Dissemination of Technical Knowledge in the Middle Ages and the Early Modern Era

New Approaches and Methodological Issues

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The diffusion of technology as an object of historical study originated partly in the years after World War II as a critique of the West's self-confidence embodied in developed countries' solutions to poverty. Such solutions, usually defined in terms of resolving technical "backwardness," promulgated a simplistic and imperialistic notion of transfer that suggested quick action, linearity in time and space, and unilateral political decisions. Two prominent scholars, Paul Bairoch and Nathan Rosenberg, argued against this portrayal of technical diffusion.[1] In their view, history showed

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1. Paul Bairoch, *Révolution industrielle et sous-développement* (1963; reprint, Paris, 1974); Nathan Rosenberg, "Economic Development and the Transfer of Technology: Some Historical Perspectives," *Technology and Culture* 11 (1970): 550–75.

that transfers of technology were uncertain and complex processes. Hence the interest of historians in technical dissemination derived from a profound skepticism concerning the diffusionist notion of transfer developed in the context of expanding Western economic power.

Did this critique imply that the circulation of knowledge could not occur, that it was a kind of illusion? Although Rosenberg stressed the high rate of failure, even between countries of similar technical cultures, he did not claim that the circulation of knowledge could not occur. Rather, he pointed to methodological issues and intellectual tools for historians that would help them better understand the complexity of the process. He denied the heuristic values of leadership and backwardness, asserting that "economic growth has never been a process of mere replication." Instead, it depended entirely on the "special environments of individual countries"; diversity was therefore the cornerstone of his analysis of development paths. Rosenberg also stressed learning and the significance of mobile, skilled personnel for transmitting "noncodified knowledge." Since his seminal work first appeared, numerous case studies have lengthened this list of questions. In the spirit of Rosenberg's investigations, this article examines recent methodological innovations in order to understand the specificity of technical dissemination in the long term.

Our principal argument is that although technology transfers might have taken place across long distances, the macroeconomic scale is nevertheless inappropriate for their study. Over many centuries, skills become embedded within specific communities because of their needs and constraints, their habits and symbols, and their territories. As Peter Mathias put it, techniques "were only the visible tip of a submerged mass of relationships."[2] Therefore the transmission of techniques relied upon a whole set of resources, material and immaterial.[3] Fundamentally, "techniques" are answers to specific needs and expectations. Their applications are not universal; they belong to a world of diversity, contingency, and heterogeneity. This has several implications.

First, intermediaries and host communities were not neutral or passive; instead, they always adapted and translated the techniques they conveyed or received. The creation of hybrids—"creative imitation"—was intrinsic to dissemination, as each locality followed its own path. This challenges any notion of a universal pattern of growth.[4] Techniques that originated from

2. Peter Mathias, "Skills and the Diffusion of Innovations from Britain in the Eighteenth Century," *Transactions of the Royal Historical Society* 25 (1977): 93–113, cf. 110.

3. Carlo M. Belfanti, "Corporations et brevets: Les deux faces du progrès technique dans une économie préindustrielle (Italie du Nord, XVIe–XVIIIe siècles)," in *Les chemins de la nouveauté: Inventer, innover au regard de l'histoire*, ed. Liliane Hilaire-Pérez and Anne-Françoise Garçon (Paris, 2004), 59–76; Carlo M. Belfanti, "Guilds, Patents, and the Circulation of Technical Knowledge: Northern Italy during the Early Modern Age," *Technology and Culture* 45 (2004): 569–89.

4. Catherine Verna has analyzed multiple hybrids in ironmaking processes at the end

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different places and belonged to distinct generations frequently overlapped. Major questions here concern the identification of techniques—including the precise skills, materials, and processes involved—in reference to the diverse communities using them. Is it possible to follow one technique across multiple territories? What resources are available to the historian to identify techniques that were so rarely recorded and codified?[5] What part did products play as conduits for technical knowledge? Are their appellations related to geographical origins or the names of their makers, or do identifying marks on the products themselves provide clues? The same sorts of questions can be applied to the routes. If failures were common, diversions were also frequent: madder dyeing, for example, which originated in India, had to be reimported several times through different routes between the sixteenth and eighteenth centuries before it was actually learned and adopted in the West. Mythical origin narratives often conceal the absence of linearity by attributing a certain technique to one place or one people—or a certain technology transfer to one group or even one individual. Deconstructing these mythologies presents challenges for historians.

Second, geography mattered. An important issue when studying technical dissemination is the choice of scale. The balance between macro- and microhistories can be critical. For instance, on the one hand, early modern historians have increasingly recognized that the nation-state was not the proper scale by which to study the Industrial Revolution. They suggest instead that there was a pan-European pool of skills and resources that fostered different technological paths, as Christine MacLeod has recently argued.[6] On the other hand, although transfers have occurred between con-

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of the Middle Ages: "Réduction du fer et innovation: À propos de quelques débats en histoire sociale des techniques," *Médiévales* 39 (2000): 79–95. One other famous example, though outside our period, is the introduction of coke smelting on the European Continent during the first half of the nineteenth century. In France, it resulted in a hybrid of charcoal blast-furnaces and puddling with coke in the forges à l'anglaise; see Jean-François Belhoste, *Fer, fonte, acier: Rhône-Alpes, XVe–début XXe siècle* (Paris, 1992); Serge Benoît and Bernard Rignault, "Le patrimoine sidérurgique du Châtillonnais," *Mémoires de la Commission des Antiquités du Département de la Côte-d'Or* 34 (1984–86): 387–448; Rainer Fremdling, "Continental Responses to British Innovations in the Iron Industry during the Eighteenth and Nineteenth Centuries," in *Exceptionalism and Industrialism: Britain and Its European Rivals, 1688–1815*, ed. Leandro Prados de la Escosura (Cambridge, 2004), 145–69; Denis Woronoff, *L'industrie sidérurgique en France pendant la Révolution et l'Empire* (Paris, 1984).

5. Catherine Verna, "The Notary as a Witness: Techniques and the Dissemination of Tacit Knowledge (XIVth–XVth Centuries)," in *Craft Treatises and Handbooks: The Dissemination of Technical Knowledge in the Middle Ages, Acts of the Córdoba Conference, 6–8 October 2005*, ed. Ricardo Córdoba de la Llave (forthcoming); Luisa Dolza, "How Did They Know? The Art of Dyeing in Late Eighteenth-Century Piedmont," in *Natural Dyestuffs and Industry in Europe, 1750–1880*, ed. Robert Fox and Agusti Nieto-Galan (Canton, Mass., 1999), 129–60.

6. Christine MacLeod, "The European Origins of British Technological Predominance," in *Exceptionalism and Industrialism*, 111–26.

tinents, it would be misleading to regard them as a process of globalization or uniformity of techniques. Not only did host communities reshape these techniques—as when England drew upon a "reservoir" of European skills (and Asian products) to construct a unique technological model based on its specific needs and resources—but also, the rhythms and territories of diffusion were not homogeneous, even within one country and, occasionally, within a single town. There were accelerations and decelerations, even breaks in continuity. Also, in some places the circulation of knowledge was more intensive than elsewhere. Historians of the Middle Ages, often facing the problematic stereotyping of objects such as the windmill, have insisted that technical dissemination was not an even, regular process. Philippe Braunstein clearly refutes "a general universal history," stating instead that the history of technology transfers

> was not a planetary vision of the diffusion of knowledge from one cultural area to another one, rather it was the critical depiction of the humble case of apprenticeship in a workshop, in a building site, in a shop, but also in the fields and in the gardens.[7]

Third, technology transfers relied on multiple mediations. Aside from treatises and all forms and channels of codified knowledge, artifacts and people played a crucial part and interfered with descriptions and prescriptions. In the final section, we therefore focus on human mobility. Considering the importance of tacit knowledge, practitioners were an essential resource for technical dissemination (although never a sufficient one). This issue has prompted numerous studies that trace individual itineraries as well as networks and the migration of groups. Nonetheless, many new inquiries are emerging, some taking the microhistory approach. Although some workers, entrepreneurs, and engineers have been depicted as leaders or chief actors, recent studies abandon biographical and heroic history to stress the part played by more modest and ordinary people (who are more difficult to identify in the sources). Other emerging themes concern distinctive groups, such as religious or political minorities. This approach is critical, because the systematic attribution of one technique to one set of people seems to be increasingly limiting. Careful, microhistorical analysis of networks, integration, and segregation can, however, help to refine and revise the narratives of inherited historiography.

Finally, it must be stressed that the techniques of production and their transmission were not only of interest to producers, but also to merchants, shopkeepers, artists, consumers, local authorities, princes, political writers, and others. Thus the actors involved in technical dissemination should not be limited to the technicians. For instance, merchants not only provided goods, materials, and information, but mercantile culture itself was crucial

7. Philippe Braunstein, "Maîtrise et transmission des connaissances techniques au Moyen Âge," *History of Technology* 21 (1999): 155–65.

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in gathering facts, making inquiries, and comparing qualities, devices, and uses. It developed an analogical method of thinking that encouraged substitutions, adaptations, and translations of techniques.[8] This points to a cross-fertilization between economic history and the history of technology.

In this article, we provide a comprehensive review of the scholarship in this field that discusses both its cumulative findings and the evolution of its methodological assumptions. Consequently, we do not refer to primary sources. In engaging the historiography of technical dissemination, our focus centers more on European than American studies, because important reassessments of the subject have recently originated in European research. We hope this article fosters a better understanding of the European experience.

Reconstituting Worlds of Openness

"OPEN TECHNIQUE"

New approaches to the study of technical change that focus on networks and exchanges call into question the assumption that, in contrast with the openness associated with scientific knowledge, technical knowledge was characterized by privatization and secrecy (both artisanal and industrial).[9] However, "open technique"—the availability of techniques to an entire community at a given time—did exist as well,[10] and it was at odds with the notion of guarded trade secrets. Indeed, if secrecy was a habit among artisans, we must ask what the uses of secrecy were, what keeping something secret actually meant, and whether it allowed for some kinds of transmission.[11]

8. Liliane Hilaire-Pérez, "Cultures techniques et pratiques de l'échange, entre Lyon et le Levant: Inventions et réseaux au XVIIIe siècle," *Revue d'Histoire Moderne et Contemporaine* 49 (2002): 89–114.

9. On the concept of open science, see Paul A. David, "Communication Norms and the Collective Cognitive Performance of Invisible Colleges," in *Creation and Transfer of Knowledge: Institutions and Incentives*, ed. Giorgio Barba Navaretti et al. (New York, 1998), 115–63.

10. Dominique Foray and Liliane Hilaire-Pérez, "The Economics of Open Technology: Collective Organization and Individual Claims in the "Fabrique Lyonnaise" during the Old Regime," in *Frontiers in the Economics of Innovation: Essays in Honor of Paul David*, ed. Cristiano Antonelliet et al. (Cheltenham, U.K., 2005), 239–54; Anne-Françoise Garçon and Liliane Hilaire-Pérez, "Open Technique between Community and Individuality in Eighteenth-Century France," in *Entrepreneurs and Institutions in Europe and Asia, 1500–2000*, ed. Ferry de Goey and Jan Willem Veluwenkamp (Rotterdam, 2002), 237–56.

11. William Eamon, *Science and the Secrets of Nature: Books of Secrets in Medieval and Early Modern Culture* (Princeton, N.J., 1994). For glassmaking, which is so often associated with secrecy, see Michel Philippe, *Naissance de la verrerie moderne, XIIe–XVIe siècles* (Turnhout, Belg., 1998).

Secrecy seldom meant a complete refusal to disseminate. Rather, it allowed actors who considered their skills to be a secret to choose the modalities of diffusion. It was, for example, invoked by political authorities when establishing regulations over the migration of workers, as in medieval Italian towns (as we shall see below). Furthermore, the meaning of secrecy had evolved since the Middle Ages, from the collective ownership of skills to individual property in techniques, especially as inventions became part of commercial strategies and government policies. This shift had important consequences for secrecy and openness within guilds and communities. The boundary between learning new techniques within a trade and imitating devices from rival masters was slight. In the Lyon silk industry of the eighteenth century, the authorities were uncertain whether they should prosecute imitators as thieves or encourage them as diffusers of new techniques that belonged to the community.[12] Even when the private ownership of devices became more common, there remained diverse opinions about what to exhibit openly and what to hide. Proper social protocol required enlightened industrialists to allow visitors to tour their commercial sites; entrepreneurs such as Matthew Boulton therefore developed careful strategies for the concealment of certain techniques and the display of others as a means of controlling information.

Technical knowledge regularly circulated. It was shared through multiple networks (both private and public), and it involved a great diversity of strategies and varying degrees of openness within families, partnerships, and guilds. Diverse media were used: verbal or nonverbal (for example, products and artifacts conveying prescriptive knowledge such as prototypes, patterns, models, and molds), oral (speech contact), and written (including all sorts of drawings, from plates to sketches). In the eighteenth century, missions of inquiry and exploration, which were typical of the growing taste for useful travels described by Daniel Roche, fostered a technical literature based on the gathering and comparison of techniques, tools, and writings, which were the basis of an upsurge in ethnography and the anthropology of techniques one century later.[13] From the Middle Ages up to the present, questions of codification and implicit knowledge were crucial. The growing part played by written descriptions and prescriptions did not abolish the need for experts—the qualified technicians who traveled

12. Liliane Hilaire-Pérez, "Inventing in a World of Guilds: The Case of Silk Fabrics in Lyon in the XVIIIth century," in *Guilds and Innovation in Europe, 1500–1800*, ed. Stephan R. Epstein and Marten Praak (forthcoming).

13. Daniel Roche, *Humeurs vagabondes: De la circulation des hommes et de l'utilité des voyages* (Paris, 2003). See also the recent English study on engineers' travels by Patrick K. O'Brien and Giorgio Riello, "Reconstructing the Industrial Revolution: Analyses, Perceptions, and Conceptions of Britain's Precocious Transition to Europe's First Industrial Society," *LSE Working Papers in Economic History* 1 (2004). We thank the authors for sending us their paper.

with new machines and equipment to set up, adjust, and repair them and to transmit specialized skills.[14]

THE IDENTIFICATION OF TRANSMISSIONS AND HYBRIDS

Although cases of transmission were a reality and could be intensive, it is often difficult for the historian to trace them accurately. Two major obstacles confront the historian of technology in this regard: the troublesome task of identifying precisely which techniques were involved, and the difficult challenge of reconstructing the paths of transmission.

Concerning technology transfers between the East and the West during the Middle Ages, two historians have shown that recent studies may still be misleading, owing to the strength of the diffusionist model since the 1970s. Considering this problem, Philippe Braunstein and Dietrich Lorhmann have tried to reassess the question by focusing on one particular artifact—for instance, the windmill. They have revisited the historiographic narrative according to which the windmill was diffused from East to West (from Afghanistan and Persia to Europe) in the twelfth century, because of the Crusades.[15] Although this inquiry is not new, it is recurrent. Bertrand Gille, in *Histoire générale des techniques* (1962), was already dubious, not about the existence of windmills in Persia from the tenth century on, but about their diffusion from East to West during the Crusades. Gille remarked that "it is evident that we must reject, not only some charters whose falsehood has widely been shown but the very legend which bestows on the crusaders the introduction of the windmill in Europe."[16] These doubts have necessitated critical and scrupulous research.[17]

In ironmaking, belief in the initial spread of the indirect process called Walloon (a process that was the basis of military and economic might in early modern Europe) is, at least in the region from Liège and Luxembourg

14. See the pioneering study by Mathias, "Skills and the Diffusion of Innovations from Britain in the Eighteenth Century" (n. 2 above); more recently, the question was revisited by Kristine Bruland in *British Technology and European Industrialization: The Norwegian Textile Industry in the Mid-Nineteenth Century* (Cambridge, 1989); and by Joel Mokyr in *The Gifts of Athena: Historical Origins of the Knowledge Economy* (Princeton, N.J., 2002).

15. Braunstein, "Maîtrise et transmission des connaissances techniques au Moyen Âge" (n. 7 above); Dietrich Lorhmann, "Echanges techniques entre Orient et Occident au temps des Croisades," in *Occident et Proche-Orient: Contacts scientifiques au temps des croisades*, ed. I. Draelants, A. Tihon, and B. Van Den Abeele (Turnhout, Belg., 2000), 117–44.

16. Bertrand Gille, "Le Moyen Âge en Occident (Ve siècle–1350)," in *Histoire générale des techniques: Des origines au XVe siècle*, ed. Maurice Daumas (Paris, 1962), 471.

17. Parviz Mohebbi, *Techniques et ressources en Iran du 7e au 19e siècle* (Téhéran, 1996); Parviz Mohebbi, "Intégration et refus des nouveautés techniques européennes en Iran (les lunettes, l'horloge mécanique et les armes à feu, 14e–17e siècles)," in *Les chemins de la nouveauté* (n. 3 above), 283–90.

to Champagne and Normandy, founded on a small and fragile clue: the Walloon consonances of the masters' names in new forges.[18] More often than they would like, historians are forced to recognize that while some technical diffusion undoubtedly occurred, its routes remain obscure or unknown. Another good example is the case of medieval glasses. According to Braunstein:

> [The] eyeglasses that are listed in one Italian account of 1316 also appear in the bishop of Exeter's probate of personal goods in 1326, and have again been found in excavating the stalls of the choir of Wienhausen near Celle and then in a dump of the Augustine convent of Fribourg in Brisgau, also dated from the fourteenth century.[19]

How is it possible to explain this spatial scattering of eyeglasses? In fact, we can do no more than take notice of it. That is what Vincent Serneels proposes for the ironmaking techniques of the early Middle Ages. Nevertheless, the discovery of a distinctive Merovingian technique in eastern Gaul has prompted him to ponder its relationship with techniques in other territories and the breakthrough it represented when compared to techniques known in late antiquity.[20] Not surprisingly, because questions of identification have become central, archaeologists are playing a major role in the revision of the history of technical dissemination. For the early modern era, it must be stressed that art historians and curators, particularly in England, have led the way in reconsidering the origins of artifacts by careful analysis of names and markings, which can so often be misleading.[21]

As we are dealing here with the identification of the routes through which specific techniques spread, it is useful to remind ourselves that these routes are not linear, but rather manifold and multicentered. Indeed, their nonlinearity derives in part from the numerous resources necessary for the transmission of a technique from one milieu to another.

For example, Gracia Dorel-Ferré has argued that the adoption of calico

18. Philippe Braunstein, "Savoir et savoir-faire: Les transferts techniques," in *L'innovation technique au Moyen Âge: Acts of the VIth International Congress of Medieval Archaeology*, ed. Patrice Beck (Paris, 1998), 303–9, referring to works by Jean-François Belhoste.

19. Ibid.

20. Vincent Serneels, "Circulations techniques et changements économiques en Suisse entre l'époque romaine et le haut Moyen Âge," in *Les circulations techniques: En amont de l'innovation—hommes, objets et idées en mouvement*, ed. Michel Cotte (Belfort/Besançon, France, 2004), 37–53.

21. Victoria Beauchamp and Joan Unwin, *The Historical Archaeology of the Sheffield Cutlery and Tableware Industry, 1750–1900* (Stroud, U.K., 2002); Helen Clifford, "Concepts of Invention, Identity and Imitation in the London and Provincial Metal-Working Trades, 1750–1800," *Journal of Design History* 12 (1999): 241–55; Roger Smith, "The Swiss Connection: International Networks in Some Eighteenth-Century Luxury Trades," *Journal of Design History* 17 (2004): 123–39; John S. Forbes, *Hallmark: A History of the London Assay Office* (London, 1998).

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printing in Catalonia during the nineteenth century relied on mixed imports of equipment: plain cylinders from Manchester that were engraved in Mulhouse (which also provided patterns, samples, and machines for engraving) and chemical products from Paris.[22] The nexus of these imports was Marseilles. It was a crossroads, a site for the condensation of techniques through which machines from the north, madder dye from Comtat-Venaissin, the know-how of operating braziers necessary for the production of copper sheets for vats, and other information were imported. In a similar way, products and apparatus, although simple, might require multiple technical resources. Artifacts are the material representations of sociotechnical networks; unless working processes were centralized, their realization relied on a whole range of exchanges, as has been demonstrated for Argand's lamp in the eighteenth century.[23] The development of the prototypes of the Swiss entrepreneur Argand in England implied the coordination of a cluster of activities: some artisans improved the glass for the lamp's chimney, others the varnish for the metal sheet, others still handled the soldering or fabricated the small pieces of the mechanism. A web of relationships between Paris, Birmingham, Sheffield, and London was therefore necessary to contrive Argand's lamp, a web supported through the movement of men and equipment and the close correspondence among entrepreneurs.

Hence, the acquisition of technical knowledge implied plural and multicentered circulations, with spatial strategies contrived according to the operative chains and the diverse processes necessary for a particular manufacture, object, or process. Each technique was embedded in a material and immaterial environment: a set of resources (tools, equipment, materials, and so on) and a web of skills, abilities, and representations. Transferring this environment wholesale might prove to be impossible. Still, at the very least, we should investigate the complexity of the links among the centers that exported techniques and those that received them, as well as the heavy costs of these exchanges and other obstacles. Indeed, Carlo Belfanti, in his study of the technical relationships among northern Italian cities during the early modern period, has underscored the importance of proximity and synergies of resources, both human and material.[24] The dissemination of skills in the silk industry required not only those who had experience work-

22. Gracia Dorel-Ferré, "Le rôle de Marseille dans l'industrialisation catalane: Le cas de la España Industrial," in *Els països catalans i el Mediterrani: Mites i realitats*, Second Conference of the French Catalanists (Montserrat, 2001), 89–101.

23. Besides the thorough study by John J. Wolfe, *Brandy, Balloons, and Lamps: Ami Argand, 1750–1803* (Carbondale, Ill., 1999), see the essay devoted to Argand in *Les circulations techniques*.

24. Belfanti, "Corporations et brevets" (n. 3 above); Belfanti, "Guilds, Patents, and the Circulation of Technical Knowledge" (n. 3 above); Carlo M. Belfanti and Fabio Giusberti, eds., "Institutions and Technical Change in Early Modern Europe," special issue, *History and Technology* 16 (2000).

ing with silk itself, but also the availability of artisans who worked with wood and metal and who had experience in the construction of complex looms for weavers. Also necessary was access to raw materials, to unfinished products (half-worked beads from Venice were exported to centers where expatriated glassworkers had settled), and to the control of sales and commercial networks. Host cities that were already involved in the trade and were of equal technical maturity were more likely to welcome these foreign artisans, while the prior settlement of compatriots was an important advantage in easing their integration and in benefiting from their skills, equipment, materials, and information.[25] Expatriates often maintained continuous links with their homelands as well.

The absence of any of these resources could lead to failure, however, as Parviz Mohebbi has shown with regard to the problematic introduction of mechanical clocks in Persia at the end of the fifteenth century. One such clock was brought into the country at the request of the monarch. It was then copied by a Persian engineer who had authored a treatise on clockworks. Still, the desire of the monarch and abilities of the engineer were not sufficient: the mechanical clock diffused no further than the royal court, both because there was no outside demand—the clepsydra served the traditional needs of Persian society well—and because the country as a whole lacked the artisanal skills needed to reproduce a mechanical clock.[26]

Still, when techniques circulated, the multiplicity of devices and contrivances that concentrated in one site could foster technical change. The study of technical dissemination is in fact closely linked to the history of invention. Recent reassessments of industrialization over the long term insist on the role of exchanges in fostering invention and innovation.[27] The establishment of networks among a wide range of working people, artisans, and entrepreneurs and the acceleration of diffusion made Europe a pool of materials and skills in which producers could discover devices, equipment, and processes.[28] Historians stress the relationship between the capacity to

25. On this question, see the recent work of Lien B. Luu, especially her history of the silk industry in Spitalfields. Huguenots were attracted to Bishopgate by the settlement there of former French-speaking weavers from the Low Countries: "French-Speaking Refugees and the Foundation of the London Silk Industry in the Sixteenth Century," *Proceedings of Huguenot Society* 26 (1997): 564–76. Similar assessments for Paris are found in Alain Thillay, *Le faubourg Saint-Antoine et ses "faux ouvriers": La liberté du travail à Paris aux XVIIe et XVIIIe siècles* (Seyssel, Fr., 2002).

26. Mohebbi, *Techniques et ressources en Iran du 7e au 19e siècle* (n. 17 above); Mohebbi, "Intégration et refus des nouveautés techniques européennes en Iran" (n. 17 above).

27. Natacha Coquery, Liliane Hilaire-Pérez, Line Sallmann, and Catherine Verna, eds., *Artisans, industrie: Nouvelles révolutions du Moyen Âge à nos jours*, Acts of the International Conference of the CNAM of June 2001, *Cahiers d'Histoire et de Philosophie des Sciences* 52 (2004).

28. MacLeod, "The European Origins of British Technological Predominance" (n. 6 above).

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invent and the practices of exchanging, appropriating, and using techniques. Invention was based on combinations, borrowings, substitutions, comparisons, and synthesis, all promoted by collective efforts.[29]

Consequently, intermediaries were crucial not only because they transmitted techniques, but also because they interpreted and transformed these techniques according to local needs and constraints. No dissemination could occur without translation, and this process, grounded in human communities, territories, and environments, fostered invention and innovation. For example, the patent claims of inventors were long equated with the claims of those who imported new techniques. This was because many new devices resulted from the adaptation of foreign techniques. During the Middle Ages, for instance, the horizontal loom was fundamental to the economic growth of Europe. Walter Endrei and, later, Dominique Cardon have revisited the case of this loom with the help of new documents and archaeological data; uncertainties remain, as is often the case in medieval history, but they have made some important clarifications. The horizontal loom stemmed from a wooden-framed Oriental silk loom that was used in the western Mediterranean (Sicily and Al-Andalus, for example) and was quickly adapted in Europe to the weaving of draperies as early as the tenth and eleventh centuries.[30] In the complex field of medieval dyes, technical circulations also fostered adaptations of this sort.[31]

These borrowings lead us to the question of identification. Taxonomies often reveal geographical origins (Turkey red, Damascus glassware, Bolognese mills, Genovese forge, German steel, "marroquin," "japanning," chinaware, and so on), but how are we to understand them?[32] The answer is critical. On the one hand, if names allow us to trace the direction of circulations, they also conceal the hybridization that took place during the process of dissemination. Behind the name "Turkey red" were multiple transformations of madder dyeing by Armenians and Greeks in the Ottoman Empire. In the same way, Cordoban leather embodied alum tech-

29. Jean-Louis Le Moigne and Hélène Vérin, "Sur le processus d'autonomisation des sciences du génie," *De la technique à la technologie*, *Cahiers STS* 2 (1984): 42–55.

30. Dominique Cardon, *La draperie au Moyen Âge: Essor d'une grande industrie européenne* (Paris, 1999), 393.

31. Dominique Cardon, *Le monde des teintures naturelles* (Paris, 2003).

32. Katsumi Fukasawa, *Toileries et commerce du Levant d'Alep à Marseille* (Marseille, 1987); Angélique Kinini, "La fabrication du rouge turc dans la Thessalie de la fin du XVIIIe siècle: Les manufactures de la ville d'Ampélakia," in *Natural Dyestuffs and Industry in Europe, 1750–1880* (n. 5 above), 71–100. Danièle Foy, *Le verre médiéval et son artisanat en France méditerranéenne* (Paris, 2001), 377; Jean Cantelaube and Catherine Verna, "La forge à la génoise: quel transfert d'innovation?" in *Il ferro nelle Alpi, Giacimentiu, miniere e metallurgia dall'antichita al XVI secolo, Atti del convegno*, ed. Contanza Cucini Tizzoni and Marco Tizzoni (Bienno, 2000), 152–63; Kenneth C. Barraclough, *Steelmaking before Bessemer: The Importance of the North East of England* (Cleveland, 1976).

niques that came from the Middle East, as Eva Halasz has shown.[33] As these techniques spread, multiple variations were introduced. Consequently, there emerged a complex geography of adaptations and technical territories that is difficult to chart with precision.

On the other hand, we should question these taxonomies, which occasionally conceal processes considerably more complex than mere geographical notes of origin. Let us take the example of the Catalan forge. Jean Cantelaube has shown that there was a chronological hiatus of an entire century between the emergence of this forge and its designation as "Catalan." In this case, the appellation was ascribed by geographical and cultural outsiders: not by the ironmasters, merchants, or smiths themselves, but by academicians and engineers. The name remained unquestioned until recently because of its general acceptance; however, this forge did not come from Catalonia but from the county of Foix, in the central Pyrenees.[34] Finally, behind these taxonomies also stood commercial strategies that played an active part in the process of technical dissemination over the long term.

MARKETS AND INSTITUTIONS

A major feature of "open technique" was its relationship with commercialization and knowledge-based economies.[35] Studying the diffusion of products is one way to explore the impact of markets. The study of products as conduits for technical knowledge is a pioneering approach in history, standing at the crossroads of economic history and the history of technology. Products embodied techniques; therefore, the market tested and validated techniques.[36] On the one hand, the price of products (and tariffs) influenced the adoption of foreign techniques, and on the other, strategies of substitution, copying, and forgery could allow skills and knowledge to circulate. For instance, the imitation of fabrics was a common practice during the Middle Ages. Copied fabric was labeled "in the manner of" a region or town, meaning that its maker faithfully duplicated the technical processes and characteristics of the original product.[37]

33. Eva Halasz, *Le cuir à fleur de peau* (Paris, 2001); Ricardo Córdoba de la Llave, ed., *Mil Años de Trabajo del Cuero* (Córdoba, 2003).

34. Jean Cantelaube, *La forge à la Catalane dans les Pyrénées ariégeoises: Une industrie à la montagne, XVIIe et XIXe siècles* (Toulouse, 2005).

35. Jean-François Belhoste, "Mutations techniques et filières marchandes dans la sidérurgie alpine entre le XIIIe et le XVIe siècle," in *La sidérurgie alpine en Italie, XIIe–XVIIe siècle*, ed. Philippe Braunstein (Rome, 2001), 516–92.

36. Catherine Verna, "De la forge aux marchés des fers: Les espaces emboîtés de la réduction directe," in *L'obtencio del ferro pel procediment directe entre els segles IV i XIX: Acts of the 6th Conference of Archeology of Andorre, 2000* (Andorre, 2001), 63–78.

37. Cardon, *La draperie au Moyen Âge* (n. 30 above); for the early modern era, see Corine Maitte, "Fabriquer des bérets à la levantine à Prato et à Orléans au XVIIIe siècle,"

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Similarly, Danièle Foy cites the case of a glassworker from Marseilles who contracted with a Venetian merchant to produce a thousand copies of two samples of fashionable Venetian ewers—at a fraction of the samples' cost.[38] In other cases, the product that was circulating was not necessarily imitated, but instead bore the trademark of the original even though its quality was inferior. Fraudulent copies were a means by which to take advantage of the reputation of a product without the effort of learning the techniques necessary to produce it properly. This was a well-documented practice. Examples include medieval iron- and small metalware in eighteenth-century England, when Birmingham and Sheffield still experienced competition from London.

The role of markets was not limited to products: markets also influenced the circulation of men (traveling merchants, industrialists, and technicians under contract) and information. Commercial orders for equipment or consumer goods contained technical prescriptions and descriptions in their specifications for products and materials.[39] There were also specific markets for knowledge, considered to be a commodity. During the early modern era, the growth of knowledge economies was supported by the prevalence of courses, handbooks, how-to leaflets, the diffusion of notices to assignees and subscribers, and public shows.[40] In this process, patents were crucial. Historians of the nineteenth and twentieth centuries often emphasize the relationship between patents and technical transfers, but to some extent, exclusive rights and privileges have been relevant since the Middle Ages.

As Pamela Long has shown, exclusive privileges relied on a process of codification of technical knowledge in response to a movement initiated by medieval guilds.[41] Although it is difficult to establish whether privileges and patents as tools for building up markets had any impact on the diffusion of new techniques, they were attractive for foreign workers seeking

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in "Echanges et cultures textiles dans l'Europe pré-industrielle," ed. Jacques Bottin and Nicole Pellegrin, special issue, *Revue du Nord* 12 (1996): 193–213.

38. Foy (n. 32 above), 378.

39. Paul Benoit and Philippe Braunstein, "Les comptes miniers d'Hurtières en Savoie (1338–1350)," in *Mines, carrières et métallurgie dans la France médiévale* (Paris, 1983), 183–206; Michel Cotte, "From Trade to Industry: The Independent Informative Networks of European Firms (Early Nineteenth Century)," *ICON* 5 (1999): 167–87; Michel Cotte, *De l'espionnage industriel à la veille technologique* (Belfort/Besançon, Fr., 2005), 93–95.

40. Liliane Hilaire-Pérez and Marie Thébaud-Sorger, "Les techniques dans l'espace public: Publicités des inventions et littérature d'usage en France et en Angleterre au XVIIIe siècle," *Revue de Synthèse* 2 (2006); Larry Stewart, *The Rise of Public Science: Rhetoric, Technology, and Natural Philosophy in Newtonian Britain, 1660–1750* (Cambridge, 1992).

41. Pamela O. Long, "Invention, Authorship, 'Intellectual Property,' and the Origin of Patents: Notes toward a Conceptual History," *Technology and Culture* 32 (1991): 846–84.

patronage.[42] Belfanti has shown that there was a complementary link between exclusive privileges and the policy of diffusion as developed by Italian guilds: the former fostered a renewal of local techniques, and the latter integrated new techniques into the common set of knowledge.[43] Moreover, such privileges could be used on an international scale.[44] Since the fifteenth and sixteenth centuries, the system of exclusivity had spread from Venice and Italian towns to western Europe, thanks to the migrations of Italian engineers and artisans looking for patronage and markets in courts, towns, and nation-states. Exclusive privileges and patents were a well-known resource among a handful of highly skilled artisans, engineers, and entrepreneurs.

The correspondence between inventing techniques and importing them furthered the use of privileges in supporting transfers of technology, at least during the fifteenth and sixteenth centuries; for example, foreigners obtaining patents in England were obliged to teach their know-how.[45] Over the long term, some powerful international networks and partnerships used this institutional resource strategically to profit from their inventions. Ownership of exclusive rights in several countries, for example, afforded them the opportunity to use the legal differences between those countries to their competitive advantage.[46] Several pioneering techniques were introduced in eighteenth-century France through the aid of exclusive privileges (three-color copperplate engraving, the flying shuttle, Arkwright's machinery, and Watt's first engine, for example).

But exclusive privileges, patents, and *brevets* could also slow down the diffusion of knowledge, as historians and economists have clearly shown. Such rights were difficult to gain, either because they were expensive or because they were issued only after close examinations by public authorities. They were granted to a fortunate few who could then erect barriers to restrict dissemination. Therefore the markets for inventions soon required other kinds of regulations, both to provide institutional protection to inventors who could not afford exclusivity on their own and, moreover, to

42. Christine MacLeod, "The Paradoxes of Patenting: Invention and Its Diffusion in 18th- and 19th-Century Britain, France, and North America," *Technology and Culture* 32 (1991): 885–910.

43. Belfanti, "Corporations et brevets"; Belfanti, "Guilds, Patents, and the Circulation of Technical Knowledge."

44. Pamela O. Long, *Openness, Secrecy, Authorship: Technical Arts and the Culture of Knowledge from Antiquity to the Renaissance* (Baltimore, 2001).

45. Lien B. Luu, *Immigrants and the Industries of London, 1500–1700* (Aldershot, U.K., 2005), chap. 3.

46. Luisa Dolza and Liliane Hilaire-Pérez, "Inventions and Privileges in the XVIIIth Century: Norms and Practices—a Comparison between France and Piedmont," *History of Technology* 24 (2002): 21–44; Liliane Hilaire-Pérez, "Transferts technologiques, droit et territoire: Le cas franco-anglais au XVIIIe siècle," *Revue d'Histoire Moderne et Contemporaine* 44 (1997): 547–79.

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create a balance between promoting invention and maintaining the social benefit of the collective appropriation of new techniques. Since the sixteenth century, exclusivity coexisted with incentive systems (for example, premiums and grants) that facilitated public appropriation of inventions and promoted patterns of "collective invention."

In the early modern era, public funding became even more attractive than exclusivity for foreigners. Mercantilist states as well as enlightened monarchies relied heavily on rewards and fiscal exemptions to promote the dissemination of knowledge. One exception to this was England, where no such policies were devised to promote transfers or innovation, as Christine MacLeod shows. By contrast, in France, public subsidies played a major role in the management of technical dissemination. Dense networks developed between central state administrators and local authorities, reflecting an economic policy that was based on the rationalization of the economy and the ideal of a homogeneous territory. For instance, in 1750, the Lyonnais dyer François Gonin was sent to Rouen for trials of his new method of dyeing cotton, which were supervised by the local inspector of manufactures, the chamber of commerce, guilds, and entrepreneurs.[47] Other experiments also took place in Limoges under the aegis of Jacques Turgot (who would become minister of the treasury prior to the Revolution). In Rouen, Gonin was compelled to teach apprentices, who then became masters after their skills had been examined by Hellot, an academician. Traditional institutions such as guilds promoted the dissemination of innovation, an arrangement that seemed more successful than exclusive privileges.

There was another limitation to the impact of exclusive rights: they relied on private ownership and initiative and therefore on the management of techniques in enterprises. This meant that they were dependent on the accelerated and risky rhythm of business. Such an arrangement could not fit well with techniques long-established in communities, such as the draw looms in Lyon's silk industry. The introduction of the Jacquard loom in London in the nineteenth century was a failure, despite the protection of patents, because the mastering of this loom (apprenticeships, repairing, and so on) was rooted in a milieu of highly skilled and polyvalent artisans who shared a collective knowledge accumulated over many generations.[48] The technique was embedded in a political municipal organization; it belonged to a territory. Dissemination of technologies was never simple: it depended heavily on temporal and spatial variables.

47. Liliane Hilaire-Pérez, *L'invention technique au siècle des Lumières* (Paris, 2000), 63, 70, and 137.

48. Alain Cottereau, "The Fate of Collective Manufactures in the Industrial World: The Silk Industries of Lyons and London, 1780–1850," in *World of Possibilities: Flexibility and Mass Production in Western Industrialization*, ed. Charles F. Sabel and Jonathan Zeitlin (Cambridge, 1997), 75–152.

Territories and Temporalities

THE PACE OF TECHNICAL DISSEMINATION

Technical dissemination varies in intensities of time and space. Some technologies spread in short and halting bursts; others spread more slowly and continuously over several generations. Sometimes, and very often in remote eras, it is impossible to gauge how dissemination worked and evaluate it even approximately. This is certainly the case for agricultural techniques in all periods. Historians can detect vague hints of dissemination's influence in particular areas but cannot weave them into a coherent whole.[49]

In some places, the pace of dissemination accelerated, while elsewhere, within the same country or even the same town, the process was slower.[50] Concentrated sites are much better documented in archives than more dispersed ones. French administrators and entrepreneurs mobilized themselves in pursuit of specific devices or techniques, such as in the leading state-promoted manufactures of the eighteenth century. A well-known example of this was the textile mechanization that took place under the aegis of John Holker in his Sens and Rouen factories, which has been studied by Serge Chassagne.[51] The chronology of technology transfer was in accord with the rhythm of business, the individual itineraries of innovative entrepreneurs, and the timing of enlightened administrative reform between the 1750s and 1780s. Among the privileged manufacturers that were close to the networks of power (the monarchy, its financiers, and scientific

49. Georges Comet, "Orient–Occident: Moulin manuel à bielle-manivelle," in *Techniques et économies antiques et médiévales: Le temps de l'innovation*, ed. Dimitri Meeks and Dominique Garcia, International Conference of Aix-en-Provence, May 1996 (Paris, 2001), 79–81; Georges Comet, "La transmission des connaissances techniques," *Cahiers d'Histoire des Techniques* 3 (1995); Georges Comet, *Le paysan et son outil: Essai d'histoire technique des céréales (France, VIIIe–XVe siècle)* (Rome, 1992); and François Sigaut and Marie-Claire Amouretti, eds., *Traditions agronomiques européens: Elaboration at transmission depuis l'Antiquité* (Paris, 1998).

50. Concentration might also depend on segregation processes, for instance in the case of minority enclaves in cities; the diffusion outside them could prove difficult, as it was for London immigrants in the sixteenth century. See Lien B. Luu, "Assimilation or Segregation: Communities of Alien Craftsmen in London in the Sixteenth Century," in "The Strangers' Progress: Integration and Disintegration of the Huguenot and Walloon Refugee Community, 1567–1889—Essays in Memory of Irene Scouloudi," ed. G. Gibbs and R. Vigne, special issue, *Proceedings of the Huguenot Society* 26 (1995): 160–72; Lien B. Luu, "Ségrégation spatiale, enclaves d'activités professionnelles et diffusion des techniques: les artisans étrangers et l'économie londonienne (1550–1600)," in *Les étrangers dans la ville: Minorités et espace urbain du bas Moyen Âge à l'époque moderne*, ed. Jacques Bottin and Donatella Calabi (Paris, 1999), 453–64. Similar features existed in Paris, although the integration of strangers' communities seems to have been quick and easy in the eighteenth century, at least in one quarter; see Thillay (n. 25 above).

51. Serge Chassagne, *Le coton et ses patrons: France, 1760–1840* (Paris, 1991).

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experts), there was intense diffusion of materials, specialized technicians, and workers trained in the new techniques, such as the female master-spinners taught by Holker.

These technical French networks within which (rewarded) inventors circulated developed a pedagogy of innovation and a renewal of apprenticeships. The Conservatoire des Arts et Métiers, created in 1794, inherited the pedagogical experience of the Quinze-Vingts Hospital in the Rue de Charenton of the 1780s, a place where new and imported techniques were tried out and taught; the Conservatoire was also closely related to the first official repository of machines, the Hôtel of Mortagne, Rue de Charonne (formerly Vaucanson's workshops).[52]

In the Middle Ages, the accelerated pace of technical dissemination can be observed in the building yards. Philippe Braunstein has often remarked on the importance of these yards as centers of technical dissemination, of contacts between workers, and of teaching and learning. The well-documented example of the Milano Duomo sheds light on the pace of dissemination:

> One would not see in building sites the timorous attitude of concealment that was in use in numerous guild trades . . . nor is it opportune to limit the field of training to prestigious careers. . . . [R]ulers of the Milanese yard recommended that workers be recruited in the quarries of Lake Major so that they could learn the craft and become good masters in their turn.

Meanwhile, in the same place, specialists such as Gabriel Stornalocho from Plaisantia, who was *experto in arte geometriae*, were required to solve the critical problems of elevation that appeared during construction in 1391.[53]

Other transmissions could be more diffuse in time and space, such as those through continuous migrations of populations, over several generations, of the kind of highly skilled dynasties of workers for whom mobility was a mode of valorizing their know-how. An example of these are the *francs-comtois* glassworkers and tilt-hammer workers (*platineurs*) of the nineteenth century, which Jean-Luc Mayaud has studied.[54] It is the same if

52. Hilaire-Pérez, *L'invention technique au siècle des Lumières* (n. 47 above).

53. Guy Beaujouan, "Calcul d'expert en 1391 sur le chantier du Dôme de Milan" and "Réflexions sur les rapports entre théorie et pratique au Moyen Âge," in *Par raison de nombres: L'art du calcul et les savoirs scientifiques médiévaux* (Aldershot, U.K., 1991), chaps. 15 and 16; Roland Bechmann, *Villard de Honnecourt: La pensée technique au XIIIe siècle et sa communication* (Paris, 1993). Braunstein, "Savoir et savoir-faire: Les transferts techniques" (n. 18 above); Philippe Braunstein, "La communication dans le monde du travail à la fin du Moyen Âge," in *Kommunikation und Alltag in Spätmittelalter und Früher Neuzeit* (Vienna, 1992), 75–95, republished in Philippe Braunstein, *Travail et entreprise au Moyen Âge* (Brussels, 2003), 459–75.

54. Jean-Luc Mayaud, "La mobilité spatiale: Logique socio-professionnelle et logique capitalistique," in "Les mobilités," ed. Laurence Fontaine, special issue, *Bulletin du Centre Pierre Léon d'Histoire Économique et Sociale* 2–4 (1992): 85–99.

we consider dissemination as a means of learning a trade, such as with journeymen associations in early modern France and Germany. In all cases, such transmissions were a professional *habitus*, embedded within the culture of the craft.

In such dynasties and guilds, techniques also migrated across generations, like inheritances. But this logic of technical memory not only concerned the lineage's transmission of skills, it also relied on institutional creations, such as the repositories of machines and models that appeared in the seventeenth century in scientific circles, the guilds, and the mercantile sphere.[55] This geography of places where technical knowledge was held and transmitted was reinforced by collections of writings (transactions, memoirs, encyclopedias, catalogues of patterns, and so on). All these institutional devices could preserve techniques, but they might also bury them in memory. This did not mean that the techniques were lost, but rather that dissemination would be more latent. It has been shown that inventions were fostered by rediscoveries and the reappearance of forgotten techniques.[56] Therefore, the pace of dissemination was not linear and uniform; rather, it experienced diversions and delays. Indeed, some techniques might even be imported twice. The flying shuttle was introduced into Languedoc by John Kay between 1747 and 1750 but was subsequently forgotten (this needs further research); in 1788, John MacLeod reimported it into Amiens, then Paris (the Quinze-Vingts and Hôtel of Mortagne), and eventually throughout the kingdom.

TERRITORIES AND SCALES

Whereas national boundaries provide the context of most studies of the growth of early modern economies, and medieval economic studies have privileged large regional entities, two other territorial scales seem more appropriate for the analysis of technical dissemination: the local and the international.

On the international level, technical transfers belonged to enlarged territories built up by a plurality of rules, practices, and networks within Braudelian world economies wherein cohesion relied on the intensity of exchanges beyond national boundaries. Western technical circulations in the early modern era were promoted by numerous devices: governmental policies of spying and enticement; long-distance apprenticeships for some European artisans; business strategies that led entrepreneurs and craftsmen

55. Patrice Bret, Christiane Demeuleneaere-Douyère, and Liliane Hilaire-Pérez, eds., "Des matériaux pour l'histoire: Archives et collections scientifiques et techniques du XVIIIe à nos jours," special issue, *Cahiers d'Histoire et de Philosophie des Sciences* 48 (2000).

56. Patrice Bret, "Genèse et légitimation patrimoniale d'une invention individuelle: Les archives de l'Artillerie à l'origine d'une innovation dans la Marine au XIXe siècle," in *Les chemins de la nouveauté* (n. 3 above), 385–410.

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to expand by establishing subsidiary firms abroad, which employed natives and expatriated workers and organized complex circuits of tools and unfinished goods; private networks involving scientific sociability (with the development of academies, societies of arts, and freemasonry); and familial ties and kinship.[57] Examples are numerous, such as the friends of the cosmopolitan entrepreneur Ami Argand and the republic of chemists-dyers described by Agusti Nieto-Galan.[58] Additionally, translations, useful travels, and visits to factories and industrial exhibitions played an important role, as did the frequent forgeries of models, devices, and trademarks across Europe. For several products, as historians of art and curators have shown, there even existed an international division of labor, a process that makes more difficult the identification of the geographical origins of techniques and artifacts. What did it mean to own a London- or Paris-made watch in the eighteenth century, when both the workers and the pieces of the mechanism were overwhelmingly Swiss, as shown by Roger Smith?[59] It must be emphasized that the international exchange of skills and the networks among highly specialized metropolises in Europe contributed to a "pan-European" context of production.[60]

Border crossings that were sometimes open and sometimes closed, depending on the circumstances, aided these diffusions of technology. Dissemination did not spread over one supranational territory, but across flexible territories and boundaries. As Eric Robinson has shown, England legislated to forbid the emigration of skilled workers and the export of machines during the eighteenth century, but a businessman like Matthew Boulton used this legislation to control his workforce while simultaneously opening his factory to foreign visitors, thus setting up a complex system of exchange.[61] Moreover, as John Harris remarked, prohibitions were only effective against workers, not entrepreneurs. The same was true in France. Although Lyonnais workers' movements in the silk, gold wire–drawing, and watchmaking trades were strictly controlled, entrepreneurs could freely set up shop abroad. For example, the Orsels, formerly clients

57. André Guillerme, ed., "De la diffusion des sciences à l'espionnage scientifique et industriel (XVe–XXe siècles)," special issue, *Cahiers d'Histoire et de Philosophie des Sciences* 46 (1999).

58. Agusti Nieto-Galan, "The Use of Natural Dyestuffs in Eighteenth-Century Europe," *Archives Internationales d'Histoire des Sciences* 46 (1996): 23–38.

59. Smith (n. 21 above); Yuna Zek and Roger Smith, "The Hermitage Peacock: How an Eighteenth-Century Automaton Reached St. Petersburg," *Antiquarian Horology* (2005): 699–715.

60. The expression "pan-European" is also used by MacLeod in "The European Origins of British Technological Predominance" (n. 6 above).

61. A. E. Musson and Eric Robinson, *Science and Technology in the Industrial Revolution* (Manchester, 1969), 216–29. For new elements in this important case study, see Peter Jones, "'England expects . . .': Trading in Liberty in the Age of Trafalgar," in *Enlightenment and Revolution: Essays in Honour of Norman Hampson*, ed. Malcolm Crook, William Doyle, and Alan Forrest (Aldershot, U.K., 2004), 187–203.

of Boulton's, became manufacturers in Birmingham, where they organized the migration of workers from the Continent.[62] This dynamic of widespread European exchanges during the eighteenth century has contributed to a reassessment of the British Industrial Revolution as a "European achievement."[63]

Moreover, this widespread movement was not limited to western Europe. It also involved Mediterranean regions, which played a major part in several fields (for example, the diffusion of silk techniques among Piedmont, Languedoc, Dauphiné, and England during the early modern period) and extra-European areas—especially the Middle East and Asia, whose role has been reconsidered, in response to the rehabilitation of overseas trade and other external factors, in more recent accounts of the industrial growth of Europe.[64] Although historians often focus on the lead of western Europe and England during the eighteenth century and regard technological transmissions from Asia to Europe as unsuccessful, more recent studies have revisited the notion of core and periphery.[65] As a result, Asian economic dynamism and technical creativity, extending well into the colonial era, have been reaffirmed, and the Mediterranean area is no longer considered to be marginal to the development of the European world economy;[66] on the contrary, it played an active part as an intermediary (a *médiatrice des techniques*, in the words of Patrice Bret).[67]

62. Liliane Hilaire-Pérez, "Des entreprises de quincaillerie aux institutions de la technologie: L'itinéraire de Charles-Emmanuel Gaullard-Desaudray (1740–1832)," in *Autour de l'industrie, histoire et patrimoine: Mélanges offerts à Denis Woronoff*, ed. Jean-François Belhoste et al. (Paris, 2004), 547–67.

63. MacLeod, "The European Origins of British Technological Predominance."

64. This area of studies is blossoming. Kenneth Pomeranz's *The Great Divergence: China, Europe, and the Making of the Modern World Economy* (Princeton, N.J., 2000) has quickly become a classic, as well as the synthesis by Gale Stokes, "The Fate of Human Societies: A Review of Recent Macrohistories," *American Historical Review* 106 (2001): 508–25. For recent publications, see, for instance, Maxine Berg, "Asian Luxuries and the Making of the European Consumer Revolution," in *Luxury in the Eighteenth Century: Debates, Desires, and Delectable Goods*, ed. Maxine Berg and Elisabeth Eger (Basingstoke, U.K., 2003), 207–18; Maxine Berg, "In Pursuit of Luxury: Global History and British Consumer Goods in the Eighteenth Century," *Past and Present* 182 (2004): 87–141; Maxine Berg, *Luxury and Pleasure in Eighteenth-Century Britain* (Oxford, 2005); and Ian Inkster and Patrick K. O'Brien, eds., "The Global History of the Steam-Engine," special issue, *History of Technology* 25 (2004). For the Middle East, see Donald Quataert, ed., *Consumption Studies and the History of the Ottoman Empire, 1550–1922: An Introduction* (New York, 2000).

65. Maxine Berg recently argued that "Asian technologies were not imported" (see her "In Pursuit of Luxury").

66. Prasannan Parthasarathi, *The Transition to a Colonial Economy: Weavers, Merchants, and Kings in South India, 1720–1800* (Cambridge, 2001); Ruth Barnes, *Textiles in Indian Ocean Societies* (London, 2004).

67. Patrice Bret, "La Méditerranée médiatrice des techniques: Regards et transferts croisés durant l'expédition d'Egypte (1798–1801)," in *Enquêtes en Méditerranée: Les expéditions françaises d'Egypte, de Morée et d'Algérie*, ed. Marie-Noëlle Bourguet et al. (Athens, 1999), 79–101.

Calico printing has played an important role in this discussion. Its techniques (in particular, the use of madder-dyeing with mordant and resist-dyeing with indigo) were at the heart of the Industrial Revolution. Mediators—particularly Armenians and Greeks who adapted Indian methods and developed the cultivation and use of madder—transmitted these techniques to the West.[68] Having formerly acted as intermediaries, Armenians became exporters of madder and calicoes from the valley of Araxe and the towns of Persia (Dyarbekir), Alep, and Smyrna to Indian markets. Olivier Raveux has underlined their skills in the production of specific textiles called *chafarcanis*, which were imitated from Indian ones.[69] Some Armenian entrepreneurs in turn settled in India. Moreover, there were Greek adaptations, linked to local skills and the natural environment specific to the regions of Andrinopolis and Ampelakia in Thessaly. In the eighteenth century, Turkey red (*rouge d'Andrinople*) was a focus of research among cotton masters, who even tried to attract Eastern craftsmen to Manchester and the Lyonnais region.[70] According to Raveux, Marseilles had benefited from the presence of an Armenian community since the seventeenth century. Although the town was formerly a free port that imported *chafarcanis*, it also became a principal center of production with its own specialties, as merchants there developed calico printing through the influence of the Armenians. On their own, native artisans could not master these complex techniques.

The Mediterranean had also been a region of shared technical cultures over the long term—indeed, since antiquity. Patrice Bret has found that during the French expedition in Egypt (1798–1801), ancient techniques for making wooden locks and some pottery, methods that had spread to France either during the Roman era or the Muslim conquest but had since been forgotten, were rediscovered. These techniques were analyzed in academic reports at the Société d'Encouragement pour l'Industrie Nationale (founded by Chaptal in 1801) and were adapted and improved by French academicians, who then realized that a shared technical history existed in the Mediterranean region.

Although it must be stressed that dissemination crossed national boundaries and even traversed vast distances—a process helped by the growing practice of codification since the eighteenth century and reinforced by a

68. Fukasawa (n. 32 above); Kinini (n. 32 above).

69. Olivier Raveux, "Espaces et technologies dans la France méridionale d'Ancien Régime: L'indiennage marseillais (1648–1793)," *Annales du Midi* 116 (2004): 155–70; Xavier Daumalin, Nicole Girard, and Olivier Raveux, eds., *Du savon à la puce: L'industrie marseillaise du XVIIe siècle à nos jours* (Marseille, 2003).

70. A. E. Musson and Eric Robinson "Chemical Developments in Dyeing," in *Science and Technology in the Industrial Revolution* (n. 61 above), 339–51, cf. 344; Hilaire-Pérez, "Cultures techniques et pratiques de l'échange, entre Lyon et le Levant: Inventions et réseaux au XVIIIe siècle" (n. 8 above).

"pan-European consensus of taste"—it would be misleading to imply any kind of "globalization" of techniques.[71] Intermediaries (towns, communities, and societies) and recipients of techniques always interpreted them according to their own needs and resources.[72] There was a constant dialectic between diffusion and localism. Consequently, echoing microhistory, local-scale studies have become a major trend in the history of technical dissemination, and the results are rich. One important outcome has been a reconsideration of the question of core and periphery. Recent medieval studies, for example, have reassessed common assumptions concerning the relationships between town and country. It is no longer possible to speak of towns as being preeminent because of their skills and as leaders of technical diffusion to their hinterlands. For instance, in Carpentras and Aix (Provence), urban builders improved their techniques by adopting practices originating in mountain areas, such as the use of larch wood to make roofs of wooden tiles (*échandoles*). Nevertheless, although these tiles presented unquestionable advantages (by being a light material and well suited to the slopes of roofs), local interest in them was not immediate. Once again, other movements of workers and commercial exchanges facilitated this country-to-town transfer.[73]

In addition, the acceleration of technical dissemination during the eighteenth century also occurred within microterritories, partly because of the growing specialization of production, which implied different kinds of circulations. Some transfers happened within manufacturing centers. There, dissemination followed two patterns, inventive emulation and the division of labor. Metropolises such as Paris, Lyon, London, Birmingham, and Sheffield attracted highly skilled craftsmen who kept on improving, adapting, and imitating specific mechanisms and processes. In Lyon, where artisans' networks were supported by a "municipalist" system of coordination, it is possible to trace the diffusion of newly invented draw looms street by street and workshop by workshop among a core of masters and thus to chart the geography of their networks, which included the joiners, turners, and locksmiths who built the looms.[74] These networks fostered the dissemination of devices, especially by stealing equipment and copying

71. Smith (n. 21 above).

72. On the emergence of local specification along a process of diffusion, see the *foyers autochtones* depicted by Pascal Brioist, "Les révolutions des techniques à la Renaissance," in *L'Europe de la Renaissance, 1470–1560*, ed. Gerald Chaix (Paris, 2002), 141–61. On the importance of micro-scale studies of migrations, see Laurence Fontaine, "Montagnes et migrations de travail: Un essai de comparaison globale (XVe–XXe siècles)," *Revue d'Histoire Moderne et Contemporaine* 52, no. 2 (2005): 26–48.

73. Philippe Bernardi and Nathalie Nicolas, "Les échandoles: Applications et rayonnement d'un matériau et d'un savoir-faire montagnard, à la fin du Moyen Âge," in *Las montañas del Mediterraneo*, ed. A. Ortega Santos and J. Vignet Zunz (Grenade, 2003), 287–304.

74. For "municipalism," see Charles F. Sabel and Jonathan Zeitlin, eds., *World of Possibilities: Flexibility and Mass Production in Western Industrialization* (Cambridge, 1997).

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techniques. Other kinds of intraurban transmission resulted from the growing specialization of urban trades since the Middle Ages. Complementary exchanges developed, as in the London goldsmiths' trades studied by Helen Clifford. Masters had to rely on the work of large subcontracted networks along the chains of fabrication.[75] The goldsmiths' products therefore embodied operations and contacts between numerous artisans, sometimes within one workshop. Although such a process could limit an artisan's skills, it also fostered technical dissemination and crossbreeding among activities, both of which were sources of artisanal inventiveness.[76]

Beyond the towns, the spread of labor in rural areas fostered other local circulations. Established research has shown how peasants may have been acculturated to techniques and cycles of production introduced by urban merchants and, later, industrialists. This was especially true in France, where manufacturers relied heavily on the domestic system. Although economic power derived from the growing devolution of operations in order to develop less-skilled tasks in the countryside, core–periphery relationships were not always unidirectional. In fact, these relationships often promoted creativity and economic success in rural areas.[77] For example, in Franche-Comté, a French region known for its metallurgical tradition that became an area of subcontracted labor for Swiss clockmakers during the nineteenth century, workers (often small independent tenants) easily adopted Swiss techniques because they were similar to their own. Doing so also contributed to the development of their own industry and inventiveness.[78]

The emergence of more integrated economies during the eighteenth century reinforced exchanges among areas with complementary skills. Maxine Berg has shown that consumption goods in the eighteenth century were the result of exchanges of half-finished products and of dissemination of technical information between the metallurgical centers of the English Midlands and the pottery region of Staffordshire, which was reflected by the close relationship between the manufacturers Matthew Boulton and

75. Helen Clifford, "Parker and Wakelin: The Study of an Eighteenth-Century Goldsmithing Business with Particular Reference to Garrard Ledgers, 1770–1776" (Ph.D. diss., Royal College of Art, London, 1989). For a recent synthesis, see Giorgio Riello, "Strategies and Boundaries: Subcontracting and the London Trades in the Long Eighteenth Century," *Enterprise and Society* (forthcoming). We thank the author for sending us his article prior to publication.

76. See, for example, the analysis of technical circulations in perfumers' tools and recipes by Catherine Lanoë, "La poudre et le fard: Une histoire des cosmétiques de la Renaissance aux Lumières" (Ph.D. diss., University of Paris-I-Sorbonne, 2003); Liliane Hilaire-Pérez, "Diderot's Views on Artists' and Inventors' Rights: Invention, Imitation, and Reputation," *British Journal for the History of Science* 35 (2002): 129–50.

77. For a reassessment of the technical skills developed in proto-industrial hinterlands, see Stephan R. Epstein, *Freedom and Growth: The Rise of States and Markets in Europe, 1300–1750* (London, 2000).

78. Mayaud (n. 54 above).

Josiah Wedgwood.[79] As a whole, regional and urban specializations intensified the circulation of products and the mobility of skilled craftsmen. In some territories, restrictive policies to control flows of knowledge developed among rival cities, such as in northern Italy during the Middle Ages, although protectionism declined from the fifteenth century on as "some kind of equilibrium had been achieved, based upon technological platforms and distinct specialties."[80]

Individuals and Communities: Choices and Constraints of Migrating People

The definition and identification of technological disseminations and the analysis of their form, pace, and scale always involve human intermediaries, whether individuals or communities. The study of human societies therefore constitutes the final aim of the history of technology. Fortunately, this is a field that has been widely analyzed by historians, partly because some individuals or groups were more active than others in technical dissemination. We can distinguish several cases, although our categories might seem restrictive compared to the complex web of human mobility.

Let us begin with the individual itineraries of artisans, engineers, technicians, and entrepreneurs, according to their strategies and networks. John Harris took this approach in his monograph about the exchanges between France and England during the eighteenth century.[81] Present research, influenced by microhistory, has deepened this biographical dimension of technological dissemination. An important point here is to emphasize the part played by familial, professional, political, and scientific networks in "chain migrations" and to suggest how techniques—in their materiality, hybrids, and routes—were expressive of human dynamism.[82]

Although famous individuals such as leading manufacturers and engineers often attract attention, lesser-known characters were also involved, as medieval studies increasingly reveal. Let us focus on a mason from Aix (Provence) named Barthélemy Guersi, who was building cellars *à la piémontaise*. He was not only an intermediary for this technique, but also a true adapter and perhaps even the creator of this new kind of vault.[83] Like

79. Maxine Berg, "New Commodities, Luxuries, and Their Consumers in Eighteenth-Century England," in *Consumers and Luxury: Consumer Culture in Europe, 1650–1850*, ed. Maxine Berg and Helen Clifford (Manchester, 1999), 63–85.

80. Stephan R. Epstein, "Journeymen, Mobility, and the Circulation of Technical Knowledge, XIVth–XVIIIth Centuries," in *Les chemins de la nouveauté*, 411–30, cf. 424.

81. John R. Harris, *Industrial Espionage and Technology Transfer: Britain and France in the 18th-Century* (Aldershot, U.K., 1998).

82. Luu, *Immigrants and the Industries of London* (n. 45 above).

83. Philippe Bernardi, "Essai, tâtonnement et pari: Le rôle de l'individu dans l'innovation," *Médiévales* 39 (2000): 14–29.

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many workmen in the building sector, he came from the Piedmont region of Italy. Thanks to an inventory of numerous lawyers' archives, precise data have been found concerning this ordinary man.

Indeed, even for more prestigious individuals, archives aren't always so rich in detail. Among the mining experts who traveled across Europe at the end of the Middle Ages, for example, what do we know about Hans Brohart—a master founder from Brisach who was recommended by another founder to the overseer of the royal silver mine of Pampailly (near Lyon)—except that he arrived at the mining works after passing through Lyon and finally left Pampailly for Lombardy? Because of his experience and skill, Brohart was called on for different tasks in the foundry as well as to work inside the mine when it was reorganized. After leaving Pampailly he did not return, even though he was bound by contract, and his name has disappeared from all remaining archives concerning this important silver mine. No doubt he capitalized on his exceptional ability somewhere else.[84] Of course, for Barthélemy Guersi as for Hans Brohart, individual itineraries and the choices they involved cannot be understood without connecting them to the networks of friends, compatriots, and companions within which they acted.

At this point, it is worth inquiring about the respective roles played by private initiatives and by the migratory policies of states in this dynamic. These questions have been analyzed by Luisa Dolza and Corine Maitte in the case of early modern Italy, and recently by Elva Kathleen Lyon for eighteenth-century Europe and North America.[85] Although individuals often migrated not because of any specific institutional policy, but because of personal motivations that the archives do not always reveal, their integration into networks of power and their conflicts with local administrations and institutions regulating work and migrations (especially guilds) nevertheless constitute regular features of the early modern era.[86]

Indeed, authorities often intervened in the dissemination of technical knowledge, either through the management of migrations or through political measures and the mobilization of states, cities, or guilds. Official attitudes ranged from hostility towards economic migrants (due to the protectionist sentiments of locals), such as in sixteenth-century London, to

84. Paul Benoit, *La mine de Pampailly, XVe–XVIIIe siècles* (Lyon, 1997).

85. Luisa Dolza and Corine Maitte, "Laine et verre en Italie au XVIIIe siècle: Circulation et intégration des hommes et des savoir-faire," in *Les circulations techniques*, 73–90; Elva Kathleen Lyon, "Invited Strangers: Technology Emergence and Transfer in Europe and the Americas, 1500–1750," paper presented at the SHOT annual meeting in Amsterdam, October 2004.

86. See Brioist (n. 72 above); Irina Gouzévitch, "De la Moscovie à l'empire russe: Le transfert des savoirs européens," *SABIX* 32 (2003); Dmitri Gouzévitch, "Le phénomène des 'ingénieurs-résidents': Reconnaissance légale ou espionnage technique?" in "De la diffusion des sciences à l'espionnage scientifique et industriel (XVe–XXe siècles)" (n. 57 above), 159–82.

open encouragement and the provision of incentives for migrating technicians who possessed specific skills or knowledge. The dissemination of indirect ironmaking in Italy at the end of Middle Ages is a good example of this: its spread was promoted by princes like the duke of Ferrara, who attracted foreign workers from the regions of Bergamo and Brescia to establish the forge at Fornovolasco.[87]

Exclusive privileges, grants, naturalizations, and exemptions from taxes, tariffs, and duties imposed on aliens (such as the *droit d'aubaine* in France, which had to be paid by the heirs of immigrants) and a wide range of exceptional and private laws coexisted with general rules aiming to restrain the emigration of skilled artisans and the export of tools and half-finished products (as in England by the act of 1719) or to control the influx and settlement of migrants (as in France by the declaration of 1785).[88] Other measures were enacted to compel aliens to teach their know-how or to employ native laborers and apprentices in their workshops, as Lien Luu has shown to be the case in sixteenth-century London. The diffusion of skills occurred because of voluntary policies regulating the labor market (but some measures were ambiguous, as natives' interest had also to be preserved).

Effective migratory policies were established on different scales, either national (such as the measure to recruit German miners for silver mines at the end of the Middle Ages by means of royal enactment, or the enticement of Italian artisans by Colbert and English workers by John Law) or local (such as in the densely urbanized and competitive regions of north-central Italy and the Low Countries).[89] Alongside these regulations, dissemination within courts and princely patronage networks have also played a part since the Middle Ages.[90] Is it possible for the historian to compare these practices to the economic and technical policies of the religious orders? This question refers in particular to the well-known case of the Cistercians. The organization of the order in a network of "mother" and "daughter" abbeys was reflected in the

87. Enzo Baraldi and Manlio Calegari, "Pratica e diffusione della siderurgia 'indiretta' in area Italiana (secc. XIII–XVI)," in *La sidérurgie alpine en Italie, XIIe–XVIIe siècle* (n. 35 above), 93–162. "Indirect" ironmaking refers to the production of an iron bar from extant cast iron, rather than from raw ore and charcoal.

88. Sometimes with the help of taxes paid by the immigrants to their cities; see Corine Maitte, "Corporation et politique au village: Altare entre migrations et processus de différenciation sociale," *Revue historique* 617 (2001): 45–79.

89. Marie-Christine Bailly-Maitre and Paul Benoit, "Les mines d'argent de la France médiévale," in *L'argent au Moyen Âge* (Paris, 1998), 17–45; Jean-François Dubost, *La France italienne XVIe–XVIIe siècle* (Paris, 1997); Epstein, "Journeymen, Mobility, and the Circulation of Technical Knowledge" (n. 80 above); Luca Mola, *La comunità dei Lucchesi a Venezia: Immigrazione e industria della seta nel tardo medioevo* (Venice, 1994); Belfanti, "Corporations et brevets"; Belfanti, "Guilds, Patents, and the Circulation of Technical Knowledge."

90. Patrick Boucheron, *Le pouvoir de bâtir: Urbanisme et politique édilitaire à Milan (XIVe–XVe siècles)* (Rome, 1998).

dissemination of ironmaking techniques among some abbeys and in the intermediary function they performed for the diffusion of techniques.[91]

Because of the political strategies they occasioned, the migrations of individuals and groups can be charted over long periods of time, from the Middle Ages to the eighteenth century. The synergies of resources necessary for technical transfers may explain why these migrants often brought their own equipment and why they kept in touch with their places of origin (in order to be provided with raw materials, semi-finished products, and information of various kinds). According to Belfanti, the immigration of highly skilled workers opened up routes through which—despite interdictions—products, tools, information, knowledge, and other workers all followed.

Among the migrations of groups, the ones most studied by historians are the organized movements of journeymen, who employed the tramping system (*Wanderzwang*); its impact on the diffusion of techniques, especially within the Germanic area, has been demonstrated by several scholars.[92] Apprenticeships could also involve less formal mobility, such as apprentices exchanged between London and the provinces or those within the urban networks of Italy and the Low Countries, as Stephan Epstein has demonstrated.[93]

Historians have also studied minorities, especially those who migrated because of persecution. Persecution was not the only reason why minorities migrated, however: their role in technical dissemination has long been stressed, sometimes giving rise to myths that attribute certain techniques to certain groups of people. Religious minorities provide the most obvious examples, although others deserve mention, too, such as political minorities like the English Jacobites, who stimulated innovation in French industry during the eighteenth century (not only by Holker, but also by John Law's associates Henry Sully and William Blakey, both of whom became prominent in the Paris Society of Arts). When considering the importance

91. Ludwig Eschenlohr, *Recherches archéologiques sur le district sidérurgique du Jura-central suisse* (Lausanne, 2001); Ludwig Eschenlohr, "Les circulations techniques au Moyen Âge: L'éclairage de l'archéologie dans le domaine de la sidérurgie jurassienne, du XIe au XVIe siècle," in *Les circulations techniques*, 55–71; Catherine Verna, *Les mines et les forges des Cisterciens en Champagne méridionale et en Bourgogne du Nord (XIIe–XVe siècle)* (Paris, 1995).

92. Josef Ehmer, "Worlds of Mobility: Migration Patterns of Viennese Artisans in the Eighteenth Century," in *The Artisan and the European Town, 1500–1900*, ed. Geoffrey Crossick (Aldershot, U.K., 1997), 172–99; Reinhold Reith, "Labor Migration and the Diffusion of Technical Knowledge: The Example of the Habsburg Monarchy in the 18th Century," paper presented at the XIIth International Congress of Economic History, Madrid, 1998; Smith (n. 21 above), 130. For the impact of *Wanderjahre* on the silver trade in London, see Luu, *Immigrants and the Industries of London* (n. 45 above), chap. 7.

93. Epstein, "Journeymen, Mobility, and the Circulation of Technical Knowledge"; Stephan R. Epstein, "Crafts, Guilds, Apprenticeship, and Technological Change in Pre-Industrial Europe," *Journal of Economic History* 58 (1998): 684–713.

of these religious minorities, it is easy to overlook the fact that in these cosmopolitan milieus, conversions and mixed identities were the keys to their integration in technological networks (the clockmaker Henry Sully, for example, a descendant of French Huguenots, converted to Catholicism in London). Religious affiliation took on added meaning when it was linked with other identities: thus, the role played by Huguenot clockmakers in technical dissemination is often linked with their association with freemasonry and other European circles of sociability.[94]

The subject of religious minorities is worth reexamining in order to take into account more recent findings. For medievalists, it is common to raise questions about the practice of some techniques, especially in the field of ceramics, in connection with the long-term settlement of a group of Muslim artisans in Christian Europe.[95] It would also be interesting to study anew the documentation concerning the role of the Cathars in technical dissemination.[96] In the early modern period, the example of the Huguenots illustrates a renewal of historical approaches. Warren Scoville, who first highlighted the topic, distinguished between the diffusion of techniques by "radiation" (borrowing and imitation) and by migrations "more spectacular and violent," which, according to him, initiated more innovations and rapid changes.[97] Following his pioneering studies, a number of historians have stressed the contribution of Protestant refugees throughout Europe since the sixteenth century, and particularly their role in England after 1685. Settled in London and various provincial cities, these refugees were considered to be the levers of growth across a wide range of industries; among them were prestigious artisans, who were celebrated among generations of historians for their achievements in silk-weaving, gold and silver, clockmaking, toy-ware (light metalware), glass, paper, and linen (for sail-making).[98]

94. See, for example, John Theophilus Desaguliers, whom Larry Stewart studies in *The Rise of Public Science* (n. 40 above).

95. Ricardo Córdoba de la Llave, "Algunas consideraciones sobre el lagado tecnológico andalusí en la Córdoba cristiana," in *Acta historica et archaeologica mediaevalia* 18 (1997): 335–75; Henri Marchesi, Jacques Thiriot, and Lucy Vallauri, eds., *Marseille, les ateliers de potiers du XIIIe siècle et le quartier Sainte-Barbe (Ve–XVIIe s.)* (Paris, 1997).

96. Catherine Verna, *Le temps des moulines: Fer, technique et société dans les Pyrénées centrales (XIIIe–XVIe siècle)* (Paris, 2001), 103–4.

97. Warren C. Scoville, "The Huguenots and the Diffusion of Technology," *Journal of Political Economy* 6 (1952): 294–311, 392–411; Warren C. Scoville, "Minority Migrations and the Diffusion of Technology," *Journal of Economic History* 11 (1951): 347–60; Warren C. Scoville, *The Persecution of Huguenots and French Economic Development, 1680–1720* (Berkeley, Calif., 1960).

98. See the articles compiled and edited by Irene Scouloudi in *Huguenots in Britain and Their French Background, 1550–1850* (London, 1985), especially the articles by Natalie Rothstein and Hugh Tait; see also Colin Holmes, *Immigrants and Minorities in British Society* (London, 1978); Robin D. Gwynn, *The Huguenot Heritage: The History and Contribution of Huguenots in Britain* (London, 1985); and Tessa Murdoch, ed., *The Quiet Conquest: The Huguenots 1685 to 1985* (London, 1985).

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Recent research has tended to downplay the impact of the Huguenots.[99] As is often emphasized in recent studies of the history of technology, the process seems to have been less dramatic and more diffuse than previously imagined. It involved an entire community of refugees (there were approximately 50,000 Huguenots in England during the eighteenth century), whose integration was accomplished via apprenticeships and subcontracting networks. Moreover, as Luu has demonstrated, because of solidarity and segregation, the dissemination of techniques could be restricted to the Huguenot community; thus, this intergroup dissemination would slow outside transmission to natives. Finally, rejecting clichés, Luu stresses the flexibility of migrants' skills according to the opportunities presented by extant communities.

Hence new questions are emerging. How are we to trace these migrants who often worked illegally as aliens, mostly as silent and anonymous artisans who were not welcomed by guilds?[100] How did technical crossbreeding actually occur? What were the means and the impact of the technical contact between natives and Huguenots? What was the role played by apprenticeships in such contacts? An interesting topic of study could also be the relationships among Huguenots and other alien artisans in London, such as (Protestant and Catholic) Germans, who also possessed specific skills (for example, in gold- and silver-working) and traveled easily across England and the Continent. On these questions, the studies by David Mitchell and Lien Luu are rich in information because they focus not only on the aliens' own characteristics, but also on their reception by compatriots, natives, and political authorities whose migratory policies had a major impact both on the aliens' status and on the transmission of knowledge.[101]

99. For a critique of local attribution of techniques to Huguenots through the French consonances of patronyms, see David Hey, "The Origins and Early Growth of the Hallamshire Cutlery and Allied Trades," in *English Rural Society, 1500–1800: Essays in Honour of Joan Thirsk*, ed. John L. Chartres and David Hey (Cambridge, 1990), 343–68.

100. Derek Keene, "Du seuil de la Cité à la formation d'une économie morale: L'environnement hanséatique à Londres, entre XIIe et XVIIe siècle," in *Les étrangers dans la ville* (n. 50 above), 409–24; James L. Bolton, "La répartition de la population étrangère à Londres au XVe siècle," in *Les étrangers dans la ville*, 425–36.

101. David Mitchell, ed., *Goldsmiths, Silversmiths, and Bankers: Innovation and the Transfer of Skill, 1550–1750* (Stroud, U.K., 1995); Luu, *Immigrants and the Industries of London* (n. 45 above). See also Helen Clifford, "The Myth of the Maker: Manufacturing Networks in the London Goldsmiths Trade, 1750–1790," in *Silver and Jewelry: Production and Consumption since 1750*, ed. Kenneth Quickenden and Neal Adrian Quickenden (Birmingham, 1995), 5–12; Helen Clifford, "'The King's Arms and Feathers': A Case Study Exploring the Networks of Manufacture Operating in the London Goldsmiths' Trade in the Eighteenth Century," in *Goldsmiths, Silversmiths, and Bankers*, 84–95; Helen Clifford, "In Defence of the Toyshop: The Intriguing Case of George Willdey and the Huguenots," *Proceedings of the Huguenot Society* 27, no. 2 (1999): 171–88; Christopher Hartop, "Art and Industry in 18th-Century London: English Silver, 1680–1760, from the Alan and Simone Hartman Collection," *Proceedings of the Huguenot Society* 27, no. 1

Conclusion

The historiography of technical dissemination inherits its agenda from pioneers in the history of technology (Nathan Rosenberg) and, more broadly, in economic and social history (Fernand Braudel). Traditionally, there was believed to be a difference between transfers and circulations, because technical knowledge was embedded in the territories of past human communities. Recent studies have stressed that technical circulations involved constant adaptations and translations in accordance with the needs and choices of the actors. Diversions, delays, slowdowns, and failures were recurrent, undermining all attempts by historians to discover any straightforward routes or instances of homogeneous diffusion. Although pools of techniques could be shared across long distances, territories were not abstract entities but human constructs. Distinctive localism always interfered with diffusion.

The time has come to rethink the intellectual and material tools for technical microhistory. This overview highlights three key methodological issues. First, while historians of technology have long studied objects and practices, they are now more mindful of words and employ lexicography as a means of identifying techniques; they also combine archaeological studies with historical ones to better trace the movements of technologies and technological knowledge. Second, the theme of hybrids and cultural cross-breeding is crucially important, resonating as it does with current research in the social sciences.[102] Finally, historians are reappraising geography, boundaries, territories, and identities, bearing in mind the weight of social constructions and representations, in order to help refine the analysis of the relationships between techniques and ideology. In these ways, the history of technology is contributing to the progress of general history.

(1998): 50–63; Renaud Morieux, "La formation de la frontière franco-anglaise: La Manche au 18e siècle" (Ph.D. diss., University of Lille-III, 2005). For the policy of London guilds toward aliens, see John Forbes, "Search, Immigration, and the Goldsmiths' Company: A Study in the Decline of Its Power," in *Guilds, Society, and Economy in London, 1450–1800*, ed. Ian Andrew Gadd and Patrick Wallis (London, 2002), 115–26; and Ian Archer, "Responses to Alien Immigrants in London, c. 1400–1650," in *Le migrazioni in Europa secc. XIII–XVIII*, ed. Simonetta Cavaciocchi (Prato, 1994), 755–74.

102. See Serge Gruzinski, *La Pensée métisse* (Paris, 1999).