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Please cite this paper as follows:

Jöns, H (2011) Centre of calculation. In Agnew, JA and Livingstone, DN (ed) *The SAGE Handbook of Geographical Knowledge*, Sage, pp.158-170, ISBN: 978-1-4129-1081-1

12

Centre of Calculation

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The notion of 'centre of calculation' was developed by the French sociologist Bruno Latour (1987) in his seminal book *Science in Action*. It is a concept about the venues in which knowledge production builds upon the accumulation of resources through circulatory movements to other places. Centres of calculation have been observed at a variety of scales, from the individual to supranational regions, and have contributed significantly to the construction and dissemination of scientific, geographical and other forms of knowledge in different times and spaces. In this chapter, it is argued that the principles for becoming a 'centre of calculation' are generic to the emergence of knowledge centres, while scientific and economic 'centres of calculation' became inextricably linked to the rise of European science, capitalism and imperialism and are as such an essentially modern project.

This chapter is divided into three sections. The first section introduces the basic assumptions of the concept in question and provides some ideas on its wider social and intellectual context. The second section presents an historical perspective on scientific centres of calculation by discussing case studies and exploring their relation to imperial projects. In the third section, economic centres of calculation are considered in regard to their role for the production and dissemination of knowledge through cities and their networks.

CONCEPT AND CONTEXT

In the late 1970s and early 1980s sociologists from France, England and Germany explored the question of how scientists and engineers work by studying their everyday practices through ethnographical observation (Latour and Woolgar 1979; Knorr Cetina 1981). Based on these laboratory studies, they developed a materialist account of scientific practice that shifted the focus of explanatory resources for knowledge production from the scientists' ideas, theories and interests to the great variety of inanimate and animate nonhumans that constitute laboratory experiments and fieldwork in the natural and technical sciences. From the perspective of what became known as actor–network theory, scientific practice resembles a network-building process between human and nonhuman 'actants'. Being both outcomes and mediators of scientific network-building, human and nonhuman actants mutually negotiate their roles, attributes and competencies in the process of knowledge production until a well-functioning web of allies is stabilized that makes up a new knowledge claim (Law 1986; Latour 1987, 1999).

According to Latour (1987: 179–257), scientific network-building is characterized by a systematic mobilization of human and nonhuman resources, or 'actants', in a few 'centres of calculation' that can afford the expensive 'proof race' of the sciences. His idea that such 'cycles of accumulation' are constitutive of 'centres of calculation' illustrates that knowledge production displays a complex geography as it is both situated within particular locations and linked to other places through mostly circulatory movements. Regardless of the academic practice involved, the circulation of people and organisms, knowledge and ideas, symbolic and material resources to and between different centres of calculation has also contributed to the emergence of geographical knowledge about the other places involved. Therefore, the following three defining processes of 'centres of calculation' are important for understanding the development of geographical and other forms of academic knowledge: first, the mobilization of resources; second, the stabilization of new knowledge claims; and third, the extension of knowledge networks for the validation, dissemination and preservation of knowledge and its products.

Mobilization

Scientists use encounters with other people and spatial contexts systematically in order to gather new resources for the production and support of their arguments. Depending on the field of study and period of time, the mobilized research objects, infrastructure and expertise may include documents, books, data, instruments, machines, methods, stones, plants, animals, people, specimen, artefacts, questionnaires, diaries, observations, maps and drawings as well as research assistants and collaborators. Latour outlines three important properties of the nonhuman resources mobilized by the scientists: first, they have to be *mobile* in order to be transported to a 'centre of calculation'; second, they have to be *stable* – at least to some extent – in order to be presented and processed in an unchanged way; and third, they have to be *combinable* in order to be aggregated, transformed and connected to other resources in the process of knowledge production (Latour 1987: 223). Therefore, the terms ‘immutable and combinable mobiles’ were coined to address nonhuman scientific resources (Latour 1987: 227).

Latour (1987: 225) points out that the recurring ‘mobilisation of anything that can be made to move and shipped back home’ in scientific centres of calculation – such as the university, the laboratory, the archive and the museum – shaped the cumulative character of European science from the ages of discovery and exploration and established Europe as the centre of the imperial age. Experiences of expeditions and individual travellers that were not transmitted to the place of departure had no impact on the construction of a knowledge centre in this place. Only a full ‘cycle of capitalization’ added to the accumulation of resources in a ‘centre of calculation’ and thus created an advantage in knowledge that made distant places familiar and thereby controllable. Subsequent journeys could build upon these previous experiences, familiarize themselves with the place of interest from a distance and thus generate new insights more quickly (Latour 1987: 219–32). An example is given by an episode from the exploration of the Pacific by Lapérouse (1741–88) on behalf of Louis XVI (1754–93), a voyage that had started in 1785:

> On 17 July 1787, Lapérouse is *weaker* than his informants [the natives]; he does not know the shape of the land, does not know where to go; he is at the mercy of his guides. Ten years later, on 5 November 1797 the English ship *Neptune* on landing again at the same bay will be much stronger than the natives since they

> will have on board maps, descriptions, log books, nautical instructions – which to begin with will allow them to know that this is the 'same' bay. For the new navigator entering the bay, the most important features of the land will all be seen for the *second* time – the first time was when reading in London Lapérouse's notebooks and considering the maps engraved from the bearings De Lesseps brought back to Versailles.
>
> Latour 1987: 217

It is this linkage between exploration, European imperialism and the modern scientific enterprise that will be further examined in the course of this chapter. The second point to be made is about the close relationship between knowledge and power that grounds Latour's concerns in the work of the French philosopher Michel Foucault, adding a profoundly materialist perspective to it. Based on the mobilization of immutable mobiles, the balance of power between the early modern traveller and a particular place shifted from an inferiority of the uninformed traveller during the first encounter to an increasing superiority of the informed traveller during the second and following encounters.

> At every run of this accumulation cycle, more elements are gathered in the centre … at every run the asymmetry … between the foreigners and the natives grows, ending today in something that indeed looks like a Great Divide, or at least like a disproportionate relation between those equipped with satellites who localise the 'locals' on their computer maps without even leaving their air-conditioned room in

> Houston, and the helpless natives who do not even see the satellites passing over their heads.
>
> Latour 1987: 221

How *geographical* knowledge was produced during the explorers' encounters *en route* has been detailed by ethnographer/geographer Michael Bravo (1999) in his re-examination of a particular episode during Lapérouse's voyage into the Pacific. Reconstructing Lapérouse's encounters in the Bay of Tartary with the aim of rebutting Latour's interpretation of the event, he points out that there was not – as Latour implied – a simple transfer between sketches drawn by locals into the sand and the explorers' new geographical knowledge about the region (Bravo 1999: 228–9). Geographical knowledge rather emerged from detailed ethnographic observations and a series of complex and often confusing encounters with locals that aimed at the mobilization of local geographical knowledge. Bravo (1999) elaborates on how both 'geographical gifts' (geographical knowledge bequeathed through navigation and local people) and 'ethnographic navigation' (based on descriptions of people's physical appearance, language, manners, habits and religious ideas as well as on comparisons between differently labelled ethnic groups) were crucial for generating new geographical knowledge and thus for settling cartographical disputes at home. By imposing ethnic labels on their informants and by replacing the natives' sketches with surveys based on precise astronomical instruments, the Europeans, however, contributed to the marginalization of these people and their knowledges as 'other', subordinate and less 'enlightened'.

Stabilization

An emerging 'centre of calculation' is both place of departure and destination of 'cycles of accumulation'. Inside such a centre the accumulated resources are systemized, classified, transformed, tied together and re-represented in order to build a strong web of associations that makes up a new knowledge claim when all the assembled human and nonhuman allies successfully control one another and thus act as a unified whole. Based on comparisons and combinations, reductions, transformations and abstractions, the aim of the work conducted inside a centre of calculation is to create efficient inscriptions in the form of maps, diagrams, tables, texts and equations that represent comprehensible and well-communicable knowledge claims about much more complex phenomena – whether these are distant in time and space, very tiny or incredibly large (Latour 1987: 232–47). The status of a new knowledge claim ideally resembles that of a 'black box' when its complex and heterogeneous history of construction is not relevant for everyday usage and has only to be reconsidered if problems occur (Latour 1987: 130–1).

Mobilization and stabilization are equally important and overlapping strategies in the course of knowledge production. Both practices resemble integrating processes of negotiation between heterogeneous elements that aim for an increased mobility, stability and combinability of the research object in question. According to Latour, 'the *logistics* of immutable mobiles is what we have to admire and study, not the seemingly miraculous supplement of force gained by scientists thinking hard in their offices' (1987: 237). Even theorists, he argues, rely on immutable mobiles in their work when they mobilize, combine and transform highly abstract *n*th order inscriptions. Their particular strategic and admired position results from their argumentations' high level of abstraction that enables them to connect with a range of debates on a lower level of abstraction:

> Once every trace has been not only written on paper, but rewritten in geometrical form, and re-written in equation form, then it is no wonder that those who control geometry and mathematics will be able to intervene almost anywhere.
>
> Latour 1987: 245

The idea of repeated circulatory movements contributing to the construction of narratives in one particular place has also been developed by the French philosopher Michel de Certeau (1986) in an essay first published in French in 1977. De Certeau's study of Jules Verne's (1828–1905) travel writing substantiates the two basic characteristics of centres of calculation discussed so far. First, the great voyages and travel adventures narrated by Verne contributed to what de Certeau (1986: 146) calls the 'stockpiling' of knowledge through a series of episodic circuits involving a repetitive going out into the world and returning to a home base. Second, at the home base, the accumulated data was combined and interwoven to a coherent and often linear narrative. In the words of geographer Mike Crang, 'each journey returns to the place of writing and reinscribes the centrality of the centre of calculation and inscription' (2003: 139). De Certeau's (1986: 146) illustration of a series of circuits adding to the stockpiling of knowledge at the home base in fact resembles a three-dimensional version of what Latour (1987: 220) depicts as cycles of capitalization in a centre of calculation. This confirms that knowledge production in modern Europe – whether in the context of fictional or factual texts – has been linked to successive circular journeys and the systematic mobilization of textual, theoretical and empirical resources in the narrative's place of production. It has also been related to a particular western strategy of capitalizing on knowledge 'in terms of deriving status, authority and academic qualifications from it' (Crang 2003: 139).

While the idea of network-building processes in centres of calculation can be applied to knowledge production in all disciplines, Latour (1987: 208–10) argues that scientific and technical arguments often appear to be 'hard' facts compared to 'soft' facts of other narratives. The scientists' sedulity of recruiting allies, trying out stronger and weaker associations and creating complex socio-material hybrids tends to produce particularly stable and durable 'black boxes' as the foundational blocks of the sciences' cumulative nature. He contends that when evaluating knowledge claims, rationalist approaches to science put too much emphasize on reason, logic and argumentation, or mental abilities, whereas relativist approaches, maintaining that judgements about rationality and irrationality mostly depend on different points of view, overlook the enormous work scientists invest into the mobilization of resources and the stabilization of knowledge claims in order to make their arguments more stable and reliable than other arguments (Latour 1987: 195–8).

Extension

The process of knowledge production is not necessarily completed with the mobilization of resources and their transformation into a new knowledge claim. A new argument has rather to prove itself outside its local context of construction in order to become a widely acknowledged fact. The value of newly constructed truth claims has to be tested in different settings, thus exposing them to what Latour (1987: 78) refers to as ‘trials of strength’. Their dissemination relies on the opportunity for and interest of other people to integrate them into their work. The validation, dissemination and preservation of academic knowledge all depend on the actions of other people in other contexts than the formative centre(s) of calculation. The construction of new facts is thus a collective process that requires the extension of knowledge networks in time and space (Latour 1987: 247–57). Widely praised qualities of scientific knowledge such as its presumed universality and the predictability of events depend on the ability to transform places of knowledge consumption in such a way that remaining differences to the context of construction have no significant impact on the existence of scientific facts and artefacts in these other places. However, as place-specificity makes it impossible to construct the *same* spatial context elsewhere, the application of scientific and technical knowledge is characterized by many complications through missing, failing or intruding human and nonhuman actants:

> This dependence and fragility [of facts and machines] is not felt by the observer of science because ‘universality’ offers them the possibility of applying laws of physics, of biology, or of mathematics everywhere *in principle*. It is quite different *in practice.*
>
> Latour 1987: 250, original emphasis

If new knowledge claims prove themselves outside of the formative centres of calculation, their spokespersons can expect a positive feedback mechanism that helps to recruit more allies for new research and to support their centrality. Based on the three basic characteristics of centres of calculation designated as mobilization, stabilization and extension of knowledge networks, it might thus be possible that 'a small provincial town, or an obscure laboratory, or a puny little company in a garage, that were at first as weak as any other place will become centres dominating at a distance many other places' (Latour 1987: 223). For a better understanding of centres of calculation and their wider political, economic, social, cultural and intellectual meaning, it is therefore important to consider the practices conducted in these venues as much as their external linkages in terms of incoming and outgoing flows of people and organisms, knowledge and ideas, symbolic and material resources.

SCIENTIFIC CENTRES OF CALCULATION

Scientific centres of calculation seem to be as old as the history of science itself as the beginnings of recorded scientific observations in Europe are marked by a prominent circular journey. At about 600 BC Thales of Milet (c. 625–547 BC) had travelled from Greece to Egypt in order to conduct measurements of shadow lengths at the feet of the pyramids that helped him to generate new knowledge about basic geometrical relations. Widely regarded as the origin of Greek geometry, he taught this knowledge back in Milet to a number of pupils in what became known as the Ionic school (Serres 1995).

About 300 years later, in the third century BC, the famous Library of Alexandria was founded by 'Macedonian rulers who had a vested interest in accumulating oriental knowledge, with the intention of installing a syncretistic Hellenism throughout the imperial world' (MacLeod 2004: 3). Historian of science Roy MacLeod reasons that

> [the Library] was the first to underwrite a programme of cultural imperialism, to become a 'centre of calculation', in Bruno Latour's phrase. For similar reasons, royal libraries were later established in all the Hellenistic centres – for prestige, for cultural intelligence, and for the practical purposes of administration and rule … Alexandria would welcome learned Greeks to come and work together, to pursue mathematics and medicine, literature and poetry, physics and philosophy … It would aim for complete coverage of anything ever written.
>
> MacLeod 2004: 3

The Ionic school and the Library of Alexandria mark powerful centres of calculation in the early centuries of the European intellectual tradition. They were important nodes in a growing network of scientific and philosophical knowledge, linked to the world by the mobilization of scholars and resources and a significant intellectual, cultural and political influence across time and space. By collecting and disseminating geographical knowledge, the Library of Alexandria functioned as a centre of imperial control, thus underlining a close relationship between scholarship and the Hellenistic imperial project. While scientific, geographical and philosophical knowledge acquired some political power in ancient civilizations, these power-geometries kept changing over the centuries to come. Exploring the ordering of knowledge in the Roman Empire, classical scholars Jason König and Tim Whitmarsh (2007: 5) argue that '[t]he structures of post-classical knowledge-ordering – in the Arabic, medieval and Renaissance worlds and beyond – are indebted to ancient models' but that knowledge-ordering texts of the Roman Empire were much less closely linked to imperial ambitions than much of the scientific writing of the British Empire.

The meaning of scientific knowledge and its relationship to political power were quite distinct in the European Middle Ages as well. In a period in which churchly religious and secular–political interests were inextricably linked to each other, scientific knowledge was subordinated to religious knowledge and often actively suppressed when it threatened the authority of the Christian Church (Grant 1996). Monasteries, the emerging universities and courts of clerics and aristocrats can be regarded as medieval scientific centres of calculation. They introduced Greek and Arabic science to Central Europe and supported those fields of study that turned out to be useful for ecclesiastical and secular authorities (De Ridder-Symoens 2004). It was not until the fifteenth century that events such as the invention of the printing press (c. 1450) by Johannes Gutenberg of Mainz (c. 1400–68), early modern discoveries and expeditions (e.g. Columbus discovery of the Americas in 1492) and the Copernican Revolution (1514) launched a cumulative process of cycles of accumulation in scientific centres of calculation that eventually led the triumvirate of European science, capitalism and imperialism to dominate what became known as the modern world-system.

London

The interconnection of modern science, commerce and empire was probably most clearly embodied by the life and deeds of Sir Joseph Banks (1743–1820), the English explorer, botanist, collector and publisher as well as confidant to the king, advisor to the government, the admiralty and the East India Company, and long-term President of the Royal Society (1778–1820). Historian of science David Miller (1996) suggests using a Latourian approach for exploring Banks' crucial role in the construction of powerful 'centres of calculation' in London as these were as much sustained by a complex network of scientific, commercial and imperial practices and shaped by geographical imaginations of unfamiliar places beyond Europe as they sustained and shaped such networks and imaginations. Interpreting 'centres of calculation' as a post-Saidian approach, Fulford *et al*. (2004) also discuss Banks' achievements in the light of this concept as they aim to extend Edward Said's (1978) critique of the western academic tradition by considering both representational and materialist aspects of interconnected networks of exploration (Fulford *et al*. 2004: 27).

Building upon his schoolboy hobby of botany, great inherited wealth and expeditions to Newfoundland and Labrador, Banks' scientific authority began to emerge after 1768 when he joined Captain James Cook's (1728–79) first of three voyages into the Pacific. This journey explored the shores of Tahiti, New Zealand and Australia and is widely regarded as one of the most important scientific explorations in the eighteenth century. Supported by a number of botanists and assistants, Banks' collection of specimens 'increased the number of plant species known to science by 25 per cent' (Fulford *et al.* 2004: 9). Back in London, his house at Soho Square and the

Royal Gardens at Kew became part of a multinodal centre of calculation in which his vast collection of rocks, plants, animals and cultural artefacts was preserved, classified and displayed. Using established Royal Society procedures and developing the classification system of Swedish botanist Linnaeus with the help of one of Linnaeus's students, Banks transformed his collection into systematic knowledge. It was Banks' ability to establish himself as the spokesperson of the publicly available collection that gained him national and international scientific recognition and increasing political influence (Miller 1996; Fulford *et al*. 2004).

Banks orchestrated a complex network of human and nonhuman resources for the 'benefit' of science and the growing British Empire, but often at the expense of other people and places (Fulford *et al.* 2004). As powerful doyen of science, he imposed his will over which scientific enquiry received validation, thus delaying, for example, the acceptance of vaccination as a useful medical practice. He initiated explorations to Africa, Australia, China, North America and the North Pole and organized the comparison, classification and reproduction of the resources they brought back, thus supporting various 'scientific' discourses, including racial categorizations and rankings that had dreadful effects for people living in the regions exploited by European mobilization processes.

Banks corresponded with gardeners, natural philosophers, politicians and administrators throughout the world, some of which had been trained in London to maintain his global networks abroad. He sent gardeners around the world to collect plants and seeds from remote climates. These were cultivated at Kew in the name of science and redistributed to Britain's new colonies as inexpensive food sources. By first sending sheep and vine to Australia and smuggling tea plants from China to India Banks supported the emergence of patterns of colonial capitalism that still shape our world today. His network of botanical gardens fuelled a new global capitalism that gave 'the nation a commercial advantage over its trading rivals' (Fulford *et al.* 2004: 44). This expansive capitalism and colonialism was consolidated by sending out military expeditions to Africa in order to bring the goldfields under British control. Banks' library became 'a repository of remote places as reconstructed by European knowledge-systems' (Fulford *et al*. 2004: 41), and he personally edited and controlled the geographical knowledge released about hitherto unfamiliar places within the reach of his networks. As an individual, Banks used existing institutions and infrastructures in London to created powerful scientific centres of calculation that in turn transformed the city into the commercial and imperial capital of an expanding British Empire.

Tanjore

Scientific centres of calculation were not only located in the metropolitan areas of early modern Europe. It has rather been argued that the notion of centres of calculation helps to reveal the inadequacy of the centre/periphery model of science as the knowledge centres are not bound to specific geographical locations but defined by particular practices (Nair 2005). Historian Savithri Preetha Nair argues that Raja Serfoji II (1798–1832) of Tanjore, a small city in the South of India, was Banks' 'native counterpart, exhibiting similar formal properties, and drawing on those very same ideas and networks of metropolitan practice to systematically produce useful knowledge', even if on a much smaller scale (Nair 2005: 279).

Serfoji had been educated by Halle Lutherian Missionaries and officials associated with the East India Company in Madras, who prepared him for his royal responsibilities as an adult. Considered as a man of knowledge in his twenties, Serfoji had internalized European education and the idea of 'useful' knowledge, thus confirming the view that the modern world-system grew, *inter alia*, through the Europeanization of non-European elites (Taylor 1999: 9). After he had established his court at Tanjore, Serfoji managed to generate and sustain cycles of accumulation for the production and dissemination of knowledge by successfully connecting himself to three larger networks: the Tranquebar missionaries and the Company officials, who both provided important links to the metropolitan Banksian network, and to a 'large group of native medical practitioners, mechanics, animal carers, painters, musicians, gardeners, hunters, bird-snarers, printers and book binders' (Nair 2005: 284). Serfoji's cycles of accumulation were enriched by eminent travellers visiting the Tanjore court; by a wide network of correspondences; by the exchange of books, instruments/machines and research objects with London and elsewhere; and by the creation of a range of institutions for the production and dissemination of new knowledge, including gardens, libraries, printing presses, a pharmacy and educational facilities. Based on translating the most recent developments in western science and English education into Marathi and Tamil, Serfoji's centre of calculation extended the networks of modern science and education to the south of India.

There were, however, striking differences between Banks' and Serfoji's centres of calculation. First, Nair argues that

> the systematic collecting project in which Serfoji engaged as a response to the western encounter, was not directed towards establishing a cabinet of curiosities [as in the European tradition] … it was aimed at re-inscribing a field-centred episteme, in resistance to the 'museum-based' knowledge production that was fast gaining ground under the Company's mercantilist regime.
>
> Nair 2005: 285–6

The reason for this was his 'intuitive and sympathetic understanding of living nature – a socialising of nature – which blurred the boundaries between the object and observer' (Nair 2005: 294), thus illustrating the impact Serfoji's Hindu beliefs had on the ways in which he practised science. By not displaying the displaced collections in a museum, his cycle of knowledge production did not produce the kind of hierarchical geographical knowledge that emerged elsewhere when displaced items (and thus the places they came from) were controlled by the eyes and minds of 'enlightened' observers. The influence of non-western forms of knowledge production thus altered some of the ways in which Serfoji's centre of calculation worked.

The second considerable difference between Banks and Serfoji was that the Indian prince was subordinated to the administration of the British Empire and thus lacked political authority and economic freedom. This is best expressed in Serfoji's pilgrimage to Benares (1820–22) that he used 'as a perfect and legitimate alibi in the face of political confinement, to satisfy both his own curiosity and to sustain his cycle of accumulation, [while] the Company officials viewed the pilgrimage as a distraction that "halted the normal routine of that praiseworthy career"' (Nair 2005: 300). Despite this subordination to British administration, the example of Serfoji's early-nineteenth-century 'centre of calculation' in the periphery of a Eurocentric world – Tanjore was even located in the periphery of India – shows how centres of calculation may emerge in different geographical contexts. They may also vanish abruptly when these practices have no relevance to changing political and economic realities – as Tanjore's centre of calculation did in the 1850s – or when these practices stop due to discontinuation on the personal level.

Modern institutions

Sir Joseph Banks and Raja Serfoji II of Tanjore were outstanding individuals who managed to knot powerful centres of calculation and knowledge networks. In their life-time, however, the trend was 'away from a situation in which a private individual, through deferential politics, could array these domains [economics, politics, science, technology, law] in such a way as to make himself [sic!] a center, and towards one in which the center was an administrative unit, or a regulated and coordinated group of administrative units' (Miller 1996: 33). Accordingly, modern institutions such as corporations (Harris 1998), learned societies (Heffernan 2000), botanical gardens (Johnson 2007), museums (Dritsas 2005), libraries (Craggs 2008), universities (Jöns 2008), government institutions (Barnes 2006) and even coffee-houses (Stewart 1999) have been discussed as 'centres of calculation' (Livingstone 2003: 171–8).

Lawrence Dritsas (2005), working in the field of science studies, reconstructs the people, practices and institutions involved in the taxonomic description of six freshwater mussel shells collected during David Livingstone's Zambesi Expedition

(1858–64). He critically reflects that '[b]y following the mussels through society, the centre of calculation proves to be a fictitious place if it is assumed to be the end of the line where all the further analytical work was performed' (Dritsas 2005: 50). In his opinion, the metropolitan centre of science rather functioned as 'an entrepôt for natural history' than a centre of calculation as '[t]he work at the [British] museum involved receiving specimens, evaluating them briefly and then sending them on to an appropriate expert for proper analysis, wherever they might be' (Dritsas 2005: 50–1). This perspective evokes the idea of a spatially distributed, or multinodal, centre of calculation, in which '[t]he sites of collection, facilitation and analysis are particular locales that fit into a larger, distributed pattern of knowledge generation necessary for the whole project to succeed' (Dritsas 2005: 52). However, as Dritsas acknowledges the possibility of the expert being located within the museum, it remains possible to regard the whole institution as a centre of calculation.

Historical geographer Michael Heffernan (2000) conceptualizes three major geographical societies as centres of calculation when comparing the involvement of the Royal Geographical Society in London (RGS), the *Société de Géographie de Paris* (SGP) and the American Geographical Society in New York (AGS) in the wartime effort of their respective countries. His findings highlight very different functions of similar types of centres of calculation in diverse geographical contexts and reveal how the wider political meaning of the geographical knowledge emerging from these venues may vary:

> While the RGS acted as a metropolitan node in Britain's 'imperial archive' and focused on the production of maps and the development of schemes to project war onto a 'winnable' imperial dimension; the SGP became a node in France's 'national archive', a 'centre of geographical calculation' that reflected a characteristically French faith that powerful intellectuals … could devise elegant geographical and historical arguments about the sovereignty of the national space.
>
> Heffernan 2000: 327

Heffernan's analysis of the AGS eventually suggests the notion of a mobile centre of calculation. Based on 'one of the most exhaustive and ambitious exercises in geographical and historical data collection ever attempted' (Heffernan 2000: 328), the AGS did not produce recommendations on Europe's geopolitical future that could have been consulted by the delegates of the post-war peace conference. US President Woodrow Wilson and his advisers rather 'hoped that a logical conclusion would emerge during the negotiations based on America's unique archive of fact'. Therefore, this 'huge collection of material was duly shipped across to Paris on the USS George Washington to be carefully reassembled … at the US headquarters' under the supervision of Isaiah Bowman and other academic geographers (Heffernan 2000: 328–9).

In the course of the nineteenth century, modern research universities superseded academies and scientific societies as the most prominent scientific centres of calculation (Burke 2000: 49). At Cambridge University, the rise of research culture went hand in hand with the growth and professionalization of academic travel for the purpose of research, visiting appointments, lecturing, conference visits and consulting (Jöns 2008). The increasing circular travels of Cambridge academics in the first half of the twentieth century can be interpreted as a twofold mobilization process in different centres of calculation, namely the home institution and the host institutions. On the one hand, the emerging research university benefited from its travelling academics through the production of new arguments, the linking to academic networks and research centres, and the access to and import of new ideas, prestige, research objects, infrastructure and funds. On the other hand, the temporary recruitment of Cambridge expertise in the United States – mainly through visiting appointments and lecture tours – contributed to the gradual transformation of American universities into new global scientific centres and fostered the development of an Anglo-American academic hegemony in the twentieth century (Jöns 2008). Conceptualizing modern research universities as centres of calculation thus draws attention to their complex external linkages and offers a promising way of exploring further the changing geographies of knowledge nodes and networks (Jöns 2009).

ECONOMIC CENTRES OF CALCULATION

In addition to individuals and institutions, cities have been characterized as 'centres of calculation', or 'places in which local information from different regions and concerning diverse topics is turned into general knowledge (Burke 2000: 75). The example of the city of Amsterdam as the leading commercial centre in Europe during the seventeenth century highlights some of the ways in which the notion of 'centre of calculation' might enhance our understanding of cities as venues in which knowledge is produced through and for economic practices. Historian Woodruff Smith argues that ‘the nature of information as a commodity and as a byproduct of the operations of trade networks led in the seventeenth century to the evolution in Amsterdam of a central information exchange for all of Europe’ (1984: 987). His notion of an ‘information exchange’ resembles that of a ‘centre of calculation’ as it is precisely about a venue in which the production of economically relevant knowledge builds upon the accumulation of resources through circulatory movements to other places (for a different take on these terms’ relationship, see Driver 2001: chapter 2).

In seventeenth-century Amsterdam, the assembling of information proceeded through ‘the correspondence of private merchants, the correspondence of business institutions, the actual movement of businessmen to and from Amsterdam, the reports of Dutch consuls in other trading centres, the reports of Dutch diplomatic representatives in political capitals, and special channels of communication set up by particular organizations’ (Smith 1984: 990). Inside the commercial centre, information was exchanged on the basis of ‘face-to-face encounters among businessmen and interchange of short-distance correspondence within Amsterdam’ (Smith 1984: 995). Institutions, firms and merchants used standardized procedures to process the collected information with the aim of generating systematic files and trade statistics, to estimate regional demand patterns across Europe, to predict market trends and to develop marketing and business strategies. The dissemination of printed lists about commodity prices, exchange rates and goods for sale at auctions was organized by enterprising publishers in cooperation with the major merchant houses, while newspapers spread political and economic information across Europe (Smith 1984:

998–9). By linking regional and international information networks, Amsterdam was also a venue in which geographical knowledge about economic centres and peripheries was constantly being produced and reproduced through practices of trade and correspondence.

Smith (1984) points out that several innovations in the modernization of information handling occurred in seventeenth-century Amsterdam. The example of systematic long-term information analysis as 'one of the central characteristics of modern capitalism' (Smith 1984: 1004–5) underlines the close linkage between the systematization of knowledge in 'centres of calculation' and the rise of European commerce since early modern times. Building upon Smith's observation that the constitutive processes of Amsterdam's information exchange 'can be identified in the operations of practically any modern information exchange, whether it be part of a commercial center such as New York City, or a government, a corporate headquarter, or an intelligence agency' (1984: 989), the notion of 'centre of calculation' appears to be useful for understanding the production and circulation of knowledge in different realms of society. Latour himself suggests that the networks of administration, management and bureaucracy, of science, politics and economics 'have to be studied with the *same* method' (1987: 255). Accordingly, he portrays a Wall Street trading room as a 'centre of calculation':

> [A] Wall Street trading room does connect to the 'whole world' through the tiny but expeditious conduits of millions of bits of information per second, which, after having been digested by traders, are flashed back to the very same place by

> the Reuters or Bloomberg trading screens that register all of the transactions and are then wired to the 'rest of the (connected) world' to determine someone's net worth … Don't focus on capitalism, but don't stay stuck on the screen of the trading either: follow the connections, 'follow the actors themselves'.
>
> Latour 2005: 178–9

CONCLUSION

Centres of calculation are venues for the production and dissemination of different types of knowledge. Constituted by cycles of accumulation, they are linked to the world by incoming and outgoing flows of people and resources. This makes them central to the generation and circulation of geographical knowledge about other places, either as a main means or a byproduct. Dominating other places at a distance, centres of calculation can be identified and analyzed on different scales, from Banks' private home to Serfoji's royal court, from the Library of Alexandria to the University of Cambridge, from cities such as Amsterdam, London and Tanjore to continents such as Europe and North America. As centres of calculation are defined by particular practices, they are not bound to specific geographical sites or areas but may emerge in a variety of places and contexts, often being linked by hierarchical relations that are subject to change.

Tracing back centres of calculation to the beginning of the history of science suggests that the principles for becoming a 'centre of calculation' are generic to the emergence of knowledge centres and capitals. This argument is inspired by Peter Taylor's (2007) discussion of two generic models of urban spatial relations, namely central places and central flows. By emphasizing the ways in which the centrality of a place is created and reinforced by circulatory flows of people and resources, the notion of 'centre of calculation' provides a link between these two generic models of urban spatial relations. On the other hand, this chapter has shown that both scientific and economic centres of calculation have multiplied in number and scale since early modern times, thus becoming inextricably linked to the global spread of European science, capitalism and imperialism and their ceaseless cycles of accumulation. Latour (1987) himself emphasizes this historically specific link by explaining the cumulative nature of the sciences with modern expeditions and scientific practice.

Acknowledging the possibility of generic processes that may become characteristic for a specific period of human history seems to dissolve an apparent contradiction between claims of being non-modern (Latour 1993) – as these refer to generic processes – and claims of being modern (Taylor 1999) – as these concentrate on historically specific processes. Centres of calculation thus provide a suitable analytical focus for understanding the historical and contemporary geographies of scientific, economic and geographical knowledge production in different times and places, including the asymmetric power-geometries resulting from cyclic mobilization processes and selective flows of people, resources and information. Avenues for future study are provided by a need for further case studies in different historical, geographical and institutional contexts as well as by the questions about the origins of centres of calculation beyond the scientific realm, and their relation to other forms of knowledge production, including non-western, prehistoric, religious and everyday knowledges.

References

Barnes, Trevor J. (2006) ‘Geographical intelligence: American geographers and research and analysis in the Office of Strategic Services 1941–1945’, *Journal of Historical Geography*, 32(1): 150–168.

Bravo, Michael (1999) ‘Ethnographic navigation and the geographical gift’ in David N. Livingstone and Charles W.J. Withers (eds), *Geography and Enlightenment*. Chicago: University of Chicago Press, pp. 199–235.

Burke, Peter (2000) *A Social History of Knowledge: From Gutenberg to Diderot*. Cambridge: Polity Press.

Craggs, Ruth (2008) ‘Situating the imperial archive: The Royal Empire Society Library, 1868–1945’, *Journal of Historical Geography*, 34(1): 48–67.

Crang, Mike (2003) ‘Telling materials’ in Michael Pryke, Gillian Rose and Sarah Whatmore (eds), *Using Social Theory: Thinking Through Research.* London: Sage, pp. 137–144.

De Certeau, Michel (1986) *Heterologies: Discourse on the Other*. Manchester: Manchester University Press.

De Ridder-Symoens, Hilde (2004) ‘The changing face of centres of learning, 1400–1700’ in Alasdair A. MacDonald and Michael W. Twomey (eds), *Schooling and Society: The Ordering and Reordering of Knowledge in the Western Middle Ages*. Leuven: Peeters Publishers, pp. 115–138.

Dritsas, Lawrence (2005) ‘From Lake Nyassa to Philadelphia: A geography of the Zambesi Expedition, 1858–64’, *British Journal for the History of Science*, 38(1): 35–52.

Driver, Felix (2001) *Geography Militant: Cultures of Exploration and Empire*. Oxford: Blackwell.

Fulford, Tim, Lee, Debbie and Kitson, Peter J. (2004) *Literature, Science and Exploration in the Romantic Era: Bodies of Knowledge*. Cambridge: Cambridge University Press.

Grant, Edward (1996) *The Foundations of Modern Science in the Middle Ages: Their Religious, Institutional and Intellectual Contexts*. Cambridge: Cambridge University Press.

Harris, Steven J. (1998) 'Long-distance corporations, big sciences, and the geography of knowledge', *Configurations*, 6(2): 269–304.

Heffernan, Michael (2000) 'Mars and Minerva: centres of geographical calculation in an age of Total War', *Erdkunde*, 54(4): 320–333.

Johnson, Nuala (2007) 'Grand design(er)s: David Moore, natural theology and the Royal Botanic Gardens in Glasnevin, Dublin, 1838–1879', *Cultural Geographies*, 14(1): 29–55.

Jöns, Heike (2008) 'Academic travel from Cambridge University and the formation of centres of knowledge, 1885–1954', *Journal of Historical Geography*, 34(2): 338–362.

Jöns, Heike (2009) '"Brain circulation" and transnational knowledge networks: Studying long-term effects of academic mobility to Germany, 1954–2000', *Global Networks*, 9(3): 315–338. IT WAS ONLY CITED IN THE SECTION ON "FURTHER READING" THAT SEEMS NOT TO BE PART OF THIS CHAPTER BUT IS NOW ALSO CITED IN THE MAIN TEXT OF THIS CHAPTER.

Knorr Cetina, Karin D. (1981) *The Manufacture of Knowledge: An Essay on the Constructivist and Contextual Nature of Science*. Oxford: Pergamon Press.

König, Jason and Whitmarsh, Tim (2007) 'Ordering knowledge' in Jason König and Tim Whitmarsh (eds), *Ordering Knowledge in the Roman Empire*. Cambridge: Cambridge University Press, pp. 3–11.

Latour, Bruno (1987) *Science in Action: How to Follow Scientists and Engineers through Society*. Cambridge, MA: Harvard University Press.

Latour, Bruno (1993) *We Have Never Been Modern*. Cambridge, MA: Harvard University Press.

Latour, Bruno (1999) *Pandora's Hope: Essays on the Reality of Science Studies.* Cambridge, MA: Harvard University Press.

Latour, Bruno (2005) *Reassembling the Social: An Introduction to Actor–Network Theory*. Oxford: Oxford University Press.

Latour, Bruno and Woolgar, Steve (1979) *Laboratory Life: The Social Construction of Scientific Facts*. London: Sage.

Law, John (ed.) (1986) *Power, Action, and Belief: A New Sociology of Knowledge?* London: Routledge & Kegan Paul.

Livingstone, David N. (2003) *Putting Science in its Place: Geographies of Scientific Knowledge*. Chicago: The University of Chicago Press.

MacLeod, Roy (2004) 'Introduction: Alexandria in history and myth' in Roy MacLeod (ed.), *The Library of Alexandria: Centre of Learning in the Ancient World*. London: I.B. Tauris, pp. 1–15.

Miller, David (1996) 'Joseph Banks, empire, and "centers of calculation" in late Hanoverian London' in David .P. Miller and Peter H. Reill (eds), *Visions of Empire: Voyages, Botany, and Representations of Nature.* Cambridge: Cambridge University Press, pp. 21–37.

Nair, Savithri Preetha (2005) 'Native collecting and natural knowledge (1798–1832): Raja Serfoji II of Tanjore as a 'centre of calculation', *Journal of the Royal Asiatic Society*, 15(3): 279–302.

Said, Edward (1978) *Orientalism*. New York: Pantheon.

Serres, Michel (1995) 'Gnomon: The beginnings of geometry in Greece' in Michel Serres (ed.), *A History of Scientific Thought: Elements of a History of Science.* Oxford: Blackwell, pp. 73–123.

Smith, Woodruff D. (1984) 'The function of commercial centers in the modernization of European capitalism: Amsterdam as an information exchange in the seventeenth century', *The Journal of Economic History*, 44(4): 985–1005.

Stewart, Larry (1999) 'Other centres of calculation, or, where the Royal Society didn't count: Commerce, coffee-houses and natural philosophy in early modern London', *British Journal for the History of Science*, 32(2): 133–153.

Taylor, Peter J. (1999) *Modernities: A Geohistorical Interpretation*. Cambridge: Polity Press.

Taylor, Peter J. (2007) Cities, World Cities, Networks and Globalization. *GaWC Research Bulletin 238*. Available at: http://www.lboro.ac.uk/gawc/rb/rb238.html, accessed on 9 July 2009.