.g. Institut Royal d'Agriculture at Grignon or the private agricultural school at Nivière, near Lyon) or even individuals (e.g. Charles Dombal, scientist, inventor and founding father of the first French agricultural school at Roville, near Nancy in 1822). Linovskij took part in the first agricultural meeting held in Paris in 1844. In his writings he thanked eminent French scientists for their help in his chemical researches, in particular A. Payen and J.B. Dumas and the botanist Mirbel. He attended some famous institutions which trained industrial engineers, namely the Ecole Centrale des Arts et Manufactures and the Conservatoire des Arts et Métiers. In this way, Linovskij introduces us to the domain of education and training which came under the particular scrutiny of Russian scientific travellers in the following two decades:[28]

> In order to study in a most complete way a wide discipline like pedagogy, my studies abroad were programmed according to a pre-arranged plan which can be divided into two parts: theoretical, followed in the universities where the very foundations of pedagogy are taught consistently as well as auxiliary philosophical and anthropological disciplines, and practical, requiring personal knowledge of (...) the best schools, of the best pedagogues and pedagogical societies (...), as well as the understanding of the position that the school occupies with regard to the State, church, society and family. If in the first case, quiet cabinet studies are sufficient, to reach the second aim one is obliged to travel.

These words introduce the 20-page travel report of Lev Modzalevskij, candidate for the position of professor of pedagogy. This report, dated 1 December 1863, was published in the *Journal of Ministry of Public Instruction*.[29] It dealt with Modzalevskij's short stay in France where he had spent his holiday visiting "some of the primary and secondary French scholarly institutions." This document offers a fine example of what a formal professional exercise could be when written by a man of intelligence but partial and obsessed with his own observation. His short study provides a very picturesque overview of the French educational system, which the author does not hesitate to criticise, especially when he compares it to the German system. In fact, he argues with such passion that the whole text can be taken for a pamphlet. Modzalevskij insists on visiting provincial schools because he is persuaded (and not without reason) that Paris, better known to tourists and specialists, is not representative of provincial France. He says about pedagogy in France:[30]

> [France is] a classical country of exams, "concours," licences, commissions, reports of all kinds, and governmental protection. In a few words, it is a country of extreme bureaucracy and administrative foxiness, interspersed only from time to time by terrifying bursts of the will for freedom artificially restrained but breaking immediately into a horrible flame of insubordination and anarchy.

His account contains many interesting details concerning school systems and habits. It analyses the syllabus in a critical way, it criticises training methods and teachers' low salaries by remarking that "even by their physique they represent an accomplished type of a narrow-minded and frightened formalist."[31] He concludes in a patriotic key: "the Russian system of education, although far from being perfect, is better than the French; it has much more means for its own development. Therein lies our belief, our strength and our pride."[32]

In spite of his mixed style, or maybe precisely because of it, Modzalevskij's professional report is indicative of changes which were then seizing the public mind. The rise of these patriotic feelings and the critical attitude towards France, whose educational system had served as a reference for generations of Russian intellectuals, became, in fact, from the mid-nineteenth century, a characteristic feature of Russian social and public life. Regarding our subject some important political events could explain this new state of mind. [33]

The defeat of the Russian Empire in the Crimean War and the death of Nicolas I brought serious political and economic consequences. A new period started in 1857, coinciding with what was later to be called "the second French invasion" (after Napoleon's campaign of 1812). However, this second French incursion was not military but rather financial. Following the Crimean war, France was granted an exclusive concession to build railways in the Russian Empire. The importation of French capital greatly favoured the flow of French specialists. The technological choices made by the owners of French concessions (particularly E. Collignon), were not necessarily the best. The imported technologies often turned out to be less efficient than local ones. At the same time, travels of Russian students abroad increased, especially in the university milieu. Despite the critical mood, Germany and France remained among the most visited countries. A two- or three-year stay abroad in order to prepare a professorship became, from this period onwards, a normal trend in official State policy. Modzalevskij's travels are precisely of this kind. By contrast, the policy of inviting foreigners was nearly over in the state sector whereas in the private sector it was still maintained, as Frederic Le Play's example portrays.

6. BY WAY OF CONCLUSION

The history of engineering travels is part of European history and underlies the processes of knowledge transfer and technological change. Travelling was also part of various national development policies. On the one hand, these travels were essential to the globalisation of modern engineering and to the harmonisation of various scientific and educational practices. On the other, they played an important role in the development of national engineering elites and styles. The rise of engineering travel and the diversification of its forms are everywhere in line with the process of the institutionalization of engineering as a profession.

This process was not simultaneous in the various countries, and in the Russian Empire it took place in the first half of the nineteenth century. The rise of engineering travels occurred in the reign of Alexander I, whose policies gave a prominent place to exchanges with France. Preference was given to the French system of technical training, and French engineers were invited to set up technical schools for higher education in the Russian Empire. Students were sent abroad and intelligence travels were also part of the programme. The growing professionalization of engineering led to the establishment of professional societies and a variety of missions emerged: the hydraulic missions, the missions of resident engineers and those of legal reconnaissance.

The reign of Nicholas I kept the former routines, but introduced innovations. The number of foreign specialists invited to Russia was reduced, but the number of Russian engineering students abroad together with intelligence travellers grew. A network of resident engineers in Western Europe working at the service of the Russian Empire was established. The missions of resident engineers as mediators of circulation of technical knowledge crowned the "golden age" of engineering travels.

By the late 1820s, a movement in the opposite direction emerged and some French military engineers were entrusted missions in the Russian Empire. They enrolled in the Russian service, but kept theirs positions as French officers, a situation impossible for their Russian counterparts. During this period, some engineers-travellers engaged in the writing of books in which they systematised all aspects involved in these technically-oriented missions, thereby providing guidelines for potential travellers.

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Table: Chronology of Engineering Travels from Russia to Western Europe: 1792 - 1840

Years	Engineer-traveller	Destination	Purpose
1792	S.E. Gur'ev, graduate of the Corps of Cadets of Artillery and Military Engineering	England	Educational travel aiming to study hydraulic works
1802	L.Vaxel, I.Markov, fellows of the Cabinet and Admiralty Commissioners	England	Educational travel aiming to study hydraulic works
1806–1809	Head: L.Vaxel; members: P.Dewitte, N.Janish, Waterway officers	England and Scotland	Hydraulic mission
XII.1808-I.1811	Head: A.Maûrov, officer of Mining administrat.; member: Dusaev, draughtsman	France and Holland	Hydraulic mission
VII.1810-X.1812	Ja. Potozky, colonel of Ways of Communication	Austria,Ita-ly, Bavaria	Journey in order to "visit hydrotechnical works"
XII.1819-III.1820	P.D.Bazaine, major-general of Ways of Communication	France	Professional mission while being on leave
1824	A. Kauling and Menelas	England	Journey aiming to collect information about the ways of communication
1826-1827	Dolgorukov, artillery colonel aide-de-camp of the Head of Artillery	Western Europe (France)	Journey aiming to collect information about gunpowder factories
I-VIII. 1828	P.D.Bazaine, major-general of Ways of Communication	Germany, France and England	Legal reconnaissance aiming to collect informa-tion about engineering
1830	G.Lamé, colonel of Ways of Communication	England and France	Journey aiming to collect information about railways
IV. 1833 – III.1835	M.Volkov, lieutenant-colonel of Ways of Communication	France	Professional journey while being on leave
1835	N.Kraft, engineer of Ways of Communication	Bohemia	Journey aiming to see the Moldavia-Danube railway
II.1835-IX.1838	P.D.Bazaine, lieutenant-general of Ways of Communication	France	Mission of resident engineer
VI.1836-V.1837	M.Volkov, lieutenant-colonel of Ways of Communication	France	Professional journey while being on leave
1836–1837	I.Résimont, major-general of Ways of Communication	France	Private journey (retired) with professional aims
1837	M.Destrem, major-general of Ways of Communication	France	Professional journey while being on leave
VI.1837-X.1838	P.Mel'nikov and S.Kerbedz, engineers of Ways of Communication	France,Bel-gium, other countries	Mission of legal scientific reconnaissance (railways)
1839–1840	P.Mel'nikov and N.Kraft, eng. of Ways of Communication	United States	Mission of legal scientific reconnaissance (railways)

NOTES

Abbreviations:
AEP – Archives de l'Ecole polytechnique
CARAN – Centre d'accueil et de recherche des Archives Nationales
RGADA – Rossijskij Gosudarstvennyj Arhiv Drevnih Aktov
RGIA – Rossijskij Gosudarstvennyj Istoricheskij Arhiv
RGVIA – Rossijskij Gosudarstvennyj Voenno-Istoricheskij Arhiv
SHAT – Service Historique de l'Armée de Terre
ŽGUPSiPZ – Žurnal Glavnogo Upravleniâ Putej Soobšeniâ i Publicnyh Zdanij
ŽMNP – Žurnal Ministerstva Narodnogo Prosvešeniâ

[1] The Petrine epoch (1689-1724) was really pioneering from this point of view: a series of technical schools in the main fields of engineering created in Russia during his reign were among the earliest European institutions of this kind. For example the Navigation School (1701), Gunnery School (1701), Military Engineering School (1709), etc. See D. Gouzévitch, *Razvitie mostostroeniâ v Rossii v XVIII – pervoj polovine XIX veka i problemy sohraneniâ i ispol'zovaniâ tehničeskogo naslediâ otečestvennyh mostostroitelej* (Moskva: unpublished Ph.D thesis, 1990); I. Gouzévitch, *La mise en place de l'enseignement technique en Russie et les problèmes du transfert des connaissances au XVIII-XIX siècles* (Paris: unpublished DEA thesis, 1993); I. Gouzévitch, *Le transfert du savoir technique et scientifique et la construction de l'État russe: Fin du XVe – début du XIXe siècle* (Paris: unpublished Ph.D thesis, 2001).

[2] See A.N. Medušеvskij, *Utverždenie absolûtizma v Rossii: Sravnitel'no-istoričeskoe issledovanie* (Moskva: Tekst, 1994).

[3] See A.I. Andreev, "Petr I v Anglii v 1698 g." and N.A. Baklanova, "Velikoe posol'stvo za granicej v 1697-1698 gg.: Ego žizn' i byt po prihodo-rashodnym knigam posol'stva" in A.I. Andreev, ed., *Petr Velikij: Sb. statej* (Moskva; Leningrad: Izd-vo AN SSSR, 1947), pp. 3-103; M.M. Bogoslovskij, *Petr I: Materialy dlâ biografii*, T.2: *Pervoe zagraničnoe putešestvie: 9 marta 1697 - 25 avgusta 1698 g.* (Moskva: OGIZ-Socègiz, 1941); D. Gouzévitch, *La Grande Ambassade (1697-1698) comme percée informationnelle sur l'axe Europe Occidentale-Russie* (Paris: unpublished DEA thesis, 2000); I. Guzevič (Gouzévitch), D. Guzevič (Gouzévitch), *Velikoe posol'stvo, ili gde korni Peterburga* (SPb.: Phenix, 2003), in press; *Petr I i Gollandiâ: Russko-gollandskie hudožestvennye i naučnye svâzi: K 300-letiû Velikogo posol'stva (Peter the Great & Holland: Russian-Dutch artistic & scientific contacts: Dedicated to the 300th anniversary of the Great Embassy)* (SPb.: Slavia art books, 1996); N. Kopaneva, ed., *Petr I i Gollandiâ: Russko-gollandskie naučnye i hudožestvennye svâzi v èpohu Petra Velikogo: Sb. nauč. tr.* (SPb.: Evropejskij dom, 1997); N. Ustrâlov, *Istoriâ carstvavaniâ Petra Velikogo,* 3: *Putišestvie i razryv so Švedceû*, (SPb.: 1858); etc.

[4] The setting up of the first Russian schools for higher education was, perhaps, one of the greatest achievements of this period from the point of view of transfer of knowledge. Among the main engineering schools for higher education created in the early nineteenth century was the Institute of the Corps of Engineers of Ways of Communication (1809/10), the General School of Military Engineering (1819) and the Higher Artillery School

(1820), shaped upon the French model. They were followed by a whole ramified system of engineering training.

5 "Rahmanov Petr Aleksandrovič" in *Russkij biografičeskij slovar,' Pritvic-Rejs* (SPb., 1910), pp. 512-516; "Zapiski Nikolaâ Nikolaevića Murav'eva," *Russkij arhiv*, 3 (1885), 17-18; AEP, VI 2 b 1: *Auditeurs externes français et étrangers*; VI 2 b 2, cart.1: 1795-1845.

6 See: D. Gouzévitch, *op.cit.* (1), pp. 192-193 ; RGIA, f.155, op.1, d.57; RGADA, f.1239, op.3, d.56485.

7 A. Rumeu de Armas, *Ciencia y technologia en la España ilustrada: La Escuela de caminos y canales* (Madrid: Ed. Turner, 1980), pp. 37-62.

8 D. Gouzévitch, *op.cit.* (1); RGIA, f.155, op.1, d.57; F.207, op.10, d.813; RGVIA, f.93, op.1, d.330, ff. 1-8.

9 RGIA, f.155, op.1, d.57, ff.46.

10 RGIA, f.155, op.1, d.57, ff.114-115.

11 RGIA, f.155, op.1, d.57, ff.90-117, 139-142, 157-158.

12 RGIA, f.159, op.1, d.86, ff.10; D.485.

13 AEP, VI-2-b-2, cart.1: *1795 – 1845*, part. 1809, ff. [4-8]; RGIA, f.159, op.1, d.86: *O obozrenii inženerom Majorovym gidrotehničeskih rabot v Severnoj Francii i v nekotoryh mestah Gollandii i o zamečaniâh ego, 1810-12.*

14 *Akademija nauk SSSR: Personal'nyj sostav,* 1: *1724-1917* (Moskva: Nauka, 1974), pp.100, 107.

15 I. Gouzévitch, D. Gouzévitch, "Les contacts franco–russes dans le monde de l'enseignement supérieur technique et de l'art de l'ingénieur," *Cahiers du Monde russe et soviétique*, 34-3 (1993), 345-368; I. Gouzévitch, "Technical Higher Education in Nineteenth-Century Russia and France: Some thoughts on a historical choice," *History and Technology,* 12 (1995), 109-117.

16 RGIA, f.159, op.1, d.130; D.485, ff.76; D.561; I. Gamel' (Hamel), "Istoričeskij očerk èlektričeskih telegrafov," *ŽGUPSiPZ*, 32 (1860), 87/2.

17 I. Gouzévitch, D. Gouzévitch, *Petr Petrovič Bazen (Bazaine): 1786-1838* (SPb.: Nauka, 1995), pp. 189-195, 206; I. Gouzévitch, D. Gouzévitch, "Le phénomène des 'ingénieurs-résidents': reconnaissance légale ou espionnage technique?," *Cahiers d'histoire et de philosophie des sciences*, 47 (1999), 159-181, 167-70.

18 This practice of transfer of knowledge is very close to the action of drawing up so commonly associated with the functioning of the vacuum cleaner. This image, as well as the term itself, was inspired by the regular and global character of the transfer. For a more detailed explanation, see: I. Gouzévitch, *Le transfert du savoir technique et scientifique, op.cit.* (1).

19 RGVIA, f. 827, op. 1, d. 930: *O Vysočajšem dozvolenii osmotret' francuzskoj služby polkovnikam Denkuru i Katale zavedeniâ v S.Peterburge po Voennoj časti i o vydače im planov gvardejskim kazarmam i drugih svedenij,* 1825, ff. 1-58; SHAT, MR/1491: *Dossier de 17 lettres concernant le voyage en Russie par MM. d'Hincourt et Cathala*, 1826; SHAT, MR / 1489-1490, 1495, etc.

20 I. Gouzévitch, D. Gouzévitch, *op.cit.* (17); L.F. Nikolai, *Kratkie istoričeskie dannye o razvitii mostovogo dela v Rossii* (SPb., 1898), pp. 38-41; A.M. Larionov, *Istoriâ Instituta Inženerov putej soobŝeniâ Imperatora Aleksandra I za pervoe stoletie ego suŝestvovaniâ: 1810-1910,* (SPb., 1910), pp. 26-55.

21 CARAN, F^{14} 2729^2, ff. 8, 11; F^{14} 2729^2, lettre du 21.6.1820.

22 A. de Démidoff, *La Crimée*, 2^e^ éd. (Paris: Ernest Bourdin, 1855); A. de Démidoff, *Voyage dans la Russie méridionale et la Crimée*, 3^e^ éd. (Paris, 1855?). The whole collection of

materials issued from this expedition is edited in 4 volumes, in English, German, Spanish, Italian and Russian versions); SHAT, MR 1495: *Notes sur le résultat des recherches faites par les ingénieurs envoyés par M. Démidoff dans le bassin houiller de Donetz*; SHAT, MR 1495: *Mémoire sur les avantages qu'on pourrait tirer de l'exploitation du bassin houiller du Donetz, sur les établissements qui pourraient y avoir les différents services et sur l'état de ceux qui y existent.*

[23] F. Le Play, *Voyages en Europe: 1829-1854: Extraits de sa correspondance publiés par Albert Le Play* (Paris: Plon, 1899).

[24] F. Le Play, *La Méthode sociale* (Paris: Méridiens Klincksieck, 1989). About Le Play see: M.Z. Brooke, *Le Play: engineer and social scientist* (London: Longmann, 1970); B. Kalaora, A. Savoye, *Le Play et ses continuateurs aux origines des sciences sociales* (Seyssel : Champ Vallon, 1989). In his introduction to *La Méthode sociale*, Antoine Savoye presents it as "a manual of sociological method" which contains general sociological conclusions (pp. 8, 10) and Le Play himself as an "expert-sociologist" (p. 34).

[25] F. Le Play, *op. cit.* (24), p. V.

[26] This article is quoted in S.S. Dmitriev, "Agronomičeskoe putešestvie po Francii professora Â.A. Linovskogo v 1842-1844 gg." in *La Russie et l'Europe: XVI^e - XX^e siècles* (Paris-Moscou: S.E.V.P.E.N., 1970), pp. 369-396. Its original and full reference (note 3, p. 370) is: M. Pavlov, "Agronomičeskie putešestviâ" in *Russkij zemledelec*, III-7 (1838), pp. 3-14. Unfortunately, this periodical is very rare, and we could not consult it while preparing our own text. According to Dmitriev at least, Pavlov's merit consisted in introducing and *theoretically* substantiating the very notion of scientifically-oriented educational agronomic travel (p. 370).

[27] S.S. Dmitriev, *op. cit.* (26).

[28] L. Modzalevskij, "[Izvlečenie iz otčeta]," *ŽMNP,* 121 (1864), 79-100, 79-80.

[29] L. Modzalevskij, *op. cit.* (28), pp. 100.

[30] L. Modzalevskij, *op. cit.* (28), pp. 80-81.

[31] L. Modzalevskij, *op. cit.* (28), p. 84.

[32] L. Modzalevskij,.*op. cit.* (28), p. 99.

[33] The German-oriented cast of Modwalevskij's criticism could of course be emphasized by the very fact that he belonged to the university milieu. The Russian university system, including classical gymnasia as its lower stage, was created at the turn of the eighteenth century under the strong influence of German university culture. This well-known fact was, in particular, stressed by the American historian A. Vucinich, *Science in Russian Culture* (Stanford: Stanford University Press, 1963-70). It is also worth noticing, in a more general way, that since 1810s two rival educational trends had dominated academic life in Russia: institutes or schools for higher education very close to the French *grandes Ecoles*, and universities with gymnasia inspired by the German model. By the end of the 19th century, the example of the latter gave way to *polytechnical institutes,* a Russian version of technical universities based on German prototypes. The engineers who visited France during the same period were much more favourable towards the French educational system, although they also criticized it. All things considered, it seems that Modzalevskij's anti-French mood had, finally, mostly Russia-rooted origins linked to, among other things, the frustration of Russia's defeat in the Crimean War. This general attitude towards France changed only after the French-Prussian war.

MARCO SEGALA

BABBAGE, THE ANALYTICAL ENGINE AND THE TURIN ACADEMY OF SCIENCES

> Il chiarissimo sig. Babbage di Londra, venuto ad illustrare la nostra Adunanza, raccolse più volte nella sua abitazione parecchi membri della nostra Sezione, mostrando diverse produzioni del suo fecondo ingegno, e fra le altre cose descrivendo il progetto di una ingegnosissima macchina per eseguire i calcoli sì numerici che algebrici, macchina che ove potesse essere effettivamente costrutta, sarebbe al certo di un grandissimo vantaggio alla Società. (*Atti della seconda riunione degli scienziati italiani tenuta in Torino nel settembre del 1840*)[1]

1. BABBAGE'S MACHINES AND THE TRIP TO TURIN

Called a "pioneer of the computer," Charles Babbage (1792-1871) is a prominent figure in the history of mathematics, engineering technology and statistical economics. His fame is connected with his attempt to build two kinds of calculating machines: the Difference Engine and the Analytical Engine. As Babbage repeatedly stressed, the purpose of these machines was not simple calculation, but computation and printing without the errors of most mathematical and numerical tables. That meant offering a highly reliable instrument to pure and (this was an important argument) applied sciences. Mathematicians and astronomers could obtain logarithmic, trigonometric and astronomic tables. Shipping merchants and the insurance companies could acquire nautical and life assurance tables. Babbage was conscious of the unlimited possibilities offered by his machine: "as soon as an Analytical Engine exists, it will necessarily guide the future course of science."[2] In this sense he was really the "pioneer of the computer."

Babbage developed his ideas at the end of the 1810s, and in 1822 he was able to build a small experimental model of the Difference Engine. However, the development of the projected machine (Difference Engine no. 1) came to a halt in 1833 as only one seventh of the calculating part of the machine was

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finished. The following year Babbage conceived a more ambitious calculator, the Analytical Engine: a revolutionary device which is an authentic forerunner of the computer. Incomprehension and lack of funding led to its complete failure and the building of the engine never got under way. After years of frustrated hopes Babbage designed a second Difference Engine (1847-49), but this was never built either.

After 1833 Babbage's ideas on calculating machines suffered from increasing incomprehension. Neither scientists, technicians nor political authorities showed any further interest. Work on the Difference Engine no. 1 cost the government £17.470, an enormous sum if compared with the £780 it cost to build the "John Bull" steam locomotive designed by Robert Stephenson in 1831. The failure of Babbage's project was a tragic shock for the financing body, for the trust in English technological capabilities and, of course, for Babbage himself.

In 1830 Babbage had almost exhausted his prestige in campaigning for the reform of science in England. The Difference Engine was a sort of *pars construens* of the new course of science promoted by Babbage. As *pars destruens* he planned a fierce debate against the core of the English scientific establishment: the Royal Society. In May 1830 Babbage published *Reflections on the Decline of Science and some of its Causes*, the most controversial of his writings. It was part of a strategy to secure the reform of the Society (restricting admission to professional scientists) and to gain its Presidency for John Herschel. In the winter of 1830 the reformers did not win the elections and Babbage gained some new enemies.[3] When he failed with the Difference Engine, in 1833, many people saw Babbage's new defeat as an act of good fortune. "Mr. Goulborn, Chancellor of the Exchequer, asked my opinion on the utility of Mr. Babbage's calculating machine, and the propriety of spending further sums of money on it. I replied, entering fully into the matter, and giving my opinion that it was worthless."[4] This sharp judgement came in 1842 from a first rank scientist, the Astronomer Royal George Airy, and exemplifies the cultural and political climate around Babbage.

Travelling to Italy in 1840, on the occasion of the second meeting of Italian scientists held in Turin, meant a break in Babbage's isolation and gave him the opportunity to discuss the languishing project of his Analytical Engine. According to Babbage's biographer, going to Italy was a great scientist's concession to a provincial scientific community.[5] On the contrary, Babbage was looking for international prestige to counterbalance his diminishing reputation in England, and hence the reason he accepted the invitation to Turin.

In Italy Babbage received attention from politicians and scientists, something he could no longer expect in his own country. In Turin he gave the first and only presentation of the Analytical Engine in front of a highly qualified audience. During several meetings with the mathematicians and engineers of the Royal Academy of Sciences he submitted his project to open and constructive criticism. He did not find new sources of funding or practical commitment regardind the realization of the machine, but his ideas gained access to a vast learned public thanks to Menabrea's paper *Notions sur la machine analytique de M. Charles Babbage*. This was published in 1842 (the same year as Airy's harsh comment) in the widely circulated review *Bibliothèque universelle de Genève.*[6] As Babbage himself pointed out later, "the elementary principles on which the Analytical Engine rests were thus in the first instance brought before the public by General Menabrea," whose paper was a "lucid and admirable description" of the projected machine.[7]

2. ITALY AND THE ADVANCEMENT OF SCIENCE

Babbage was well acquainted with Italy. The country had always deserved his admiration and not only for its glorious traditions concerning arts and science. Notwithstanding the political backwardness of the Italian States, he realized that their governments were much more committed to science than those in his own country.[8] That meant, in his opinion, great opportunities to develop scientific research, as his second journey to Italy in 1828 emphasizes.[9]

In Florence, Babbage submitted to the Grand Duke Leopold II, who showed an enthusiastic interest in science, a project for the foundation of a European Academy for the advancement of physical sciences. The *Esquisse d'un projet pour la formation d'une Académie Européenne pour l'avancement des sciences physiques*, a manuscript conserved in the State Archive of Florence, was published for the first time by the historian Luigi Bulferetti.[10] It exemplifies Babbage's ambition to promote science as a strongly institutionalized enterprise, capable not only of moulding the human mind to look introspectively at itself and the world, but also of managing political action without being subject to governments, ideologies and religion.

> Comme l'object d'une telle Académie ne doit etre que de faciliter la communication des connoissances et des decouvertes dans les sciences physiques, les recherches qui s'appliquent a la morale, à la politique ou à la religion en seroient rigoreusement exclues.
> Les elections devroient s'arranger d'une telle manière qu'aucune nation n'ait un nombre disproportioné de membres à moins qu'elle ne conte parmi ses savans un très grand nombre d'hommes distingués.
> Il serait à desirer que ni l'etendue ni les rapports politiques d'un pays n'aient aucune influence sur l'election de quelqu'un qui aurait augmenté les connoissances physiques.[11]

The independence of science from non-scientific pressures and authorities did not entail, in Babbage's mind, autarky. He was well aware of the economic necessities for research, as he had learned from his own experience. In the *Esquisse* there is a peculiar and eloquent passage:

> Celui qui voudroit exclus d'une telle Academie des hommes appellés par leur naissance a remplir d'autres devoirs, mais qui auroient aidés la science par leur moyens, manquerait egalement sur les rapports d'interest et de reconnoissance. C'est a cette classe que nous devons nos bibliothèques et nos collections d'histoire naturelle, l'argent necessaire pour les experiences dispendieuses, l'accueil des etrangers savans, et quelque fois même les depenses des expeditions pour les decouvertes.[12]

3. THE IMPORTANCE OF BEING IN TURIN

Babbage understood and recognized the economic needs of science and gratefully acknowledged financing bodies during and after the Difference Engine experience. But after the interruption of work on his first machine and before the start of the new project, the Analytical Engine, Babbage was too proud to ask again for financial support. A letter to his friend Giovanni Plana (1781-1864) — mathematician and astronomer at the Academy of Sciences of Turin and famous in Europe for his theory of the movement of the Moon[13] — clearly expresses Babbage's mood:

> Les parties les plus difficiles de la machine sont déja imaginées et dessinées; peut être les dessins de l'entière machine seront finis dans un an.
> J'ai dépensé beaucoup d'argent dans mes recherches et jusqu'à prèsent je n'ai reçu de mon pays aucun encouragement. Je ne suis pas en état de faire exécuter une machine d'après les dessins, et je ne m'inquète pas, car lorsque [*deleted*: le besoin] l'avantage d'une telle machine sera apprécié, que ce soit de mon vivant ou non, on aura toujours recours a mes dessins.

> Le sujet est en effet trop au dessus de l'intelligence des personnes qui s'en étaient occupées d'abord; et les hommes à la tête de nos affaires, qui en connaitraient le prix, sont trop occupés à conserver leurs places, pour faire la moindre attention à des sujets de haute science.[14]

It is Babbage's awareness of the need to communicate his ideas and to be given the opportunity of being appreciated ("le sujet est en effet trop au dessus de l'intelligence des personnes qui s'en étaient occupées d'abord") which explains the following story and the reason for his trip to Turin. He did not choose the capitals of European mathematics (Paris or Königsberg) but the peripheral Turin seemingly for two reasons: the affinity of his approach to mathematics with the mathematical tradition in Turin and his personal acquaintance with Plana. Plana and his school in Turin represented the disciples of the glorious Lagrangian tradition in Europe, and from the 1810s the Lagrangian tradition was a model for the mathematicians (Babbage and John Herschel among them) of the Cambridge Analytical Society who had promoted the modernization of English mathematics. Babbage's project to construct a machine for mechanizing mathematical procedures also has its roots in this tradition. Turin was the natural place to visit: there Babbage could find a sympathetic reception and scientists capable of understanding the difficult topics he had described to Plana. Nowhere else in Europe could he find both of these qualities.[15]

Babbage's letter, cited above, shows another important aspect: the author's awareness of the need for funding. This demonstrates something somewhat different from Swade's opinion: "daunted perhaps by the fate of the Difference Engine, Babbage expected that if he built an Analytical Engine it would be at his own expense."[16] On the contrary, Babbage says that *he cannot afford* ("je ne suis pas en état de faire exécuter une machine d'après les dessins") the construction of the machine. Babbage writes that at the moment he is not worried ("je ne m'inquète pas") about the fate of the machine. He seems content about one thing which is certain: when the time is ripe, the machine will be built from his ideas and his drawings. Here Babbage is grounding the figure of the solitary intellectual hero: he needs nothing from the world, but the world needs (or will need) him. When thirty years later he wrote his autobiography, the recollection of his visit to Turin was conditioned by the myth that he himself had created:

> In 1840 I received from my friend M. Plana a letter pressing me strongly to visit Turin at the then approaching meeting of Italian philosophers. In that letter M. Plana stated that he had inquired anxiously of many of my

> countrymen about the power and mechanism of the Analytical Engine. He remarked that from all the information he could collect the case seemed stand thus: "hitherto the legislative department of our analysis has been all powerful – the executive all feeble. Your engine seems to give us the same control over the executive which we have hitherto only possessed over the legislative department."[17]

It appears that Babbage yielded to the Italians' pressure and agreed to honour them with a visit. This perspective has become history. Through Hyman's biography, heavily dependent upon Babbage's autobiography and not concerned with the documents kept at the Academy of Sciences of Turin, the image of the prestigious English scientist committed to promote research in a scientifically backward country has been consolidated.

It is true: as organizer and promoter of scientific institutionalization Babbage has left his mark on the history of science. His activities ranged from the reform of the Royal Society to the founding of the British Association for the Advancement of Science.[18] In Florence, during his second trip to Italy, he presented to the Grand Duke the project of a European Academy of Sciences and tried to convince him to support the birth of an *Italian* Association of scientists. Meetings of Italian scientists held since 1839 owe their origin to Babbage.[19] But Babbage's visit to Turin in 1840 had different reasons and aims. This time it was not a prestigious English scientist who raised his hand in a blessing on Italian science. It was as the scientist who had fallen into disfavour looking to regain his prestige abroad. Correspondence with the academicians of Turin provides evidence for this reading.

4. INVOLVING PLANA

In 1828 Babbage's calculating machine was under construction and still benefited from government funding. In 1834, when Babbage conceived the Analytical Engine and presented it to Plana, everything had changed for the worse. The first machine had not been built and the government was no longer interested in Babbage's ideas. In his letter to Plana, Babbage said he was not worried about the future, but other statements show otherwise.

The letter contains a detailed description of the functions of the machine. As he later wrote, it is "a *finite* machine" able to "make calculations of *unlimited* extent."[20] Babbage stresses that it is a completely new project ("elle n'à plus rien à faire avec l'ancienne") much more powerful than the Difference Engine (and for this reason he states: "je ne m'en suis plus occupé dans la suite"[21]). However, together with the letter he sends both the printed version and the minutes of a *Report of the Committee, appointed by the Council of the Royal Society, to consider ... Mr. Babbage's calculating engine* which dated back to February 1829. The question arises: why is he sending an old report concerning the old machine? Because he wants to remind the reader of the excellence of the project, notwithstanding the failure of its realization. In the printed report members of the Committee conclude: "in present state of Mr. Babbage's engine, they do regard it as likely to fulfil the expectations entertained of it by its inventor." In the minutes there is a more prestigious statement, besides the decision to fund the project: "Affirmative. ... while Mr. Babbage's mind is intently occupied on an undertaking likely to do so much honour to his country, he may be relieved, as much as possible, from all other sources of anxiety."[22]

Babbage was looking for Plana's help and advice. This is confirmed by Giuseppe Filippo Baruffi, who visited the English scientist in London in October 1834 with a letter of recommendation from Plana. Babbage had said to Baruffi that he hoped to meet Plana in order to discuss his new project of the Analytical Engine.[23] Babbage's wish becomes clear in the following letter to Plana, sent from London on 30 November 1835. He writes that he is pleased by Plana's understanding of the mathematical principles of the Analytical Engine, and he knows that its description is not enough to fully explain its mechanical structures:

> but I hope you will yourself be able to examine them next summer and I assure you nothing will give me more delight than to give you every opportunity of judging of it for yourself and of discussing with you the varied uses to which it can be applied.

Babbage is warmly inviting Plana to visit him, he wants his Italian friend to be able to appreciate every aspect of the new machine. Babbage confirms that after having finished with the drawings "I shall then rest satisfied that the invention cannot perish and that the want of analysis will ultimately become sufficiently great to demand its completion." But still at the end of the letter he renews the invitation to Plana to come to England the following summer, mentioning the meeting of the British Association for the Advancement of Science at Bristol "about the end of August. I hope you may be able to be present."[24]

Like the previous letter, this one speaks the language of resignation: "I shall then rest satisfied... ," but Babbage has no intention of resting and waiting. He knows that he can (and therefore must) stimulate interest in his machine. Asking Plana to come to England might reopen the debate about his project: Plana, as a celebrated scientist, would be able to understand mathematical and mechanical details and be able to speak of the Analytical Engine to the assembly of the British Association for the Advancement of Science.

Unfortunately Plana declined his friend's invitation. Babbage waited for a new occasion to involve the famous mathematician. It came in September 1840 with the second meeting of Italian scientists in Turin.[25] Plana invited his English colleague to collect his models and drawings of the Analytical Engine, to come to Turin and to present his project to some scientists of the Academy of Sciences.

> As soon as the first bustle of the meeting had a little abated, I had the great pleasure of receiving at my own apartments, for several mornings, Messrs. Plana, Menabrea, Mossotti, MacCullagh, Plantamour, and others of the most eminent geometers and engineers of Italy.
> Around the room were hung the formula, the drawings, notations, and other illustrations which I had brought with me. I began on the first day to give a short outline of the idea. My friends asked from time to time further explanations of parts I had not made sufficiently clear. M. Plana had at first proposed to make notes, in order to write an outline of the principles of the engine. But his own laborious pursuits induced him to give up this plan, and to transfer the task to a younger friend of his, M. Menabrea, who had already established his reputation as a profound analyst.
> These discussions were of great value to me in several ways. I was thus obliged to put into language the various views I had taken, and I observed the effect of my explanation on different minds. My own ideas became clearer, and I profited by many of the remarks made by my highly-gifted friends.[26]

5. "THE GREAT OBJECT OF MY VISIT TO TURIN..."

In accepting the invitation to Turin in 1840 Babbage was aiming not to lecture Italian scientists about the Analytical Engine, but rather to secure international support and to counterbalance English dismissal of his project.[27] This appears evident when considering Babbage's behaviour after his return to England. He stayed in contact with the Academicians of Turin, writing to Plana and to the geologist Angelo Sismonda; he accepted the honour of his election as foreign fellow of the Academy on 10 January 1841;[28] he repeatedly invited Plana to deliver a report on the Analytical Engine to an official session of the Academy.

In a letter to Sismonda on 24 March 1841 he was quite explicit about the nature of his relationship with the Academy of Turin:

> The great object of my visit to Turin was to convey to Plana and to some of the analysts of Italy the principles on which I had contrived an engine to perform - as he has beautifully expressed it – "the whole executive of Analysis." The discovery is so much in advance of my own country and I fear even of the age, that it is very important for its success that the fact should not rest upon my own unsupported authority. I therefore selected the meeting at Turin as the time of publication partly from the celebrity of its Academy and partly from my high estimation of Plana, and I had hoped that a report on the principles on which the Calculating Engine is founded would have been already made to the Royal Academy. I am aware of the difficulty of the subject and of Plana's ill health; but you have amongst you several others who favored me with their attention who are quite able and I hope not unwilling to assist him. If you could in any way accelerate this report it would be of great importance.[29]

As if this were not clear enough, the *Postscript* reiterates Babbage's major concern: "I have just received a letter from Plana but I fear no Report has been made to the Academy."[30] And so it was. Consequently the Academy proceedings did not publish a presentation of Babbage's machine.[31]

Nevertheless he was able to gain the international prestige he was looking for and he began once again to solicit his government for attention. His election as foreign fellow of the Academy of Turin and, even more important, the publication of Menabrea's article offered him the chance to regain his reputation in England and to clear up all misunderstandings about his project. In Babbage's words, Menabrea's paper and his English version, revised and increased by Ada Augusta Lovelace (Byron's daughter), "taken together furnish, to those who are capable of understanding the reasoning, a complete demonstration *that the whole of the developments and operations of analysis are now capable of being executed by machinery.*"[32]

6. PRESTIGE AND NEW HOPES

In Turin Babbage found what he had been looking for: understanding and recognition for his Analytical Engine. And he found something that, in his opinion, his compatriots had forgotten:

> I feel that the respect with which I was treated was yielded to the objects I pursued rather than to the individual who cultivated them, and that the highest in rank as well as the most elevated in understanding had expressed in their kindness towards myself their own deep conviction of the importance of science for the happiness of mankind.[33]

He was awarded the Common Cross by the King in Turin and, even though it was not a very important honour, he used the occasion once again to denounce England: "I am confident as distinction so honorably conferred, so entirely free from any of those political or family motives which too frequently destroy the value of such distinctions in my own country would throw a glean of sunshine over her [Babbage's mother's] remaining years."[34]

Such a private utterance – as the reference to his mother – is not surprising. Meeting Plana and the academicians of Turin was a unique experience in Babbage's life. To Sismonda he wrote: "I beg you to present my best respects to my valued friends the Count of Salluce and his brother: assure them and my many other friends that I look back at the period which made me personally acquainted with them as one of the happiest of my life."[35]

During his trip to Turin, Babbage personally experienced those values (like international co-operation and devotion to research) which he had tried to spread promoting science and scientific organization in England and abroad.[36] Babbage was impressed by the curiosity and enthusiasm he found within and outside the Academy. Even the King, "whose appreciation of science had already excited my admiration,"[37] was moved by Babbage's competence and love for knowledge. It is meaningful that the dedication of Babbage's autobiography is "to Victor Emmanuel II, King of Italy." This dedication is far from conventional:

> Sire,
> in dedicating this volume to your Majesty, I am also doing an act of justice to the memory of your illustrious father.
> In 1840, the King, Charles Albert, invited the learned of Italy to assemble in his capital. At the request of her most gifted Analyst, I brought with me the drawings and explanations of the Analytical Engine. These were

thoroughly examined and their truth acknowledged by Italy's choicest sons.
To the King, your father, I am indebted for the first public and official acknowledgment of this invention.
I am happy in thus expressing my deep sense of that obligation to his son, the Sovereign of united Italy, the country of Archimedes and Galileo."

It is this "sense of obligation" which expresses the meaning of Babbage's scientific trip to Italy: not the voyage from centre to periphery, but the search for prestige and new hopes.

7. A REVERSE PERSPECTIVE

Babbage's life and dreams offer us much food for thought. I would like to make a general remark. Until 1833 Babbage was capable of harmonizing some different aspects of his enterprise: the values of scientific research, which is in principle only dependent on its own requirements; the needs of society, through a fascinating rhetoric of modernization; and the expectations of the public financing body, with a satisfactory relationship between science and politics. The failure of the first machine destroyed this balance and Babbage was overwhelmed by his own ambition to keep under control so many diverging forces. Soon politicians refused to consider the financial and economic payback of the calculating engine, became suspicious about the correspondence between pure and applied science, and decided that it was unwise to fund long term projects. If one thinks how the computer is changing our world, it is stimulating to wonder what the impact of the Analytical Engine in the nineteenth century could have been.[38] From this point of view, Babbage's story is paradigmatic if one is looking for arguments in order to explain to government agencies what the consequences are of concentrating public funding on applied sciences and neglecting pure research.

Even Babbage's visit to Turin stimulates some questions and comments. Of course, they are less general and relate to some specific aspects of our work as historians. Babbage's trip to Turin is not easy to interpret. Does it offer some new inklings that may help to identify the relationship between "centre" and "periphery" in science? Or is it not a "centre-periphery" case at all? Babbage's biographer describes it as a standard situation: Babbage, the important scientist of a "central" country, tries to stimulate the scientific organization and activity in a "peripheral" country. According to this reconstruction, the Italians "asked him if he could suggest any methods for aiding the progress of science in Italy" and he "accepted an invitation from Plana to present the Analytical Engine before the assembled philosophers of Italy."[39]

The archival sources of the Academy of Sciences in Turin reverse this perspective. The active party in promoting the meeting with the mathematicians of the Academy was Babbage. It was Babbage who asked for help and support from some of the few people who were capable of understanding his reasoning and his mathematics. It was Babbage who was looking for international recognition in order to regain prestige in his own country.

This perspective comes out in the archival sources previously neglected by historians and it is convincing if one considers the extraordinary importance of the calculating machine in Babbage's life. The machine was more important to him than anything else. He was not interested in honours or academic positions. When elected Lucasian Professor of Mathematics at Cambridge (1828), Babbage wanted to refuse the position in order to avoid distractions from his work on the Difference Engine, and in 1839 he resigned from the appointment for the same reason. After the first failure he felt that he could not dedicate his energies to anything other than the machine.[40] The fact of holding the Lucasian chair, like Newton one century earlier, meant little to Babbage. As a scientist he had enough prestige and power to fight against the Royal Society and to establish a rival association, the British Association for the Advancement of Science, but he was not satisfied. He judged himself according to his success in projecting and constructing the calculating engine. He measured his prestige according to the appreciation for his work on the machine. After the failure of the first Difference Engine he felt he had fallen into disfavour in his own country. When he had ascertained that British scientists and politicians did not support his new project of the Analytical Engine, he asked for help and understanding abroad. He asked Plana to join him at the Bristol meeting of the British Association for the Advancement of Science. Later, as we have seen, he decided to go to Turin. The Italian mathematicians appreciated his work and the King encouraged his enterprise: it was enough to receive the Common Cross, the only official honour he ever accepted.

Babbage's trip to Turin is difficult to judge having in mind the standard dichotomy of "centre and periphery." It warns us against the use of "centre" and "periphery" as entities defined once and for all. It warns us against the accommodation of historical sources in order to fit within the "centre-periphery" frame. "Centre" and "periphery" are historiographical concepts. They are created and modified when historians take into account new documents and write their case studies. The discovery of new sources can contribute to bring into question old perspectives.

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NOTES

[1] *Atti della seconda riunione degli scienziati italiani tenuta in Torino nel settembre del 1840* (Torino: Tip. Cassone e Marzorati, 1841), p. 47: "The distinguished Mr. Babbage of London, come to shed lustre on our Assembly, frequently gathered at his residence many members of our Section, demonstrating many products of his fertile intellect. Among them he described the project of a very ingenious machine for performing both numerical and algebraic calculations. If such a machine could be built, it would certainly be an enormous advantage to Society."

[2] Babbage, *Passages from the Life of a Philosopher* (London: Longman-Green, 1864), p. 137.

[3] On the projected reform and the role of the 1830 book, see Anthony Hyman, *Charles Babbage. Pioneer of the Computer* (Princeton: Princeton University Press, 1982), pp. 88-102.

[4] Cited in Doron Swade, *Charles Babbage and his calculating engines* (London: Science Museum, 1991), p. 26.

[5] Hyman, *op. cit.* (3), p. 181: "in 1840 ... Babbage did feel ready, and accepted an invitation from Plana to present the Analytical Engine before the assembled philosophers of Italy." But Babbage did not speak of his project at the Meeting of Italian scientists.

[6] Luigi Federigo Menabrea di Valdora, "Notions sur la machine analytique de M. Charles Babbage," *Bibliothèque universelle*, 41 (1842), 352-376.

[7] Babbage, *Passages*, *op. cit.* (2), pp. 135-136.

[8] Babbage, *Passages*, *op. cit.* (2), p. 430: "in 1827 I visited Italy, and during my residence at Florence had many opportunities of observing the strong feeling of the reigning Grand Duke Leopold II, not only for the fine arts, but for the progress of science, and for its application to the advancement of the arts of life."

[9] See Hyman, *op. cit.* (3), pp. 67-72. His first time in Italy was in summer 1821 (see Hyman, *op. cit.* (3), pp. 60-61) but there is no indication of more than a touristic interest.

[10] See appendix V (pp. 123-125) in L. Bulferetti, "Un amico di Charles Babbage: Fortunato Prandi," *Memorie dell'Istituto Lombardo di Scienze e Lettere. Classe di lettere*, XXX (1968), 82-165. A second publication of the manuscript, seemingly without Bulferetti's knowledge, was by Giuliano Pancaldi, "Nuove fonti per la storia dei congressi. Scritti inediti di Charles Babbage, Carlo Luciano Bonaparte e Lorenz Oken," in G. Pancaldi, ed. *I congressi degli scienziati italiani nell'età del positivismo*, (Bologna: CLUEB, 1983), pp. 181-201 (see pp. 184-187).

[11] Babbage, *Esquisse d'un projet pour la formation d'une Académie Européenne pour l'avancement des sciences physiques*, Archivio di Stato di Firenze, Segreteria di gabinetto, Appendice n. 69/3, 9. The quotation is from Bulferetti, *op. cit.* (10), p. 123.

[12] Babbage, *Esquisse d'un projet pour la formation d'une Académie Eurpéenne pour l'advancement des sciences physique*. The quotation is from Bulferetti, *op. cit.* (10), p. 124.

[13] Amongst his contributions (mathematical analysis, mathematical physics, astronomy, geodesy), his masterwork was *Théorie du mouvement de la Lune*, (Turin: Imprimérie Royale), 1832, the solution of the lunar movement problem based only on the law of universal gravity.

[14] Accademia delle Scienze di Torino, Plana II 13, n. 12, sheets 5-6. The handwriting is not Babbage's and the document does not bear a date or Babbage's signature. It is a French translation – not by Plana: it is not his handwriting. Its content suggests a date around the end of 1834 and the beginning of 1835 (see sheet 1: "la prémière machine je l'avais commencée il y a environ 14 ans").

[15] I thank Massimo Mazzotti for having discussed with me this aspect of the history of mathematics.

[16] Swade, *op. cit.* (4), p. 12.

[17] Babbage, *Passages*, *op. cit.* (2), p. 129. Babbage had appreciated Plana's metaphor so much, that he had already quoted it in a letter of 24 March 1841 to Angelo Sismonda (Accademia delle Scienze di Torino, Archivio, cart. 22341).

[18] Hyman, *op. cit.* (3), chap. 7.

[19] See Pancaldi, "Nuove fonti per la storia dei congressi," *op. cit.* (10), pp. 181-182.

[20] Babbage, *Passages*, *op. cit.* (2), p. 128. Description of the machine covers 7 sheets of 8 of the letter: Accademia delle Scienze di Torino, Plana II 13, n. 12, sheets 2-8.

[21] Accademia delle Scienze di Torino, Plana II 13, n. 12, sheets 8 and 1.

[22] Accademia delle Scienze di Torino, Plana II 13, n. 11 and n. 10.

[23] Baruffi's meeting with Babbage was narrated by himself in *Pellegrinazioni autunnali ed opuscoli* (Torino: Cassone e Marzorati, 1840), pp. 279-280, and recalled by Plana's biography: Albert Maquet, *L'astronome royal de Turin Giovanni Plana (1781-1864). Un homme, une carrière, un destin* (Bruxelles: Palais des Académies, 1965), p. 161.

[24] Accademia delle Scienze di Torino, Plana II 13, n. 14.

[25] It is worth mentioning that Babbage declined the invitation of the Grand Duke of Tuscany to be present at the first meeting of Italian scientists, held at Pisa in 1839. He was one of the promoters of the historical event, but he did not participate. Was his decision perhaps connected with Plana's absence from Pisa?

[26] Babbage, *Passages*, *op. cit.* (2), p. 130.

[27] Babbage did not speak at the Meeting. On 29 September 1840 Menabrea described Babbage's idea for collecting in a book all the "constants of nature." The Proceedings of the Meeting mention that Babbage met privately some of the Italian scientists to discuss the Analytical Engine (*Atti della seconda riunione degli scienziati italiani tenuta in*

Torino nel settembre del 1840, Torino, *op. cit.* (1), pp. 46-47). It is also worth mentioning that he did not attend any other meeting of the Italian scientists. He definitely went to Turin to meet Plana and his scholars.

[28] His election as "socio corrispondente" was proposed by Plana, Sismonda and Menabrea (Accademia delle Scienze di Torino, Archivio, Cat. III, Adunanze di Classe e Verbali, Classe I, Mazzo 22, p. 35).

[29] Babbage to Sismonda, 24 March 1841 (Accademia delle Scienze di Torino, Archivio, cart. 22341-22342). Hyman, *op. cit.* (3), p. 185 quotes part of this same letter (from the manuscript kept at the British Library: the text is slightly different). It is the only passage where he admits that Babbage went to Turin not to give but rather to obtain support.

[30] Babbage to Sismonda, 24 March 1841 (Accademia delle Scienze di Torino, Archivio, cart. 22342).

[31] The only official record of Babbage's visit is in the minutes of the 22 November 1840 session at the Academy of Sciences: Plana read a letter informing them that Babbage had made the Academy a present of drawings and a wood model of the Analytical Engine (Accademia delle Scienze di Torino, Archivio, Cat. III, Adunanze di Classe e Verbali, Classe I, Mazzo 42, p. 227).

[32] Babbage, *Passages*, *op. cit.* (2), p. 136.

[33] Babbage to Sismonda, 1 December 1840 (Accademia delle Scienze di Torino, Archivio, cart. 22339).

[34] Babbage to Sismonda, 1 December 1840 (Accademia delle Scienze di Torino, Archivio, cart. 22339-22340).

[35] Babbage to Sismonda, 24 March 1841 (Accademia delle Scienze di Torino, Archivio, cart. 22342).

[36] In *Reflections on the decline of science in England and on some of its causes*, (London, 1830) he denounced the lack of values in English science: it was a strong attack on the scientific establishment which contributed to Babbage's isolation in England.

[37] Babbage to Sismonda, 1 December 1840 (Accademia delle Scienze di Torino, Archivio, cart. 22339).

[38] The argument is intriguing and is the plot of a novel: William Gibson, Bruce Sterling, *The Difference Engine* (New York: Bantam Dell, 1991).

[39] Hyman, *op. cit.* (3), pp. 72 and 181.

[40] Babbage, *Passages*, *op. cit.* (2), pp. 29-31.

ANA CARNEIRO, DORES AREIAS, VANDA LEITÃO, LUÍS TEIXEIRA PINTO

THE ROLE OF TRAVELS IN THE INTERNATIONALISATION OF NINETEENTH CENTURY PORTUGUESE GEOLOGICAL SCIENCE

1. INTRODUCTION

This paper focuses on the importance of travelling to the internationalisation of Portuguese geology, in the nineteenth century, taking into consideration both the mainland and overseas territories. First, however, it is worth analysing the context in which this process occurred.

In both the eighteenth and nineteenth centuries Portuguese science is not rich in cases in which scientific production achieved internationalisation. In general, when internationalisation occurred this was due to the fact that some Portuguese men of science lived or spent considerable periods of time abroad.[1] Therefore, their contributions are grounded more in international standards of scientific practice than in what might be called "Portuguese science." By this expression is meant the articulation and conjugation of a local scientific tradition with the criteria established by the international community for the practice of a scientific discipline. In the eighteenth and nineteenth centuries Portuguese science may be characterised, among other aspects, by certain insularity and by the lack of a regular and consistent output.

In the nineteenth century, geology as practised in the context of the Geological Survey of Portugal went through a golden period, achieving some international prestige. Various factors contributed to this unusual situation, some more directly linked to the nature of geological knowledge, others deriving from both the national and the international contexts.

First, geology is a science to which political and administrative boundaries are irrelevant, because the boundaries of geological units do not comply with territorial conventions or nationalistic prejudices. In its essence, in addition to being intrinsically historical, geology has inherently a spatial dimension, which makes it a transnational science. Thus, when dealing with geological data, there are no political or scientific peripheries. A country

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with little political influence and generally irrelevant from a scientific point of view may become geologically significant if it possesses geological or palaeontogical features which may be decisive for the affirmation or refutation of geological hypotheses or models. While on the one hand this led nineteenth-century geologists to cross borders and spend considerable periods of time studying geological units in foreign countries, on the other, it made the contributions of geologists of peripheral countries relevant to those of the centres.

In the nineteenth century territory was envisaged as a resource to be conquered, dominated and exploited, since territorial expansion would bring wealth and power.[2] This concern in effectively occupying and controlling territory extended from the mainland to the colonial possessions of European empires. The creation in Portugal of institutions devoted to territorial surveys should be understood in this context. In 1848, the first Geological Survey was founded as part of the Academy of Sciences of Lisbon. Its main purpose was to carry out a geological description of the country and to produce an inventory of materials useful to civil works, of strata, which might provide fuel, and of metal mines. A geological map was to accompany these descriptions. In addition to these tasks, the Survey had to organise mineral and geological collections.[3] This institution, however, was to be officially suspended in 1855 due to a lack of personnel and funds, and was later re-instated in a different institutional setting.

Meanwhile, in 1852, within the Ministry of Public Works Trade and Industry (MOPCI), an essential structure of the Liberal Regime, the Geodesic Office was created, with the main purpose of making geographic, chorographic and hydrologic charts.[4]

In 1857, the Geological Survey was re-established as a section of the Geodesic Office of the MOPCI. The Survey was led by the geologists Pereira da Costa (1809-1888), professor of mineralogy, geology and metallurgy at the Lisbon Polytechnic School, and Carlos Ribeiro (1813-1882), a military engineer. Later on, in 1882, Ribeiro was succeeded by another military engineer, Néry Delgado (1835-1908) who led the Survey until 1908.[5]

One of the direct causes which favoured the internationalisation of Portuguese geology was the very dynamics of the MOPCI, which acted as a "centre of calculation."[6] The many technical and scientific activities of the Ministry are characterised by an unusual concern in keeping its enterprises in accordance with international standards, which translated into the importation of technology associated with railways and the telegraph; the building and improvement of bridges, roads and ports; regular stays abroad of engineers working under its jurisdiction with the purpose of improving techniques and methods, which were regularly applied and reported in the Ministry's journal, the *Boletim de Obras Públicas e Minas* (Bulletin of Public Works and Mining); and finally, the application of statistics, and the official introduction of the decimal metric system nation-wide. Despite the lack of a comprehensive historical assessment of the endeavours of the MOPCI, it can be said that the activities of its various offices represented a tremendous effort towards the modernisation of the country, taking into account the state of under-development in which the Regeneration government took over the country, in the 1850s. This effort, however, was hardly acknowledged by large sectors of the intellectual elite, in particular, the so-called "70s Generation" as Filomena Mónica argues convincingly.[7] This was a group of Portuguese intellectuals and writers, ideologically very much inclined to Republicanism and utopian Socialism, and strongly influenced by French culture. Their meetings, the Casino Conferences, and writings stirred Portuguese society and the political sphere by vigorously criticising the backwardness of the country. However, its members failed to recognise and support the steps taken by technicians and engineers to promote applied science and technology, in an attempt to endow the country with fundamental technology-based structures. There was not even a two-culture debate, since the two sides of the Portuguese intellectual elite, the literary and the technical, simply ignored each other.

Needless to say, as part of the MOPCI, the Geological Survey, despite its many difficulties, was to profit from the dynamics of this governmental institution. From 1857, we can identify a clear intention towards the internationalisation of the geological research carried in the context of the Survey through a strategy which encompassed various fronts, of which travelling was an important one.

The Survey geologists engaged in an intense exchange of correspondence with foreign experts. Indeed, they discussed scientific questions with foreign geologists and palaeontologists rather than with their Portuguese colleagues working in higher education, whose outcomes seemed to be embedded in a distinct scientific culture. Despite the need for further historical research, geologists working in the context of Portuguese academia seem to have been cabinet scientists rather than field researchers, as were those working in the Geological Survey.

The Survey geologists regularly published the results of their research; in particular, they published monographs and memoirs in French, especially after the 1860s, with the clear intent of internationalising their work. This effort was complemented by subscriptions to various specialist foreign journals, the regular acquisition of foreign books and maps and the creation, in the 1890s, of the Survey journal, the *Comunicações dos Serviços Geológicos de Portugal.*

Occasionally, the Survey also resorted to the collaboration of foreign experts: the Swiss palaeontologist Oswald Heer (1809-1883) who studied the flora of the Tertiary between 1880-1881;[8] the Frenchman Marquis of Saporta (1823-1895) who worked on the Mezosoic flora, in 1890;[9] C. L. P. de Loriol Le Fort (known as Perceval de Loriol (1828-1908), a Swiss expert who analysed the Cretaceous and Jurassic faunas, in 1888, 1890 and 1896.[10] Finally, the Survey contracted the Swiss geologist Paul Choffat (1849-1919) on a permanent basis, and he lived in Portugal from 1879 to 1919.

Of the various strategies put in place by the Portuguese Survey, undoubtedly travelling played a major role at various levels: in shaping the standards of research practices; in negotiating interpretations of geological data with foreign experts; in affirming abroad work carried out locally, notably with the participation of Survey geologists in the meetings of the International Geological Congress; and finally in attempting to systematise geological data coming from missions carried out in Portuguese African colonies, either by isolated individuals or in the context of the Geographical Society of Lisbon.

2. TRAVELING AS A STRATEGY OF INTERNATIONALISATION

2.1 Foundational Travels to the Centre

As already stated, in 1857 the Portuguese Geological Survey was re-established as a part of the Geodesic Office at the MOPCI.[11] Its main purpose was to carry out a survey of the general geological constitution of the different Portuguese regions. As the work progressed, the almost total absence of means soon became clear, in particular the lack of reference collections with which geological rocks and fossils could be compared. In addition, geologists also lacked instruments required for fieldwork, books and specialised journals. The urgent need to establish scientific relationships with similar European institutions and specialists was also unanimously recognised. On 22 June 1858 the Geological Survey proposed that the Government send abroad one of its members, as a first move to tackle these difficulties. Permission came at the end of June,[12] and Carlos Ribeiro was assigned the mission of going to Spain, France, Italy, Austria and the German States in order to fulfil the following aims:[13] to carry out a revision of the fossil collections of the Tertiary basins of the rivers Tagus and Guadiana already classified by the Geological Survey, by comparing them with foreign collections; to purchase books on palaeontology and geology indispensable to office work; to purchase physical and topographical instruments, and apparatus for photography and chemical analysis; to acquire reference collections to be used in the classification of the Survey's collections and compare them with the "primitive faunas" of the Western Peninsula and those of Europe; and to establish scientific relationships with foreign institutional counterparts, geological societies and foreign experts on geology and palaeontology.

On 4 July 1858, Carlos Ribeiro departed from Lisbon, arriving in Paris eight days later. He took with him fossil samples from the Tertiary basins of the Tagus and the Guadiana, and thanks to the intervention the Portuguese ambassador, the Viscount of Paiva,[14] he was introduced to Elie de Beaumont (1798-1874). Beaumont gave Ribeiro access to the collections of the Ecole des Mines[15] and advised him to see Achille Valenciennes (1794-1865), professor of conchology at the Jardin des Plantes.[16] Valenciennes made available to Ribeiro the palaeontological collections, the laboratory, his substitute lecturer, and his *préparateur* to help him in revising the classification of Portuguese fossils. However, the collections of the Jardin des Plantes only enabled them to compare and analyse one tenth of the items.

Ribeiro then decided to approach the palaeontologist G. P. Deshayes (1796-1875), who allowed him to use his library and fossil collections.[17] He took the initiative to revise the items of the Portuguese collection, leaving to the Portuguese Survey the task of publishing the classification of new species, which nevertheless he did categorise. The revision of the classification of the collection of the Tagus and Guadiana basins took much of Ribeiro's time in Paris, and made him stay longer than anticipated.[18]

Carlos Ribeiro left Paris for Vienna on 29 September, taking with him a reference letter from Deshayes addressed to M. Hörnes (1815-1868), then director of the Imperial and Royal Mineralogical Cabinet. In Vienna, in addition to Hörnes, Ribeiro met W. K. Haidinger (1795-1871), advisor to the imperial government, president of the Imperial Geographical Society, and director of the Geological Institute of Vienna. He also became acquainted with F. Rolle (1727-1887), E. Suess (1831-1914) and Gratelich (?-?), all geologists working both at the local university and at the Imperial Cabinet of

Mineralogy and Palaeontology. Carlos Ribeiro hints at the reaction of his Austrians colleagues to his visit:[19]

> I was most welcomed by these German [sic] experts, who truly love science. It was the first time they had ever seen a Portuguese individual, who claimed to be a geologist, and gave them some news about Portuguese geology. They already knew all geologists of all parts of Europe, with whom they had scientific and personal relationships.

Accompanied either by Hörnes or Rolle, Ribeiro was able to thoroughly examine the Imperial Cabinet. Hörnes remarked that the collection lacked samples both from Portugal and Spain, and the Portuguese geologist promised to send some items as soon as possible.

After visiting nearby cities such as Baden, Karlsburg, Rotan, Bertholdsdorf and Grinzing, Ribeiro went to Hungary, accompanied by Suess. Bohemia was one of the regions he wished to visit in order to examine the Carboniferous basin and also to contact A. E. Reuss (1811-1873),[20] but most especially to meet Joachim Barrande (1799-1883).[21]

Ribeiro returned to Vienna on 14 October to leave for Trieste via Adelsberg. A visit to Laibak and to Carinthia was also part of his programme, mainly because these regions were known for the use of charcoal in iron-smelting. In particular, he wished to examine the industrial and economic policies implemented in the most famous foundries. However, these visits would take 15 days to a month, which was outside Ribeiro's permit.

From Trieste he went to Padua via Venice. Haidinger had written letters to some Italian colleagues informing them of Ribeiro's arrival. He met Salvadio (?-?) and Baron Achille de Zigno (1813-1888), then professor at the University of Padua, who gave him various publications. From Padua, Ribeiro left for Turin, where he arrived on 22 October to meet various Piemontese geologists and naturalists such as Angelo Sismonda (1807-1878) and L. Bellardi (1818-1899). They accompanied the Portuguese geologist on a two-day visit to the Tertiary formations on the right bank of the River Po, and to the local Natural History Museum.[22]

From Turin, Ribeiro returned to Paris to meet Viscount E. J. d'Archiac (1802-1868), P. E. Verneuil (1805-1873), A. T. Brogniart (1801-1876), H. Milne Edwards (1800-1885) and A. E. Delesse (1817-1881). While he waited for the material he had ordered he decided to go to Bordeaux and Toulouse, where he met A. Leymerie (1801-1878)[23] and F. V. Raulin (1815-1905).[24] Ribeiro returned to Paris on 18 November. Two days later he left for Madrid, where he arrived on 1 December.

In the Spanish capital Ribeiro established contacts with Cassiano de Prado (1797-1866), vice-president of the Spanish Geological Survey, Guilherme Schultz (1800-1877)[25] and Joaquín Ezquerra del Bayo (1789-1859), chief mining engineer of Spain, Juan Vilanova y Piera (1821-1893) and José d'Aldama (?-?), also mining engineers. Vilanova accompanied Ribeiro to the Madrid Natural History Museum, and Aldama showed him the Mining School, where the Portuguese geologist had the opportunity to examine the collections. Ribeiro returned to Lisbon on 14 December 1858.

In addition to meeting European geologists, another purpose of Ribeiro's mission abroad was to buy instruments and other fieldwork equipment. He was asked to buy a dredging machine to be used in the exploration of the Portuguese coast. He also ordered a portable dredge, a rake for shallow waters, and a machine to extract corals from deep waters. These instruments were to be used to collect not only geological items but also species as required for the study of the Portuguese maritime fauna.

In Paris Carlos Ribeiro also bought three Captain Brunier compasses, a sextant, a portable theodolite, a topographic compass with a lunette, four Fortin barometers to measure altitude, and two aneroid barometers. The purchase of these topographic instruments was of paramount importance to the Geological Survey because they greatly reduced the workload of geologists.

A kit for mineral analysis was also purchased, which included equipment for the analysis of mineral and sulphurous water, as well as two sets of thermometers to determine the temperature of spring water.[26] Finally, he also bought a microscope and a camera with various accessories.[27]

Another purpose of Ribeiro's mission was the acquisition of textbooks and reference books to endow the library of the Geological Survey. As he was given complete freedom to decide which items to buy, he sought the advice of Deshayes and d'Archaiac in Paris, and Suess and Hörnes, in Vienna. He bought various German, French, British, Spanish and Italian books and periodicals on geology and palaeontology, the majority of which were totally unknown to Portuguese libraries and unavailable in national bookshops.[28] In addition, in Paris, Vienna, Turin and Madrid he purchased various atlases and collections of geographical and geological maps, in particular R. Murchinson's (1792-1871) European geological map, the geological map of France, and that of the Austro-Hungarian Empire produced by Haidinger.

Regarding the reference collections, Ribeiro approached the geologist L. Saemann (1821-1866), who had been recommended by German and French geologists as the most suitable supplier. Notably, he had supplied the Imperial and Royal Mineralogical Cabinet of Vienna. Ribeiro purchased a collection of echinoderms from different Mesozoic and Tertiary formations of Europe, another of Miocene fossils from the Tertiary marine basin of Southwest France (Bordeaux and Dax),[29] and ordered a collection of Jurassic fossils from France and the Rhine. He also ordered from Deshayes a collection of all species found in the Tertiary basin of Paris, whose classification would be carried out by the French palaeontologist and collector.[30]

As a result of Ribeiro's mission, Portuguese geologists working for the Geological Survey became acquainted with the latest developments in their fields through subscriptions to specialised journals. At the same time the acquisition of reference collections enabled regular classification of fossil and rocks collected in Portuguese territory, often with the advice of foreign specialists. Deshayes, for instance, took the initiative to offer some guidance on the geological research carried out by the Geological Survey whenever necessary and to follow up the publication of prints of fossils if the Portuguese Survey decided to order this kind of work in Paris.[31] They also began corresponding with colleagues abroad, exchanging views and fossil samples.[32] However, the situation was apparently far from satisfactory, as indicated in a report written by Ribeiro and Pereira da Costa to their superiors in 1864 pointing to the lack of adequate bibliographical and reference collections.[33]

The activities of the Geological Survey were suspended again, in 1868, for a period of nearly two years due to deep disagreements between Ribeiro and Pereira da Costa.[34] They were finally resumed at the end of 1869 under Ribeiro and Néry Delgado. However, by then the situation had changed considerably.

Because of his political connections, Pereira da Costa managed to get the Survey's geological collections and the laboratory of chemistry transferred to his workplace, the Lisbon Polytechnic. In this way they became unavailable for further use by members of the Survey, forcing Ribeiro and Néry Delgado literally to start all over again.[35] Furthermore, the composition of the Survey was now quite different. Whereas before it had included (military) engineers as well as academics,[36] under Ribeiro and Néry Delgado its range of expertise was somewhat more limited.[37] In addition, the two geologists had set themselves one main task in the re-instated Survey: to publish Portugal's first geological map on a 1:500 000 scale, a task that was eventually completed in 1876.[38] In pursuing this "territorial imperative"[39] they had to face difficulties associated with the interpretation of stratigraphical data and the need to ensure coherence and transnational correlations. It is likely that the combination of all these circumstances strengthened Ribeiro's and Delgado's resolve to expand the Survey's range of contacts abroad.[40]

2.2 *Travels of Negotiation with Other Peripheries and the Centre*

Following Néry Delgado's admission to the Geological Survey in 1857, he soon became one of the leading Portuguese geologists involved in a scientific international dialogue, due to both his vast correspondence and his travels. He travelled when the Portuguese Geological Survey was better established, and this is why his trips abroad differ fundamentally from the mission to Europe undertaken by Carlos Ribeiro back in 1858.[41] Delgado's main scientific interest became the study of the Palaeozoic, and his contributions in this field earned him an international reputation. In this context, he visited Spain in 1878, in 1881-1882 he travelled to Italy, France, Germany and the Austro-Hungarian Empire, and in 1888 he went to England. He left written reports of all these visits abroad.

At first, Delgado's report on his trip to Spain in 1878 was meant to remain private, as he confides to a Spanish colleague.[42] The normal procedure would have been to address a manuscript to Carlos Ribeiro, then director of the Portuguese Geological Survey, who in turn would have handed it on to the Minister of Public Works. Carlos Ribeiro, however, decided otherwise and published Delgado's report, in this way setting a precedent, which can be read as an important strategic move. By going public he was justifying the very need for travelling as part of the work of a geologist, but more importantly he was legitimising the research carried out by him and by the geologists working under his supervision. Therefore, those in power could not ignore their role, which was reinforced by the fact that in other countries their work was being acknowledged, and similar research was being carried out and held in high esteem.

Delgado's concise and accurate accounts of his travels are rich in details not only relevant to the history of Portuguese science but also to the European history of geology. However, only a selection of a few topics is to be addressed. In particular, a few episodes of his travel to Spain will be dealt with as examples of negotiation of scientific knowledge between two peripheries; aspects of his participation in the meetings of the International Geological Congress in Bologna and London will be discussed as an example of the involvement of peripheries in international affairs; his personal contacts with foreign geologists will show how data from a periphery may become central. Finally, a few impressions of his three journeys will show that he also used them as a subtle way of criticising the inside from the outside.

2.2.1 Sharing Common Ground—Spain 1878

The visit of Néry Delgado to Spain in 1878 was preceded by an intense exchange of correspondence, which was to extend until his death in 1908. This correspondence shows that the relations between geologists of the Portuguese Survey and their Spanish counterparts developed in a friendly climate and in a communion of views grounded in nineteenth century Liberal ideology. They were framed in a kind of chivalric ideal of an international brotherhood of engineers, as the letter of introduction to Delgado of the Spanish geologist Joaquim Gonzalo y Tarin (1838-1910) eloquently shows: "As an engineer of the Mining Corps (...) I have the honour of addressing you with no other merit or link than that which unites the engineers of the various countries."[43]

During his scientific mission in Spain,[44] Delgado visited the provinces of Huelva, Ciudad-Real, Madrid, Leon and Asturias.[45] The purpose of the visit to Huelva was to establish an agreement regarding the classification of the Palaeozoic formations located on the southern borders of the two Peninsular kingdoms; in particular, to compare the results of the research carried out in the Alentejo (Southern Portugal) with those obtained previously by the Spanish mining engineer and member of the Spanish Geological Survey, Gonzalo y Tarin. The visits to Leon and Asturias, in addition, had the purpose of understanding the relationships between the schist formation, which was supposed to contain the "primordial fauna," with contiguous Palaeozoic formations. Néry Delgado wanted to acquire practical knowledge in order to renew research on this topic carried out in Portugal, which up to date had been fruitless. At the same time, he examined sites at Colle and Almaden in the provinces of Leon and Ciudad-Real, which he considered particularly interesting for the study of both the Silurian and the Devonian. Delgado aimed at collecting data which could clarify the investigations on the same systems in Portugal, in particular in Buçaco and Portalegre. In this way new references and means of comparison could be gathered in order to describe as thoroughly as possible the Palaeozoic formations, which for some time — as he rightly claimed — "have been deserving special attention from geologists of all countries."[46]

The excursion to Huelva was the longest, lasting more than three weeks. He was accompanied by Tarin, who had a comprehensive knowledge of the province since he had produced a mining-geographic map of that region. The first scientific issue he discussed with Tarin was the age of the formation on which the city of Huelva was built. Huelva sits on a group of hills composed of clay and fine yellowish/greyish sandstone with characteristics similar to those of the shell marls of Cacela, and near Lisbon, of Adiça and Mutela. The Spanish formations were abundant in fossils, the majority being molluscs similar to those found in Portugal. The fossils of Huelva had been studied by Justo Egozcue y Cia (1833-1900), then professor of geology and palaeontology at the Mining School of Madrid and attached to the Spanish Geological Survey, and Lucas Mallada, a palaeontologist serving the same institution. Given the abundance of certain species, and the existence of others which Egozcue and Mallada thought to be characteristic of the Pliocene, they had classified the fossils of Huelva accordingly, a classification which Tarin accepted.[47] However, Delgado disagreed and contended that the fauna which inhabited Huelva during the Tertiary was the same as had existed in Cacela and in the mouth of the Tagus (Lisbon). The only difference, said, was that some extra species had been found and others had vanished, which only amounted to a modification or local variation; he concludes that "our fauna (...) corresponds perfectly to that of the Vienna basin classified as belonging to the upper part of the middle stage of the Tertiary (Upper Miocene)."[48]

In order to support his view, Delgado reports that he found in the sandstone of Huelva different types of *Foraminifera* also present in the basin of Vienna. This was material proof, which for the moment settled the issue and confirmed his interpretations. The outcome of this negotiation could not have pleased Delgado more: the final conclusion was consistent with the classification that he and Carlos Ribeiro had made in the Portuguese geological map published in 1876.[49] A much smaller country, Portugal already had a geological map, whereas Spain was still struggling to produce a precise national geographic map and thus progress beyond the stage of regional maps. As in a chess game, it was only natural that by then the Portuguese Survey became interested in reaping the advantages of the first move by making Spanish geological interpretations conform to its own.

The analogies of the schist formation of the Lower Alentejo and Huelva with the Taconic of North America, which Néry Delgado had mentioned in his memoir on the Silurian of Alentejo published in 1876,[50] were also confirmed by the recent findings made by his Spanish friend of many years, José MacPherson (1839-1902) of a form of *Arcoeocyathus* (*Archaeociatid*), a polypary, in the limestone occurring in Northern Seville. Up to then, *Arcoeocyathus* had only been found in the sandstone of Potsdam (Canada), but MacPherson's discovery proved the existence of the Cambrian in the south of the Iberian Peninsula.

MacPherson's confirmation of Delgado's views had a special meaning for the Portuguese geologist. Carl-Ferdinand von Roemer (1818-1891), then professor of geology at Breslau, who had contested Delgado's classification of the strata of S. Domingos (Alentejo) as being Silurian,[51] was in this way led to revise his own arguments.[52] However, Delgado recognised that further studies were required in Portugal, notably in the surroundings of Barrancos, a region up to then only barely studied and difficult to explore.[53] He then made a short trip to Seville to meet José MacPherson, and clarify some points regarding *Arcoeocyathus*. Afterwards he moved to Madrid, where he was able to appreciate the efforts of the Spanish Geological Survey, in particular the role of Manuel Fernández de Castro (1825-1895) then presiding over this institution.

2.2.2 Addressing Large Issues Relevant to the Centre and the Peripheries: the Meetings of the International Geological Congress

The first meeting of the International Geological Congress, held in Paris in 1878, marks the formal recognition by geologists of the international character of their science.[54] Subsequently other meetings were organised. They were devoted to geological nomenclature, the range of colours to be used in geological cartography, and the questions and negotiations which inevitably came to surround the preparation of the European geological map.[55]

On his way to Bologna to attend the second meeting of the International Geological Congress, Néry Delgado left Lisbon on 15 September 1881, arriving in Madrid two days later. On this journey he endured the "most unbearable dust and heat," as he confides in his diary, [56] reminding us that travelling can also be a source of some agony. He then proceeded to Barcelona and then to Bologna, where he arrived by rail on 25 September after some delays.

When he checked in, the list for the meeting's permanent committee to be voted on the next day had already been drawn up. Nevertheless, Giovanni Capellini (1833-1922), the President of the Organising Committee, knowing that Delgado would attend as the Portuguese representative, proposed that his name be part of the list as vice-president, a suggestion that was accepted. The voting took place and Delgado became a member of the committee who discussed all issues prior to their presentation to the general assembly.[57] The

Portuguese geologist reports that while in Bologna he received testimonies of the highest esteem not only from Capellini[58] but also from many foreign colleagues. Delgado considered Capellini's courtesy a sign of appreciation regarding the meeting of the International Congress of Palaeoanthropology and Archaeology that had taken place in Lisbon in 1880. Besides its scientific interest, this event proved to be another important strategic move undertaken by Carlos Ribeiro, who in this way managed to put Portugal on the map of international scientific events. Internally, the congress acted as a vehicle for propaganda and legitimisation, as the presence of the Portuguese Royal Family and of key political figures testifies.

The issues at stake in the Bologna session were of considerable importance. Delgado makes an evaluation and hints at the atmosphere surrounding the event: [59]

> The success of the congress was decided when Britain, represented by the knowledgeable Prof. Hughes of the University of Cambridge and by Mr. Topley, member of the *Geological Survey*, indulged in making concessions. They took the initiative to agree upon the use of the word *formation* to mean exclusively and exactly what the French committee suggested.[60] The Germans, represented by the authoritative geologists Beyrich, Hauchecorne1900), Mojsisovics and Zittel, immediately expressed their agreement.

The record of the lively discussions on geological nomenclature that followed is provided by the document written by Edmond Hébert (1812-1890), member of the French delegation. Many questions remained to be discussed in future meetings, but the agreements reached were, according to Delgado, outstanding. The terms for the main stratigraphic divisions were agreed upon, as well as the corresponding divisions in the geologic time scale.

Geologists attending the meeting were well aware of the traditional rivalries between Britain and France, and the long-lasting sequels of the Franco-Prussian War. Apparently, national interests were partially overcome, prompting the following comment from Delgado: [61]

> I have heard many renowned members of the congress saying that it was really extraordinary that the British geologists and after them the Germans were able to make such concessions. Undoubtedly, the conventions will be hard to implement in their own countries, but this fact shows exuberantly the conciliating spirit with which all seemed to be animated.

Delgado adds that although he was personally displeased by some of the conventions, the need for the unification of nomenclature took precedence and deserved to be generally adopted.

As the meeting proceeded, the choice of the colour code to be used in the geological map of the world became intimately linked to the European geological map. A major obstacle was raised when the representatives of Russia and Germany read a formal declaration in which their respective governments opposed the creation of a geological international committee, which would be in charge of a geological map of Europe. Heinrich L. W. Hauchecorne (1828-1900) then director of the Geological Institute of the Mining Academy of Berlin suggested instead that a committee should be secretly elected, and Delgado proposed that its composition should be reduced to a bare minimum. It was then agreed that the committee would be composed of representatives of 5 nations[62] and would be responsible for the publication of a geological map, which as Delgado emphasised was not of central Europe, but of Europe.[63] If keeping the committee small was a diplomatic way of avoiding bad feelings from those potentially excluded, emphasising that the whole of Europe would be involved was undoubtedly a means of relieving the tension between neighbouring empires eager to display individually their territorial power and to prevent foreign interference. According to the new formula, each state would contribute a proportional sum to cover expenses, and Berlin was chosen as the headquarters of the European map commission. Later on, in a letter addressed to the French archaeologist, Baron Baye (1853-1931), Delgado discloses some backstage manoeuvring. Baye was at that time having problems with the Germans regarding the organisation of the meeting of the International Congress of Palaeoanthropology and Archaeology. Delgado advised him and explained that choosing a German city to host an important event (as happened with the European geological map) had proven to be an effective move to circumvent political skirmishes and a way to get the Germans to agree on an international project.[64]

In fact, the Bologna meeting of 1881 closed with the announcement that the next session would be held in Berlin, in 1884. Néry Delgado did not attend the Berlin session, for reasons to be clarified, but he was sent to the London meeting, in 1888.

In his report of 1888, he begins by recognising that the number of associates of the International Geological Congress had grown substantially, as had the number of participants in the London meeting.[65] The programme consisted of discussions of topics which had not been addressed in Berlin or had been only partially discussed. The classification of Cambrian and

Silurian rocks and Tertiary strata, together with the European Geological Map, were again central issues. An additional session was devoted to crystalline schist and to various topics on nomenclature, though with a flexible character. Delgado reports that the congress advised that norms should not be strict, otherwise instead of contributing to the progress of science they would turn into obstacles.[66]

One of the issues addressed was the division of the Lower Palaeozoic, a question that divided British geologists, and the British from the Americans. The divisions of the Palaeozoic had a long tradition of controversy, notably between Murchinson and Adam Sedgwick (1785-1873). At this meeting Charles Lapworth (1842-1920), based on Charles Lyell (1797-1875), suggested the names Cambrian, Ordovician and Silurian. Henry Hicks (1837-1899), Sterry Hunt (1826-1892) and Friedrich H. E. Kayser (1845-1927) agreed but John E. Marr (1857-1933) suggested the name Barrandian instead of Silurian. He wished to honour his opponent in the dispute over Barrande's colonies. Gilles J. Gustave Dewalque (1828-1905) supported the views of the American sub-committee and favoured the names Taconic, Cambrian and Silurian. A lively discussion ensued involving various renowned geologists and palaeontologists including Sir Archibald Geikie (1835-1924).[67] However, a consensus was reached regarding the tripartite division of the Lower Palaeozoic, leaving a more definitive agreement regarding the names of these divisions to the next meeting in Philadelphia.

2.2.3 Discussing Data and Interpretations in the Centre. How Geological Data from a Periphery Becomes Central

After the Bologna meeting of 1881, Néry Delgado visited Germany, the Austro-Hungarian Empire and France. He reports that while in Bologna he had discussed the engravings of Silurian fossils he had brought along with him, with the American geologists James Hall (1811-1898) and Thomas Sterry Hunt, the British geologist Thomas McKenny Hughes (1832-1917), the Italian Giuseppe G. A. Meneghini (1871-1889) and the German Karl A. von Zittel (1839-1904). Delgado says that they expressed the greatest interest in the special features of the Portuguese Silurian fauna and praised the artistic quality of the engravings. Given Delgado's interest in studying the particular facies of the Silurian in Thuringia, von Zittel, then Dean and professor of palaentology at the University of Munich, advised him to visit that city first. There he made available to Delgado invaluable fossil collections, in particular the graptolites which had been classified by

Lapworth. Delgado also met Carl W. von Ritter Gümbel (1823-1898), examined the collections in his view masterfully organised by his German colleague, and was led to make some re-evaluations when he compared his data with the collection of the Fichtelgebirge.

Prior to examining this collection, Delgado was persuaded that the fossil deposits of S. Domingos in Alentejo, where the first Nereites[68] had been found in Portugal and which he had classified as Silurian, belonged, in fact, to a different age from that of the schist formation of Barrancos. After examining the engravings of Silurian fossils from the Alentejo, Gümbel expressed the opinion that the layers of S. Domingos, immediately below those of the Culm of Mértola, together with the layers found in the quarry of Mestre André at Barrancos, probably belonged to the Lower Devonian. They thus corresponded to the *Nereitnschichten* of the Fichtelgebirge, which topped the Silurian series.

Delgado says that he further discussed his and Gümbel's interpretations with other foreign specialists, but his own views were reinforced rather than discarded. His fellow geologists, however, advised him to carry out new observations in the cut made throughout the schist formation of Barrancos before publishing his work, in order to ascertain whether there was a repetition of layers either by folding or by faulting.

In fact, Néry Delgado first classified the fauna of S. Domingos as belonging to the Lower Silurian (Ordovician) in 1876,[69] but in 1899 as being Devonian.[70] In his last memoir, published in 1908, however, he contended that it was part of the Upper Silurian.[71] Underlying this change of views were different interpretations rather than new discoveries. The classification of the similar fauna of the Fichtelgebirge also underwent various revisions throughout the second half of the nineteenth century because its age caused a great deal of controversy among geologists.

From Munich Delgado went to Vienna and then to Prague, where he met Joachim Barrande and observed the impressive collection of Silurian fossils from Bohemia to which the famous French palaentologist had devoted much of his work. For many years Barrande had studied Palaeozoic fossils in Bohemia, in particular trilobites. Delgado discussed with him the classification of some trilobites he had discovered in the top of the Lower Silurian (Ordovician) of Buçaco (Portugal). He thought they represented new types, but they were, in Barrande's view, new forms of known genera. When Delgado showed him the engravings of the main Silurian fossils collected in the neighbourhood of Barrancos (Portugal), Barrande claimed that Delgado's work came at the right time to serve as an argument in the controversy that he was having with British geologists.[72]

Barrande was at that time interested in getting as much ammunition as possible to argue against the Cambridge geologists, in particular John E. Marr.[73] In an article published in the *Quarterly Journal of the London Geological Society*,[74] Marr argued vehemently against the existence of 'colonies' in Bohemia, something that many geologists including Delgado had considered an indisputable fact, notably the influential Murchinson.[75]

Barrande had formulated a theory, known as the theory of colonies, which at the time generated a wide and lively controversy, notably with Jan Krejci (1825-1887) of Prague, and with Lapworth and Marr, among others.[76] In his studies of the Palaeozoic fossils Barrande had observed that in some places in Bohemia younger fossils alternated with older rocks. He explained this phenomenon as being the result of migrations of organisms from one region to another, and these assemblages of younger fossils he called colonies. As this was a purely palaeontological phenomenon, and therefore independent from stratigraphic considerations,[77] it called into question the well-established principle of William Smith (1769-1839), for whom the identification of strata of a particular age was associated with fossils of a specific kind.[78] Alternative interpretations to Barrande's included that of Krejci who claimed that the Bohemian strata had been dislocated by earth movements, and Marr's more elaborate interpretation, arguing that these palaeontological/ stratigraphic discrepancies could be explained by faulting. For both, tectonic movements resulted in a confused stratigraphic sequence, whose cause was a disturbed physical structure rather than an abnormal reaction of organisms colonising a previous fauna.[79] The comments of Delgado on these debates seem particularly interesting because he makes a connection between the theory of colonies and Darwinian evolution, drawing attention to what he perceived as a paradox in the dispute:[80]

> It is highly remarkable that British geologists, being the most interested in supporting the theory of evolution formulated by Darwin—a theory which undoubtedly found a good basis in the theory of colonies—come now (without providing new evidence, one should say) fighting against this theory advocated by an expert who, on the contrary, does not subscribe to transformist ideas.

Historians of geology have addressed the relationship between palaeontology and evolution in various works.[81] However, the way in which the theory of colonies could be used as an argument in favour of Darwinian evolution is an episode which, to our knowledge, has not yet been fully explored. Barrande's peculiar form of creationism, which at times can be mistaken for transformism was analysed by the historian Goulven Laurent.[82] He claims that initially Barrande had a more flexible attitude regarding transformism, but his attacks became increasingly virulent as Darwinian evolution reached the status of a doctrine.[83] Given the richness of the "primordial fauna," and in order to be consistent with their theory, transformists suggested the existence of a series of more ancient faunas. However, as no trace of these faunas could be found in geological strata, they conceded that they had vanished owing to metamorphism. Barrande, in turn, countered that if geologists were unable to find fossils in the Azoic rocks, the reason was not that metamorphism had destroyed their remains but simply because they had never existed.[84]

Delgado avoids taking sides in the report, but he seems more inclined to share the view that Barrande's theory of colonies was, nevertheless, an argument in favour of transformism. Following these discussions he left for Paris, where he stayed longer than intended, due to "his personal relations with those in charge of the main scientific establishments."[85] In Paris, rather than discussing research topics he benefited from having access to the geological collections to settle issues linked to his own investigations devoted to the Silurian.

2.2.4 The Impressions of a Traveller: Criticising the Inside from the Outside

Travelling provides references with which comparisons can be made, the recourse to foreign examples giving authority to criticism. Delgado's reports, though official, are a fine example of how he subtly makes evaluations of foreign scientific practices and takes them as an opportunity to indirectly criticise current Portuguese procedures. Always with the greatest cordiality, he also draws attention to weak points he identifies in foreign science, thus excluding the possibility of his admiration for what he sees abroad being interpreted as an expression of naïve parochialism.

When he visited Madrid in 1878 he was taken to the Geographic and Statistics Institute whose director, General Carlos Ibañez de Ibero (1825-1891), also presided over the International Committee of Weights and Measures. There he saw the wonders of the standard metre, which with the exception of the French-made micrometre, had been constructed in Spain under Ibañez's supervision. The lithographic techniques used to print maps and the printing methods original to Spain were also thoroughly examined by the Portuguese geologist, who was not particularly impressed by them. With a clear sense of practicality, he argues:[86]

> I do not dare to express an opinion about the course of action taken by the wise director of the Geographic Institute. However, it seems to me that the efforts of General Ibañez — concentrating on the scientific and artistic improvement of these partial maps with the purpose of matching or even overcoming the best that has been published in more advanced countries — are not entirely profitable. It would be more advantageous if, as happens in Portugal, those efforts were directed towards a presentation of a general geographic map of Spain, precise enough to provide a basis for the work of the Spanish Geological Survey.

Delgado points to the difficulties of his Spanish colleagues, in particular the lack of an accurate geographic map of Spain, which could have helped them draw the boundaries of the different geological units. Despite his criticism, what really impressed him favourably was the recent emancipation of the Spanish Geographic Institute from the government, as he remarks:[87]

> Up to then the Institute had endured a difficult existence due to its dependence on the central government, which now cannot appoint or dismiss personnel arbitrarily. The hiring of staff is carried out through competition, dismissals are subject to strict rules, and the only reasons can be those directly linked to work.

Coming from a state geologist his comment is all the more significant. It is a clear criticism of current Portuguese practices, of which the imbroglio underlying the suspension of the Portuguese Geological Survey back in 1868 was but one of various examples.

Delgado was undoubtedly in favour of the autonomy of scientific institutions and claims that the work of the Spanish Institute, "free from the ups and downs of politics, which in Spain like everywhere else sterilises the most productive scientific activity, has developed rapidly and securely."[88] On his return to Portugal, he even wrote to Eduardo Benot (1822-1907), then the Spanish Minister of Development, asking him for details about the organisation of that autonomous institution.[89]

Delgado also seems to empathise with individual initiative. On his visit to England, in 1888, to attend the International Geological Congress, at the same time as he praises the "eminently practical spirit, which singles out England," he remarks:[90]

> The English Government had no direct or indirect involvement in the organisation of this event. While on the continent national governments have funded the organising committees, in London, the considerable costs involved were covered by private donations of geologists and people interested in the study of geology.

Within the social programme of the London meeting Delgado visited Chester, where he attended an exhibition at the Town Hall organised by the local natural sciences society. As an expression of his personal penchant for fundamental research he claims to be impressed by the fact that unlike in Manchester or Newcastle, where science progressed due to the requirements of industry, in Chester science was cultivated owing to the devotion of its inhabitants. He further added, "the spirit of scientific research in England is not confined to the big centres, but flourishes equally in small cities like Chester."[91]

From Spain to the Austro-Hungarian Empire, Delgado observed many geological collections and carefully reports on all of them. During his travels of 1881-1882, he spent a considerable time studying French collections, especially those located at the Sorbonne, the Ecole des Mines and the Muséum d'Histoire Naturelle. He rates the collections of the Muséum highly, but not those of the Ecole des Mines, which he found disorganised, some items even lacking labels. At the Sorbonne, Hébert[92] opened the collections and library to Delgado's examination. The Portuguese geologist admired the organisation of the collections but noticed the cramped premises, in which they were housed, a remark with which most of his French fellow scientists would agree. In nineteenth century France the habit of turning a spare part of any old and inadequate building into a laboratory or a natural history cabinet was well-known and deplored by many *savants*.[93]

In Germany, Austria-Hungary and England, the size and organisation of the collections exceeded his expectations. Naturally, the monumental buildings built in those countries to house natural history collections and laboratories, giving a majestic sense of empire to scientific enterprise, fascinated him. He literally measures the importance ascribed to geology. He describes the premises and their dimensions, the furniture specially designed to house and display the collections, and even the costs involved, huge when compared with Portuguese budgets for similar purposes. Once again his empathy towards private initiative re-surfaces. In contrast to what could be expected in his country, when he refers to the fossil collection of the London Natural History Museum, he stresses that it was largely a result of "private donations, as happens in other sections of this museum and in all British museums."[94]

Delgado compares some foreign collections with those of the Portuguese Geological Survey in whose organisation he participated. He proudly claims that their organisation had similarities with those he had studied in Vienna and Munich, and in this way he is once again measuring the endeavours of the Geological Survey by the standards of an international scientific culture. At the same time, he emphasises their importance in the national context: "As one can see, despite the extreme modesty of our collections, they are organised in the best way possible to provide the geological study of the country with the kind of service for which they were intended."[95]

2.3 *Travels from the Centre to the Periphery: Paul Choffat's First Stay with the Portuguese Geological Survey (1878-1880)*

As stated above, 1878 is a key year for European geology. The first International Geological Congress was held in Paris and a forum was thus created for formal exchanges between geologists on issues such as nomenclature and cartography. As head of the Portuguese Survey, Ribeiro attended the Paris meeting, though so far no written report of his presence has been found. It is likely that he used the opportunity to strengthen his links with foreign colleagues and to make new contacts. One encounter, in particular, was to play a crucial role in the development of Portuguese geology over the next few decades: Ribeiro's meeting with the Swiss geologist Paul Choffat.[96]

Léon Paul Choffat was born in Porrentruy, in the Jura region, on 14 March 1849.[97] He was the son of a former mayor of the town, a local banker and industrialist. The naturalist Jules Thurmann (1804-1855)[98] was one of his father's friends and a frequent visitor to their home. Although Choffat had never met him, he was influenced by two of his students who taught at Porrentruy's *Ecole cantonale*, Thiessing (?-?) and Ducret (?-?), and accompanied them on geological field excursions.[99] After finishing secondary school he left for Besançon, where he trained for three years as a bank clerk and became a member of the Société d'Emulation du Doubs.

In 1871, Choffat was in Zurich, where he enrolled in the local Polytechnic School and attended courses in natural sciences and chemistry. Here he met A. E. von der Linth (1807-1872) and A. Heim (1849-1937), whose theoretical and practical courses he followed.[100] At the university and later on, during his travels in the Alps and in particular the Jura region, he made friends with L. von Lóczy (1849-1920), O. Heer, K. Mayer-Eymar (1826-1907) and J. Marcou (1824-1898), among others.[101] He graduated from the University of Zurich and in 1875 was appointed *Privat Dozent* at the Polytechnic School. By then he was actively engaged in palaeontological research and doing fieldwork mainly in the French Jura and the Bern region. He had already published extensively in both Switzerland and France by the time he attended the Geological Congress in Paris.[102]

2.3.1 Paul Choffat's First Stay in Portugal (1878-1880)

The details of Ribeiro's meeting with Choffat in Paris are as yet unclear.[103] The two most certainly discussed palaeontological and stratigraphic issues and the head of the Portuguese Survey invited Choffat to visit Portugal. It has been suggested that Choffat's poor health[104] and his wish to spend a few months in a warmer climate were the main motive behind his decision to travel south. Although this was certainly a strong argument in favour of coming to Portugal, it is clear from a letter that he wrote to Ribeiro that he intended to spend his time usefully:[105]

> Je désire naturellement visiter un pays où je puisse faire une étude géologique intéressante et parmi celles-ci, le jurassique supérieur du Portugal occupe le premier rang, à en juger du moins par ce que vous m'en avez communiqué.

Far from suggesting that Choffat simply did not want to remain idle while recovering from his illness, this early letter to Ribeiro shows that he had a clear purpose in mind. Choffat seems to have been aware that the Jurassic in Portugal was still largely unknown and that its similarities with some structures he knew from his studies of the Jura region might help him in clarifying certain classificatory issues:[106]

> Ce que vous m'avez fait voir dénote un faciès analogue à ce que nous avons dans l'Ouest du Jura, soit le faciès franc-comtois. Les quelques mots de M. Mac-Pherson[107] montrent au contraire le faciès tithonique aux environs de Cadiz. Il est donc certain que l'étude de ces contrées donnera sinon la solution du moins des données nouvelles et d'une grande importance sur cette question depuis si longtemps débatue.

Already at this very early stage Choffat outlined a work programme, suggesting ways of avoiding conflicts with other geologists whose data he would have to use. He tried to ensure that there would be no overlap with the work of other Survey members and clarified issues of authorship and ownership of the fossils. He proposed to become an unpaid temporary collaborator of the Survey for a couple of months. He ended his letter by asking Ribeiro's advice on whether to visit Cadiz on his way to Lisbon or on his return in Spring, presumably to check on MacPherson's work.[108]

Choffat received a swift and positive reply from Ribeiro and arrived in Lisbon less than a month later.[109] The correspondence received at the Geological Survey provides some indications about Choffat's activities throughout the next 18 months and the network of contacts that he had in Switzerland and France.

He spent the last two months of 1878 examining the Survey's fossil collections. In January 1879 he was officially asked to undertake a study of Portugal's Mesozoic formations, a task that was suspended in July for reasons as yet unknown.[110] His presence in Portugal was mentioned in letters sent to Ribeiro early in 1879 by J. R. Tournoüer (1822-1882),[111] with whom Choffat exchanged fossils.[112] In May, it was C. F. Fontannes (1839-1886)[113] who counted on his "dear colleague" Choffat to recommend him to Ribeiro, announcing that he was following a suggestion of the former and sending a copy of his work on ammonites to the Survey library. He also asked for fossils from the Lisbon region.[114]

By then, Choffat had settled in the Survey and was apparently pleased with the arrangements.[115] He had acquired a significant degree of autonomy and was already taking an active part in the running of the institution. He had realised the true size and nature of the institution and identified some of its shortcomings. In particular, he had found the existing library quite inadequate and had engaged in an active correspondence with several bookshops with a view to acquiring books that were up-to-date and relevant to the Survey's purposes.[116] Later that year (1879) he was to be found in Central Portugal, doing fieldwork and keeping in touch with colleagues abroad.[117]

His research on Mesozoic formations led him to collect fossils for whose description and classification he required the help of an expert. Early in 1880 he decided to contact his fellow countryman O. Heer, who was renowned for his work on Tertiary flora.[118] Heer became interested in Choffat's findings and was willing to help him but wished to establish a formal setting for his collaboration with the Portuguese Survey.[119] He did not know Ribeiro at the time and Choffat acted as an intermediary between the two men.

By May, a consignment of fossils had arrived in Zurich and been delivered to Heer, who immediately passed on some of the specimens to other colleagues and carried out a preliminary palaeontological analysis.[120] Meanwhile, negotiations on the terms of Heer's collaboration with the Survey were probably under way with Ribeiro and culminated in a proposal, which Heer promptly accepted.[121]

Early in June Choffat was back in Paris. He read a paper before the Société Géologique de France summarising the findings of his work on Portugal's Jurassic formations.[122] He used the opportunity to enquire, on behalf of Ribeiro, about various people's willingness to travel to Lisbon for the meeting of International Congress of Palaeoanthropology and Archaeology to be held there later that year. Choffat ended his first stay in Portugal and left for Porrentruy but expressed his wish to return to Lisbon one day.[123]

Choffat was soon to return to Portugal, where he engaged in a long and distinguished career with the Geological Survey, which lasted over 40 years. Until 1883 he had kept his job in Zurich but in that year he began working under contract for the Portuguese government,[124] the said contract being renewed on a regular basis. He published extensively on a wide range of topics, viz. on the palaeontology and stratigraphy of the Jurassic and Cretaceous, his major field of research, but also on applied geology and on more practical issues. He sat on the Portuguese committees on nomenclature at several geological congresses and organised the geological bibliographies published yearly in the Survey's journal. He wrote biographical notes on Portuguese and foreign geologists and, more generally, about the history of Portuguese geology, thus helping in establishing a tradition. He was possibly also responsible for translations and other administrative tasks at the Survey.

2.4 Travelling to Other Continents: Geological Expeditions in the African Colonies during the Nineteenth Century

Most studies of the history of science concerned with colonial science and imperialism have looked at the topic from the point of view of the Great European powers. Here, the ambivalent situation of Portugal, a peripheral country in the European context, but a centre in relation to its African possessions, will be addressed by looking at two different classes of travel and travellers.

On the one hand there were the expeditions organised by the Lisbon Geographical Society with a geographical objective in mind but in many instances contributing to the amassing of zoological, botanical and geological information. On the other hand, there were the contributions of those "isolated explorers" of different backgrounds and professions who for different reasons had settled in Africa and who on a more or less regular basis sent zoological and geological specimens to the mainland. Such was the case of the Austrian naturalist Frederich Welwitsch (1806-1872) who worked for the Portuguese government, Lourenço Malheiro (1842-1890), a mining engineer working for a private enterprise, and Freire d'Andrade (1859-1929), a general in the Portuguese army. On the mainland the geologists Néry, Delgado, Paul Choffat and Alfredo Bensaúde (1856-1941) studied the geological data and maps they received.

Throughout the last half of the nineteenth century Portugal took part in the European geographical movement. Two important scientific expeditions were organised (1877-80 and 1884-85) following the creation of the Lisbon Geographical Society in 1875. Representing the first class of travellers, Navy officers Hermenegildo Capelo (1841-1917) and Roberto Ivens (1850-1898), explorers with wide experience in travels to Africa of a military character, had as their main objective the preparation of the General Chart of Angola, attempting to fill in a map which still had large blank areas. Besides delimiting the hydrological basins of the rivers Zaire and Zambeze, a trade route between the provinces of Angola and Mozambique was to be found. Although an "isolated explorer," Freire d'Andrade, an engineer who graduated from the Ecole des Mines, can be associated with Capelo and Ivens, in the sense that he represented a man of the establishment. His intermittent trips to Africa were simultaneously politically and militarily oriented and predominantly scientific in the context of the geology of Mozambique.

Without the support of any scientific institution, the other class of travellers crossed Africa with relative success. Such is the case of Welwitsch, who in the 1850s worked for the Portuguese government and took charge of studies of Angola's fauna and flora, during a seven-year scientific expedition. Another case is that of Malheiro, who despite being a member of the Geological Survey, throughout his long career as a mining engineer carried out missions for a private company. Besides his research on the geology of Angola, Malheiro contributed to the outline of strategies for the geological exploration of the overseas territories.

The study of Africa's geology by these two classes of travellers, and clarification of the links they more or less successfully established with metropolitan Portugal, in order to legitimise their actions, may help to clarify the position of a peripheral country such as Portugal in relation to the European powers, which at the time were challenging the status of Portuguese colonies.

2.4.1 From Vienna to Africa

Right from his start in the academic life of Vienna, Welwitsch[125] concentrated on botany, an area that had always fascinated him. Linked to the Vienna Museum, Welwitsch worked on the geographical distribution of plants, and became one of the most important forerunners of modern phytogeography. Both a scientist and an artist, he tried to escape the bohemian life of Vienna, leaving his country on a sojourn which eventually turned out to be a permanent stay abroad. Welwitsch managed to obtain from the Itinerary Union of Wurtemburg a botanical mission to the islands of the Azores and Cabo Verde and travelled, via London, to Lisbon in order to arrange for transportation. In 1839, the year of his arrival in Portugal, he became a member of the Lusitanian Pharmaceutical Society. In the next year he became correspondent of the Medical Science Society and was appointed Keeper of the Ajuda Botanical Garden. In December 1840, he was appointed as a civil servant in this same position.[126]

In 1850, Welwitsch was assigned a scientific expedition to Angola by the Portuguese government, a project that only materialised three years later. He left Lisbon in August and seized the opportunity to visit the islands of Madeira, Sal, Santiago, Príncipe and S. Tomé. He stayed in Angola for the next seven years. Although botany had been Welwitsch's main area of research, he did not neglect geological observations. References to them can be found in letters he wrote along the way as well as in several botanical journals to which he contributed.

After visiting the Ambaca and Ambriz regions, Welwitsch returned to Luanda. Then he went to Benguela and remained for a while in Mossâmedes. The Huila plateau was his last destination. In January 1861, Welwitsch returned to Lisbon, carrying with him the results of several years of research in Africa. In 1863, he settled in London, and used the many local libraries and collections to help him in classifying his specimens and organising his notes. After Welwitsch's death in 1872, few documents were sent from London to the National Museum in Lisbon.[127] The remainder, including his diary, had disappeared.

Among the documents found in the National Museum, the Count of Ficalho, director of the Department of Botany, singled out an envelope containing geological notes, which he forwarded to Paul Choffat for analysis and future publication. The paper, which Choffat published, reproduced Welwitsch's diagrams, which despite their secondary importance from a geological point of view reflected the view of a naturalist, and not just the purely picturesque aspects, typically the main focus of attention of landscape artists.[128] The analysis of Welwitsch's material seemed to imply to Choffat that Welwitsch was preparing a geological memoir, "(...) une mémoire special des renseignements circonstanciés sur les mines de fer et de cuivre, ainsi que sur les autres produits minéralogiques du pays."[129] The analysis of Welwitsch's notes was not an easy task for Choffat:[130] they had been intended for his own study, and he often mingled German, Portuguese, English and Latin in the same sentence. Some of the geological profiles included in the article pointed to Welwitsch's willingness to prepare geological cuts, an idea going back to 1858[131] when he had stressed the necessity of elaborating a transverse cut of Angola.

The formation of the Pungo Andongo massif was to become a familiar subject for some travellers in Angola, as demonstrated by Choffat's detailed examination of the Quisonde's profiles as outlined by Welwitsch. When Choffat saw the well-defined ridges in all the diagrams that represent the massif, it became clear to him that Welwitsch had been right in considering that the conglomerates were nothing more than the basis of these rocks. The ensuing geological observations completed the phytogeographic map of the province of Angola.

In 1875 Joachim John Monteiro,[132] a naturalist who stayed for a few years in Angola, where he met Welwitsch, published a geological chart of the Ambriz and Bembe zone, based on Welwitsch's own studies. Directly or indirectly, Welwitsch was always present in Choffat's considerations on Angola. His notes, references, sketches and conclusions were often the starting point for the elaboration of concepts by Choffat, who had never actually set foot in Africa.

Since its creation in 1857, the Portuguese Geological Survey often changed its name, structure and organisation. Its evolution can be seen as a crucial element in the history of geology in Portugal. In a more or less direct way, the materials gathered in Africa were associated with the geologists of the Geological Survey. Such was the case of Choffat and of Néry Delgado.

Owing to the shortage of geological studies of the Portuguese mainland, the Geological Survey at least at first did not consider the study of African geology a priority. In publications associated with this institution, the colonies' section always followed the sections on geology in the Metropolis, and content-wise it paralleled and extended the topics addressed by geologists on the mainland.

2.4.2 The Place of Portugal

In 1876, the Brussels Conference revealed a change in the attitudes of the great European powers towards their African possessions. The presence of Portugal in the European geographical movement became imperative as a consequence of projects to delimit territories, and the struggle of the European countries for supremacy in Africa. The Geographical Society of Lisbon was founded in 1875 mainly as a response to international pressure, which challenged the historical right of Portugal to keep its colonies in

Africa, in this way forcing Portuguese policy-makers to implement measures promoting the effective occupation of these possessions.

The Society was meant to promote study, discussion, teaching, and research on geography and to foster geographical explorations. The increase of geographical studies all over Europe due to the abundance of data gathered in expeditions to the African mainland made expeditions one of the main aims of the newly founded society.[133]

On 3 April 1876, and two sessions later on 7 July 1876, the Society passed a proposal which was subsequently presented to the Government, underlining the scientific, economic and political importance of a coast-to-coast expedition on the African mainland. The Government approved the 30 *contos*, the sum needed for the scientific expedition, and planning for the trip began. The report of the Standing Central Committee of Geography, dated 8 May 1877, made the government's instructions clear: the primary goal of the expedition was the study of the river Cuango in its relation to the river Zaire and to the Portuguese territories of the western coast. The expedition was also meant to study the region which to the south and south-east included the sources of the rivers Zambezi and Cunene, and to the north the basins of the Cuanza and the Cuango rivers.

The journey undertaken in 1877/1880 by Capelo and Ivens, the two Royal Navy officers, covered part of Angola's territory, over a distance of some four thousand kilometres. The study of the Cuango, Congo-Zaire's great tributary thoroughfare, and the reconnaissance to the south, of the origins of the rivers Cunene and Zambezi, made the hydrographic basins associated with these watercourses the main routes of the expedition.

The fauna and flora specimens shipped to the Portuguese mainland by Capelo and Ivens became part of the collections of the National Museum. They were organised thereafter, and also included the materials sent from Africa by José de Anchieta, a Portuguese naturalist who had lived in Africa since 1864, and by Welwitsch. From November 1879 to 1884, the articles published in the *Jornal de Ciências Matemáticas, Físicas e Naturais*[134] refer mainly to zoological material—fish, crustaceans, mammals, insects—sent by Capelo and Ivens. They also included materials sent by Serpa Pinto, another explorer who participated in the expedition, but who took a different route from the other two.

The report of the expedition, which contained the journey's itinerary, a description of the contacts established with natives, observations and records became quite a successful book.[135] Geographical charts were appended at the end of the book, together with summaries of meteorological and magnetic observations as well as contributions to the study of the fauna and flora of

Central and Western Africa. From a geological point of view, the few contributions, mainly sample classifications and the identification of fossil specimens were referred to in Choffat's future publications.[136] The brief geological sketch, which described the great geomorphologic units, covered no more than two and a half pages and contained several anthropological descriptions, thus reflecting the subordinate place of geology in the context of the exploration.

In a way, the 1884-85 expedition anticipated the Portuguese reply to the challenges emerging from the Berlin Conference of 1885, in which Bismark called for the participation of Portugal. The location of the civilising stations reflected the urgent need to establish effective occupation of the territories under Portuguese administration.[137] The expedition's goals were therefore connected with the preparation of the General Chart of the Province of Angola, in particular the need to delineate a trade route between the Portuguese provinces of Angola and Mozambique, by means of which the west coast trade could easily reach the lake region; the identification, in the Great Lakes region, of the relation between the hydrological basins of the rivers Zaire and Zambezi; and, finally, the mapping of many obscure areas of previous charts.

The four thousand five hundred kilometres covered in approximately seven months by Capelo and Ivens, members of the newly-founded Cartographic Committee, included territories of Angola and Mozambique positioned between parallels 10° and 20° South, from West to East. The study of the territories stretching between the provinces of Angola and Mozambique and, notably the study, in the central regions, of the relation between the hydrographic basins of the river Zaire and the river Zambezi, were the main objectives of the two explorers. They began their journey in the west, in Porto Pinda, and ended in Quelimane, on the Indian Ocean. On 26 July 1884, Capelo and Ivens sent a box to the metropolis containing fauna and geological specimens from the regions explored.

The book titled *De Angola à Contra-Costa,*[138] just like the previous book written by these explorers, summarised in one chapter all the scientific data gathered during the journey. Besides geographical, magnetic and meteorological observations, there are also sections devoted to terrestrial and fluvial shells, notes on botanical collections and a list of the specimens of fossil and rock minerals. In the metropolis, the Geological Survey, under the direction of Néry Delgado, classified the samples and Bensaúde carried out their microscopic analysis.

2.4.3 Two Different Trajectories

The mining engineer Malheiro[139] wrote articles on a regular basis in the *Diário de Portugal*, reflecting upon and criticising Portuguese colonisation policies. For three centuries Portugal had occupied vast territories in Africa; governments and generations succeeded each other and still, according to Malheiro, Portugal had not managed to adopt a "rational" system of colonisation. On 17 January 1881, Malheiro, a member of the Lisbon Geographical Society, delivered a lecture at a conference in which he outlined the outcome of the geological and mining explorations in the Portuguese territories during the previous centuries, as well as the financial and human resources involved. The Society's members heard a twenty-six-page speech, which was highly critical of the guidelines adopted by the Portuguese administration on the ground. Malheiro had touched a very sore spot: close to the turn of the century, scientific research in the Portuguese colonies would have to start from scratch as "the present state is unbearable and harmful to the country!"[140]

This conference made a decisive contribution to the establishment of a close connection between colonial and scientific policies, and the Geographical Society at once requested a report from the African Commission to be presented to the government, explaining the need to organise a mineralogical and geological expedition. The African Commission's report was approved a few days later, on 31 January.[141] On 19 February 1881, the General Board of the Colonies informed the Geographical Society that the Minister was planning to send a mineralogical mission to Angola, as soon as approval was granted to the proposal submitted to the Court. Meanwhile, the Minister decided to take advantage of Malheiro's research in the sulphur mines in the Benguela district, while he was working for the Mining Company of Dombe Grande. At the session of 21 February 1881 at the Lisbon Geographical Society, Malheiro's speech was brief and harsh. The Society should no longer expect any contribution from him in the future exploration of Africa, since all his time was going to be dedicated to the study of mines. It was very unlikely that he would extend his investigations to purely scientific matters such as mineralogy. He did not intend to serve his country any more as scientific expeditions were not normally regarded seriously by the State. In fact, at the session of 7 March, the Lisbon Geographical Society members were informed that the Ministry of the Colonies did not have enough funds for geological explorations.

In 1881, when Malheiro was in charge of the study of sulphur and malachite deposits in Benguela, he seized the opportunity to sketch out a geological chart and to perform some geological profiles to add to those already in existence. In June 1886 he lectured on his research at the Portuguese Association of Civil Engineers, where he exhibited some of the specimens he had gathered. Later on, he sent all his samples from Spain to Choffat.[142] Malheiro never returned to Lisbon and it was in vain that Choffat wrote to him asking for detailed information on the procedures and places where he had gathered his material and requesting the profiles that Malheiro had presented in Lisbon.

The publication in 1888 of a paper concerning the stratigraphy and palaeontology of the province of Angola, titled "Materiaux pour l'étude stratigraphique et paleontologique de la Province d'Angola," authored by Choffat and a Swiss ex-colleague, summarised their conclusions concerning the materials gathered by Malheiro.[143] This article was published at a time when geological information about Angola was still scarce. The little knowledge gathered was scattered in travel records. Often travellers gathered only a few rock samples, which were not sufficient for definite conclusions to be drawn about soil formations.[144] Choffat and his co-author re-organised the relevant information being sent from Angola on the Mesozoic.[145] The samples analysed came from three different places: São Paulo de Luanda, Catumbela, the north of Benguela and Dombe Grande, a county south of Benguela. The samples were numbered consecutively in each region, but it was hard to see on what grounds they had been classified, and it was therefore impossible to put forward an interpretation of neither their palaeontological and petrographical characteristics, nor any hypothesis about the relative positions of the strata containing fossils.

Freire d'Andrade,[146] a graduate of the Lisbon Polytechnic School, studied engineering at the Army School and became a second lieutenant in the engineering regiment in 1883. Freire d'Andrade attended the Ecole des Mines in Paris on a scholarship awarded by the Portuguese Government. In 1888, after concluding his education, he was appointed General Commissioner for Mines, Gems and Precious Metals of the Colony of Mozambique.

His participation in some missions gave Andrade the opportunity to study geological units and to gather material and notes that were later included in a monograph on the geology of Mozambique.[147] Initially published in the journal of the Portuguese Association of Civil Engineers (*Revista de Obras Públicas e Minas*), this monograph was used in his application for the post of substitute Lecturer of Docimasy, Metallurgy and Mining of the Polytechnic School, in 1894. In Africa, Freire d'Andrade found a vast and unexplored natural laboratory where he could put into practice the scientific and technical expertise he had acquired in Paris. His reputation as a geologist and expert in mining exploration grew each year and his monograph became an extremely important work. In the 1890s the scarcity of data concerning stratigraphy and palaeontology was still overwhelming, it was difficult to establish the links between various local episodes, and it was often necessary to resort to geographical data in order to make sense of corresponding geological data: "It is not possible to establish a clear division between geology and geography, because the nature of the earth's crust reveals its geological structure and is the result of former geological processes."[148]

In 1905, in an essay published by the Geological Survey, Choffat organised the samples and proceeded to the analysis of specimens most of which had been gathered by Andrade on his most recent geological mission to Angola. The materials received after 1881, the date of publication of the "Materiaux pour l'étude stratigraphique et paléontologique de la province d'Angola,"[149] revealed quite clearly a concern for the study of coastlines. In fact, the majority of the materials collected previously were brought from inland, and the coastline had so far been ignored. In the introduction to the "Contribuitions à la connaissance géologique des colonies Portuguaises d'Afrique,"[150] Choffat lamented that "studies on railway construction had little impact on the scientific evolution of Portugal."[151] For the first time in 1904, the Geological Survey for the first time received some rock samples collected by Andrade after the railway reached Ambaca. The large quantity of samples collected by Andrade in the Congo and Luanda enabled him and Choffat to study the palaeontology and stratigraphy of the coastline of Angola.[152]

Updated knowledge on the Cretaceous in Angola extended the research underlying the "Matériaux," and put it in the context of the investigations of some European scientists, mainly French and German, whom Choffat had met before. Andrade, who kept up a regular correspondence with Choffat, was put in charge of the stratigraphical synthesis. Andrade's collections were assembled on his trip to the Portuguese Congo and to Luanda, and were studied in the mineralogy laboratory of the Muséum, Paris. Petrographical knowledge of Luanda was still scarce but was enhanced by a note published in 1913.[153]

It must be stressed that Freire d'Andrade does not easily fit into any of the categories of travellers referred to previously. Although he was a man of the establishment, his contributions stemmed from personal endeavours, and therefore he should be seen at the interface between the two classes: on the one hand he had freedom to act independently, while on the other he had support from the official establishment.

The contributions of all these travellers constituted the only attempts towards increasing the geological knowledge of the Portuguese African colonies in the nineteenth century. Although modest, they contributed to the participation of Portugal in the international movement of European empires to appropriate their overseas territories through scientific surveys of their resources.

3. CONCLUDING REMARKS

In the second half of the nineteenth century, geology as practised by the Geological Survey of Portugal focused mainly on the knowledge of the European mainland and to a lesser extent of the African colonies. In both instances travelling played a major role in the internationalisation of Portuguese geological science.

Various factors contributed to this unusual process, including on the one hand, the transnational character of geological knowledge, and on the other, the "territorial imperative," by which territory was perceived by the great European powers as a resource to be kept under control. It was within this framework that the Geodesic Office and the Geological Survey of Portugal were created as part of the Ministry of Public Works, Trade and Industry, followed by the creation of the Geographical Society of Lisbon, a private institution that retained strong links to the political sphere.

The Geological Survey of Portugal benefited greatly from the very dynamics of the MOPCI, which can be seen as a "centre of calculation" with the peculiarity of having to apply technical knowledge in basic material structures. The Ministry's efforts towards the modernisation of the country in accordance with international standards went hand in hand with the concern to keep up with the latest technical and scientific developments in Europe, by sending engineers abroad and by disseminating technical and scientific news in its journal.

From the late 1950s, the Geological Survey shows a clear drive towards internationalising its scientific production, a strategy that encompassed subscription to specialised foreign books and journals; intense correspondence with foreign specialists; the regular publication of monographs and memoirs in French; occasional or permanent collaboration with foreign experts; the collaboration of national and international explorers in the African territories, and travelling abroad. The purposes of these journeys abroad varied over time.

The "foundational" travel of Carlos Ribeiro, the Head of the Survey, in 1858, throughout various European countries, produced immediate results: the acquisition of fieldwork equipment and the purchase of books, journals and maps otherwise unavailable in Portugal. Reference collections of minerals and fossils were also acquired and a network was established of personal and institutional contacts with experts with whom long-lasting scientific correspondence and some co-operation was initiated.

The "travels of negotiation" of Néry Delgado — in 1878 to Spain, in 1881-82 to Italy, France, Germany and the Austro-Hungarian Empire and to England in 1888 — on the other hand, occurred at a stage in which the work and reputation of the Geological Survey were more established. They show how a geologist from a peripheral country related to his foreign colleagues working both in the periphery and in the centre. The major outcome of his journey to Spain in 1878, in addition to improving the relationships with the geologists of the neighbouring country, allowed him to collect data in the field that was useful for the geological characterisation of the southern Portuguese regions. He was also able to negotiate and look for data which could persuade his Spanish colleagues to subscribe to interpretations consistent with the Portuguese geological map, published in 1876.

Delgado's participation in the meetings of the International Geological Congress — events which show that geology was becoming more and more of an international science — marked the presence of Portugal in a forum where the visual and verbal language of geology was being negotiated. The visits he made to various countries gave him the opportunity to talk as an equal with colleagues and to show data which could be used in scientific debates with an international scope, such as that involving Barrande's theory of colonies.

Delgado also used his travels as a subtle means of criticising Portuguese practices by comparing them with foreign ones, thereby giving authority to his criticisms. In the national context, the publication of the reports of his travels, in addition to demonstrating that travelling abroad was part of the normal work of a geologist, enhanced his authority and served the purpose of politically legitimising the work of the Geological Survey.

Paul Choffat, as a scientist of the centre moving to a periphery, portrays yet another kind of travelling and another means of internationalising Portuguese geology. He came to Portugal to work at the Geological Survey at the invitation of Carlos Ribeiro, whom he met at the meeting of the International Geological Congress in Paris in 1878. Following a first stay between 1878 and 1880, he soon returned as a staff member, living in Portugal until 1919. He contributed greatly to attracting the collaboration of Swiss specialists such as Heer and Loriol. Choffat published extensively on a variety of topics, especially on the palaeontology and stratigraphy of the Jurassic and the Cretaceous, and sat on various Spanish-Portuguese commissions on nomenclature for several international meetings. He wrote biographical notes on Portuguese and foreign geologists and about the history of Portuguese geology, thus helping in this way to establish a tradition. Choffat, together with Delgado, was also one of the few geologists in Portugal interested in the geological study of the Portuguese African colonies.

As a result of international pressure and the lack of a coherent response from the government regarding the Portuguese African colonies, the creation in 1875 of the Geographical Society of Lisbon was an attempt to establish a framework for the effective occupation of the territories then under Portuguese administration. The society organised some journeys of exploration in Africa, which had, however, negligible impact on the geological knowledge of the Portuguese possessions. Two classes of travellers contributing in some way to the geological knowledge of the Portuguese colonies in Africa were identified: those working within the framework of the Geographical Society and/or under the auspices of the government; and those who travelled for private reasons and interests.

When dealing with issues of imperialism and centre versus periphery, the metropolis is usually seen as a decision centre, outlining methodological strategies, and collecting and processing data. In the Portuguese case, though, the metropolis did not play a determining role in guiding the geological exploration of the Portuguese colonies in Africa.

In fact, personal rather than institutional interests played a major role in the geological study of the Portuguese African colonies. Néry Delgado, Bensaúde, and most especially Choffat may be considered the sole representatives of the metropolis in this question. The latter carried out the organisation of the geological information and data collected in Africa, in an attempt to carve out a place for Angola and Mozambique's geology on the European scientific scene. Choffat never set foot in Africa but the travellers with whom he interacted became his own eyes and hands. Despite the modesty and the inconsistencies of the geological information and data he received, he made a definite mark and his work was legitimised because other European eyes were looking at the same kinds of issues.

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NOTES

* This chapter is based on previous work published independently by the above authors in the *Comunicações do Instituto Geológico e Mineiro*, 88 (2001).

Abbreviations: IGM - Institute of Geology and Mining.

[1] A. Carneiro, A. Simões, M. P. Diogo, "Enlightenment Science in Portugal: the Estrangeirados and their Networks of Communications," *Social Studies of Science*, 30 (2000), 591-619; M. P. Diogo, A. Carneiro, A. Simões, "The Portuguese Naturalists Correia da Serra (1751-1823) and his Impact on Early Nineteenth-century Botany," *Journal of the History of Biology*, 34 (2001), 353-393.

[2] David Oldroyd, *Thinking About the Earth: A History of Ideas in Geology* (Cambridge Mass.: Harvard University Press, 1996), pp. 108-130.

[3] 1st item of the decree signed by the Duke of Saldanha then Prime Minister, 2 May 1849. Copy of the decree signed by the Duke of Saldanha, National Archive of Torre do Tombo, Ministério do Reino, 1852, 3ª Direcção, 2ª Repartição, Proc. 392, Liv. 11, folhas 3390.

[4] R. M. C. Branco, *O Desenvolvimento da Cartografia Territorial em Portugal no século XIX* (unpublished M.A. thesis, Faculty of Human and Social Sciences, New University of Lisbon, 1999), p. 17

[5] It is worth remarking that the role of military officers in the development of science and technology in nineteenth century Portugal has yet to be fully assessed.

[6] Expression coined by Bruno Latour to mean centres where specimens, maps, diagrams, logs, questionnaires and paper forms are accumulated and used by scientists and engineers. See

B. Latour, *Science in Action. How to Follow Scientist and Engineers through Society* (Milton Keynes: Open University Press, 1987), p. 232.

[7] M. F. Mónica, *Eça de Queirós* (Lisboa: Círculo dos Leitores, 2000), and *Fontes Pereira de Melo* (Lisboa: Edições Afrontamento, 1999).

[8] J. M. de Oliveira Simões, "Os Serviços Geológicos em Portugal," *Comunicações dos Serviços Geológicos de Portugal*, 14 (1923), 5-123 and F. Moitinho de Almeida, A. Barros e Carvalhosa, "Breve História dos Serviços Geológicos em Portugal," *Comunicações dos Serviços Geológicos de Portugal*, 53 (1974), 241-265 .

[9] Simões, *op. cit.*, (8), 7.

[10] *Ibid.*

[11] Decree, 8 August 1857.

[12] Decree, 25 June 1858.

[13] *Relatorio da Commissão Geologica do Reino, á cerca da viagem feita aos diversos paizes da Europa pelo membro da mesma Commissão Carlos Ribeiro* (Lisboa, 31 January 1859) (typescript), pp. 2-3, IGM Historical Archive, Bookcase 1, Shelf 2, Box 9, File 7.

[14] Letter from the Viscount of Paiva dated 13 July 1858, IGM Historical Archive, Bookcase 1, Shelf 2, Box 9, File 6.

[15] According to Ribeiro's description, the impressive amount of items was kept in cupboards in accordance with their geographic location, labelled with reference numbers and nothing else. The investigations of many engineers, private collectors and French geologists were published in journals such as *Bulletin de la Société Géologique de France* and the *Annales des Mines*, which led the French Geological Survey to give up the organisation and co-ordination of the collections. This is why in his report he only acknowledges the size and the importance of the collections. In fact, they were not of much use for the comparative work undertaken by Carlos Ribeiro. Ribeiro, *op. cit.* (13), pp. 3-4.

[16] Elie de Beaumont advised Ribeiro to write a memoir to be presented at the Institut de France. Beaumont would take care of appointing a commission to examine the results of Ribeiro's comparative study of fossil species. In this way the Portuguese classification was given credibility. Ribeiro, *op. cit.* (13), p. 4.

[17] Carlos Ribeiro observed that the zoological collection gathered all species and known varieties of any formation belonging to the Tertiary. Each species and genus was arranged in both chronological and geological order, and the genera and species which defined the type were singled out. To each genus collection was added one or more species belonging to periods prior to the Tertiary and chosen according to the greatest number of affinities with the type. In this way a table was constructed in which not only could one see the period in which each genus emerged for the first time in the scale of beings but also the changes that the vanished species went through. The table also showed the new species that had meanwhile emerged from the first Tertiary strata until the Quaternary, and the type by which they were represented in contemporary living forms. This collection of Tertiary fossils included an impressive number of fossils from all European Tertiary basins with the exception of Portugal and Spain. Ribeiro, *op. cit.* (13), pp. 6-7.

[18] In order to classify the species Carlos Ribeiro arranged to meet with Deshayes two days every week. Ribeiro would choose a certain sample of fossils, which he would show to Deshayes to be verified. He also set aside new species, the whole work taking two and a half months. Regarding the echinoderms Deshayes asked J. L. Michelin (1786-1867) for help. Like Deshayes, Michelin allowed the Portuguese Survey to announce the new

species publicly. Concerning the vertebrate fossils of the Tagus basin, it was Paul Gervais (1816-1879), then professor of comparative anatomy at the Science Faculty of Montpellier, who revised the classification. However, this process was extremely time-consuming, which prompted Ribeiro to ask Deshayes to undertake a revision of the whole Portuguese collection, while he visited other countries. Deshayes agreed. Ribeiro, *op. cit.* (13), p. 8.

[19] Hörnes appointed Carlos Ribeiro as corresponding member of the Vienna Institute and offered the Portuguese Survey a copy of all works published by the Institute. He promised to send publications regularly to Lisbon. Ribeiro, *op. cit.* (13), p. 20.

[20] An expert on Cretaceous faunas, he was then working on the divisions of *Foraminifera*. He offered the Portuguese Survey various publications and promised to send a collection of those fossils. Ribeiro, *op. cit.* (13), p. 23.

[21] However, the fog and intense rain forced Ribeiro to leave Bohemia due to severe rheumatism. Ribeiro, *op. cit.* (13), p. 26. See also a letter from Ribeiro to Hörnes, Paris, 5 November 1858, in which he complains bitterly of his rheumatism. IGM Historical Archive, Bookcase 1, Shelf 2, Box 9, File 6.

[22] Sismonda invited Ribeiro to stay at his country house but Ribeiro's rheumatic problems led him to refuse this visit to the Alps. Ribeiro, *op. cit.* (13), p. 29.

[23] Professor of geology at the local Science Faculty he was in charge of drawing the geological map of Haute Garone and of the French Pyrenees.

[24] Geologist and professor at the Science Faculty of Toulouse.

[25] Schultz discussed with Ribeiro the phytogenic rocks of Galicia (Spain) whose geology is related to that of the Portuguese provinces of Trás-os-Montes and Minho. Ribeiro, *op. cit.* (13), p. 33.

[26]Concerning its geological and mineralogical classification the Portuguese Geological Survey had available Delesse, a mining engineer then teaching geology at the Ecole Normale. He was an expert on metamorphism and took the initiative to classify rocks collected in Portugal. Ribeiro recognised the need to apply inorganic chemistry, but the personnel of the Portuguese Survey, being only composed of three people, did not allow the creation of a speciality devoted to chemical testing. That is why he restricted his purchases of chemical apparatus, and only bought what was strictly necessary for qualitative analysis of rocks. Ribeiro, *op. cit.* (13), p. 18.

[27] Ribeiro took a course on photography at the conchology laboratory of the Jardin des Plantes. Ribeiro, *op. cit.* (13), p. 11.

[28] He bought second-hand publications because they were obviously cheaper and subscribed to the following journals: *Journal de Conchyliologie, Comptes Rendus de l'Académie des Sciences, L'Institut — Journal Scientifique, Annales des Mines de France, The Quarterly Journal of the Geological Society of London, The American Journal of Sciences and Arts by Silliman, Archive von Karston as Dechen, Neues Jahrbuch für Mines Geol. und Paleont. von Leonard und Bronn*, and *Revista Minera d'España* among others. Ribeiro, *op. cit.* (13), pp. 12-13.

[29] It was particularly important to the Portuguese Survey, because Ribeiro had considered it the most similar to the Tertiary basins of the Tagus and the Guadiana. Ribeiro, *op. cit.* (13), p. 14.

[30] Part of this collection was already in Lisbon at the beginning of 1859. It included about 1400-1800 species and the price paid had been about 1600 French francs. Carlos Ribeiro also wished to buy a collection exclusively composed of Mediterranean molluscs and species which inhabited the Portuguese and the Spanish coast. In all the places he visited,

Trieste, Veneza, Padua, Turin, Paris, and Vienna, he did not find a single collection available. Hörnes recommended a naturalist living in Cairo who was about to send collections to Vienna and Trieste. Carlos Ribeiro asked him to include the Portuguese Geological Survey provided the collection was well preserved and the costs involved did not exceed 500 Florins. Ribeiro, *op. cit.* (13), pp. 15-16.

[31] So far, in the research carried out at the IGM Historical Archive some correspondence between Carlos Ribeiro and Deshayes has been found. IGM Historical Archive Bookcase 1, Shelf 2, Box 9, File 6.

[32] Other contacts established in the early days of the Survey included Bernardino Antonio Gomes (1806-1877), who graduated in medicine from the University of Paris, worked as a palaeobotanist and seems to have had connections in Germany, viz. with German stratigrapher G.E. Geinitz (1854-1925) in Stuttgart, and Czech palaeobotanist O. Feistmantel (1848-1891) in Breslau, to whom fossil samples from the Carboniferous were apparently sent by Pereira da Costa. See M. Telles Antunes, "Sobre a História da Paleontologia em Portugal" in *História e Desenvolvimento da Ciência em Portugal (Publicações do II Centenário da Academia das Ciências de Lisboa)* (Lisboa: Academia da Ciências, 1986), vol. 2, pp. 773-814

[33] See Carlos Ribeiro and F. A. Pereira da Costa, "Relatorio. — Noticia sobre a Comissão Geologica de Portugal e seus trabalhos," Lisboa, 4 de Abril de 1864, p. 5 (typescript included in Carlos Ribeiro, *Geologia Vária I*), where they state that apart from Gomes, who was describing and classifying plant fossils, the Survey had no other external collaborators. Interestingly enough, the report was sent to the Italian geologist Cristoforo Negri (?-?) who published it in the *Atti della Societá Italiana di Scienze Naturali*, 8 (1865).

[34] See Antunes, *op. cit.* (32), pp. 794-6 for further details on this episode. Also Moitinho de Almeida and Barros e Carvalhosa, *op. cit.* (7), 241-65.

[35] J. F. Néry Delgado, "Elogio Histórico do General Carlos Ribeiro," *Revista de Obras Públicas e Minas*, 36 (1905), 19-21. See also Paul Choffat, "Notice Nécrologique sur Carlos Ribeiro," *Bulletin de la Société Géologique de France*, [3], 11 (1883), 325.

[36] Apart from its senior geologists, Carlos Ribeiro, a military engineer, and Pereira da Costa, a professor of geology and mineralogy at the Lisbon Polytechnic School, the Geological Survey had originally included two junior members: Néry Delgado, also a military engineer, and Antonio Augusto Aguiar (1838-1887), a professor of inorganic chemistry at the Polytechnic, although the latter only stayed with the Survey between 1862-64.

[37] As noted by Néry Delgado himself in a report sent in 1899 to the Minister for Public Works and published posthumously:

> In its original formation, our Institution included personnel from the two fields of knowledge that are required to undertake geological studies: technology and the natural sciences. The top-level staff of the former Geological Survey included two mining engineers and two professors from the Polytechnic School, one of geology and palaeontology, the other a professor of chemistry.
>
> The reform of 1869 assigned such studies exclusively to engineers (...). Now, engineers are very seldom knowledgeable in biological matters; that is why geological literature in different countries, which is to a large extent authored by individuals attached to their geological surveys,

> is the work not only of mining engineers, but also of many professors of geology and other naturalists attached to such institutions.

J. F. Néry Delgado, "Relatórios sobre a Reorganização dos Serviços Geológicos apresentados ao Ministro das Obras Públicas," *Communicações da Commissão do Serviço Geológico de Portugal*, 7 (1907-1909), 171

[38] During the period under discussion and up to 1878, Ribeiro and Delgado also carried out research in their respective fields of study and did some work of a more practical nature. For further details see Choffat, *op. cit.* (34), p. 325 and J. M. Cotelo Neiva, "A Geologia em Portugal no Século XIX" in *História e Desenvolvimento da Ciência em Portugal (Publicações do II Centenário da Academia das Ciências de Lisboa)* (Lisboa: Academia das Ciências, 1986), vol. 2, pp. 723-5.

[39] Oldroyd, *op. cit.* (2).

[40] As was indeed explained by Néry Delgado, *op. cit.* (37), p. 171:

> As palaeontology is a very complex science, it becomes necessary for different experts each to take charge of a restricted domain of this science, and it is to them that geologists from all nations turn for help. We have followed this example, which for us is most convenient, as the fossil fauna in Portugal is largely different from that of other countries. (...)

[41] See Vanda Leitão, "The Travel of the Geologist Carlos Ribeiro (1813-1882) to Europe, in 1858," STEP Meeting, Lisbon, September 2000.

[42] In a letter to José MacPherson (1839-1902) (Belas, 8 March 1879, IGM Historical Archive, Bookcase 10, Shelf 1, Box 5), Delgado says:

> Last year on my return from Spain, I submitted to my director an official report of what I had done, which has not really of a scientific character, nor was it written to go around the world. My director thought otherwise and the report was printed. As you will probably find something that might interest you I will ask him permission to send you some copies. If you feel that I deserve that honour please send a copy to your brother Don Guilherme MacPherson and another to Don Antonio Machado, because I do not dare to do it myself given its insignificant value.

[43] Néry Delgado, in turn, in a letter to the Spanish mining engineer Jacobo Rubio (?-?), dated 27 March 1870 (IGM Historical Archive, Bookcase 10, Shelf 2, Box 15), confides:

> At least in the Peninsula we have to commit ourselves towards making the efforts of the corporation of Portuguese civil [as opposed to military] engineers known, and destroy the false impression people have about them, which is favoured by petty partisan interests that unfortunately impose on our lives as if they were state interests.

[44] This mission was carried out between 28 May and 12 August 1878.

[45] Néry Delgado, *Relatorio da Commissão Desempenhada em Hespanha no Anno de 1878 por Joaquim Filipe Nery Delgado, adjunto da Secção dos Trabalho Geologicos do Reino* (Lisboa: Typographia da Academia Real das Sciencias, 1879).

[46] Néry Delgado, *op. cit.* (45), p. 5.

[47] Néry Delgado, *op. cit.* (45), p. 7.

[48] Néry Delgado, *op. cit.* (45), p. 8.

[49] C. Ribeiro, Néry Delgado, Portuguese Geological Map (1:500,000), Lisbon, 1876.

[50] Néry Delgado, *Terrenos Paleozoicos de Portugal. Sobre a Existencia do Terreno Siluriano no Baixo Alemtejo*, (Lisboa: Typographia da Academia Real das Sciencias, 1876), or its French version *Terrains Paléozoïque du Portugal. Sur l'Éxistence du Terrain Silurien dans le Baixo-Alemtejo* (Lisboa: Typographia da Academia Real das Sciencias, 1876).

[51] Roemer referred these strata to a lower division of the Culm.

[52] Roemer wrote (Quoted by Néry Delgado, *op. cit.* (45), p. 9):

> For very good reasons you have advocated the classification of the Nereites of S. Domingos as belonging to the Silurian (...) It seems to me almost certain that the system of schist strata from which that fossil came, which is located immediately below the layers of *Posidonomya Becheri*, in the province of Seville, belongs also to the protozoic division of the Silurian.

[53] As he concludes: "If my visit to Huelva did not clarify me completely about the Silurian stretch of S. Domingos, and if in the research carried out by Tarin I could see no good reasons to change the results obtained in Portugal, the discoveries made near Ensinasola shed an intense light which will greatly help me in pursuing my future investigations". Néry Delgado, *op. cit.* (45), p. 9.

[54] Up to now only this first meeting has been the subject of historical analysis in a paper authored by Ellenberger, but the subsequent meetings still remain to be analysed. F. Ellenberger, "The First International Geological Congress, Paris, 1878," *Episodes*, 1 (1978), 20-24.

[55] It is worth remarking that in these matters also Portuguese and Spanish geologists were to make joint contributions and to enter into discussions both for the purposes of the European Geological Map and on matters of nomenclature. In preparing the meetings of the International Geological Congress of Bologna of 1881, and that subsequently held in Berlin 1884, two reports of the Portuguese sub-commission of nomenclature were published. Néry Delgado, P. Choffat, "Rapport des membres Portugais des Sous-Commissions Hispano-Lusitaniennes en vue du Congrès Géologique International devant avoir lieu à Bologne en 1881," *Jornal de Sciencias Mathematicas, Physicas e Naturaes*, 39 (1884), 1-18; "Rapport de la Sous-Commission Portugaise de nomenclature en vue do Congrès géologique international devant avoir lieu à Berlin en 1884," *Communicações da Secção dos Trabalhos Geológicos*, 1 (1884) 19-32.

[56] Néry Delgado, Fieldwork notebook kept at the IGM Historical Archive, Bookcase 10, Shelf 3, Box 20.

[57] Néry Delgado, "Officio acerca das resoluções tomadas no congresso de Geologia," in Néry Delgado, *Relatorio e Outros Documentos Relativos à Comissão Scientifica Desempenhada em diferentes Cidades da Italia, Allemanha e França, por Joaquim*

Filippe Nery da Encarnação Delgado, (Lisboa: Imprensa Nacional, 1882). This document was addressed to Carlos Ribeiro, Director of the Portuguese Geological Survey.

[58] Before and after the Bologna meeting Delgado and Capellini exchanged correspondence. Capellini was also a stamp collector and on several occasions asked Delgado to send him collections of Portuguese stamps. See letters from Capellini dating especially from 1894, Bookcase 10, Shelf 1, Box 6. This correspondence was handled by Dr. António Carvalhosa, to whom we are very grateful.

[59] Néry Delgado, *op. cit.* (57), p. 59.

[60] The word *formation* that the British and the Germans used to signify *terrain* or *étage*, from now onwards should be used as suggested by the French committee to mean the *process of formation.* It was allowed to say "sedimentary formation" or "eruptive formation" but not, as before, "Jurassic formation" or "Silurian formation". See "Résolutions votées par le Second Congrès Géologique International, 2ème Session, Bologne, 1881," in Néry Delgado, *op. cit.* (57), p. 67. His italics.

[61] Néry Delgado, *op. cit.* (57), p. 60.

[62] Initially France, Britain, the Austro-Hungarian Empire, Germany and Russia. As the President was German, Germany gave its place to Italy and because the Swiss geologist Eugène Renevier (1831-1906) had made an important contribution on this matter, he was also appointed to this commission. Néry Delgado, *op. cit.* (57), p. 60-61.

[63] Néry Delgado, *op. cit.* (57), p. 61.

[64] In his letter (Letter from the Baron of Baye, Château de Baye, 11 Novembre 1885), the Baron of Baye, complains:

> Le gouvernement grec avait accepté de recevoir l'année prochaine notre congrès international d'anthropologie préhistorique. Une lettre de Santorin me mande que ce Congrès d'Athènes serait indéfiniment remis sur la demande des membres allemands. Ainsi donc après avoir fait échouer le projet de Bucharest si favorablement accueilli dans toute l'Europe, ils font remettre le Congrès d'Athénes définitivement accepté et annoncé. Si la politique guide et préside aux décisions relatives à nos Congrès, je crains beaucoup que celui de Lisbonne si brillant ne puisse avoir de successeur. La politique devrait rester étrangère à une institution scientifique. J'espère que de généreux efforts seront accomplis dans le but de relever nos réunions si utiles et si fécondes pour le progrès de la science.

In his reply (Reply from Néry Delgado to the Baron of Baye, Lisbon, 29 December 1885. IGM Historical Archive, Bookcase 10, Shelf 31, Box not numbered), Delgado says:

> C'est très grave ce que vous me dites par rapport à l'opposition systématique que les allemands font à la réunion du congrès anthropologique. Il est à présumer que les difficultés disparaitraient lorsque une ville allemande serait choisi pour la réunion du congrés. Dans le Congrès géologique de Bologne il s'est présenté des difficultés de toute genre pour que leur bureau international géologique fût chargé de l'impression de la Carte géologique de l'Europe; toutes ces difficultés ont

disparu lorsqu'on a décidé qu'un Comité directeur avec son siège à Berlin fut chargé de cette publication. Il est par conséquent très probable que l'idée à Dresde, ou à une autre ville allemande sera accueillie avec le même enthousiasme.

[65] According to Néry Delgado the numbers are as follows. Meeting held in Paris, 1878: of 304 participants, 194 were French and 110 were foreigners from 20 different countries. Meeting held in London: of 835 participants, 348 were foreigners from 26 countries. Those who effectively participated were 380, 140 being foreigners and from the British colonies. Néry Delgado, *Relatório Ácerca da Quarta Sessão do Congresso Geologico Internacional realisada em Londres, no Mez de Setembro de 1888, por Joaquim Filippe Nery da Encarnação Delgado* (Lisboa: Imprensa Nacional, 1889).

[66] Néry Delgado, *op. cit.* (65), p. 8

[67] Néry Delgado, *op. cit.* (65), pp. 10-13.

[68] To Delgado, Nereites and associated forms were not remains of marine plants, nor were they traces of worms as many palaeontologists believed. Rather they were prints of bodies of annelids. See Néry Delgado, *Etudes sur les fossiles des schistes à Nereites de San Domingos et des schistes à Nereites et graptolites de Barrancos* (ouvrage posthume) (Lisboa: Typographia da Academia Real das Sciencias, 1910).

[69] Néry Delgado, *Terrenos Paleozóicos de Portugal. Sobre a existência do terreno siluriano no Baixo Alemtejo* (Lisboa: Typographia da Academia Real das Sciencias, 1876).

[70] Néry Delgado, P. Choffat, Geological Map of Portugal (1:500,000), Lisboa, 1899.

[71] Néry Delgado, *Système du silurique du Portugal. Etude de stratigraphie paléontologique* (Lisboa: Typographia da Academia Real das Sciencias, 1908).

[72] Néry Delgado, *op. cit.* (57), p. 36.

[73] On Marr's work see, D. Oldroyd, "John Edward Marr (1857-1933. The Foremost Lake District Geologist of His Era," *Proceedings of the Cumberland Geological Society*, 6 (2000, for 1998-1999), 361-379.

[74] J. E. Marr, "On the Predevonian Rocks of Bohemia," *Quarterly Journal of the London Geological Society,* 36 (1880), 591-619.

[75] According to the same historian, Murchinson's adherence to colonies was not straightforward. In the first edition of his book *Siluria: A history of the oldest known rocks containing organic remains, with a brief sketch of the distribution of gold over the earth* (London: John Murray, 1854) he did not mention Barrande's colonies, in the second edition of 1859, p. 401, he mentions them but not with entire acceptance. They were given full prominence in the third edition of 1867, p. 380. See D. Oldroyd, *The Highlands Controversy. Constructing Knowledge through Fieldwork in Nineteenth-Century Britain* (Chicago/London: The University of Chicago Press, 1990), p. 224.

[76] For Barrande's controversies, which went on for about 20 years, see J. Perner, "Les colonies de Barrande," *Bulletin de la Société Géologique de France*, [5], 7 (1937), 513-52. For a comparison of Barrande's interpretations with modern stratigraphy see J. Kriz, J. Porjeta Jr., "Barrande's Colonies Concept and a Comparison of his Stratigraphy with the Modern Stratigraphy of the Middle Bohemian Lower Paleozoic Rocks (Barrandian) of Czechoslovakia," *Journal of Palaeontology*, 48 (1974), 489-494.

[77] In Barrande's words (J. Barrande, *Défense des colonies* (Prague/Paris: Chez l'Auteur, 1861), p.14):

> Les colonies, en général, étant des apparitions partielles et anticipées d'une faune, durant l'existence de la faune précédente, constituent un phénomène purement paléontologique, et qui, par conséquent, pourrait être complètement indépendant des phénomènes stratigraphiques, c. à d. de la nature et de la succession des roches.

Subsequently Barrande published various memoirs defending the colonies against various opponents, notably the British. See J. Barrande, "Colonies dans le bassin silurien de la Bohême," *Bulletin de la Société Geólogique de France, [2], 17 (1859-1860), 602-609* and *Défense des Colonies V. Apparition et Réapparition en Angleterre et en Ecosse des espèces coloniales siluriennes* (Prague/Paris: Chez l'Auteur, 1881).

[78] Oldroyd, *op. cit.* (75), p. 224

[79] *Ibid.* and *op. cit.* (73), p. 363, fig.1.

[80] Néry Delgado, *op. cit.* (57), p. 36.

[81] M. J. S. Rudwick, *The Meaning of Fossils. Episodes in the History of Palaeontology* (Chicago/London: The University of Chicago Press, 1972); Oldroyd, *op. cit.* (2); M. T. Green, *Geology in the Nineteenth Century. Changing Views of a Changing World* (Ithaca/London, Cornell University Press, 1982).

[82] Goulven Laurent, *Paléontologie et Evolution en France, 1800-1860* (Paris: Editions du CTHS, 1987).

[83] Laurent, *op. cit.* (82), p. 305.

[84] Laurent, *op. cit.* (82), p. 303.

[85] Néry Delgado, *op. cit.* (57), p.44.

[86] Néry Delgado, *op. cit.* (45), p. 15.

[87] Néry Delgado, *op. cit.* (45), p.12.

[88] Néry Delgado, *op. cit.* (45), note on p.12.

[89] Reply from Eduardo Benot, Madrid 8 August 1878, IGM Historical Archive, Bookcase 10, Shelf 1, Box 5.

[90] Néry Delgado, *op. cit.* (65), p.7.

[91] Néry Delgado, *op. cit.* (65), p. 42.

[92] Néry Delgado says that at last he had met Hébert personally at the Bologna meeting after many years of correspondence.

[93] Throughout the nineteenth century French *savants* often complained about the inadequacy of their research facilities and compared them with the German, often with a mixture of admiration and nationalistic revulsion. H. W. Paul, *The Sorcerer's Apprentice. The French Scientist's Image of German Science, 1840-1919* (Gainesville: University of Florida Press, 1972).

[94] Néry Delgado, *op. cit.* (65), p. 52.

[95] Néry Delgado, *op. cit.* (65), p. 54.

[96] The precise circumstances of the encounter between Carlos Ribeiro and Paul Choffat are as yet unknown, although the two geologists certainly met, since a reference to such a meeting is to be found in a letter from Choffat to the Head of the Portuguese Geological Survey from Zurich, dated 29 October 1878 (IGM Historical Archive, Bookcase 12, Shelf 3, Box 64). Choffat's biographers tend to assume that the meeting took place in Paris, at the Congress itself. See E. Fleury, "Une phase brillante de la Géologie portugaise. P. Choffat 14 mars 1849-6 juin 1919," *Mémoires publiés par la Société Portugaise des*

Sciences Naturelles, Série Géologique, 3, (1920), 4; also J. M. Oliveira Simões, "Biografia de Geólogos Portugueses," *Comunicações dos Serviços Geológicos de Portugal*, 13 (1919-1922), vii-viii; and J.L. de Vasconcellos, "Paul Choffat," *O Archeologo Português*, 24 (1919-20), 298.

[97] There are several short biographies on Paul Choffat. The most comprehensive article is by Fleury, *op. cit.* (96), from which most of the biographical information included in this paper was taken.

[98] A former student of Elie de Beaumont (1798-1874), Jules Thurmann was the author of an *Essai sur les soulèvements jurassiques* and a well-known figure in Porrentruy, where he promoted the study of the natural sciences.

[99] He mentions other influences: the stratigrapher A. Gressly (1814-1865) who developed the notion of facies, the palaeontologist J.B Greppin (?-1881) who published a geological description of the Jura formations in the Bern region and mining inspector and geologist A. Quiquerez (1801-1882), among others. Fleury, *op. cit.* (96), 4.

[100] For a discussion of the contributions made by these two leading Swiss geologists, see A. V. Carozzi, "La géologie en suisse des débuts jusqu'à 1882 - digression sur l'histoires de la géologie suisse depuis Konrad Gesner (1565) jusqu'à Heinrich Wettstein (1880)," *Eclogae geol. Helv.*, 76/1 (1983), 12-14, 19-20. On Heim's role in the institutionalisation of Swiss geology see also W. K. Nabholz, "Die Gründung der Schweizerischen Geologischen Gesellschaft und ihre seitherige Entwicklung," *Eclogae geol. Helv.*, 76/1 (1983), 33-45.

[101] Hungarian stratigrapher and structural geologist L. Lóczy (1849-1920. Swiss palaeobotanist O. Heer (1809-1883), author of *Flora tertiaria Helvetiae* (1855-59) and *Die Urwelt der Schweiz* (1865), a major early work in palaeoecology. French stratigrapher and palaeontologist K. Mayer-Eymar (1826-1907. French stratigrapher, structural geologist and palaeontologist J. Marcou (1824-1898.

[102] Fleury, *op. cit.* (96), pp. 34-5.

[103] See footnote (96).

[104] He suffered from chronic laryngitis which must have hampered his teaching duties.

[105] Letter from Choffat quoted in footnote (96).

[106] *Ibid.*

[107] J. MacPherson (1839-1902), Spanish structural geologist and stratigrapher.

[108] Indeed, he wrote (Letter from Choffat quoted in footnote (95):

> Il est clair que je ne pourais pas étudier suffisamment ces terrains si j'en étais réduit à mes propres observations, surtout dans un pays dont je ne connais pas la langue. Ce n'est qu'en pouvant compter sur les communications des géologues portugais que je puis espérer atteindre un résultat. Ceci n'est possible que si aucun de ces messieurs ne songe à entreprendre un travail semblable, pour le moment du moins; même dans ce cas la question est assez délicate puisque les observations amassées par la Commission géologique formeraient le point de départ de mes recherches.
>
> Je crois que la seule manière d'avoir de part et d'autre une position franche consiste en ce que la Commission géologique veuille bien accepter mes services gratuits et m'admettre pour quelques mois au nombre de ses collaborateurs.

> Dans ce cas je lui livrerais le résultat de mon travail me reservant toutefois le droit de le faire paraître, soit en extrait, soit en entier dans les publications d'autres contrées et de conserver tout ou partie des fossiles que j'aurais récoltés moi-même.

His remarks suggest that he was unaware at the time of the size and activities of the Portuguese geological community and of the Geological Survey in particular.

[109] Letter from Choffat to Ribeiro, Lisbon, 26 November 1878, IGM Historical Archive, Bookcase 12, Shelf 3, Box 64.

[110] J. F. Néry Delgado, "Les Services Géologiques du Portugal de 1857 à 1899," *Communicações da Direcção dos Serviços Geológicos de Portugal*, 4 (1900-1901), x.

[111] French palaeontologist and stratigrapher.

[112] Letters from Tournoüer to Ribeiro, Paris, 15 January 1879 and 21 January 1879, IGM Historical Archive, Bookcase 12, Shelf 3, Box 64.

[113] French palaeontologist and stratigrapher.

[114] Letter from Fontannes to Ribeiro, Lyon, 24 May 1879, IGM Historical Archive, Bookcase 12, Shelf 3, Box 64.

[115] In a letter to Ribeiro, Fontannes makes reference to "(...) Mr. Choffat, qui a trouvé à Lisbonne des sujets d'étude aussi attrayants que les relations qu'il y cultive sont agréables (...)" and a letter sent by Heer to Choffat early the following year reads (French translation): "C'est avec grand plaisir que j'ai appris par votre lettre du 12 fevrier ct. que vous avez reçu un bon accueil à Lisbonne et que l'on vous y a soutenu dans vos recherches géologiques." Letters from Fontannes to Ribeiro, Lyon, 5 August 1879; and from Heer to Choffat, Zurich, 23 February 1880, IGM Historical Archive, Bookcase 12, Shelf 3, Box 64.

[116] Letters from: Librairie F. Savy to Choffat, Paris, 1 June 1879; J. B. Baillière et Fils to Choffat, Paris, 8 July 1879; R. Friedländer & Sohn, Buchhandlung to Choffat, Berlin, 24 November 1879; R. Friedländer & Sohn, Buchhandlungand to Ribeiro, Berlin, 4 November 1880, IGM Historical Archive, Bookcase 12, Shelf 3, Box 64.

[117] Letter from Choffat to Ribeiro, Batalha, 8 October 1879, IGM Historical Archive, Bookcase 12 Shelf 3, Box 64.

[118] See footnote (101).

[119] In his reply Heer wrote (Letter from Heer to Choffat, Zurich, 23 February 1880, IGM Historical Archive, Bookcase 12, Shelf 3, Box 64, French translation):

> La découverte de plantes du Trias, du Jurassique et du Crétacé est très importante et je suis prêt à en entreprendre la description, pourtant je dois poser la condition que mes déboursés relatifs aux ports et au dessin des planches me seront remboursés. Les planches seraient dessinées dans ma chambre, sous ma direction et mon aide et exécutées de la même manière que celles que j'ai publiées dans les mémoires de l'académie de S. Petersbourg et de Stockholm et que celles de ma Flora fossilis Helvetiae. Je les accompagnerais d'un texte court et la section des travaux géologiques pourrait recevoir ce travail et les planches dans ses publications; si elle ne veut pas de cet arrangement il faudrait que je me réserve le droit de publier comme je jugerai convenable. Si quelques pièces des doubles peuvent être données au musée géologique du

> Polytechnique, nous en serons reconnaissants et je vous prie de marquer ces pièces d'un signe spécial. J'aurai toujours grand plaisir de recevoir de vous nouvelles et de celles de vos travaux; il est très intéressant d'apprendre quelque chose de détaillé sur la structure géologique de cette extrémité occidentale de l'Europe.

120 On a postcard acknowledging the arrival of the consignment Heer wrote (Postcard from Heer to Choffat, Zurich, 18 May 1880, IGM Historical Archive, Bookcase 12, Shelf 3, Box 64.):

> The crate with the fossils has arrived safely. I took out the little box for Mr. Loriol and sent it straight to him. He has already acknowledged its arrival. I also sent to Mr. Kenngot [G.A. Kenngot (1818-1897), Austrian petrologist, crystallographer and mineralogist] the rock samples and the wonderful Silurian trilobites. I have had a look at the plants but it's too early to say anything definite about them. Some can easily be identified, viz. those from Serra d'Aire (Toartian) the *Chondrites Bollensis* in its "minor" var, such as that of Betznau, and from the Bajotian the *Taonurus Trocerus Heer* and the *T. Scoparius Th.* However, most specimens will require a long and detailed examination. I shall inform you as soon as I have concluded the work but I cannot set a date for that. The plants from the Cretaceous are in a better condition but they seem to be from the Wealdian.

121 Wire from Heer to Ribeiro, Zurich, 25 May 1880, IGM Historical Archive, Bookcase 12, Shelf 3, Box 64.

122 In its session of 7 June 1880. We have been unable to find any reference to Choffat's talk in the session's proceedings, *Bulletin de la Société Géologique de France*, [3], 8 (1879-80), 369-89. The work by Choffat was his *Etude Stratigraphique et Paléontologique des Terrains Jurassiques du Portugal – Première Livraison - Le Lias et le Dogger au Nord du Tage* (Lisboa: Académie Royale des Sciences, 1880).

123 Letter from Choffat to Ribeiro, Paris, 8 June 1880, IGM Historical Archive, Bookcase 12, Shelf 3, Box 64.

124 Fleury, *op. cit.* (96), 5.

125 Frederich Welwitsch was born in Mariasaal, Carinthia, in 1806. He studied botany and published in 1834 "Observation on the Cryptogamic flora of the lower Austria", winning a award given by the Vienna Municipium. In 1836, Welwitsch published a synopsis on the *Nostochineae* and had contact with E. Fenzl and other scientists from the Vienna Museum. Later on, he became an expert on African flora.

126 The circumstances surrounding Welwitsch's departure from Vienna and his joining the Portuguese society are still to be clarified. His biographer, J. Almeida, in "Dr. Frederich Artur Welwitsch and his work in Angola," *Boletim Geral das Colonias*, (1926), 13, has given a quite clear account of his life and work.

127 After the integration of the Natural History Museum in the Lisbon Polytechnic School, a decree of January 1862 renamed it the Lisbon National Museum.

[128] P. Choffat, "Dr. Welwitsch – Quelques notes sur la géologie d'Angola coordonneés et annoteés par Paul Choffat," *Comunicações dos Serviços Geológicos*, 1 and 2, (1885 - 92), 27-51.

[129] Welwitsch's notes are quoted in Choffat, *op. cit.* (128), 30.

[130] Choffat, *op. cit.* (128), 33-34.

[131] *Ibid.*

[132] Monteiro, a naturalist working for the Royal Mining School of London and member of the Zoological Society went to Angola to investigate metal deposits. In 1873 he published a book entitled *Angola and the river Congo.*

[133] J. Veríssimo, "Scientific Societies, Expeditions and Power in Portugal in late nineteenth and early twentieth century," talk delivered at the second STEP meeting "Scientific Travels," Lisbon, September 2000.

[134] The *Jornal de Ciências Matemáticas, Físicas e Naturais* was published by the Royal Academy of Sciences of Lisbon.

[135] B. Capelo, R. Ivens, *De Benguela às Terras de Iaca — Descrição de uma viagem através do Continente Africano* (Lisboa: Imprensa Nacional, 1881), 2 vols.

[136] Choffat, *op. cit.* (128), 41; P. Choffat, P. de Loriol, "Materiaux pour l'etude stratigraphique e paleontologique de la Province d'Angola," *Mémoires de la Société Physique et d'Histoire Naturelle de Geneve*, (1881), 12, 33, 35, 36.

[137] Oliveira Martins, *Hermenegildo Capelo e Roberto Ivens — Documentos* (Lisboa: Agência Geral das Colónias, 1951), vol. 1, pp. 349-350.

[138] B. Capelo, R. Ivens, *De Angola à Contra Costa — Descrição de uma viagem através do Continente Africano* (Lisboa: Imprensa Nacional, 1886), 2 vols.

[139] L. A. P. Malheiro graduated in civil engineering from the Polytechnic Academy of Oporto, and worked with the Geological Commission and later on with the mining services. Throughout his twenty-six year career as an engineer, Malheiro combined important public missions with services for private companies. He started a Minerographical Chart, under the advice of the Mining Department.

[140] L. Malheiro, "Explorações Geológicas e Mineiras nas Colónias Portuguesas," *Sociedade de Geografia de Lisboa* (1881), 6.

[141] "Parecer da Comissão Africana acerca da exploração mineralógica a Angola," *Boletim da Sociedade de Geografia de Lisboa*, [2], 5 (1881), 371.

[142] Choffat and Loriol, *op. cit.* (136), 3.

[143] *Ibid.*

[144] Choffat and Loriol, *op. cit.* (136), 5.

[145] Choffat and Loriol, *op. cit.* (136), 29–58

[146] His appointment as General Commissioner of Mines gave him the responsibility for studying the resources and to collect information for the Geological Chart of Mozambique and adjacent territories. At the beginning of the twentieth century, all the mining legislation in use in Mozambique was baesd on Freire de Andrade's work. In 1895 Antonio Enes, the Royal Commissioner of the province of Mozambique, took Freire de Andrade with him on a campaign against some rebel groups. Andrade organised the defence and was responsible for the victory of the Portuguese army. In 1906 he was appointed General Governor of Mozambique.

[147] Freire de Andrade, "Reconhecimento geológico dos territórios compreendidos entre Lourenço Marques e o Rio de Zambeze," Dissertação para o concurso da 7ª cadeira da Escola Politécnica, Imprensa Nacional, 1894.

[148] Credner quoted by Freire de Andrade in. *op. cit.* (147), p. 4.

[149] P. Choffat, " Matériaux pour l'étude stratigraphique et paléontologique de la province d'Angole," *Mémoires de la Société de Physique et d'Histoire Naturelle de Genève*, 30 (1888), 1-59.

[150] P. Choffat, "Contribuitions à la connaissance géologique des colonies Portuguaises d'Afrique – II – Nouvelles données sur la zone littoral d'Angola," *Comission du Service Géologique du Portugal*, (1905), 28–70.

[151] Choffat, *op.cit.* (150), 32.

[152] Choffat, *op.cit.* (150).

[153] M. Pereira de Sousa, "Contribuitions à l'étude petrographique du nord d'Angola," *Comptes Rendus des Séances de l'Académie des Sciences de Paris*, 2 (1913), 1450-1452.

TIMO MYLLYNTAUS

DISCOVERING SWITZERLAND

Internationalisation among Nordic Students of Technology prior to World War II

1. SPECIAL RELATIONSHIP

Die Eidgenössische Polytechnische Schule in Zürich was one of many polytechnics that were established in Europe during the nineteenth century. Swiss polytechnics began to grant doctoral degrees in 1909 and two years later the name was changed to *Die Eidgenössische Technische Hochschule,* (ETH). In English, it is called *The Swiss Federal Institute of Technology*. In terms of the number of students, it is not among the largest universities – not even among the biggest technical universities. Prior to World War I, its annual enrolment remained at fewer than 2,000 undergraduate and graduate students and exceeded 6,000 students only in the late 1970s. Nevertheless, the ETH has maintained a good reputation among Nordic students of technology. Young men from Norway, Finland, Sweden and Denmark were among the first foreigners to enter the ETH in the late 1850s and early 1860s. Why then did they bother to travel 2,000 – 3,000 kilometres on foot, in post wagons, by steamship and train from their hometowns to remote Zurich?

Another question under scrutiny is why the ETH has managed to preserve its popularity over the decades. Considering the period of the past 140 years as a whole, Nordic students constitute one of the largest groups of foreign students at the ETH. Almost 2,000 Scandinavians and Finns studied there between 1858 and 2001, their number being surpassed only by students from Switzerland's closest large neighbours, such as Germany and France. In the post-1945 period, increasing numbers of students from Luxemburg, Austria and Italy have also enrolled in the ETH.

This paper aims to analyse the studies of Nordic students at the ETH and to explain why they left their countries and chose that particular university of technology. For practical reasons, my focus is on the period before the outbreak of World War II.

Ana Simões, Ana Carneiro, Maria Paula Diogo (eds.), Travels of Learning. A Geography of Science in Europe. (299-328)

2. FACTORS OF INTERNATIONAL MOBILITY

In historical studies on emigration, the reasons why people move from one country to another are often classified in two main groups: pushing factors and pulling factors, which constitute combined forces of migration. This approach can undoubtedly also be applied to the mobility of students.

Since the Middle Ages, when the basis of the European university system was established, students have travelled from one country to another to receive the higher education they have wanted. Factors pushing them to leave their own country and to enrol in foreign institutions of education tend to change periodically, but in general they include the following:

- Political circumstances in the home country
- Flaws in the national or regional educational system
- Poor quality of teaching
- Lack of laboratories and other research facilities
- Poor employment prospects in the home country

These factors may be significant enough for students to leave their own country. Nevertheless, they do not necessarily explain why they are drawn to particular educational institutions in certain foreign countries. Pulling factors may do so, however, and in fact they may be even more significant than pushing factors. Students may leave their own countries even though a reasonable education is available there. The magnitude and qualities of the gap between the supply of education abroad and in the home country can be decisive.

Pulling factors of student mobility include both tangible and intangible inducements:

- Attractive spectrum of education in various disciplines
- High quality of teaching and access to the latest technology
- Interesting educational system
- Opportunities for scholarships or other forms of financial support
- Good facilities and pleasant atmosphere
- Promising prospects for a future career
- Opportunities to enhance language skills and/or social prestige

Students' international mobility is thus a result of dynamic interaction between both pushing and pulling factors. It is an old tradition comparable to the wanderings of journeymen, who wished to learn skills from the best masters in their craft. *Wanderlust,* a passion for travelling, and the search for new things are also often intrinsic features of youth. Students in remote areas have to devote special effort to gathering information on the various educational opportunities available to them. Mobility increases the ability of students on the periphery to evaluate and compare the various options available to them, while continuous information flows via other media also tend to affect migration flows. The experiences of older students are often quickly shared among their younger fellows searching for appropriate educational options. Once mobility is achieved internal dynamism has a significant effect on its development. Studies abroad have traditionally provided an important channel through which new technology has been transferred between countries. In various peripheral countries without lucrative investment or marketing opportunities, this transfer channel has had a major significance for scientific and technological development.[1]

3. THE INTERNATIONAL IMAGE OF MID-NINETEENTH CENTURY SWITZERLAND

It was only in the early nineteenth century that Nordic people actually "discovered" Switzerland. There were several reasons why this Alpine land began to arouse international curiosity. Firstly, the nineteenth century was the era of transport revolution: steamships, railways and better roads. Ever larger numbers of people were on the move. International tourism rapidly gained a foothold among the wealthy. Switzerland became famous for its extraordinary scenery, its mountains, valleys, lakes and rivers. A stopover in Switzerland during a trip round Central Europe often meant days of relaxation for various Nordic tourists, who had become tired of visiting operas, theatres and museums in Berlin, Munich, Vienna and Paris. Switzerland could offer something different. Frequently, early tourists described their experiences in newspapers, journals and guidebooks, and thus made Switzerland familiar to their countrymen.

Secondly, political life in Switzerland aroused interest as well. Nordic people paid attention to the neutrality of Swiss foreign policy, and to the Swiss ability to stand up to pressure from its larger neighbours. They were keen to learn the options available to small countries in a changing world.

Thirdly, Norwegians and Finns admired the political independence of Switzerland. Both nationalities were looking ahead and weighing up their opportunities to gain political sovereignty. A republic as a form of government and the system of cantons as a political structure were seen to be worthy of consideration.

Fourthly, the Swiss case was exceptionally significant for Finns; the amazing extent of political freedom in the Alpine republic contrasted sharply with the situation in Finland and Russia. Switzerland was seen as a free country. The lack of tight political control, the freedom of the press and the freedom to set up associations were extraordinary phenomena that contrasted conspicuously with the political situation in Finland, a grand duchy under the heavy-handed government of the Russian tsar. In addition, Finns regarded Switzerland as a country in which people with different native languages were able to live peacefully together. A heated conflict between Finnish and Swedish speakers prevailed in late nineteenth-century Finland. These rival parties argued for years in the press about whether the Swiss formed a nation and whether they could have a common national identity because they were divided into four linguistic sections.[2]

Several politically influential persons from the Nordic countries visited Switzerland in order to become acquainted with Swiss solutions. The Finnish national philosopher, journalist, and later senator, Johan Wilhelm Snellman, travelled in German-speaking Switzerland in 1840–1841, and noted his observations. He transmitted his impressions to his compatriots through the press. Although he did not accept all Swiss solutions, he wrote that the Swiss experience could provide "building material" for Finland. He especially appreciated the Swiss educational system and the light and cheap system of military defence.

4. "IN INDUSTRIAL TERMS, TOO, SWITZERLAND IS AN EXTRAORDINARY COUNTRY"[3]

At the time, Switzerland was generally regarded as a land of both freedom and rising industry. In 1856–1858, a leading Finnish journalist, August Schauman, made a two-year trip to the "European countries of culture." After spending ten months in Paris, he travelled to Switzerland for two months in the summer. As a tourist, he mainly enjoyed the Swiss scenery from Lake Geneva to Lake Boden. Meanwhile, he also visited towns and cultural institutions. The third Swiss industrial exhibition in Bern made such a great impression on him that he wrote a report on it. The report is included in his series of travel accounts published in a Finnish newspaper.[4] Even decades later, he remembered to emphasize that particular article in his memoirs, which first appeared in print in 1892–1894.[5] He praised the Swiss economy as follows:

> Switzerland is situated a long way from the sea; it must obtain raw materials for its most important industries (cotton, silk and clock manufacturing) from remote countries. It allows all foreign goods easy access to its home market, whereas the prevailing system of prohibition in its neighbouring countries prevents the sales of its products within a short distance, and therefore it ought to find markets in the remote parts of the world. Nevertheless, in relative terms Switzerland has a larger industrial base than any other country and that achievement is attributed to the freedom of trade and to the diligence of its citizens.[6]

It was through such articles that Nordic people came to know of Switzerland as a land of technology, manufacturing and trade. They followed Swiss achievements in science, innovation, and business in both the domestic press and foreign publications.

In the mid-nineteenth century, a great many Nordic intellectuals considered Switzerland a model, a *beau ideal*, of a free, democratic and prosperous country. They knew a lot about this Alpine republic and openly compared its social circumstances to those of their own country. This exceptionally favourable image of Switzerland was certainly a significant factor in attracting Nordic students to its educational institutions.

In terms of population, Switzerland with its 3.9 million inhabitants in 1913 was about the same size as the four Nordic countries, each with an average of 3.5 million inhabitants. With regard to GDP per capita, however, only Denmark could match the Alpine republic, a country that was already among the most affluent nations in the world a hundred years before. With respect to GDP, Sweden was 21% and Norway 33% behind, whereas in terms of this indicator, Finland had a 44% lower living standard than Switzerland, as shown in Figure 1.

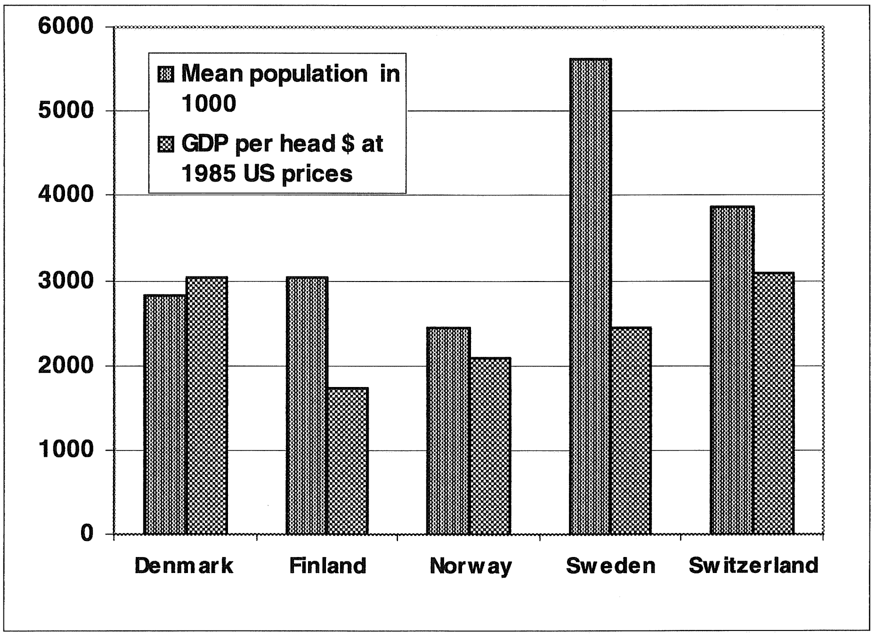

Figure 1. Population and GDP per Capita in Denmark, Finland, Norway, and Switzerland in 1913

Sources: Angus Maddison, *Dynamic Forces in Capitalist Development. A Long-run Comparative View* (Oxford: Oxford University Press 1991), pp. 6-7, 198, 232-234; *Statistical Yearbook of Finland 2000* (Helsinki: Statistics Finland 2000).

5. THE ETH AS A TRAILBLAZING INSTITUTION

In Continental Europe, higher technical education began in France with its special institutes. The *Ecole nationale des ponts et chaussées* was opened in Paris in 1747. This was followed by the *Ecole nationale supérieure des mines* in 1778. The first polytechnic institute, the *Ecole polytechnique,* was also set up in Paris in 1794, and provided the model for various other Continental polytechnics, such as in Berlin (1799), Prague (1806), Vienna (1815), Karlsruhe (1825), Dresden (1828) and Stuttgart (1829). By World War I, most of these polytechnics had expanded and become universities of technology with the right to grant degrees of graduate engineer and doctor of technology.[7]

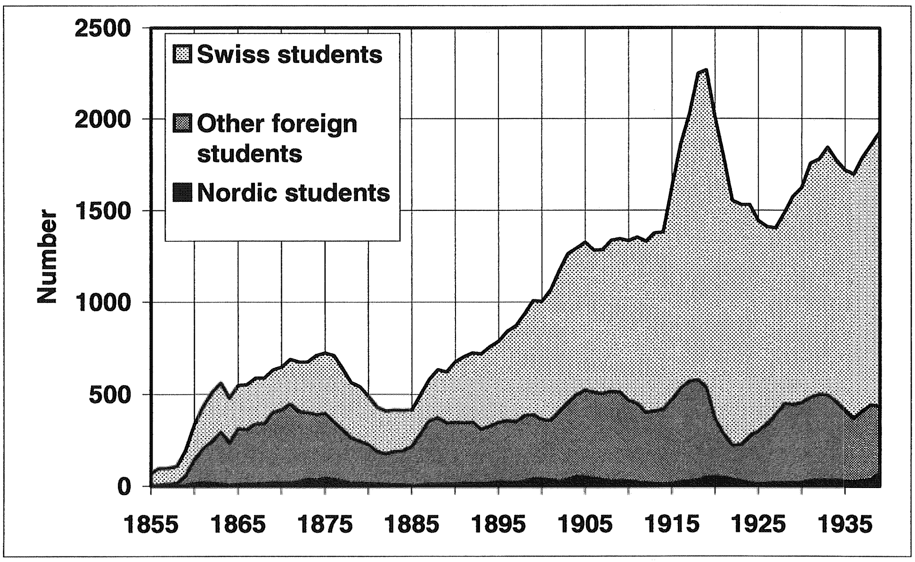

Figure 2. Students Number at the ETH, 1855–1939

Sources: ETH Programm und Stundenplan 1856/57–1967/68, ETH Archives, Zürich; Eidgenössische Technische Hochschule Zürich 1955–1980, Festschrift zum 125 jährigen Bestehen (Zürich 1980).

Die eidgenössische polytechnische Schule was the first Swiss polytechnic. Soon after it was established in 1855, word spread throughout the Nordic countries that this new technical institution possessed some outstanding qualities. French technical schools (*Ecole Polytechnique*) had previously been considered models for engineering education. They emphasized theoretical education and focused on educating officials for government posts. Although the Swiss school was a state-owned institution, it aimed primarily to train engineers for practical jobs in manufacturing, transport and the rest of private business life, and not only to educate technical experts for government posts. The second objective, which was closely connected to the first one, was to provide students with a broad curriculum. Consequently, from the very beginning, besides mathematics, physics and other sciences and engineering, the Swiss polytechnic included economics, law, and humanistic subjects, such as foreign languages, literature and history, in its syllabus as voluntary subjects *(Freifächer)*. The lectures on these subjects were held after regular school hours, i.e. 5 – 7 p.m. To emphasize the significance of a broad curriculum, students have been obliged since 1924 to attend at least one *freifach* course each semester.

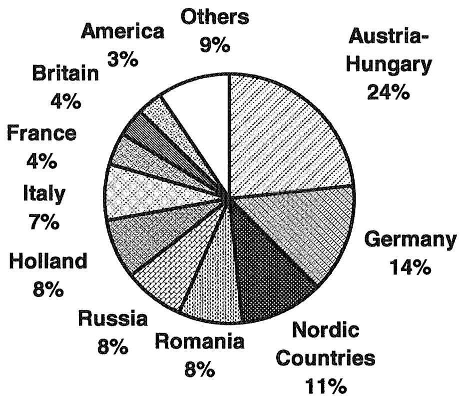

Figure 3. Enrolment of Foreign Students at the ETH, 1900/01 (N = 362)

Source: *Programm der Eidg. Technischen Hochschule für das Wintersemester 1900/01* (Zürich 1900), ETH Archives, Zürich.

Thirdly, the Swiss polytechnic school set ambitious international goals for itself. An ETH bulletin prepared for the Paris world exhibition in 1889 claims that the Institute was not only established for the Swiss, but that "it should and will also provide a place of education for the whole world" *(Auch soll und will sie aller Welt eine Bildungsstätte bieten)*.[8]

Clearly, these objectives were widely welcomed abroad. In the very first year (1855), three foreign students enrolled in the ETH and five years later the number of foreign students had risen to over fifty. The school attracted increasing numbers of foreign students during its first decades, and the Swiss periodically found themselves in a minority of the student body, especially in the years 1865–1876 and again between 1885 and 1891. In addition, internationalism was emphasized by the fact that, from 1855 to near the end of the nineteenth century, most professors were also foreigners.

The industrialization of Switzerland accelerated during the last two decades of the nineteenth century and the Swiss became increasingly interested in technology. As shown in Figure 2, the late 1880s were a turning point in the history of the ETH, when the number of both Swiss students and teachers began to grow much more quickly than that of their foreign counterparts. Just after World War I, the Swiss authorities decided to strengthen the position of Swiss teachers and students at the ETH. With the onset of economic and political problems in many countries, the inflow of foreign students diminished somewhat in the following years. Their numbers soon revived, however, and their proportion of total enrolment remained at about 25% from the mid-1920s to the end of the 1930s. The reputation of the ETH as an institution of qualified teaching has remained high in the post-1945 period, and the proportion of foreigners has fluctuated between 10 and 22 per cent. In 1995 they accounted for 14% of all undergraduate and graduate students and for up to 40% of postgraduates and doctoral students.[9]

At the turn of the century, citizens of Switzerland's neighbouring countries have been well represented among the foreign students, as depicted in Figure 3. Prior to World War I, the situation changed. At the time, Russians accounted for a larger proportion of foreign students than Scandinavians and Finns together did, but the tsarist empire was a country of 182 million inhabitants in 1913.[10] In contrast, in terms of the ETH enrolment related to the population, the Nordic countries of around 14 million people in total surpassed all other foreign nations, even Switzerland's immediate large neighbours such as France, Germany, Austria-Hungary and Italy. According to this enrolment-per-capita relationship, only the Netherlands could match the Nordic countries.

The proportions of different nationalities in the student body varied markedly, even over a few years. Nevertheless, Nordic students tended to stay within the ten biggest national groups. Figure 4 illustrates the images of different nationalities in the eyes of a contemporary Swiss artist.

Ausländeranteil Wintersemester 1906/07. Im Schuljahr 1906/07 zählte die ETH 1281 Studierende, davon stammten 35% aus dem Ausland. «Akademie 1907», Bierzeitung des Akad. Ingenieur-Vereins.

Figure 4. Enrolment of Foreign Students at the ETH, 1906/07

German universities of technology (*Technische Hochschulen,* TH) were the first to follow the model of the ETH and orient themselves to educating practical engineers mainly for the private sector. However, they excluded a broad liberal education from their curriculum. Due to their great number (12 in 1918) and large enrolment, German THs were able to admit many more Nordic and other foreign students than the Swiss Federal Institute. In 1900/01 foreign students accounted for 2017 or 18% of the total enrolment in nine German THs, while their proportion of the student body in the ETH was 362 or 36%.[11] In the German THs, Scandinavians composed 9% of the foreign students at the time, and that figure was quite close to their respective proportion in the ETH.[12] For example, it has been estimated that, in the period 1900–1914, about 520 Finns were enrolled in German universities. Nearly half of them (235 or 45%) began their studies at THs and the rest in other universities. During the interwar years, the popularity of German higher education institutions decreased markedly among Nordic as well as other foreign students.[13] In contrast, the popularity of France rose. In the mid-1930s, France ranked first in terms of the enrolment of foreign students (14,430), and Britain (5,150) ranked second ahead of Germany (4,460).[14]

6. TECHNICAL EDUCATION IN THE NORDIC COUNTRIES

Because so many Nordic students began their studies in Central European polytechnics or universities of technology, one might ask whether Denmark, Finland, Norway and Sweden lacked a system of higher education in technology. It is true that engineering education started later in these countries and expanded more slowly than in the more advanced Continental countries. However, at least one university of technology had been established in each of the four Nordic countries by 1914. To put it simply, studying technology abroad did not primarily replace studies at home universities of technology, but it did supplement the education received at national institutions.[15]

Only a minority of Nordic students moved from a grammar school or other higher secondary school to study in a foreign university of technology. Studies abroad were usually preceded by studying in renowned national institutions.

Table 1. Technical Schools in the Nordic Countries prior to 1939

Country **Lower-level technical schools**	**Intermediate technical schools**	**Higher institutions of technology**
SWEDEN		
Laboratorium Mechanicum (1697) Högre artilleriläroverket i Marieberg (Marieberg Higher School of Artillery, 1818),		
Falu Bergskola (Falun Mining School, 1822)	Teknologiska Institut, Sthlm (Technological Institute, 1827->)	KungligaTekniska Högskolan (Royal Univ. of Technology, 1877, **1927**)
Chalmerska slöjdskolan, Gbg (Handicrafts School, 1829->)	Chalmerska tekniska institut (Chalmers Technical Institute, 1875->)	Chalmerska tekn. högskolan (Chalmers University of Technology, **1937**)

Country **Lower-level technical schools**	**Intermediate technical schools**	**Higher institutions of technology**
DENMARK		
Orlogsvaerfts Skibskonst-ruktörsskole (Orlog Shipbuilding School, 1690)		
Institute for Metalarbejdere (Institute for Metal Workers Cpn, 1807)		Den Polytekniska Læreanstalt, Cpn (Polytechnical Academy, 1829) Den Militaere Højskole (Military Academy, 1830)
FINLAND		
Tekniska realskolan, Hfors (Technical School, 1849->)	Polytekniska Institut (Poly-technical School, 1872->)	Polytekniska Institut i Finland (Finnish Polytechnics, 1879) Transformed to: Teknillinen korkeakoulu/ Tekniska Högskolan (University of Technology, **1909**)
Tekniska realskolor, Åbo & Vasa (Åbo & Vasa Technical School, 1849)		
Industriskolor i Tammerfors, Kuopio & Viborg, (Indus-trial Schools, 1886)	Tampereen teknillinen opisto (Tampere Polytech-nical School, 1912)	
Industriskolor i Uleåborg (1897) Industriskolan i Björne-borg (1901)		
	Tekniska lärovärket, Hfors (Helsinki polytechnical school, 1916)	Tekniska fakultet i Åbo Akademi, Åbo (Faculty of Technology in Åbo Akademi, 1921)
NORWAY		
Hortens tekniske skola (Horten Technical School, 1855)	Three polytechnics (1870s)	Norges Tekniske Högskole, Trondheim (Norwegian University of Technology, 1910)

The names of the schools are given according to their current linguistic and orthographic form.
The year of establishment is given in parentheses
Cpn – Copenhagen; Gbg – Gothenburg; Hfors – Helsingfors/Helsinki; Sthlm – Stockholm; Åbo – Åbo/Turku
Dates in bold: the year the institution was first entitled to grant doctoral degrees.

Sources: Gunnar Nerheim, "Patterns of Technological Development in Norway," in Jan Hult and Bengt Nyström, eds., *Technology & Industry, A Nordic Heritage* (Canton MA: Science History Publications /USA, 1992); Henrik Harnow, "The Danish Engineer in Transition – The Reformation of Danish Engineering Education c. 1890–1933," in Dan. Chr. Christensen, ed., *European Historiography of Technology* (Odense: Odense University Press 1993); B. Wuolle, *Suomen teknillinen korkeakouluopetus 1849–1949* (Helsinki, 1949); L. Rousi, "Katsaus teknillisten oppilaitosten vaiheisiin," *Höyrykoneesta tietotekniikkaan – 100 vuotta teknikko- ja insinöörikoulutusta* (Helsinki, 1986); Rolf Torstendahl, *Dispersion of Engineers in a Transitional Society. Swedish Technicians 1860–1940* (Uppsala: Almqvist & Wiksell 1975); Göran Ahlström, *Engineeers and Industrial Growth, Higher Technical Education and the Engineering Profession During the Nineteenth and Early Twentieth Centuries: France, Germany, Sweden and England* (London: Croom Helm 1982).

Some Nordic countries had a long tradition in technical education. It started in Sweden as early as the seventeenth century in institutions such as the *Laboratorium Mechanicum.* This "chamber of models," as it was called, was founded by the famous Swedish inventor Christopher Polhem. It was later merged with a "Mechanical School" set up in 1798, which gave way to a Technological Institute in 1827. Gradually its educational pattern began to correspond to that of polytechnic institutes in German-speaking countries. The Institute in Stockholm was reorganised in 1877 under the name the Royal Institute of Technology (*Kungliga tekniska högskolan*).[16] Another university of technology was developed from the Chalmers School for Handicrafts established in 1829 in Gothenburg, the largest industrial and commercial centre on the west coast of Sweden. Although from the beginning it was more science-oriented than its larger counterpart in Stockholm, the school obtained the status of university only in 1937.[17]

While technical education emerged in the Sweden of the Enlightenment on the basis of an indigenous mix of practical and theoretical orientations, continental countries in the eighteenth and early nineteenth centuries were seeking their own approaches. Higher technical training began in France with increasing emphasis on theoretical education, particularly mathematics, chemistry, and physics. This scientific approach, which was close to that of traditional universities favouring written theses and academic degrees, came to be called the French model of technical education. In Germany, in contrast, technical education was directed more toward practical training and traditional handicrafts. Thus, *Gewerbeschulen,* technical schools with a vocational orientation, comprised the core of the German model in the early nineteenth century.[18] Another characteristic of the German model was the principle of the *Fachschule*, which meant specialized schools for different industrial sectors, such as mechanical engineering. These schools, first set up by the Karlsruhe Polytechnic in 1832, came to resemble faculties in traditional universities.[19]

A polytechnic of the French type was established in Denmark as early as 1829. The Danish educational system is characterised by a large number of local, lower-level schools providing primarily practical training without a demanding scientific syllabus. By 1917, the number of lower-level technical schools supported by the state was 197.[20]

In Finland, elementary technology education was institutionalised in the early nineteenth century. The Helsinki Technical School, the largest in the field, was reorganised in 1872 and seven years later it was expanded again and renamed the Finnish Polytechnic. It became a fully-fledged university of technology in 1909. Like its Swedish and Norwegian counterparts, it was organised according to the German model, including practical orientation and the division into *Fachschulen.*[21]

The development of technical education was slowest in Norway, where the first technical school was opened only in 1855. Three polytechnics were set up in the 1870s, and in 1910 teaching began at the first Norwegian university of technology, situated in Trondheim. Although its seven *Fachschulen* provided a fairly versatile education, and its annual enrolment had increased from 200 to 700 by 1918, the university could not meet the needs of all Norwegian technical students. Consequently, studying abroad continued to be very common among Norwegian students after World War I.[22]

7. FIVE WAVES OF NORDIC INFLOW

During the period under study (1855–1939), the number of Nordic students enrolled at the ETH varied annually from zero to seventy. Taken as one group, as Figure 5 shows, these students produced five successive enrolment waves, which did not primarily reflect any particular behaviour of Nordic students, but were closely related to similar and almost concomitant fluctuations both in the numbers of other foreign students and in the total enrolment at the ETH. The multitude of factors underlying these considerable fluctuations complicates the explanation of these waves. According to the annual ETH enrolment statistics, it seems likely that numbers decreased due to economic depression and increased as a result of economic booms, wars and even military offensives.

The Norwegian, Lauritz Nissen from Arendal, was the first Nordic student to enrol at the ETH in 1858. He studied forestry for two years and civil engineering for a further year. Nissen was in the vanguard of the first wave of Nordic students that peaked in 1861 when 20 young Nordic men were registered. They accounted for 10% of the foreigners and 5% of all students in that year. Of them, 11 came from Norway, eight from Finland and only one from Sweden. At least in some respects, such a distribution reflects the situation of higher technical learning in the respective countries. The poorer the facilities were in the home country, the greater the number of students who went to study abroad. For example, the number of Finns at the ETH in 1861 was fairly high compared to the student body at the Helsinki Technical School, where only four students successfully completed their studies in that year.[23]

Several students in the first wave had studied at a polytechnic or university before enrolling in the ETH, and some had even gained an M.A. degree. Several of the first wave students went on to careers as teachers in technical or other schools after leaving Switzerland. For example, five of those eight Finns, who studied at the ETH in the peak of 1861, later became teachers at the Helsinki Polytechnic School.[24] At least one Norwegian, Thorbjörn Lekve, also took up a teaching career in his home country. After studying at the Helsinki Polytechnic School and the ETH, he taught at a technical school in Christiania (Oslo) from 1877 to 1891.[25]

The first wave lasted from 1858 to 1864, when the lowest enrolment of five Nordic students was reached. The second wave was longer, lasting twenty-one years from 1865 to 1885, and was characterized by the arrival of the first Danes. The trailblazing Dane, Louis Heegard from Copenhagen, enrolled at the ETH in 1865, and ten years later (1875), when the number of Nordic students reached its second peak of 43, there were as many as 20 Danes and 20 Norwegians studying at the Federal Institute, but only two Swedes and one Finn were registered. The Federal Institute was not able to attract many Swedish technical students during its first decades, and by the turn of the century, the number of Swedes registering annually had never reached a dozen.

The Danes came to the ETH primarily to study civil engineering. In the peak year (1875) fifteen, or 80% of them, were among the registered students of the *Bauingenieurschule.* Nearly half of the Norwegians were studying civil engineering, while others were following the preliminary course in mathematics or majoring in mechanical engineering or forestry.

After a short time lag, the decrease in the number of Nordic students followed the slump of the mid-1870s and the beginning of the "long depression" in the European economy. In the trough year of 1885, only one Nordic student, the young Swedish chemist Julien Holm, was attending the ETH as a regular student. There was a similar trend among the other foreigners; between 1871 and 1881, their numbers dropped from 429 to 166. One reason for this fall was associated with the emergence of German universities of technology. In the 1870s and 1880s, famous institutions such as the *Technische Hochschulen* in Berlin, Hanover, Karlsruhe, Darmstadt, and Dresden, increased in popularity among foreigners.

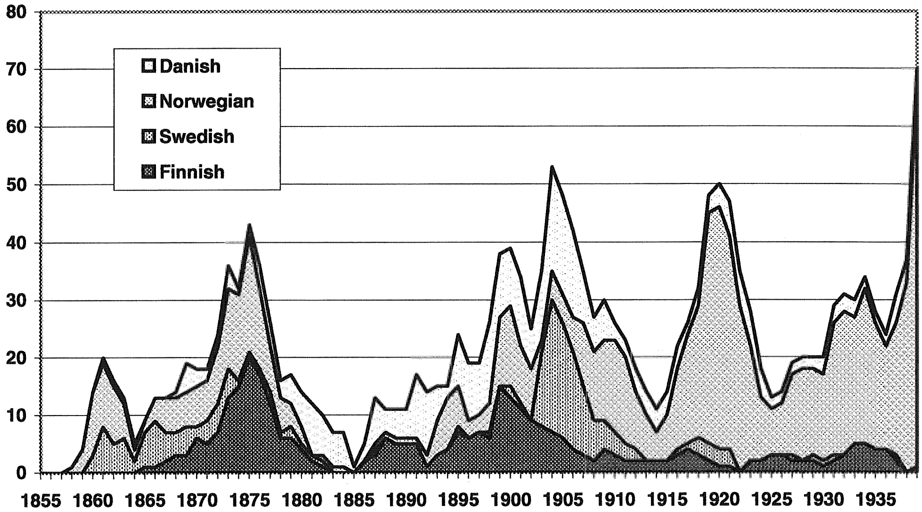

Figure 5. Enrolment of Nordic Students at the ETH, 1858–1939

Sources: See Figure 2.

The third wave started slowly but lasted nearly three decades from 1886 to 1914. In the peak year of 1904, as many as 53 Nordic students enrolled at the ETH. This period could be called a golden age for studies abroad for students from the European periphery. They had fairly easy access to good Continental universities, while their own governments and educational institutions encouraged and financially supported study trips to foreign countries. As a neutral country with a central location, Switzerland was favoured by holders of governmental grants. During this period, the national patterns of Nordic students varied significantly: one peculiarity was that Swedes formed the biggest group of Nordic students at the ETH, outnumbering Norwegians, Danes and Finns.

Scandinavians, i.e. Danes, Norwegians and Swedes, were numerous at the ETH at the turn of the nineteenth and twentieth century when the European economy was booming. However, both Finns and Swedes reached their highest numbers in 1904. The fact that Finns constituted the biggest Nordic group for a short period (1903–1907) is conspicuous. This sudden peak is surprising, especially because only very sporadically had even a single Finn been a regular student at the ETH in the 1880s and 1890s.

Between 1903 and 1912, the social backgrounds of Finnish students at the ETH were more varied than in the nineteenth century. They included the offspring of some famous industrial families, such as Arppe, Nottbeck and Paulig, on the one hand, and Jarl Emerik Jaatinen, the first student with a linguistically Finnish surname and probably a lower social status, on the other.[26]

The peak inflow of Finnish students in 1903 – 1904 paralleled the great boom in Finnish emigration to the USA. It is likely that political tensions constituted the major reason for the exodus. The new political aims of the tsarist regime, such as the Russification of Finland and the conscription of Finnish youths into the Russian army, provoked resistance among the Finns. Travelling abroad was one manifestation of this resistance. For decades, political factors had been very important in driving students in tsarist Russia to leave their country and enter foreign universities. Consequently, the political motives for studying abroad developed later in Finland than in Russia.

During the three decades prior to 1914, studies at the ETH became more demanding and Nordic students began to stay in Zurich for longer periods. Earlier it was typical for them to spend only one or two terms there, and a similar period at one or two German universities of technology. During the nineteenth century, students quite often came to the ETH just to listen to lectures by one or two famous professors, and did not aim to obtain any formal qualifications there. Towards the end of the nineteenth century, however, the laboratory and other facilities became an increasingly significant factor in their choice to study at the ETH. For instance, the famous Finnish chemist and later professor, Gustav Komppa, went there in the 1890s as a postgraduate partly due to the good laboratory facilities, which then brought him back to Zurich after attaining his Ph.D. in Helsinki.[27]

It was apparently typical for the students of the first and second waves to become teachers in technical schools or engineers in railway construction after studying at the ETH. In contrast, those of the third wave were increasingly recruited by manufacturing industries and energy companies. One example was the Swede Sigfrid Edström who, after studying mechanical engineering at the Federal Institute in 1891–1893, made an outstanding career in the electrical engineering industry, rising to the post of executive manager of ASEA, the leading Swedish manufacturer of electrical equipment.[28] The trough occurred in 1914 when only eleven Nordic nationals were attending the ETH as regular students.

During and after World War I, the numbers of Danish, Finnish and Swedish students at the ETH remained very small, ranging from zero to six per country annually. It was the influx of Norwegians that gave rise to the fourth wave of Nordic students in 1915–1925. There were as many as 42 Norwegians at the ETH in the peak year of 1920, when the total number of Nordic students was 50. The neutrality of Switzerland during World War I probably attracted some additional Norwegians to the ETH, because the war did not encourage them to apply to technical schools in belligerent countries. The above-mentioned enrolment peak of Norwegians was surpassed only in 1939 when World War II broke out. They were clearly more used to studying abroad than Danes, Finns and Swedes, and seem to have reacted more markedly in wartime crises than their Nordic counterparts.

During the fifth wave (1926–1939), the annual number of foreign students remained under 500, i.e. at a lower level than before the Great War. The peak of the fourth wave, 545, which was achieved in 1918, was surpassed only after World War II, in 1945. Thus it seems that wars tended to boost the enrolment of foreigners at the ETH. Their numbers declined by more than half during 1919–1922, and the pre-war figure (395) was only reached in 1928. One reason for this drastic drop was that fees for foreign students were doubled in 1919/20: they had previously been the same for all students.[29] Despite the policy changes towards foreigners, Norwegians remained loyal to the ETH. In the interwar years on average 23 students from the land of the *fjords* studied there annually, while only a handful of students arrived from the other Nordic countries. In the 1920s and 1930s, it was mechanical engineering and chemistry that attracted the Norwegians most. The annual quota of two or three Danes was interested in the same subjects, and nearly all of them graduated from the Federal Institute.

Between 1858 and 1939, more than 680 Nordic students were registered as regular students at the ETH. In addition, each year the Institute received dozens of observers or visiting students (*Zuhörer*), who generally spent a few weeks or months in Zürich and were entitled to attend some courses after paying a special fee. The national registers of engineers contain data on individuals who claimed to have studied at the ETH, but their names cannot be found on the lists of regular students (*regelmässige Schülern*) published in the official programme.[30] After 1921, the names of these students are available on the stencilled address lists in the ETH archives.[31] The rector's office has a card file listing the observers, but it is not accessible to visiting researchers. Therefore, the number of Nordic observers is difficult to calculate: a rough estimate might be between 200 and 400 during the abovementioned period. If visiting researchers using laboratories or other facilities are also included, it is likely that in total more than a thousand Nordic students, engineers and scientists derived direct benefit from the ETH before World War II. It seems possible that over five per cent of Nordic engineers and technical scientists had personal contacts with the Federal Institute, and because this was only one of dozens of institutions providing technical education in Europe at the time, that figure is not insignificant.[32]

During the period under study, Norwegians constituted half (49%) of the Nordic students at the ETH. Studying in Zürich became an established tradition for them; a sign of persistent loyalty is that they formed the majority in four of the five waves. Swedes constituted a quarter (24%) of the Nordic students, and ranked first in the long wave of 1886–1914. The Danes accounted for 15 per cent and the Finns for 12 per cent. The proportion of Finns was higher in the early decades but remained very low in the interwar years. Improvements in technical education in the home country were perhaps one reason for the shrinking influx of Finns. After gaining political independence in 1917, the Finnish government changed its policy toward studies abroad: the number of travel grants to students was cut compared with the pre-war practice and financial resources were directed toward developing national universities and technical schools. In addition, the doctrine of economic nationalism put its imprint on education, whereas internationalism lost part of its former glamour.[33]

8. NATIONAL PROFILES

8.1 Disciplines

Even in the nineteenth century, educated groups in the Nordic countries were in close communication with each other. People were familiar with technical education in their neighbouring countries, and changes in goal setting, ideological standpoint and fashion in one country fairly quickly became known in others. This made a certain similarity in educational conditions very likely. Nevertheless, questions of national peculiarities still arise. Did the Nordic students follow their national strategies when they pursued their studies at the ETH? Did the natural conditions in the home country, the industrial structures or national needs, inspire them to enter the ETH and choose certain subjects as majors?

Like the German model, the ETH was also organized according to the principle of *Fachschulen*, departments, and of them, mechanical engineering was the biggest.[34] According to the enrolment figures, the department of civil engineering ranked second up to 1897/98, when the department of chemistry surpassed it. In 1904/05 the latter was divided into two departments: chemistry and pharmacy. Nevertheless, the department of chemistry held its position among the top three departments even also in the interwar years, although the growth rates of the medium-sized departments, architecture and pharmacy, were faster. Other departments, such as forestry, agriculture, geodesy, mathematics and physics, geology and other "earth sciences" (*Erdwissenschaften*), and military science, as well as humanities and the social sciences, were much smaller.[35]

One might presume that the Nordic students were distributed among the departments like the other students at the ETH. However, their choice of disciplines was somewhat narrower. Surprisingly, a good half of them studied mechanical and electrical engineering, whereas the corresponding proportion of all ETH students was about a third. Similarly, civil engineering was more popular among Nordic students than among other undergraduates, accounting for 27% of those registered. Thirteen per cent of Finnish and Scandinavian students had chemistry as their major, and that figure corresponds to the percentage for the other students. Fewer Nordic students studied architecture and other disciplines than ETH undergraduates on average. Not even forestry was popular among them. Figure 6 shows the distribution of Nordic students at the ETH in 1855–1939 by department and nationality.

Civil engineering was the most popular subject major among Nordic students of the two first waves. The third wave raised mechanical engineering to first place, a position it held for many decades. What is fascinating is an increasing interest in chemistry from the 1890s. Over four decades, almost thirty Nordic students studied chemistry at the ETH, and among them it ranked second in popularity.

National differences were perhaps most apparent in the nineteenth century. The Norwegians focused more on civil engineering than their Nordic counterparts, whereas the Swedes concentrated on mechanical engineering. The Finnish students were divided more evenly between these two disciplines. The Norwegians and the Swedes evidently studied chemistry more than the Finns or the Danes, which might have been a reflection of the fact that the chemical industry was fairly significant in the Scandinavian Peninsula. Moreover, Sweden had long research traditions in chemistry. The Finnish peculiarity was that, although the number of Finnish students was the smallest, the group was more evenly dispersed among the various disciplines.

8.2 *Duration of Studies*

At first, students had to pass two or three annual courses of study *(Jahreskurs)* in order to graduate from the ETH. The length of the course in civil engineering was extended from three to four years in 1869/70, and other departments followed suit later. In the early decades, only a few Nordic students pursued all the required courses of study, and most stayed at the ETH for only one or two academic years. Some had been studying at their home university of technology beforehand, while others just wanted to become acquainted with the teachers and educational system at the ETH. They usually had no intention of studying for a degree in Zurich.

The average time Nordic students spent studying at the ETH varied from two years in the 1860s to nearly two and a half years in the following two decades, but this figure dropped to one and half years in the 1890s. It gradually increased again to almost four years in the 1930s.

National styles can be observed in the number of years spent studying at the ETH. For example, in the period 1855–1939 Danes studied for an average 3.2 years (standard deviation 1.5 years). In their case, the fluctuations between decades remained small. It seems that they were not just "academic tourists," but aimed to complete their annual courses of study and possibly to obtain the degree of *Diplom eines Ingenieurs*. Considering the entire research period, the average Norwegian spent 3.1 years at the ETH (standard deviation 1.5 years), although the average stay between 1890 and 1910 was only 1.6–1.7 years. The Finns studied for 2.6 years on average (the standard deviation being the highest at 1.7 years) and variations between decades were also considerable. It seems that successive generations of Finnish students had different goals, or alternatively, their ability to achieve their goals varied. The Swedes spent the shortest time at the ETH, only 2.3 years on average (standard deviation 1.3 years). Before World War II, it was common for Swedes to spend just two years studying at the ETH, and it was only in the interwar years, that the duration of their studies increased to over three years.

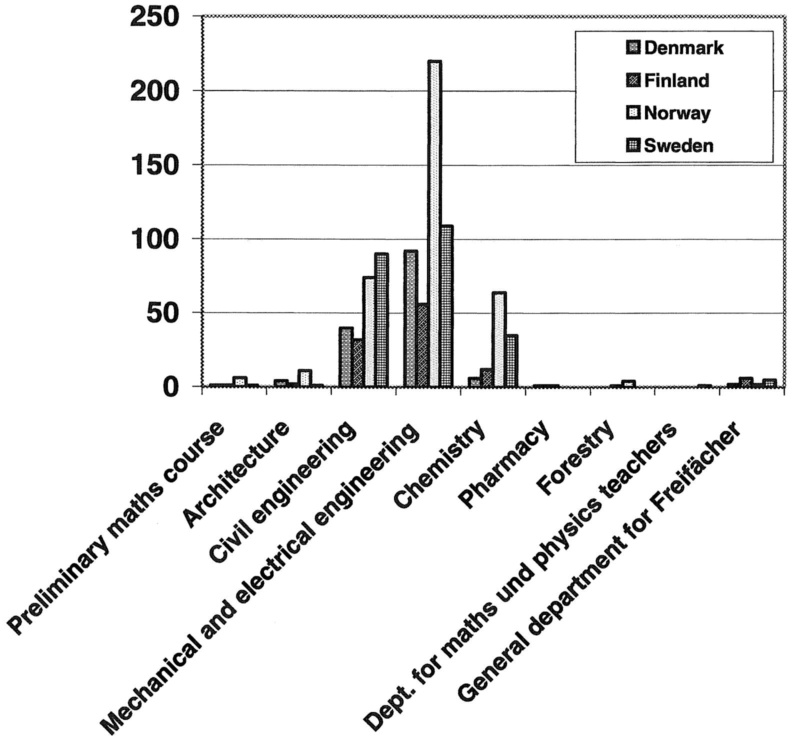

Figure 6. Nordic Students at the ETH by Department, 1858–1939

Sources: *Programm der Eidg. Technischen Hochschule für das Wintersemester 1919/20* (Zürich 1919); *Adressverzeichnis der (regulären) Studierenden der E.T.H.* 1920–1939, Wissenschaftshistorische Sammlungen, ETH-Bibliothek, Zürich; *ETH Diplome I, 1858–1915*, Rektorat der ETH-Zürich 1985, Signum Hs 1184:1, ETH Archives, Zürich; *ETH Diplome II, 1916–1944*, Rektorat der ETH-Zürich, Signum Hs 1184:2 ETH Archives, Zürich; *ETHZ, Dissertationenverzeichnis 1909–1971*, Schriftenreihe der Bibliothek, Nr 15 (Zürich 1972).

8.3 Degrees

Since 1855, the Swiss Federal Institute of Technology has issued the degrees of graduate engineer; all main courses (*Diplomlehrgänge*) had different diplomas (*Diplome*). The *Diplom eines Ingenieurs* was one of them.[36] In 1909 ETH began to grant doctor's degrees and three new titles were introduced: *Doktor der Technischen Wissenschaften,* doctor of technical sciences, *Dr. der Naturwissenschaften,* doctor of sciences, and *Dr. der Mathematik.*[37]

Although these degrees were highly valued, obtaining one was not, as a rule, the prime reason for foreigners to study in Zurich. Particularly in the nineteenth century, the goals of the Nordic students were frequently more modest, including taking courses run by some famous professors, or becoming familiar with the Swiss system of higher education in technology. In addition, studying even for a short period at the ETH could also enhance social prestige.

These modest objectives reflected the insufficient resources of foreign freshers. First, many students did not have the funds to enable them to stay in Zurich for three or four years. Second, they were required to pass exams at the end of each academic year, which demanded fluent proficiency in the German language and often also good knowledge of mathematics and the basics of some other sciences. Foreigners frequently lacked at least one of these basic requirements. Overcoming financial difficulties and updating linguistic and scientific skills were major challenges for them. Thus, Nordic students considered it a great achievement if they managed to pass all of their end-of-semester exams. For example, the Danish engineer and entrepreneur Peder Hofman-Bang mentioned in his CV, published in the national register of engineers, that in 1873–1877 he had "passed the exams of all seven terms at *Abtheilung für Bauingenieurwesen des eidgenössischen Polytechnicum,* Zurich, and received his final report in 1877."[38]

The toughest and most successful students at the ETH earned the degree, *Diplom eines Ingenieurs* (or *Architekten/technischen Chemikers/Forstwirtes/ Landwirtes*). The first Nordic student to be awarded a degree in engineering was the Swede Friedrich Almgren as early as 1863. The Norwegian, Gunnar Saetren, was the second. However, they were early birds. It took another ten years for the next batch of degrees to be conferred on Nordic students, who happened to be four Norwegians.

In the nineteenth century, only nine Norwegians, eight Danes and three Swedes were awarded degrees in engineering at the Federal Institute. After the turn of the century, it became more usual to pass the final exams. The first Finn to graduate at the ETH was Karl Robert von Pfaler in 1907. In the interwar years, Nordic students became more degree-oriented. Then most of them who started their studies also graduated.

Obtaining a doctoral degree in technical sciences was fairly rare before World War II. The first Nordic student to achieve this was the Finnish chemist Lennart Frosén, from the small town of Gamlakarleby/Kokkola. This happened in 1913, just two years after he had received his *Diplom eines technischen Chemikers* from the ETH. Prior to 1940, only six Nordic postgraduates, three Finns and three Norwegians, obtained doctoral degrees at the Swiss Federal Institute of Technology, including the Finnish engineer Erik W. Jusélius. He was awarded his Ph.D. in 1929, and then worked for some time at Gebrüder Sulzer in Winterhur before returning to Helsinki. Later he embarked on a career as a technical manager serving Finnish and Swedish refrigeration-engineering companies.[39]

Table 2. Enrolment and Degrees Gained by Nationality at the ETH, 1855–1939

Nationality	Enrol-ment no.	Graduate engineers (Dipl.ETH) no.	Doctors no.	Graduate engineers, % of all enrolled Nordic students	Doctors, % of all enrolled Nordic students
Danish	105	28	0	26.7	0
Finnish	79	8	3	10.1	3.8
Norwegian	337	118	3	35.0	0.9
Swedish	165	22	0	13.3	0
Nordic total	**686**	**176**	**6**	**25.7**	**0.9**

Sources: *Programm der Eidg. Technischen Hochschule für das Wintersemester 1919/20* (Zürich 1919); *Adressverzeichnis der (regulären) Studierenden der E.T.H.* 1920–1939, Wissenschaftshistorische Sammlungen, ETH-Bibliothek, Zürich; *ETH Diplome I, 1858–1915*, Rektorat der ETH-Zürich 1985, Signum Hs 1184:1, ETH Archives, Zürich; *ETH Diplome II, 1916–1944*, Rektorat der ETH-Zürich, Signum Hs 1184:2 ETH Archives, Zürich; *ETHZ, Dissertationenverzeichnis 1909–1971*, Schriftenreihe der Bibliothek, Nr 15 (Zürich 1972).

The distribution of engineering degrees among the disciplines reflected the respective distribution of Nordic undergraduates at the ETH. Among these students, the degrees of civil engineer and mechanical engineer were the most popular, and that of technical chemist ranked third. An interesting observation is that degrees were distributed quite unevenly between the various Nordic nationalities, as shown in Table 2.

National differences between the Nordic students are conspicuous. A third of the Norwegians registered as students at the Federal Institute obtained a degree. The first Dane to graduate completed his studies in 1880, but from the late 1890s, the number of Danes obtaining *Diplomas*, certificates of the DI degree, increased, and they seem to have been very good students in the interwar years. Therefore, taking the research period as a whole, a quarter of the Danish students at the ETH passed the graduation exam, while only an eighth of the Swedish students and a tenth of the Finnish students did likewise. It is also clear from Table 2 that the closer the average duration of studies was to 3–4 years, the more frequently degrees were earned. This was one reason for the success of the Norwegians, who generally stayed in Zürich longer than other Nordic students.

As far as graduation was concerned, it was not only a question of students' ability, but also of different national educational strategies. Governments and various foundations influenced these strategies by means of educational policies and scholarships to young people to study abroad. During the nineteenth century, both the Finnish and Norwegian governments considered it cheaper to send up to a few dozen students to foreign technical schools than to set up their own universities of technology.[40] For example, in the Russian period, after the Crimean war (1854–1856), the authorities in Finland urged students to enrol at foreign institutions, but most Finnish students were only given one- or two-year scholarships to study at foreign universities of technology such as the ETH. It was extremely difficult to obtain a degree within that short time span. This implies that producing graduate engineers was not the top priority among Finnish educational policy-makers, who were satisfied with a lower level of expertise.

9. CONCLUSIONS

National comparisons of Nordic students at the ETH clearly highlight the large number of Norwegians who attended and their determination to earn degrees. By population, Norway has long been the smallest of the four Nordic countries, but between 1858 and 1939, this land of 2.2 million (in 1900) sent half of all Nordic students enrolled at the ETH. Norway did not only stand out among its neighbours. In the period 1930–1979, Norwegians accounted for 13.4% of all foreign students at the ETH, and constituted the largest nationality group after the Swiss. Thus Norwegians have been very devoted to the Swiss Federal Institute of Technology for a long time, with dozens regularly enrolling at the ETH each decade even up to the 1990s. Only a set of very special circumstances can explain such loyalty.

First, of the Nordic countries, higher technical education developed most slowly in Norway. Thus, studying abroad has been necessary there, and the ETH was only one among various foreign educational institutions that Norwegians favoured. According to data compiled by Gunnar Nerheim, prior to

World War I three German universities of technology (Dresden, Charlottenburg/Berlin and Hanover) were more popular than the ETH.

Second, the high-quality teaching and good reputation of the ETH attracted Norwegians as well as other Nordic students to Zurich. The similar mountainous terrain of Norway and Switzerland also justified their choice. The technical problems encountered in the construction of railways, roads and bridges and in other civil engineering projects, as well as in building hydroelectric power plants with high heads and developing the chemical industry, were similar in the two countries. Several of the best Norwegian engineers who specialized in the construction of hydroturbines had studied at the ETH. Presumably, Swiss technical solutions were easily applicable in Norway.

Third, as a small but politically independent, self-reliant and rapidly industrialising country, Switzerland was a model for nineteenth-century Norwegians and also for other Nordic people. It was believed that a lot could be learned from this Alpine land with high international prestige. Being connected with such a fashionable country enhanced the social status of the technical specialist.

Fourth, studying in Zurich in the nineteenth century generally made a big impression on Nordic students, who then recommended the ETH to their friends and relatives, and thus set off a chain reaction. Sometimes even sons followed in their fathers' footsteps. For example, thirty years after the Swede Herman A. Nydqvist studied at the ETH (1880-1883), his son Anteror entered the Swiss Federal Institute and obtained his Dipl. EP degree there. Such personal links and group behaviour were most common among the Norwegians. Of the nine students with *Lund* as their surname in the ETH records, five of them came from Christiania/Oslo, and six *Jebsens* and five *Bulls* from Bergen and four *Jensens* from Christiania studied technology in Zürich. Whether or not all those with the same surname were relatives, it is likely that there were strong, local ETH-oriented personal networks in these two cities – Oslo and Bergen. Another strong indication of such networks is that more than 170, or half, of the Norwegian students at the ETH came from Oslo or Bergen. Only a dozen were from Trondheim or Stavanger, which were the next biggest cities in Norway.

The ETH was not just an institution of higher technical education. It was also a famous research centre and an excellent place for establishing worldwide contacts. Various graduating students found jobs through the network of personal relationships established in Zurich. Professors and fellow students provided valuable assistance. Many students became trainees in Swiss firms, such as Sulzer and Brown & Boveri Cie. ETH graduates often started their careers as draughtsmen or constructors in engineering firms in the

USA, Germany or France, and many of them succeeded in their work. Some became inventors: the Swede Gustaf N. Dalén – the inventor of the automatic, solar-controlled lighthouse – was the most successful of them. In 1912 he was awarded the Nobel Prize for physics.[41]

There were various attractive features at the ETH that together comprised a hub of pulling factors, although the Federal Institute did not advertise its education or actively recruit Nordic students. As in other peripheral countries of Europe, students and their teachers were the active partners, arranging study trips to Zurich. The freshers' aim was to enrol at the ETH, learn about the latest technology and apply that learning in their home countries. Receiving students from peripheral countries played the role of initiator in this kind of technology transfer, and sometimes the transfer worked quite satisfactorily. The electrification of Finland is just one case in point.[42]

After returning to their home countries, Nordic ETH students often first worked on railway construction. Some were given permanent positions and joined the staff of the State Railways, others made successful careers as managers in private industry, and a few became entrepreneurs. A fair number came from well-known industrial families and entered the family business after their studies abroad. Several former ETH students were given teaching posts at universities of technology or polytechnics in their home countries. Before 1940, at least ten Nordic professors had studied at the ETH. Thus, the Swiss Federal Institute influenced the development of teaching technology in Scandinavia and Finland.

In sum, former ETH students constituted a heterogeneous but still very influential group in their home countries. Although their Zurich experience might not have been the sole or decisive success factor, clearly several engineers seemed to find it very beneficial. It could be claimed that the Swiss Federal Institute of Technology educated a technological elite for the Nordic countries, and that its graduates acted as important agents of technology transfer and industrial development in their home countries.

Acknowledgments

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NOTES

[1] A model of transfer channels is examined in more detail in Timo Myllyntaus, "The Finnish Model of Technology Transfer," *Economic Development and Cultural Change* (Chicago), 38 (3) (1990), 625-43 and Timo Myllyntaus, "The Transfer of Electrical Technology to Finland, 1870–1930," *Technology and Culture*, 32 (2) (1991), 293-317.

[2] For example, the newspaper *Papperslyktan* 1859–1861.

[3] August Schauman, Bitar af reseminnen IV, En schweizisk nationalfest, *Papperslyktan* no. 20, 16 Maj 1859, p. 153.

[4] Schauman *op. cit.* (3), p. 159.

[5] August Schauman, *Kuudelta vuosikymmeneltä, Muistoja elämän varrelta,* vol. 2, Finnish translation (Porvoo: WSOY 1967), p. 141.

[6] Schauman *op. cit.* (3), p. 153.

[7] Frederick B. Artz, *The Development of Technical Education in France, 1500–1850* (Cambridge, Mass, 1966), p. 161.

[8] Die Eidgenössische Polytechnische Schule in Zürich, Weltaustellung in Paris 1889 (Zürich, 1889).

[9] *Jahresbericht 1995*, ETH (Zürich, 1996), pp. 50, 56.

[10] *Commercial Year-Book of the Soviet Union 1925*, compiled and edited by Louis Segal and A.A. Santalov (London, 1925), p. 192.

[11] *Hochschul-Nachrichten* vol. 11 (Mai 1901) no 8, pp. 178-179.

[12] *Hochschul-Nachrichten* vol. 9 (März 1899) no 6, pp. 117-118.

[13] See Timo Myllyntaus, "'The Best Way to Pick Up a Trade,' Journeys Abroad by Finnish Technical Students, 1860–1940," *ICON*, 2 (1996), 138-63.

[14] *Studies Abroad,* Half-Yearly Bulletin no 1, League of Nations, Institute of Intellectual Cooperation (Paris, 1935).

[15] For a more detailed analysis of Nordic technical education, see the article manuscript by Timo Myllyntaus, "Foreign models and national styles in teaching technology in the Nordic countries."

[16] Henrik Björk, *Teknikerns art och teknikernas grad. Föreställningar om teknik, vetenskap och kultur speglade i debatten kring en teknisk doktorsgrad, 1900–1927,* Stockholm Papers in History and Philosophy of Technology, TRITA-HOT-202 (Uppsala: Royal Institute of Technology, 1992), pp. 22-25, 32-36, 86-89.

[17] Göran Ahlström, *Engineers and Industrial Growth, Higher Technical Education and the Engineering Profession during the Nineteenth and Early Twentieth Centuries: France, Germany, Sweden and England* (London: Croom Helm, 1982), pp. 34-36, 68, 80.

[18] Wolfgang König, "Technical Education and Industrial Performance in Germany: A Triumph of Heterogeneity," in Robert Fox and Anna Guagnini, eds., *Education,*

Technology and Industrial Performance in Europe, 1850–1939 (Cambridge: Cambridge University Press, 1993), pp. 65-75.

[19] Ahlström *op. cit.* (18), p. 33; Göran Ahlström, "Technical Education, Engineering, and Industrial Growth: Sweden in the Nineteenth and Early Twentieth Century," in Robert Fox and Anna Guagnini, eds., *Education, Technology and Industrial Performance in Europe, 1850–1939* (Cambridge: Cambridge University Press, 1993), pp. 116-120.

[20] *Nordisk familiebok,* (Stockholm, 1918), p. 690; Michael F. Wagner, "Danish Polytechnical Education between Handicraft and Science," in Dan. Chr. Christensen, ed., *European Historiography of Technology* (Odense: Odense University Press, 1993), pp. 146-163; Michael F. Wagner, "Ingeniørens betydning for formningen af industrisamfundet Danmark indtil 1920. Udviklingen fra standtil profession," in Hans Buhl and Henry Nielsen, eds., *Made in Denmark? Nye studier i dansk teknologihistorie* (Århus: Klim, 1994), pp. 237-260.

[21] The Helsinki University of Technology had five *Fachschulen* at first: those for architecture, civil engineering, mechanical engineering, chemistry and land surveying. B. Wuolle, *Suomen teknillinen korkeakouluopetus 1849-1949* (Helsinki: Otava, 1949), pp. 41-52, 93-114, 305-14.

[22] Håkon With Andersen, "Germany and the Education of Norwegian Engineers, with Some Reflections on the Role of the Engineers as a Social Group," *Bürgentum und Bürokratie im 19. Jahrhundert. Technologie, Innovation, Technologietransfer,* Bericht über das 2. Deutsch-norwegische Historikertreffen in Bonn, Mai 1987, Norges allmennvitenskapelige forskningsråd and Sifterverband für die deutsche Wissenschaft (Oslo, 1988), pp. 104-109.

[23] *Matrikel öfver tekniska realskolans och Polytekniska skolans i Helsingfors samt Polytekniska institutets i Finland lärare och elever 1849–1897 jämte historik öfver läroanstalten, Teknologföreningen och Polyteknikernas förening* (Kotka: Polyteknikernas förening, 1899), pp. 158-9.

[24] Ferdinand Ahlmann, Hendric Pantsar, Ernst Qvist, Theodor Uschakoff and Alfred Wahlfors.

[25] *Matrikel öfver tekniska realskolans, op. cit.* (23).

[26] *ETH Programm und Stundenplan* 1903/04–1912/13, ETH Archives, Zürich.

[27] Komppa was the first Nordic scholar to receive the silver von Hofmann medal of the *Gesellschaft Deutscher Chemiker.* Lauri Niinistö, "Kemistikilta ja vuosisadan vaihteen Suomi," *Kemia-Kemi,* 18 (11-12) (1991), 1008; Veikko Komppa, "Professori Gust. Komppa ja Suomen kemianteollisuus," *Kemia-Kemi,* 18 (11-12) (1991), 1014-5.

[28] J. Sigrid Edström, *En levnadsteckning,* vols 1-2, Ed. K.A. Bratt (Stockholm, 1950); Mats Fridlund, *Den gemensamma utvecklingen: Staten, storföretaget och samarbetet kring den svenska elkrafttekniken,* Stockholm papers in history and philosophy of technology series: Trita-HOT no. 2036 (Eslöv: B. Östlings bokförl. Symposion, 1999).

[29] The annual fee rose to 400 frangs. *Programm der Eidg. Technischen Hochschule für das Wintersemester 1919/20* (Zürich, 1919), p. 7.

[30] *Programm der eidgenösischen polytechnischen Schule*, the annual lists of regular students are included in the programmes for the years 1856–1921.

[31] *Adressverzeichnis der (regulären) Studierenden der E.T.H.* 1920–1939, Wissenschaftshistorische Sammlungen, ETH-Bibliothek, Zürich.

[32] An educated guess would indicate that about 20,000 graduate engineers and technical scientists were working in the four Nordic countries between 1855 and 1939. Göran Ahlström, *Engineers and Economic Growth* (London: Croom Helm, 1982), pp. 107-8; Timo

Myllyntaus, *Electrifying Finland, The Transfer of a New Technology into a Late Industrialising Economy* (London: Macmillan & ETLA, 1991), p. 153.

[33] Myllyntaus, *op. cit.* (13), 138-63.

[34] In autumn 1935, this department was divided into two: mechanical engineering and electrical technology. *Eidgenössische Technische Hochschule Zürich 1955–1980, Festschrift zum 125-jährigen Bestehen* (Zürich, 1980), p. 659

[35] *Eidgenössische, op.cit.,* (34), pp. 641-55.

[36] In 1909 an abbreviation *Dipl. EP* was introduced and in 1924 it was replaced to *Dipl. ETH.*

[37] The holders of degrees are listed in the archival materials at the Federal Institute; see *ETH Diplome I, 1858–1915*, Rektorat der ETH-Zürich 1985, Signum Hs 1184:1; *ETH Diplome II, 1916–1944*, Rektorat der ETH-Zürich, Signum Hs 1184:2; *ETHZ, Dissertationenverzeichnis 1909–1971*, Schriftenreihe der Bibliothek, Nr 15 (Zürich, 1972).

[38] R. Jespersen, Biografiske oplysninger angaaende den Polytekniske laereanstalts kandidater 1829–1929, Udgivet af Dansk ingeniorsforening (København, 1930), p. 605.

[39] Erik Jusélius, *Finnlands Wasserkräfte und ihre Ausbauwürdigkeit gegenüber kalorischen Kraftwerken für die Landesversorgung mit elektrischer Energie*, Diss. (Zürich: Leemann 1929); *Suomen korkeakouluinsinöörit ja arkkitehdit 1956* (Helsinki, 1956), p. 292.

[40] Gunnar Nerheim, "Technology Transfer from Germany to Norway at the Turn of the Century," *Bürgentum und Bürokratie im 19. Jahrhundert. Technologie, Innovation, Technologietransfer,* Bericht über das 2. Deutsch-norwegische Historikertreffen in Bonn, Mai 1987, Norges allmennvitenskapelige forskningsråd and Sifterverband für die deutsche Wissenschaft (Oslo, 1988), p. 161.

[41] Jan Hult, "Technology in Sweden," in Jan Hult and Bengt Nyström, eds., *Technology & Industry, A Nordic Heritage* (Canton, MA: Science History Publication/USA, 1992), pp. 88-89.

[42] Myllyntaus, 1990, *op. cit.* (1); Myllyntaus, *op.cit.* (32).

GÁBOR PALLÓ

ACCOMMODATION TO A NEW CENTRE

Albert Szent-Györgyi's trip to the Soviet Union

Many publications analyse Charles Darwin's trip on board the "Beagle" to the Galapagos Islands, begun in 1831.[1] Similarly, most biographies on Niels Bohr mention the significance of his visit to Ernst Rutherford's laboratory in Manchester in 1912.[2] Travelling seems to belong to the normal practice of science throughout history. Moreover, scientists seem to like travelling so much that trips can perhaps be considered a special attribute of scientific activity, or at least a way of life for scientists in modern times. Yet, a substantial difference could be postulated between Darwin's trip to the Galapagos and Bohr's visit to Manchester. The difference originates from the purpose of their respective travels. Indeed, while the reasons that scientists travel so much could certainly be very different, they seem to contain one common element: scientists want to gain some kind of knowledge at the site they visit which cannot be found where they commonly live and work.

This paper focuses on one trip made by the Hungarian biochemist Albert Szent-Györgyi to the Soviet Union in 1945. My goal is to analyse a special type of trip characteristic of a particular kind of centre-periphery relationship. First I try to outline some ideas concerning the general features of trips securing communication between the scientific centres and peripheries. Then, by depicting his personality and career, the paper intends to introduce Szent-Györgyi as a "scientist on the move." This will be followed by a description of the trip to the Soviet Union with its results, and finally some conclusions will be drawn concerning centre-periphery relationships.

1. TACIT KNOWLEDGE AND CLASSIFICATION OF SCIENTIFIC TRIPS

Assuming that the goal of scientific trips is to acquire knowledge at a site different from the permanent address of the researcher, three kinds of trips can be distinguished. The first type of trip is related to an object, while the

Ana Simões, Ana Carneiro, Maria Paula Diogo (eds.), Travels of Learning. A Geography of Science in Europe. (329-344)

second type is related to people, mainly to other scientists. The third type is a combination of the two.

Darwin visited the Galapagos Islands in order to observe the local wildlife, including species of animals, which could not be found in Britain. Here, among other things, he observed various kinds of finches, a group of birds, which helped him to conclude that species are not immutable. This statement belonged to the core of his general theory. Darwin's long trip on the "Beagle" represents a clear case of the object-related trip. Since the object of his research was located far from Britain, the research could only be done if Darwin visited the site. In the case of the Linnaean research programme in the eighteenth century, research also had to be done on site but the goal was different from that of Darwin's. In the framework of this programme, all existing plants were going to be found and placed into the system created by the Swedish botanist, Carl von Linné. Collecting plants required visiting practically all known areas of the Earth.[3] To draw maps was also a typical goal of eighteenth century scientific trips. Bruno Latour gave a detailed analysis of a mapping trip taken to the Sakhalin Islands, in East Asia. The researchers brought all their instruments on the ships to carry out the measurements on a site far from Lisbon, the centre, their permanent home.[4]

Another type of object-related trip aims at using expensive equipment that cannot be found at the site where the researcher permanently works. Modern "Big Science" gives numerous examples of this. International teams use particle accelerators, observatories, space telescopes and a number of other instruments. The European high-energy physics centre, CERN, was organised on the basis of this principle.[5] In the fields of Big Science, scientists travel to the equipment, they use it for measurement and return home to evaluate the results.

People-related trips show a more colourful picture. A number of forms have been devised to institutionalise personal contacts between scientists. Conferences, workshops, lecture tours, study trips, fellowships in foreign countries, occasional invitations and visits, visiting professorships, and common research projects serve the goal of scientists' personal relationships.

While the purpose of the object-related trip originates from the research activity itself, the reason that researchers are keen on establishing and keeping personal contacts is not so obvious. They seem to consider it insufficient to rely just on the printed publications of specialists working in a scientific field to acquire the whole body of knowledge that they desire.

This attitude can be analysed in the framework of the theory of tacit knowledge, first propounded by Michael Polanyi, the chemist and philosopher of science. Polanyi said, "we can know more than we can tell."[6] He thought that all kinds of knowledge had a "tacit dimension," a component that cannot be expressed explicitly by spoken or written words. Tacit knowledge exists in scientists' minds and often in their hands. This dimension manifests itself through some kinds of actions such as showing how to do something, showing instruments or their use. The work and the implications of some theories can be better understood through consultations and discussions with experts than by solitary reading and calculating in the researcher's office. Polanyi described "this fusion of the personal and the objective as Personal Knowledge," because, he thought, there is a "personal participation of the knower in all acts of understanding."[7] This personal element in scientific activity makes permanent contacts between scientists inevitable.

Most twentieth-century scientific trips belong either to the people-related category or to a combination of the object- and people-related categories. Niels Bohr, for instance, joined not only Rutherford but also a group of excellent scientists, in the Rutherford laboratories. The "laboratory" meant both working with Rutherford and with his laboratory instruments.[8] Bohr could see the equipment and learn underlying tacit knowledge.

2. CENTRE-PERIPHERY RELATIONS IN TRIPS

Trips made from the centres to the peripheries seem to have different characteristics from those made from the peripheries to the centres. A scientific centre exerts political influence upon the scientific communities working in the peripheries. The centre dictates almost everything: the pattern of scientific research, the ruling theories, the institutional structure, the central values and the evaluation of results and researchers, the language and the most important terms, the greatest authorities, in short the whole paradigm of the field. In Pratt's analysis, for instance, the researchers who, in the framework of the Linnean programme, travelled in order to map the plants in many parts of the Earth, contributed to spreading a global language for mapping nature. This language eliminated local differences by giving a European-based vocabulary to various natural formations. By doing this, it swept away the expressions developed from local cultures. In other words, the centre forced local cultures to accept its conceptual framework: the European, male, printed way of thinking.[9]

Similarly, Latour's study explores the mechanism of acquisition of knowledge by the centre. He showed that through the cycles of accumulation, the researchers of the Sakhalin Islands gradually carried to the centre the knowledge necessary for the making of a correct map. Each cycle provided new "extraordinary means" for collecting further knowledge.[10] Latour showed that knowledge collection was not insulated from many other aspects of social life, and, therefore, the accumulation process can only be analysed in the context of the history of science, history of technology, economic history, politics, administration and law. As a result of a complex activity, knowledge has been processed under the control of the centre at its own site and then it returns to the periphery as validated scientific knowledge.[11]

The goal of the scientific trips to the centre taken by scientists working in the peripheries is to learn the "most advanced" tacit and explicit knowledge and/or to carry out experiments with the equipment located there. Bohr's study trip in Britain, both in J. J. Thomson and Rutherford's laboratories, exemplified this kind of scientific trip. Szent-Györgyi, when visiting the Soviet Union right after the Second World War, might have seemed something like an indigenous individual in the eighteenth century who wanted to see the place from which the colonialists came. He wanted to understand the knowledge of the new rulers in the hope of some future advantage. While in many cases in the twentieth century the centre so strongly attracted visiting scientists that they could not resist staying there, both Bohr and Szent-Györgyi returned to their native lands. Besides explicit science, they carried home tacit knowledge related to a mass of intellectual matters, including the institutional paradigm of doing science. Bohr established a new scientific centre in Copenhagen; Szent-Györgyi contributed to introducing substantial reforms in the organization of science in Hungary.

3. ALBERT SZENT-GYÖRGYI

According to his biographers, Szent-Györgyi was an eccentric and exciting person with many whims, strange ideas, and the intuitive insights of a scientific genius.[12] He was born in 1893 in Budapest. After graduating from Budapest University in 1917 the young physician could not find a research position in Hungary. He decided to move and began working in Prague, then he went on to Berlin (with L. Michaelis), Hamburg, and Leiden, and finally he moved to Groningen in 1923.

Here he started to study the energetic aspects of biological processes, particularly, the oxidation of foodstuffs in the living organism. His first remarkable result was the reconciliation of the two competing current views concerning the fundamental chemical process of burning food. While according to Heinrich Wieland the essence of this process consisted in the activation of hydrogen, Otto Warburg held that oxygen played the main role. Szent-Györgyi proved experimentally that both processes had their own significance.

His next results in the field of biological combustion originated from the simple observation that some fruits change colour in air after they have been cut. Szent-Györgyi assumed that a special substance existed in these fruits, which affects oxidation in the air. As the skin colour of people suffering from Addison disease also changed, Szent-Györgyi supposed that this colour change could be caused by the presence of the same substance existing in the fruits that become brown after having been cut. He then attempted to isolate the substance.

After his first steps in finding the colouring factor, he moved to London to continue his research in H. H. Dale's laboratory. Then, in 1926, Szent-Györgyi found his way to Cambridge to work with F. G. Hopkins, the head of a leading centre of biochemistry at that time. Here, besides separating a small quantity of the substance he assumed to be responsible for colour changes, Szent-Györgyi found something like a scientific home. Throughout his life, he identified himself with the style and mentality surrounding Hopkins. Besides using the equipment of the laboratory for his experiments, he learnt a lot from the tacit knowledge of biochemistry, including a "style" of doing research or a taste in science.

As his Rockefeller grant, which supported him while he was in England, was about to expire and he had no hope of getting a job in Cambridge, in 1928 Szent-Györgyi accepted an invitation to become a professor in the newly established Szeged University, in Southeast Hungary. Before actually occupying his new position, he spent some time at the Mayo Clinic, in Rochester, USA, to isolate more of his elusive substance. During this trip he only made use of the good equipment and materials offered by the Mayo Clinic, without acquiring any new special expertise.

In Szeged University, he soon organised a very productive laboratory with ambitious young assistants and students. To his surprise, the substance he isolated in the USA proved to be vitamin-C. He also succeeded in finding a very rich source of vitamin C in the locally grown vegetable, Hungarian pepper (paprika). Having a large amount of this substance, he could also determine its chemical structure. Meanwhile, his group continued to do research on biological oxidation. They were able to identify a series of reactions of dicarboxylic acids taking place in biological oxidation. In 1937, Hans Krebs, relying on Szent-Györgyi and others' results, combined the reactions into a cycle, now called the "citric acid cycle."[13]

Szent-Györgyi received the Nobel Prize for Physiology or Medicine in 1937, for the above-mentioned results. He became the only scientist ever to win the Nobel Prize while living in Hungary. This very fact radically changed his position in the Hungarian scientific community. Previously, his activity, and particularly, his lifestyle, had shocked his colleagues. The mandarin-like Hungarian fellow professors, who occupied a high status in the German-type academic system resented Szent-Györgyi's Anglo-Saxon manners. His Anglophile tastes seemed incompatible with his peers' traditional, dignified style. Szent-Györgyi wore tweed jackets instead of traditional dark business suits. He went to his lab by motorbike and played volleyball with his students during coffee breaks. When it was hot, he and the staff of his lab went swimming together in the nearby river Tisza. As a result, though he occupied high offices at the university (dean, rector), some circles of his colleagues detested him. Probably this is why he was elected a member of the Academy of Sciences as late as 1938, after being awarded the Nobel Prize. (He was a corresponding member before that.)

This resentment also had some political aspects. In the 1930s a wide circle of university professors and professionals expressed their pro-German cultural and political commitments. The Nazi wave gradually arrived at Szeged University when Szent-Györgyi was in charge (first as dean, then as rector). Though Nazi-type anti-Semitism permeated official politics in the country, he did his best to protect the university from all kinds of anti-Semitism experienced both among students and professors.

Knowing his political leanings, at the end of 1941 some politicians asked Szent-Györgyi, the most reputed scientist of the country, to become the leader of their anti-fascist political movement. The goal of this movement was to organise an opposition party to the pro-German parliamentary parties and to establish contacts with the Allied powers so that they, and not the Soviets, would occupy Hungary after the inevitable German defeat. They also sought help to defend the country against the anticipated Soviet rule. The movement hoped to grow into the leading political force after the war when, they were fully convinced, a modern democratic political system would take the place of the old authoritarian system.

Szent-Györgyi accepted the challenge. He established contacts with the most influential political circles. In meetings with the Prime Minister and other political leaders he prepared a secret mission to Istanbul in order to meet the representatives of the Allied powers (Intelligence Service). With many others, he hoped that the Allies would initiate a military action against the Germans in the Balkans and that Hungary could join them in due course. In February 1943 Szent-Györgyi, whose British leanings were instrumental, carried out the mission and reached an agreement with the representative of the Allied powers. Finally, however, the mission proved a total failure. The plan of the Balkan military action was soon dropped and the Gestapo revealed Szent-Györgyi's action.

After his Istanbul mission, the Gestapo considered Szent-Györgyi a dangerous enemy of the Reich. He moved to Budapest to escape persecution. Yet, he remained active in politics. In early 1944, his movement began to reorganise itself into a political party with the goal of winning seats in Parliament and finally seizing political power. Szent-Györgyi hoped to become the first Prime Minister of the country after the war. In March, however, the Germans invaded Hungary. This was the end of Szent-Györgyi's organisation and meant Szent-Györgyi himself was in danger of life. Realising that after the war Hungary would belong to the zone controlled by the Soviet Union, he made several attempts to establish contacts with the Soviets to save his own life and to make arrangements for the future. Nevertheless, during the war he failed in his efforts to do this.[14]

Szent-Györgyi was barely able to escape from the Gestapo's persecution. For him, as for many others, the Soviet occupation of Hungary in 1945 meant real liberation.

4. SZENT-GYÖRGYI'S TRIP TO THE SOVIET UNION

Szent-Györgyi first encounters with Soviet troops did not impress him favourably. Paradoxically, however, even the rude behaviour of the fighting soldiers was a relief to him, because their very presence meant that his life was no longer in danger. As the front line moved on from his hiding place, Szent-Györgyi started to look for his family. However, as he remembered "I hardly reached the place a Russian major appeared with a small detachment, introduced himself to me and told me that he was sent by the commander of the army, field marshal Malinovsky to find me and bring me to safety."[15] He was allowed to take his large family with him to a comfortable but guarded cottage in southern Hungary, which he was not permitted to leave. Whether it was detention or a holiday to regain his strength is difficult to say. All the wishes of the large family were fulfilled by the Soviets, who behaved with great friendliness. Szent-Györgyi liked them. Following a period of starvation during the heavy siege of Budapest, the members of the family enjoyed being very well fed and they received all the comforts they needed.

It is doubtful whether the Soviets' goal was to save the country's most respected scientist or in fact they wanted to isolate the most famous non-Communist, anti-Nazi politician from the public till the Hungarian communists, returning from their Moscow emigration, could occupy the key political positions.

Szent-Györgyi's experiences with the Soviets during his detention were agreeable, sometimes even warm. Still, he soon became critical about some measures taken by the Soviet officers. He wanted to express his objections with the intention that the good relationship between the Hungarians and Soviets would not be spoiled. The Soviet officers he approached, however, rudely refused his criticism on the basis that the Soviets had defeated and occupied enemy Hungary, which made them feel entitled to special prerogatives. Szent-Györgyi was convinced that in the interest of Hungary it was essential to establish a good relationship and mutual understanding between the two countries.

These circumstances explain why Szent-Györgyi happily accepted an invitation in the mid-1945 to spend two months in the Soviet Union. He was to attend the celebration of the 220th anniversary of the Soviet Academy's foundation and to see Soviet science. He wrote in his English memoirs:

> I was delighted. I could see the Soviet from close range, see the mysterious world with my own eyes and meanwhile gain time, have a few months passing without wearing out in vain the enthusiasm and good will I had collected . . . I had a secret hope: to meet Stalin, tell him about our desire of understanding and tell him about the mistakes his people were doing endangering this understanding for ever.[16]

Besides politics, he also had a scientific goal: to meet his Soviet colleagues, particularly Vladimir Aleksandrovich Engelhardt and Militsa Nikolaevna Lyubimova. These two researchers made a breakthrough in muscle biochemistry, a new field of utmost interest to the Szeged group during the war. Engelhardt and Lyubimova proved that in muscular contraction a protein, called myosin, plays the decisive role by means of its enzymatic property. It catalyses the hydrolysis of adenosine triphosphate (ATP), the reaction that provides the energy for muscular contraction.[17] After repeating the Soviet researchers' experiment in Szeged, Szent-Györgyi found out that myosin consisted of two components with special features and functions. His group clarified some steps of the mechanism governing the work of muscles.[18] In spite of the stormy wartime conditions, the Szeged group contributed to "the revolution in muscle physiology," as A. V. Hill, a leading researcher in this field, called it.[19] Szent-Györgyi considered that the most thrilling experience of his scientific career occurred when he first saw *in vitro* through his microscope the movement of the protein responsible for muscle contraction.[20] Because he considered the results he achieved in the field of muscle biochemistry more important than any of his previous works, Szent-Györgyi was delighted to have the opportunity of meeting in the Soviet Union the scientists who had inspired his research.

In an article about his impressions on Soviet science published some time after his return to Budapest,[21] Szent-Györgyi wrote that his host was another old colleague, J. O. Parnas, director of a research institute.[22] Szent-Györgyi also mentioned with appreciation that he met and kept contact with Lina Stern, who directed a laboratory with 120 researchers.[23] He saw another colleague, Alexander Evseyevich Braunstein, whose field was close to Szent-Györgyi's. Braunstein discovered the transamination reaction that linked the ornithine cycle and the citric acid cycle that are the two core processes in intermediary metabolism.

During his two months' stay, in addition to Moscow, he visited Tbilisi, in Georgia, and Yerevan, in Armenia. "We were received in the friendliest spirit with boundless hospitality," he wrote. "Whatever I wanted to see I was shown. I have seen much good art, much good comradeship and many fine qualities of this splendid Russian people."[24]

He wrote another article about his experiences to the daily newspaper of the Communist Party.[25] Neither in this nor in any other article did he mention the new scientific ideas, methods or the way of thinking that he absorbed in the Soviet Union. Szent-Györgyi wrote rather in the tone of a politician intending to state that the Soviet Union was a friendly country with a genuine intention of living in peace. In the Communist daily he said that the Soviet Union was a highly cultured country that respects the rights of national minorities and gives outstanding importance to education and science. His underlying intention was to reassure the Hungarians that the new "ally" would secure a democratic, promising future for the country. Under the conditions prevailing at that time, any attempt to diminish fears toward the Soviets may have been an attitude of the realist politician, but his closing paragraph about a reception also attended by Stalin sounded too flattering to be true: "I was particularly impressed by this man's simplicity and modesty. He was sitting there, as if he were one of us. We could see that he is not a dictator but the father of his people."[26] Yet Szent-Györgyi did not approach him with his critical remarks on the Hungarian situation.

Speaking about Soviet science, he was impressed by its organisation, by the large institutes and by the generous sums secured in the state budget for research. "The beautiful, large and well-equipped institutes are populated by many enthusiastic young and older researchers," he wrote.[27] Soviet science seemed to him a huge and vigorously progressing social entity. Szent-Györgyi was greatly surprised to see that academic journals were sold at newsstands. This proved to him the prevalence of "a widespread scientific culture that is absolutely unique."[28] He explained all these favourable conditions by a principle he heard in the Soviet Union, according to which a modern society, particularly most branches of production, should rely on science. This ideological tenet seemed to him the source of the general respect given to science and culture in the Soviet Union.

The only critical remark he made about the Soviet situation remained unpublished: "I made many friends in the Soviet Union, some of whom I was on rather intimate terms but never during the two months of my stay did we ever touch on politics. I did not have the idea they had to restrict themselves. I think their minds are trained to avoid this dangerous topic even in their solitude."[29]

5. THE CONSEQUENCES OF SZENT-GYÖRGYI'S TRIP

Strengthened by his experience in the Soviet Union, on his return to Hungary Szent-Györgyi began to fight for the reorganisation of science according to the Soviet model. In parallel, he made sympathetic gestures to the Soviets and to the Hungarian Communist Party who were still not in power (the Communists took over in 1947). He addressed the participants at the 3rd Congress of the Communist Party in 1946.[30] With his friend, the popular novelist Lajos Zilahi, Szent-Györgyi established the Hungarian-Soviet Cultural Society in the same year.

Having understood that in the new system formed after the Soviet occupation he could not play any political role, he focused on carrying out radical changes in the structure of science.

Science in Hungary copied the traditional German model. It consisted of four universities (Budapest, Szeged, Debrecen, Pécs) and of a technical university (Budapest) supplemented by schools (e.g., a veterinary school) of lower than university level (colleges). The work and the structure of these universities were the same as in Germany. They consisted of faculties and chairs. One chair had one professor and some extraordinary professors, with many "Privatdozenten" waiting for vacancies in the chair. This system did not offer good opportunities either for the new disciplines or subdisciplines (e.g., physical chemistry, biochemistry) born around the turn of the century or for the crowd of ambitious young scientists eager to compete with their well-established colleagues. In Germany this situation was eased by the relatively high number of universities and by the existence of research institutes. In Hungary, however, research institutes, like the Kaiser Wilhelm Institutes did not exist. Apart from the universities, laboratories belonging to private enterprises and some state-owned quality control laboratories, research in the natural sciences found hardly any space.

Szent-Györgyi saw in the Soviet Union that a network of research institutes worked under the auspices and management of the Academy of Sciences without any teaching duties. He was convinced that this system would be advantageous. In Hungary, however, the Academy of Sciences was just a learned society, without research institutes. Its structure consisted of sections embracing mostly humanistic fields, without giving much attention to the natural sciences. Szent-Györgyi decided to fight against this traditionally humanistic orientation by suggesting the restructuring of the Academy into an organisation responsible for research in natural sciences. He considered this institution of the highest importance to society, in accordance with the Soviet ideology. An Academy like this, he thought, could request significant support from the government, while scientists, in turn, should promote the political goals of the government. This was in fact an essential part of the Soviet model.

According to this philosophy, "useful" (applicable) research could be conducted primarily in the natural and technological sciences. Therefore, these branches should be at the heart of activities of the whole Academy. Szent-Györgyi demanded structural changes for introducing this model but the acting leaders of the Academy rejected his suggestions. Therefore, in September 1945 Szent-Györgyi decided to take a radical step. Instead of reforming the old Academy he organised a new one, an alternative Academy, called the Hungarian Academy of Natural Sciences. Its membership consisted only of first class natural scientists and engineers, many of whom were not members of the Academy of Sciences.

With this move, Szent-Györgyi wanted to force the old Academy, basically the representatives of the humanistic branches, to accept his views rather than building up an entirely new permanent centre for the management of research which would compete with the old one. It was just an instrument in his fight to modernise the structure of science according to the Soviet pattern. A bitter debate broke out between natural and humanistic scientists, sometimes even reaching the courts, because the parties often used insulting expressions against each other. Nevertheless, during 1946, the leaders of the old Academy gradually succumbed to the attack.[31] In July, Szent-Györgyi's Academy came to compromise with the old one. All members of his Academy were incorporated into the old one, which committed itself to undergo significant structural changes. As a result, the weight of the natural and technological sciences significantly grew in the Hungarian Academy of Sciences. Szent-Györgyi was able to achieve at least a part of his aim.[32]

In addition to initiating a major structural change in the organisation of science, Szent-Györgyi took a very important and risky step in fulfilling his personal goals, which apparently showed a contradiction with all his reports on his trip. In Moscow, he organised a secret appointment with a biochemist, Eric Ashby, who represented Australia in the celebrations of the anniversary of the Soviet Academy. Szent-Györgyi asked Ashby to inform his earlier benefactor, the Rockefeller Foundation, that he had been taken to the Soviet Union for political purposes and was not allowed to re-establish his contacts with the English-speaking world. His primary interest would be to re-establish his relations with the Anglo-Saxon scientific circles that had always been vital to him. "It is isolation from the West which he is rather fearful of, wants to prevent, if possible" wrote Ashby in his letter to the Rockefeller Foundation.[33]

Soon, in 1947, Szent-Györgyi was allowed to make a trip to the West and, except for the two short visits he paid in the 1970s, he did not return to Hungary. He settled in the USA.

6. CONCLUSIONS

Albert Szent-Györgyi's trip to the Soviet Union was more than a visit paid by an indigenous individual living in a colonised territory to see curiosities in the centre. After World War II, the Soviet Union built up a new world-science meant to be an alternative to Western world-science. The centre of Soviet science was located in Moscow. Though most of the cognitive content of this new science did not differ from the Western one, some specific theories (e.g., in genetics) distinguished Soviet from Western science. One characteristic difference could be seen in the philosophy underlying science. Dialectic materialism, and particularly its role in scientific thinking, was unique to Soviet science.

The organisation of Soviet science also followed a pattern that was based on this philosophy. It was directed from one central agency working under the control of the Communist Party: the Academy of Sciences. Szent-Györgyi, intentionally or unintentionally, paved the way for the introduction of this model in Hungary, which finally occurred in 1949 when he was already living in the USA. While Szent-Györgyi promoted the import of the centre's organisation system, he did not do anything to introduce the "new" philosophy or the specific scientific tenets prevailing in the Soviet Union. His scientific programme during his trip had nothing to do with Lisenkoism or tail-wagging to the "Marxist geneticists" or any other suspicious theoreticians.[34]

The significance of his trip to the Soviet Union and his post-war activity can be understood in the framework of the peculiar situation under which Hungarian science worked after the war. Until then, it had belonged to the periphery of the German centre. This centre shifted to the USA during the war. Consequently, Hungarian science unexpectedly lost its international footing. In order to gain a new basis and to adjust to a changing world, Hungarian science tried to build up close relationships with the scientific community of the USA. This, however, proved impossible for political reasons originating not from Hungary but from the balance of international political powers. The very fact that Hungary was occupied by the Soviet Army and the country was gradually becoming part of an empire, with principles of operation markedly different from those of the Western world, set scientists the task of learning these principles.

For rebuilding and operating science in a new organisation system, scientists and administrators needed a special kind of knowledge. This knowledge also had a tacit component that could best be acquired at the site where the system was already in operation. After Szent-Györgyi many Hungarians, including students, visited the Soviet Union to study the system and to establish relationships with the new scientific centre. Some of them were object-related trips (e.g., research trips to Dubna, the Socialist high-energy physics centre), while others were human-related trips. In the latter category, some trips (both from Hungary to the Soviet Union and from the Soviet Union to Hungary) aimed primarily at adjusting the Soviet organisation system of science.[35] Szent-Györgyi's visit paid to the Soviet Union can be considered one of the first trips of this type.

Under the given conditions, Hungarian scientists could choose between two options: to leave the country and join the West, or to accommodate to the new situation as soon and as easily as possible. Szent-Györgyi's activity exemplified both options. He promoted fast adaptation but he himself chose to live in the new Western centre.

Hungarian science, as a whole, could not help but work as a periphery of the Soviet centre until 1990. The Academy of Sciences became the most important authority in science. A network of scientific institutes was established in the early 1950s working under the direction of the Academy, and five-year planning was introduced in science. Marxism became the compulsory philosophy. The Soviet centre did not want to convince Hungarian scientists of the advantages of this system by means of rational scientific discussions. Rather, it openly relied on the strength of its army, disregarding any kind of scientific convictions or norms as guiding principles. This militarily enforced relationship between the scientific centre and periphery represented a particular type in the centre-periphery relations.

Hungarian Academy of Sciences

NOTES

[1] Besides Darwin's own accounts, Charles Darwin, *On the origin of species* (New York: New York University Press, 1988), and Nora Barlow, ed., *Diary of the voyage of H.M.S. Beagle* (New York: New York University Press, 1987) and the Darwin biographies, many lot of travel advertisements can be found on the Internet in which Darwin's trip is used by travel agents as a selling point for their trips organized to the Galapagos Islands.

[2] See, e.g., Niels Blaedel, *Harmony and Unity: The Life of Niels Bohr* (Berlin: Springer-Verlag, 1988), pp. 42-59.

[3] Mary Louise Pratt, *Imperial Eyes: Travel Writing and Transculturation* (London, New York: Routledge, 1992), pp. 32-38.

[4] Bruno Latour, *Science in Action: How to follow Scientists and Engineers through Society* (Cambridge Massachusetts: Harvard University Press, 1987), Chapter 6. Centers of Calculation, pp. 215-257.

[5] See, e.g., John Krige, "Some Socio-historical Aspects of Multinational Collaborations in High-Energy Physics at CERN between 1975-1985," in Elisabeth Crawford et al., eds., *Denationalizing Science: The Context of International Scientific Practice* (The Netherlands: Kluwer Academic Publishers, 1993), pp. 233-262.

[6] Tacit knowledge has been discussed in a vast amount of literature, all of which originates from Michael Polanyi's philosophy. See, e.g., Michael Polanyi, *The Tacit Dimension* (Garden City: Doubleday and Co. 1966), p. 4.

[7] Michael Polanyi, *Personal Knowledge: Towards a Post-Critical Philosophy* (London: Routledge and Kegan Paul, 1958), pp.vii-viii.

[8] About Rutherford and his group see David Wilson, *Rutherford, simple genius* (Cambridge, Mass.: MIT Press, 1983).

[9] Mary Louise Pratt, *op. cit.* (3), pp.32-38.

[10] Latour, *op. cit.* (4), pp. 215-257.

[11] Latour, *op. cit.* (4), p. 222.

[12] About Szent-Györgyi's biography see Ralph W. Moss, *Free Radical: Albert Szent-Györgyi and the Battle over Vitamin C* (New York: Paragon House Publishers, 1988).

[13] These results were summarized in Albert Szent-Györgyi, "Oxidation, energy transfer and vitamins," *in Nobel Lectures, Physiology and Medicine 1922-1941* (Amsterdam: Elsevier, 1965).

[14] Moss wrote about this episode in his biography of Szent-Györgyi (Moss, *op. cit.* (12), pp. 126-150). Szent-Györgyi also mentioned it in his memoir, Albert Szent-Györgyi, "Lost in the twentieth century," *Annual Review of Biochemistry*, 32 (1963), 9-10. I published the details in Hungarian: Gabor Pallo, "Szent-Györgyi Albert és a szovjet kapcsolat," (A.S. and the Soviet connection). *Magyar Tudomany*, 10 (1993), 1262-1272.

[15] The quotation is from an unpublished biographical manuscript written in English by Szent-Györgyi probably in 1949. There are no date and no page numbers on the typewritten text. The original spelling has been preserved. It is stored in the USA: Library of Congress, Manuscript Division. *The Papers of John von Neumann.* Szent-Györgyi file.

[16] *Ibid.*

[17] V. A. Engelhardt, M. N. Lyubimova, "Myosin and adenosinetriphosphatase," *Nature*, 144 (1939), 668-669.

[18] The publications became known only after the war. They appeared in Albert Szent-Györgyi ed., *Studies from the Institute of Medical Chemistry University Szeged, Vol. I-IV.* (Basel, Budapest: Kerger, Gergely 1941-1944).

[19] See in Joseph S. Fruton, *Molecules and Life: Historical Essays on the Interplay of Chemistry and Biology* (New York: Wiley-Interscience, 1972), p. 369.

[20] Szent-Györgyi, *op. cit.* (14), pp. 9-10.

[21] Albert Szent-Györgyi, "Élményeim a szovjet természet-tudománnyal kapcsolatban" (My experience with the Soviet science) in *A harmincéves Szovjetunió, 1917-1947* (Budapest: Corvina, 1947), pp.164-167.

[22] I could not establish whether J. O. Parnas was in fact the same person as Jacob Parnas, a Polish biochemist, and collaborator of Otto Meyerhof in Berlin, in the 1920s, who contributed to solving some problems of metabolism, the details of glycolysis pathways and the ATP/ADP systems, in particular.

[23] Lina Stern, a professor of physiology, later became part of an anti-Semitic trial in Stalin's court. With others she was accused of Zionist conspiracy but she, with another person, was sentenced to a long term of imprisonment, while many others in the same trial were executed.

[24] "Biographical manuscript," *op. cit.* (15).

[25] Szent-Györgyi Albert, "Szovjetoroszországi utazásom benyomásai," (My impressions acquired during my trip to Soviet Russia), *Szabad Nép*, August 2 (1945), 2.

[26] *Ibid.*

[27] Szent-Györgyi, *op. cit.* (21), p.164.

[28] Szent-Györgyi, *op. cit.* (21), p.165.

[29] "Biographical manuscript," *op. cit.* (15).

[30] The speech appeared in publication. Albert Szent-Györgyi, "A tudósok helye a demokrácia odalán van" (The place of the scientists is on the side of democracy) in *A népi demokrácia útja* (Budapest: Szikra, 1946), pp. 288-289.

[31] The history of this period is described by Lóránt Tilkovszky, "A Magyar Tudományos Akadémia a felszabadulás után, 1945 – 1948" (The Hungarian Academy of Sciences after the liberation) in Zs. Pach, ed., *A Magyar Tudományos Akadémia másfél évszázada, 1825-1975* (Budapest: Akadémiai Kiadó, 1975), pp.347-361.

[32] A statistical analysis of the new situation was published in Sándor Kónya, "Az akadémiai tagság összetételének változásai 1945-1949" (The changes in the composition of the Academy's membership), *Magyar Tudomány*, 6 (1989), 496-507.

[33] Asby's letter to O'Brian, May 26, 1945. *Rockefeller Archive Centre*, RF. Record Group 1.1, Series 750, Box 2, Folder 10.

[34] The same conclusion was drawn by Gyorgy Peteri, "Modernity versus Democracy: The Politics of Albert Szent-Györgyi, 1945-47" in Tibor Frank, ed., *Culture and Society in Early 20th Century Hungary* (Budapest: Hungarian Studies, 1994), pp. 181-198.

[35] I wrote about Hungarian-Soviet relations in an earlier paper. Gábor Palló, "Internationalism in Soviet World-science: the Hungarian Case" in Elisabeth Crawford et al., eds., *Denationalizing Science, op. cit.* (5), pp. 209-232.

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