



ARTICLE

Mapping Byzantine Sericulture in the Global Transfer of Technology

Gang Wu 

Department of History, Fudan University, Shanghai, China
Email: wug@fudan.edu.cn

Abstract

The transfer of sericulture into Byzantium is a critical episode in the global dissemination of silk production technology. However, it is now widely accepted that the explanatory model portraying the transfer as a one-off event is at odds with the historical facts. This article seeks to reassess the transfer of this technology through the lens of appropriation, interpreted as a process. Based on a detailed analysis of the limited evidence available, it attempts to reconstruct the process from transregional and diachronic perspectives, embracing, on the one hand, the transmission of sericulture from China to Byzantium and, on the other, its development in Byzantium over time. This reconstruction offers an explanation for unresolved historical problems. It also constitutes a template for modelling the global transfer of technology in the premodern world, potentially of great value for an in-depth understanding of the transfer.

Keywords: Byzantium; sericulture; Silk Road; Khotan; technology transfer

The transfer of sericulture into Byzantium played a major role in the global dissemination of silk production technology. The empirical sources concerning it portray the transfer as an event that occurred during the reign of Justinian I (c. mid-sixth century). However, it is now widely accepted that sericulture in Byzantium was not satisfactorily established at this moment. Indeed, there is no solid evidence of sericulture in Byzantium before the eleventh century. At the same time, extant sources suggest that the empire still relied heavily on imported raw silk until at least the tenth century.¹ Undoubtedly, framing the transfer of sericulture into Byzantium as a one-off event fails to explain such discrepancies. This article aims to develop a more convincing explanatory model for capturing the complexities involved in the transfer. It draws upon recent developments in the studies of the global transfer of technology, approaching the transfer as a process of appropriation. Through this example, the article also provides a novel template for reconstructing premodern technology transfers on large scales. The article starts with a discussion of the methodology situated within an account of the recent scholarly literature. This clarifies how the notion of appropriation can be integrated into the investigation. The main body of the article seeks to reconstruct the transfer of sericulture into Byzantium from transregional and diachronic perspectives by deductively analysing the surviving historical evidence. Finally, a general picture of the transfer is painted, concluding with a discussion of the larger lessons to be learnt from this case study concerning the global transfer of technology.

I would like to extend my sincere thanks to the anonymous reviewers and Gagan Sood for the insightful suggestions and comments, which greatly improved the final version of this article.

¹Julia Galliker, 'Middle Byzantine Silk in Context: Integrating the Textual and Material Evidence' (PhD diss., University of Birmingham, 2014), 42; Claudio Zanier, 'The Silk Cycle in China and its Migration', in *Seri-Technics: Historical Silk Technologies*, ed. Dagmar Schäfer, Giorgio Riello, and Luca Molà (Berlin: Max-Planck-Gesellschaft zur Förderung der Wissenschaften, 2020), 18.

© The Author(s), 2023. Published by Cambridge University Press. This is an Open Access article, distributed under the terms of the Creative Commons Attribution licence (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted re-use, distribution and reproduction, provided the original article is properly cited.

Contextualizing the methodology

In the study of the global transfer of technology, scholars used to cleave to the centre-periphery model. This tendency entails the investigation of how technologies were transferred from the centres that produced them, to the peripheries that passively accepted them. Recent developments, however, reveal the malleability of technologies in different environments: they were not context-independent but actually shaped by the local traditions and conventions of the alleged peripheries. These developments hinge upon the notion of appropriation. Within the framework of the global transfer of technology, this notion signifies that the receivers of technologies also appropriated or, in other words, played an active role in fashioning what they received. Instead of portraying the transfers as one-off transmission events, such developments encourage scholars to incorporate the subsequent processes whereby technologies were adapted to the local conditions of the recipient societies.² A comparable research trend can be detected among the specialists of silk in the global context. In a recent collection of essays on historical silk technologies, Dagmar Schäfer, Giorgio Riello, and Luca Molà coin the term *seri-technics* for the collection's title to highlight its remit in studying the interactions between the technologies and different localities. A major goal of this effort is to comprehend the regional variations in the development of technical processes.³

These methodological shifts pivoting on the notion of appropriation are instructive for reassessing the transfer of sericulture into Byzantium. By also taking into account the existing scholarship on Byzantine sericulture, we can establish a few principles for this reassessment. First, although the sericulture practice in Byzantium must have borne a resemblance to its counterparts elsewhere, we should expect the empire's particular social and cultural environment to have fostered idiosyncratic features. In this case, reconstructing the Byzantine sericulture practice based on comparative external sources, as attempted by some scholars, may not capture such idiosyncrasies.⁴ Whenever possible, contemporary Byzantine sources should furnish our primary evidence. Second, perceiving the transfer as a process of appropriation instead of a one-off event necessitates an examination from two dimensions. On the one hand, the transregional dissemination from the sericulture's earliest known origin to the Byzantine world very likely incurred appropriations at each intermediary step along the transmission route. Thus, we should clarify each intermediary stage of appropriation during the transmission. At the same time, we should assume that the Byzantine sericulture practice evolved in the course of its history (between the mid-sixth and mid-fifteenth centuries) in keeping with the different stages of appropriation. Therefore, the diachronic variation of sericulture practice should constitute another category of investigation. In this vein, a complete picture of the transfer consists of both transregional and diachronic dimensions. A comprehensive reconstruction would span the practice from sericulture's earliest known origin,

²For a recent overview of this development, see: Manolis Patiniotis and Kostas Gavroglu, 'The Sciences in Europe: Transmitting Centers and the Appropriating Peripheries', in *The Globalization of Knowledge in History*, ed. Jürgen Renn (Berlin: ProBusiness digital printing Deutschland GmbH, 2017), 330–8; Jürgen Renn and Malcolm D. Hyman, 'The Globalization of Knowledge in History: An Introduction', in *The Globalization of Knowledge*, 93–4. For overviews in more specific contexts, see: Erik van der Vleuten, 'Toward a Transnational History of Technology: Meanings, Promises, Pitfalls', *Technology and Culture* 49 (2008): 987–8, 993–4; Liliane Hilaire-Pérez and Catherine Verna, 'Dissemination of Technical Knowledge in the Middle Ages and the Early Modern Era: New Approaches and Methodological Issues', *Technology and Culture* 47 (2006): 555–7.

³*Seri-Technics*, 5–11.

⁴André Guillou, 'La soie du Katepanat d'Italie', *Travaux et Mémoires* 6 (1976): 76–8; David Jacoby, 'Silk in Western Byzantium before the Fourth Crusade', *Byzantinische Zeitschrift* 84/85 (1991/1992): 472n108, 484n182; David Jacoby, 'Silk Production in the Frankish Peloponnese: The Evidence of Fourteenth-Century Surveys and Reports', in *Trade, Commodities and Shipping in the Medieval Mediterranean*, ed. David Jacoby (Aldershot: Variorum, 1997), 50nn34, 36; Anna Muthesius, *Byzantine Silk Weaving AD 400 to AD 1200* (Vienna: Fassbaender, 1997), 5–17; George Maniatis, 'Organization, Market Structure, and Modus Operandi of the Private Silk Industry in Tenth-Century Byzantium', *Dumbarton Oaks Papers* 53 (1999): 265–7; J. Eric Cooper, 'The Possibility of Sericulture in Byzantine Cappadocia', in *Discipuli dona ferentes: Glimpses of Byzantium in honour of Marlia Mundell Mango*, ed. Tassos Papacostas and Maria Parani (Turnhout: Brepols, 2017), 137n56.

embracing its appropriated forms at each intermediary step during the transmission, to sericulture in its fully developed, locally grounded Byzantine form.

Having clarified the principles, we can now turn to the evidential basis: to what extent does the historical record permit a reassessment as formulated above? In terms of the transregional phase, the reconstruction, as we will illustrate shortly below, must proceed deductively, starting with the limited direct information available. In particular, the long-debated immediate origin of Byzantine sericulture has to be addressed before any discussion is possible. This necessitates an evaluation of all probable intermediaries along the transmission route. Regarding the diachronic phase in Byzantium, we need evidence of domestic sericulture at different stages of the empire's history. Although undoubtedly not enough for a detailed examination, the available record allows us to reconstruct the transfer schematically within the framework outlined here. Textual and material sources, derived from archaeological investigations, provide reasonably good information about the transmission of sericulture to Byzantium. When it comes to Byzantium, however, non-textual sources are either unavailable or not as useful for our purposes. Both pictorial depictions and cocoon remnants, commonly used in studying historical sericulture, are absent in the Byzantine case. Although possible remains of Byzantine silk workshops have been found, the evidence they provide is highly questionable for our purposes. Interpreting these workshops on their own terms is not straightforward; to make sense of them, one has to refer to better-documented non-Byzantine sericulture practices.⁵ As for surviving silk textiles, specialists have to date focused on more advanced processes without much concern for sericulture.⁶ Even for the well-studied process of weaving, the methodologies adopted are problematic.⁷ It remains for future studies to show what concrete information about sericulture we may obtain from surviving textiles. More importantly, the strong reliance of Byzantium on imported silk arguably invalidates surviving textiles as a source for our investigation, as they may not even represent the sericulture of Byzantium but that of the areas from which they originated.⁸ For these reasons, textual records necessarily constitute our principal source of evidence. Textual records relevant to our concerns survive from different periods, and are sufficiently detailed for suggestive diachronic comparisons. Even so, it should be noted that there remains a vast gap in the evidence for domestic sericulture between the sixth century, the moment of its first transfer into Byzantium, and the eleventh century.⁹ In light of this gap, to minimize the number of potential variables, we will focus on the records concerning sericulture in and around Constantinople. Bearing these considerations in mind, the following sections examine in turn: sericulture practice when initially imported into Byzantium; the route of its transmission to Byzantium; the intermediary appropriations that occurred along this route; and the subsequent development of the practice in Byzantium over time.

⁵Charikleia Koilakou, 'Biotechniques egkatakastaseis byzantines epoches ste Theba' ('Industrial facilities of Byzantine Period in Thebes'), in *Archaiologika tekmeria biotechnikon enkatakastaseon kata te Byzantine epoche 5os-15os aionas (Archaeological Evidence of Industrial Facilities During the Byzantine Period 5th-15th Century)* (Athens: Politistiko Idryma Omilou Peiraios, 2004), 221-38.

⁶For example, see: Muthesius, *Byzantine Silk Weaving*.

⁷Gang Wu, 'How Did Byzantines Weave? A Synthesis of Textual, Pictorial, Ethnographic, and Archaeological Evidence', *Greek, Roman, and Byzantine Studies* 61 (2021), 368-95.

⁸Menander the Guardsman, *The History of Menander the Guardsman*, ed. and trans. R. C. Blockley (Liverpool: Francis Cairns, 1985), 111-27; Johannes Koder, *Das Eparchenbuch Leons des Weisen* (Vienna: Österreichischen Akademie der Wissenschaften, 1991), 94-6.

⁹The gap could be a sign of the sericulture's limited size. A conjecture in this direction will be proposed at the end of this article.

The imported sericulture practice

The entry point of our investigation is the two primary textual records that concern the transfer of sericulture into Byzantium: Procopius of Caesarea (c. 500–after 565) and Theophanes of Byzantium (fl. second half of the sixth century), the latter of which only survives to the present through a quotation by patriarch Photios (c. 810/820–93). The two records are quoted and translated as follows:

[Procopius:] About the same time, some monks came from India. Learning that the emperor Justinian eagerly wished that the Romans should no longer buy silk from the Persians, they went to the emperor and promised that they would handle the issues of silk so that the Romans would no longer purchase this product from their Persian enemies or other people. They had lived for a long time in a country where (beyond which) there were many Indian people, which is called Serinda. When there, they learned precisely how silk could be produced in the Roman territory. When they were interrogated very closely by the emperor and asked if their statement was true, the monks said that certain worms were the producers of silk, as they were bound by the teaching of nature, which compelled them to work continuously. While it was impossible to transport the worms here alive, their offspring were fertile and utterly adaptable. Each silkworm produced countless eggs. Then long after the birth of these eggs, people covered them with dung and provided sufficient warmth for a period long enough for them to hatch. After they had said these, the emperor promised to reward them handsomely and ratified the undertaking to verify their statement. They returned to Serinda again and transferred the eggs to Constantinople (*Byzantium*). With the method mentioned above, they managed to develop them into worms, which they fed with mulberry leaves. From this, silk production was hereafter established in the Roman territory.¹⁰

[Theophanes:] During the reign of the emperor Justinian, a Persian man showed in Constantinople the genesis of [silk]worms that were previously unknown to the Romans. This Persian who came from Seres (*Seron*) carried the eggs of the worms in the hollow stem of a plant and kept them alive until he reached Constantinople. At the beginning of spring, he put the eggs upon the mulberry leaves they consume. Having been fed with the leaves, they grew wings and did all the work.¹¹

For our purposes, we will focus on the features of sericulture practice detailed in the records. It should be highlighted from the outset that both describe only the practice as it was performed by importer sericulturists (i.e. Indian monks or a certain Persian). Therefore, the mentioned features characterized not only the Byzantine sericulture practice in its initial, unappropriated form but also the practice of its immediate provenance region (i.e. ‘Serinda’ or ‘Seres’) in the mid-sixth century. With this context in mind, we can summarize three main features of the practice based on the descriptions. First, both records claim that the silkworms were fed on mulberry leaves. In this case, the species were most likely the domesticated *Bombyx mori*, the only known mulberry-feeding silkworm that made its way to Europe through transportation,¹² unlike those often referred to as wild silkworms.¹³ This point is remarkable; the two species were often neither

¹⁰Procopius of Caesarea. *Procopii Caesariensis opera omnia*, ed. Jacobus Haury, 4 vols. (Leipzig: B.G. Teubner, 1905–6), 2: 576–7. All English translations of source records in this article are my own.

¹¹Photius. *Bibliothèque*, ed. René Henry, vol. 1 (Paris: Les Belles Lettres, 1959), 77–8.

¹²Richard S. Peigler, ‘Wild Silks of the World’, *American Entomologist* 39 (1993): 151–62; Xiang Hui et al., ‘The Evolutionary Road From Wild Moth to Domestic Silkworm’, *Nature Ecology & Evolution* 2 (2018): 1268–79. Apart from *Bombyx mori*, there are also other mulberry-feeding silkworm species, such as *Bombyx mandarina*.

¹³In this article, I use ‘domesticated’ to refer only to *Bombyx mori*. By saying ‘wild’, I mean all the non-*Bombyx mori* species. Therefore, while ‘wild’ species could be cultivated, they were not ‘domesticated’.

distinguishable in historical records nor specified in the existing scholarship, even though the textile industries founded on their cultivations, which have long coexisted in human history, diverge significantly.¹⁴ In addition, according to Procopius, the silkworm eggs were warmed in dung for hatching. Moreover, Theophanes gives the following description: ‘at the beginning of spring, he (the importer sericulturist) put the eggs upon the mulberry leaves they consume. Having been fed with the leaves, they grew wings and did all the work’. This detail suggests that the sericulturist performed a full circle of sericulture in Byzantium. More importantly, the silkworms were allowed to complete their metamorphosis naturally and develop into moths. Only the cocoons pierced by the moths were used for processing; thus, ‘they grew wings’, as Theophanes wrote. Compared to the intact cocoons obtained through killing chrysalides, pierced cocoons no longer retain continuous filaments; therefore, they are barely reelable. As a result, they are used as silk floss and often spun rather than reeled.¹⁵ The method resembles that used to create modern-day Ahimsa silk, a nonviolent alternative to killing silkworms at the chrysalis stage.

Thus, we may surmise that the sericulture practice of Byzantium and its immediate provenance region at the time of the transfer must have retained the following features: the silkworms were likely the mulberry-feeding *Bombyx mori*, their eggs were often warmed with dung, they could complete their natural life cycle without being killed, and their cocoons were dominantly processed as silk floss and spun.

The transmission route

Having clarified the basic features of sericulture practice imported into Byzantium, we can now turn to the complex subject of the transmission route. It is well-acknowledged that the domesticated silkworm *Bombyx mori* originated from China, a conclusion now corroborated by genetic studies.¹⁶ Following our assumption that the silkworm species to reach Byzantium was *Bombyx mori*, Byzantium and China were undoubtedly the two ends of the transmission route. The only debatable issue is what the intermediaries were, should any have existed. For centuries, scholars have been trying to discern, based on available records, the immediate origin of the sericulture imported into Byzantium. Researchers have approached the puzzle primarily by deciphering the ‘Serinda’ and ‘Seres’ designations. In many cases, they support their identifications with all possible evidence associating the proposed provenance regions with silk. In this way, many candidates along the Silk Road have been put forward, including China, the Tarim Basin (especially Khotan), Sogdiana, Ceylon, Northern India, Cochinchina, the southeast coast of the Caspian Sea, and Syria.¹⁷ However, these proposals are not considered conclusive or accepted widely.¹⁸

¹⁴Irene Good, ‘On the Question of Silk in Pre-Han Eurasia’, *Antiquity* 69 (1995): 959–68; Irene Good, ‘Strands of Connectivity: Assessing the Evidence for Long Distance Exchange of Silk in Later Prehistoric Eurasia’, in *Interweaving Worlds: Systemic Interactions in Eurasia, 7th to the 1st Millennium BC*, ed. Toby C. Wilkinson, Susan Sherratt, and John Bennet (Oxford: Oxbow Books, 2011), 218–30.

¹⁵Rajat K. Datta and Mahesh Nanavaty, *Global Silk Industry: A Complete Source Book* (New Delhi: APH Publishing, 2005), 124, 142, 285, 288.

¹⁶K. P. Arunkumar, Muralidhar Metta and J. Nagaraju, ‘Molecular Phylogeny of Silkmoths Reveals the Origin of Domesticated Silkmoth, *Bombyx Mori* from Chinese *Bombyx* Mandarinina and Paternal Inheritance of *Antheraea Proylei* Mitochondrial DNA’, *Molecular Phylogenetics and Evolution* 40 (2006): 419–27; Qingyou Xia et al., ‘Complete Resequencing of 40 Genomes Reveals Domestication Events and Genes in Silkworm (*Bombyx*)’, *Science* 326 (2009): 433–6; Xiang et al., ‘The Evolutionary Road’, 1268–79.

¹⁷Richard Hennig, ‘Die Einführung der Seidenraupenzucht ins Byzantinerreich’, *Byzantinsche Zeitschrift* 33 (1933): 295–312; Anna Muthesius, ‘The Byzantine Silk Industry: Lopez and Beyond’, *Journal of Medieval History* 19 (1993): 19–23; Anna Muthesius, ‘From Seed to Samite: Aspects of Byzantine Silk Weaving’, in *Studies in Byzantine and Islamic Silk Weaving* (London: The Pindar Press, 1995), 120–2; Hiroshi Wada, ‘ΣΗΡΙΝΔΑ. Ein Abschnitt aus der byzantinischen Seidenkultur’, *Orient* 14 (1978): 53–69.

¹⁸Muthesius, ‘From Seed to Samite’, 122.

To revisit this issue of provenance and draw a more convincing conclusion, we will take the following approach: we will exclusively devote our examination to sericulture instead of reviewing all relevant etymological and contextual information from historical scholarship; this will facilitate a comprehensive and up-to-date assessment of the sericulture-related evidence of the candidate regions. More importantly, we will exploit local characteristics in the global transfer of technology which have thus far been ignored in tackling the issue yet are already well-acknowledged in the relevant literature we have reviewed. Previous researchers who have approached the topic of sericulture have not considered the possible differences among local sericulture practices across regions along the transmission route. Such a limitation may be consequential; comparing the recorded features of sericulture practices can uncover additional evidence to solve the issue of provenance. As we have determined the basic features of the sericulture practice of the provenance region, our search now boils down to answering the following question: which of the proposed provenance regions was home to the sericulture practice with the above-specified features around the mid-sixth century? We will address this question by reviewing the sericulture-related evidence of all the candidate regions roughly from east to west.

By the sixth century, the cultivation of silkworms that fed on mulberry leaves had long been a key agricultural sector in China. The agricultural encyclopedia, *Essential Arts for the People's Welfare* (*Qimin Yaoshu*), completed in this century (c. 540) by Jia Sixie, is the earliest surviving material that provides a comprehensive account of the details of Chinese moriculture (i.e. mulberry cultivation) and sericulture. Jia, a native of Shandong in Northern China, implies that the whole sericulture process was often conducted in a house explicitly devoted to this purpose, a cocoonery. These houses' temperatures would have been controlled by fire. In this case, we can deduce that fire also produced the heat needed for silkworm hatching. There is no reference to the use of dung in the process described by Jia. In addition, he specifically mentions two methods of killing chrysalides: the applications of salt and sunlight, which would result in silk of different qualities.¹⁹ It is clear from this statement that Jia assumes that chrysalides would be killed in silk production.

Regarding contemporary Southern China, the pharmacologist Tao Hongjing (452–563), born in Jiangsu, also mentions the use of salt to preserve cocoons, pointing to a similar practice as in the north.²⁰ The prevalence of killing chrysalides in contemporary Chinese sericulture is corroborated in the poem composed during the same period, titled *Making Silk* (*Zuo Can Shi*): 'When silkworms have just completed the cocoons, many slim-figured women gather who long for their lovers. Thrown into the boiled water, (the cocoons) become precious cloths.'²¹ The poem's description suggests that the women in charge of silk processing cooked the cocoons with living chrysalides in boiled water, which seems to have been a more common way of killing chrysalides than the salt-and-sunlight method. In short, although the dominant species cultivated in China was also a mulberry silkworm, certainly *Bombyx mori*, the above records point to a sericulture practice distinctive from that imported into Byzantium: dung was not used in silkworm hatching and chrysalides were routinely killed after cocoon harvest.

In terms of the Tarim Basin, especially Khotan, the seventh-century *Great Tang Records on the Western Regions* (*Da Tang Xiyu Ji*), authored by Xuanzang (602–64), records that mulberry silkworm eggs were first smuggled into Khotan by the princess of an 'eastern kingdom' who married the Khotanese king. The new queen of Khotan reportedly issued a decree on a stone that forbade the killing of silkworms; under this decree, cocoons could only be processed after the moths departed. When Xuanzang wrote the *Records*, the rule remained binding; those who killed

¹⁹Jia Sixie, *Qimin Yaoshu* (Beijing: Zhonghua Shuju, 2015), 535–8.

²⁰[Tao] Hongjing: ... salt under government control from Donghai is white and has fine natural grains... To preserve silk cocoons, one must use salt under government control.' See: Li Shizhen, *Bencao Gangmu* (*Compendium of Materia Medica*) (Beijing: Renmin weisheng chubanshe, 1979), 629.

²¹Guo Maoqian, *Yuefu Shiji* (*Collection of Yuefu Poetry*) (Beijing: Zhonghua Shuju, 1979), 720.

silkworms for silk would be punished by being banned from silk farming for several years.²² An abridged version of this incident was included in the eleventh-century *New History of the Tang Dynasty* (*Xin Tangshu*); this record also appears in the *Prophecy of the Li Country* (*Li yul lung bstan pa*), a Buddhist religious history of Khotan, likely written in 830, with many new details derived from different sources.²³ The *Prophecy* identifies the Khotanese king as *Dza ya* and the princess as *Pu nye shwa ra*; it also recounts the king being misled by slanderers to burn the silkworm crops against the princess's wishes. These additions reveal that the crops' outputs are Kashmir (*kha che*) silk and silk floss (*mian*, literally 'the wool-like silk'). While the exact nature of the Kashmir silk is not specified, the mention of silk floss is undoubtedly a reference to pierced cocoons, which are only found at the end of the uninterrupted life cycle of the silkworm.²⁴ Although the *Prophecy* does not mention the decree issued by the princess, we are told that the king confessed his 'sin' of killing the silkworm crops to an Indian monk, indicating that the accepted sericulture practice of the time was non-killing.²⁵ In a similar vein, the seventh-century *Continued Biographies of Eminent Monks* (*Xu Gaoseng Zhuan*), authored by Daoxuan (596–667), mentions explicitly that the contemporary sericulture practice in Khotan did not involve killing silkworms, only extracting their silk floss.²⁶ Admittedly, the Buddhist stance of the above sources could have compromised their credibility, biasing their accounts toward those favouring non-killing sericulture.²⁷ However, abundant archaeological evidence found at sites around ancient Khotan can substantiate their claims. The discovery of the eighth-century painted wooden panels that portray the episode detailed in Xuanzang's *Records* and the *Prophecy* suggests that the tale was well-rooted in local culture and should have sound factual bases.²⁸ More compelling are the physical remains of non-killing sericulture practice, including a tangle of short silk filaments, four pierced cocoons (the earliest of which was dated before the fourth century), and textiles of spun silk (dated between the fourth and the sixth century).²⁹ All the above evidence shows that the Khotanese did not kill silkworms in sericulture.

Textual records also suggest that kingdoms at the northern edge of the Taklamakan Desert, including Kucha and Karasahr, followed the same sericulture practice as Khotan in the seventh century, yielding silk floss.³⁰ In addition, we know that by the early sixth century, Kucha became reputed in the region for producing textiles with warps and wefts of silk floss. In the nearby kingdom of Karakhoja, at around the same time, silk floss and the threads processed from it were frequently attested as weaving materials; Kucha's model in silk textile production was also

²²Xuanzang, *Da Tang Xiyu Ji Jiaozhu* (*An Annotated Edition of the Great Tang Records on the Western Regions*) (Beijing: Zhonghua Shuju, 1985), 1021–2.

²³Ouyang Xiu and Song Qi, *Xin Tangshu* (Beijing: Zhonghua Shuju, 1975), 6235.

²⁴See also Daoxuan's record below.

²⁵Zhu Lishuang, "'Yutian Guo Shouji" Yizhu' (*The Prophecy of the Li Country: An Annotated Chinese Translation*), *Zhongguo Zangxue* 102 (2012): 223, 251–2.

²⁶'Nowadays in countries like Kucha and Khotan, silkworms are cultivated only to extract silk floss; they are not killed either.' See: Daoxuan, *Xu Gaoseng Zhuan*, in *Dazheng Xinxu Dazangjing* (*Taishō Tripitaka*), vol. 50 (Taipei: The Buddha Education Foundation, 1990), 684.

²⁷This may apply in particular to the case of Daoxuan, who led the drive to ban silk cassocks, see Stuart H. Young, "'Bald-headed Destroyers of Living Things": Buddhist Identity in the Silk Cultures of Medieval China', *Asia Major* 32 (2017): 27–70.

²⁸Joanna Williams, 'The Iconography of Khotanese Painting', *East and West* 23 (1973): 109, 147–50.

²⁹Jia Yingyi, 'Xinjiang sizhi jishu de qi yuan ji qi tedian' ('The Origin of Silk Weaving Techniques in Xinjiang and their Characteristics'), *Kaogu* 2 (1985): 173–4; Yin Qing, 'Zhongguo gudai yangcan jishu de xichuan ji qi xiangguan wenti' ('The Westward Dissemination of Ancient Chinese Sericulture Technology and Related Questions'), *Minzu Yanjiu* 3 (1998), 59–60; Zhao Feng, 'Domestic, Wild or Unraveled? A Study on Tabby, Taqueté and Jin with Spun Silk from Yingpan, Xinjiang, Third-Fourth centuries', in *Silk: Trade and Exchange Along the Silk Roads between Rome and China in Antiquity*, ed. Berit Hildebrandt and Carole Gillis (Oxford: Oxbow Books, 2017), 95–103.

³⁰For Kucha, see: note 26; for Karasahr: '[In] Karasahr... silkworms are cultivated not for silk yarn but silk floss.' See: Li Yanshou, *Beishi* (*History of the Northern Dynasties*) (Beijing: Zhonghua Shuju, 1974), 3126.

imitated there.³¹ We can thus conclude that at least between the fourth and the seventh centuries, the sericulture practice adopted in Khotan and other nearby kingdoms very much resembled the Byzantine one in question: both cultures cultivated mulberry silkworms, keeping them alive throughout the whole process and procuring silk floss from the pierced cocoons.

For regions in South and Southeast Asia (Ceylon, Northern India, Cochinchina), we may first draw upon a recent study that utilizes genome-wide sequence analyses of silkworm strain samples from geographic locations in Europe and South and Southeast Asia (including India, Thailand, and Southern China). The study shows that after its domestication in China, the mulberry silkworm *Bombyx mori* dispersed to Europe, South Asia, and Southern China, following independent dispersal events and developing into local silkworm strains. Moreover, the earliest among these independent disseminations was to Europe.³² Assuming that the mulberry silkworm species imported into Byzantium is one, if not the only, ancestor of the European *Bombyx mori* strains sampled in this study, the above genetic evidence suggests that the species arrived at Byzantium before South and Southeast Asia. This sequence of events would preclude the latter region from first establishing this sericulture practice.

Regarding India and its adjacent areas, we can find historical materials to corroborate the same observation for South and Southeast Asia. Research and findings from the archaeological sites of Harappa and Chanhudaro have shown that as early as 2450–1900 BCE, wild silks (muga, tasar, and eri) were used for weaving in the basins of the Indus River. Analysis of a sample from Chanhudaro suggests that the silks might have been reeled.³³ Often, to be unwound on reels, silkworms had to be killed to ensure the cocoons were intact. In addition to this evidence, terms with indigenous roots meaning silk can be found in the *Mahabharata* and the *Ramayana*, textual sources dated before 600 BCE, indicating the material's local origin in India. A typical example of such terms is *kausheya*, which referred to a silkworm and, shortly afterwards, silk cloth.³⁴

The travelogues of Chinese Buddhists, despite possible distortion integrated by the agendas of their authors, can be informative regarding silk in India during the early medieval period—when treated with caution.³⁵ In the seventh-century *Great Tang Records on the Western Regions*, Xuanzang observes that the only silk clothes worn by Indians were those made of *jiaosheye*, which is undoubtedly a transliteration of *kausheya*. He defines the term *jiaosheye* as the silk of wild silkworms.³⁶ On the other hand, silk production at that time often involved the killing of silkworms. Thus, the *Tales of Returning from the South Seas with the Dharma (Nanhai Jigui Neifa Zhuan)* by Yijing (635–713) mentions that Indian sericulture committed mass butchery toward silkworms.³⁷ Hyecho (c. 700–80), probably due to the involvement of silkworm killing that Buddhists often opposed, distances Indians from that type of silk farming, erroneously claiming in his *Memoir of the Pilgrimage to the Five Kingdoms of India (Wang Wu Tianzhu Guo Zhuan)* that silk of various kinds was not used in India.³⁸

³¹... a middle-size Kucha-style brocade with yellow ground colour produced in Karakhoja; its warps and wefts are made of silk floss', 'two catties of warps and wefts made of silk floss... ten taels of silk floss', 'to make the brocade ribbon, three catties and a half of silk floss are needed...' See: *Tulufan Chutu Wenshu (Documents excavated at Turpan)* (Beijing: Wenwu Chubanshe, 1981), 1: 181, 195; 2: 7.

³²Xiang et al., 'The Evolutionary Road', 1268–79.

³³Irene Good et al., 'New Evidence for Early Silk in the Indus Civilization', *Archaeometry* 51 (2009): 457–66.

³⁴J. Mark Kenoyer, 'Textiles and Trade in South Asia During the Proto-Historic and Early Historic Period', in *Silk*, ed. Hildebrandt and Gillis, 19.

³⁵Stuart H. Young, 'Squealing Silkworms, Bug Clothes, and Maidens who Spit Silk: Indian Silk and Sericulture in Medieval Chinese Buddhism', *Journal of the International Association of Buddhist Studies* 42 (2019): 632–80; Young, "'Bald-headed Destroyers of Living Things'", 27–70.

³⁶Their [i.e. Indian] clothes include garments of *jiaosheye* and fabrics of *die*. *Jiaosheye* is the silk of wild silkworms.' See: Xuanzang, *Da Tang Xiyu ji*, 176.

³⁷Yijing, *Nanhai Jigui Neifa Zhuan*, in *Dazheng Xinxu Dazangjing*, 54: 230. Cf. Young, 'Squealing Silkworms', 653n54.

³⁸Hyecho, *Wang Wu Tianzhu Guo Zhuan*, in *Dazheng Xinxu Dazangjing*, 51: 976. Cf. Young, 'Squealing Silkworms', 639.

Such a sericulture practice is also attested in the extant Indian Buddhist scriptures, which survived to the present through Chinese translations and paraphrased passages.³⁹ For example, when the *Great Perfection of Wisdom Treatise (Da Zhidu Lun)*, debatably attributed to the editorship of the early fifth century,⁴⁰ uses the metaphor of silkworms to represent human life, it notes that after the silkworms bound themselves with the silk they spun, they would be boiled in scalding water.⁴¹ The *Scripture on the True Dharma Foundations of Mindfulness (Zhengfa Nian Chu Jing)*, translated by Gautamaprajñā-ruci sometime between the late fourth and early sixth century,⁴² claims that karma would exact horrendous retribution on those who killed silkworms in cocoons with steam or boiling water to obtain silk.⁴³ The *Dharmaguptaka Vinaya (Sifen Lü)*, translated by Buddhayaśas and Zhu Fonian in the early fifth century,⁴⁴ records a scenario in Northern India during Buddha's time (c. the fifth to fourth century BCE): monks who wished to make new beds with silk floss (*mian*) from wild silkworms watched the silk producer boil cocoons and kill the silkworms.⁴⁵ Versions of the same story also appear in other *vinayas* (i.e. Buddhist monastic rules).⁴⁶ In short, the above evidence shows that, at least around the time when sericulture was transferred into Byzantium, Indians, or inhabitants of South Asia more generally, cultivated wild silkworm species that did not feed on mulberry leaves;⁴⁷ they often killed chrysalides in the production process.⁴⁸ Both features contradict what we have learned about the imported Byzantine sericulture practice.

Turning to Sogdiana, one historical account from the sixth-century historian Menander shows that in c. 570, Sogdians under Turkish rule were eager to trade their silk with Persians and Byzantines.⁴⁹ Sogdians' involvement in silk weaving by the sixth century has also been proposed based on interpretations of fragmentary textual and archaeological materials.⁵⁰ However, there is no compelling evidence of any contemporary local sericulture in Sogdiana. Instead, it seems that the silk fabrics Sogdians possessed were imported or woven locally with imported materials. Thus, when the Sogdian envoys sent by the Turkish King Khagan Sizabul visited Justin II to sell their silk in c. 570, they were surprised by the sericulture recently imported into Byzantium, shown to them by the emperor.⁵¹ In addition, the murals of an aristocratic house at the archaeological site of

³⁹Young, "Bald-headed Destroyers of Living Things", 38–51.

⁴⁰Po-kan Chou, 'The Problem of the Authorship of the Mahāprajñāpāramitopadeśa: A Re-examination', *Taida Lishi Xuebao* 34 (2004): 281–327.

⁴¹Nāgarjuna, *Da Zhidu Lun*, in *Dazheng Xinxiu Dazangjing*, 25: 697. Cf. Young, "Bald-headed Destroyers of Living Things", 40.

⁴²Ciyi et al., eds., *Foguang Da Cidian* (Gaoxiong: Foguang Chubanshe, 1989), s.v. 'Zhengfa Nian Chu Jing'.

⁴³Gautamaprajñā-ruci, trans., *Zhengfa Nian Chu Jing*, in *Dazheng Xinxiu Dazangjing*, 17: 104. Cf. Young, "Bald-headed Destroyers of Living Things", 40–1.

⁴⁴Ciyi et al., *Foguang Da Cidian*, s.v. 'Sifen Lü'.

⁴⁵Buddhayaśas and Zhu Fonian, trans., *Sifen Lü*, in *Dazheng xinxiu dazangjing*, 22: 613. Cf. Young, "Bald-headed Destroyers of Living Things", 42–5.

⁴⁶Young, "Bald-headed Destroyers of Living Things", 46–51.

⁴⁷The silkworm species of muga, tasar, and eri, attested in the archaeological finds we have noted earlier, remain the dominant species of wild silkworms in India nowadays, see note 33; Datta and Nanavaty, *Global Silk Industry*, 217–18. There are also mulberry-feeding wild species in India that are not cultivated. The mulberry-feeding species used for silk production (i.e. the *Bombyx* genus) was possibly imported into India after the seventh century, see: Thomas Wardle, *The Wild Silks of India, Principally Tusser* (London, 1880), 5; Lotika Varadarajan, 'Silk in Northeastern and Eastern India: The Indigenous Tradition', *Modern Asian Studies* 22, no. 3 (1988): 561–70.

⁴⁸It is worth noting that in wild silkworm cultivation, it may not be easy to ensure reelable cocoons with the killing method due to the uncontrolled rearing process. For example, see: Datta and Nanavaty, *Global Silk Industry*, 217–34.

⁴⁹Menander the Guardsman, *The History*, 111–27. Cf. Hennig, 'Die Einführung der Seidenraupenzucht ins Byzantinerreich', 302–13.

⁵⁰Svetlana V. Lyovushkina, 'On the History of Sericulture in Central Asia', *Silk Road Art and Archaeology* 4 (1995/6): 37–55; D. G. Shepherd and W. Henning, 'Zandaniji Identified?' in *Early Islamic Art and Architecture*, ed. Jonathan M. Bloom (Aldershot: Ashgate, 2002), 261–2. The suggestion of Shepherd and Henning, which favours the involvement of pre-Islamic Sogdiana in silk weaving, has been considered untenable, see Zvezdana Dode, "'Zandaniji Silks': The Story of a Myth", *The Silk Road* 14 (2016): 213–14.

⁵¹Menander the Guardsman, *The History*, 111–27; Photius, *Bibliothèque*, 78, lines 3–5.

Afrasiyab in Samarkand depict an event in the mid-seventh century, when Chinese envoys paid tribute to the Sogdian king, Varkhuman; the gifts they offered to the king were silk in various forms. Based on the reconstructions, the majority of the envoys, four in number, are holding piled rolls of cloth. One envoy holds a skein of thread, and the remaining one has a handful of cocoons' strings.⁵² The fact that cocoons were among the gifts presented to the king suggests that even until the seventh century, they were not easily accessible in Sogdiana. Even if sericulture existed there, it was certainly not yet as developed as the process by which Procopius' importer sericulturists learned their craft. Even until the early eighth century, this sector remained absent or underdeveloped. In the contemporary household records of Sogdian rulers found at Mount Mugh to the east of Samarkand, silk was still listed as imported goods along with paper.⁵³ It is thus more likely that, as now accepted by many Silk Road scholars, China-originated sericulture only reached Sogdiana after the Arab conquest of the eighth century.⁵⁴ This suggestion derives evidence from the records of Du Huan, whom Arabs captured after they defeated the Chinese army in the Battle of Talas in 751. His travelogue in the Abbasid Caliphate before his return to China in 762 has survived in extracts in the *Comprehensive Statutes (Tong Dian)* of Du You (735–812). Du Huan lists four Chinese artisans he met in the Caliphate: two worked as gold- and silversmiths, bookmakers and painters, and two as silk weavers.⁵⁵ It remains unclear whether the silk weavers were also captives from the battle like Du Huan. Still, it is likely that only around that time—that is, the mid-eighth century—did China-originated silk technologies, including sericulture, begin to spread throughout Sogdiana via immigrants. Only after the ninth century was it likely that records of local Sogdian silk started to appear in sources. The earliest comes from Al-Baladhuri (820–92), who mentions silk tribute from Transoxiana to the early Arab conquerors.⁵⁶

Sericulture in regions around the Caspian Sea resembles that of Sogdiana. In sum, there is no solid evidence of silkworm farming in the regions as early as the sixth century. Relevant records started to appear only after the eighth century, pointing to a possible correlation with the above-mentioned immigrant-related technology transfer from China to the Arab world around the eighth century. In the inventories of local monasteries in Dunhuang, dated around the eighth and ninth centuries, we find silk textiles manufactured in Merv (near today's Mary, Turkmenistan).⁵⁷ In the tenth century, several geographers and travellers documented silk industries around the Caspian Sea, pointing to the possible establishment and spread of sericulture. According to Istakhri (fl. the tenth century), silk clothes were produced and exported in what is today the Fars province of Iran, especially Ram Hormuf (today Gerash), Fasa, and Dscheherm (present-day Jahrom). Berdaa's (probably today's Barda, Azerbaijan) engagement in silk production is also mentioned. Tabaristan, as Istakhri suggests, was the most important centre for silk production among Islamic countries; it manufactured silk clothes and exported its products. Silk clothes were also produced in the nearby Gorgan (referred to as

⁵²Frantz Grenet, 'The Self-image of the Sogdians', in *Les Sogdiens en Chine*, ed. É. Vaissière and É. Trombert (Paris: École Française d'Extrême-Orient, 2005), 125–7. Cf. Valerie Hansen, *The Silk Road: A New History* (Oxford: Oxford University Press, 2012), 125–9.

⁵³M. N. Bogoliubov and O. I. Smirnova, *Sogdiiskie dokumenty s gory Mug (Sogdian Documents from Mount Mug)*, vol. 3, *Khoziaistvennye dokumenty (Household papers)* (Moscow: Vostochnaya Literatura, 1963), 51–3. Cf. Hansen, *The Silk Road*, 129–32.

⁵⁴Liu Xinru, *The Silk Road in World History* (Oxford: Oxford University Press, 2010), 101–2; Hansen, *The Silk Road*, 139.

⁵⁵Du Huan, *Jingxingji Jianzhu (Notes and Commentary on the Travel Record)* (Beijing: Zhonghua Shuju, 2000), 52. Cf. Liu, *The Silk Road in World History*, 101–2.

⁵⁶R. B. Serjeant, 'Material for a History of Islamic Textiles up to the Mongol Conquest', *Ars Islamica* 11/12 (1946): 121. Cf. Dode, "'Zandaniji Silks'", 214.

⁵⁷Rong Xinjiang, 'Khotanese Felt and Sogdian Silver: Foreign Gifts to Buddhist Monasteries in Ninth- and Tenth-Century Dunhuang', *Asia Major* 17 (2004): 31.

Dschordschan and Asterabad) and Nishapur. Records specifically discuss sericulture only for the more eastward Merv: inhabitants were described as exporting both silk and silkworms.⁵⁸ Istakhri's descriptions are corroborated and supplemented by Ibn Hawqal (fl. second half of the tenth century), who attests to the manufacture of silk clothes around Fars, specifically in Fasa, Yezd, and Abarkuh. For Berdaa, Ibn Hawqal adds that it exported silk and cultivated mulberries, which implies the existence of local sericulture. The involvement of Tabaristan, Gorgan, and Nishapur in the silk industry is recorded similarly. Ibn Hawqal specifies that Merv's silkworms were introduced to many places, including Gorgan and Tabaristan. He also records Ispahan's production of silk clothes, which escaped Istakhri's notice.⁵⁹

For Syria, extensive evidence suggests its involvement in various stages of the silk industry. Archaeological finds from Palmyra indicate that by the Roman period, Syria was trading finished silk textiles from China and weaving silk textiles locally from imported silk yarn.⁶⁰ In the fifth century, Theodoret, the bishop of Cyrrhus (423–57), detailed the weaving process of textiles, including patterned silks, in a biblical commentary; the description is presumably based on what Theodoret perceived locally in contemporary Syria.⁶¹ In the time of Justinian I, Procopius describes Beirut and Tyre as accommodating merchants, workers, and artisans of silk, who then distributed the merchandise to the rest of the world, making them centres for silk garment production in ancient times.⁶² Moreover, the earliest attested *kommerkiarioi*, Byzantine officials associated with the silk trade, at least before the seventh century, were all based in Syria.⁶³ This evidence shows that the silk-related businesses of Roman Syria might have persisted well into the Byzantine period. Even in the tenth century, when Syria was no longer a part of Byzantium, such a tradition still seems to have been alive, according to the *Book of the Eparch*. The *Book*, which contains regulations of several silk-related guilds in Constantinople, portrays Syria as among the capital's foremost suppliers of dyestuffs and silk garments.⁶⁴

However, for Syria, the most significant issue remains: whether the domesticated silkworms were cultivated locally before the reign of Justinian I. The critical evidence presented in support comes from the third-century Chinese source, the *Brief History of Wei* (*Weilue*), which survives to the present through a quotation in the third-century *Records of the Three Kingdoms* (*Sanguo Zhi*).⁶⁵ The *Brief History* states that the people of Daqin, the ancient Chinese name for the Roman Empire (particularly Syria), bred mulberry silkworms (*sang can*); in context, this wording must refer to *Bombyx mori*.⁶⁶ However, considering the following reasoning, this evidence should not be accepted at face value.

⁵⁸Istakhri, *Das Buch der Länder von Schech Ebu Ishak el Farsi el Isztachri*, ed. and trans. A. D. Mordtmann (Hamburg: Rauhes Haus, 1845), 59, 73–4, 86, 100–1, 116, 121.

⁵⁹Ibn Hawqal, *The Oriental Geography of Ebn Haukal: An Arabian Traveller of the Tenth Century*, ed. and trans. Sir William Ouseley (London: Oriental Press, 1800), 132–3, 157, 169, 179–80, 214, 216–17, 227; Ibn Hawqal, *Configuration de la terre*, ed. and trans. J. H. Kramers and G. Wiet (Paris: Maisonneuve et Larose, 1964), 422.

⁶⁰Marta Zuchowska, 'From China to Palmyra: The Value of Silk', *Swiatowit* 11 (2013): 143–8.

⁶¹Theodoret of Cyrrhus, *Opera omnia*, ed. Joan Ludov Schulze, in *Patrologiae cursus completus, series graeca*, vol. 83, ed. Jacques Paul Migne (Paris: Ateliers catholiques, 1864), 617C–620B. Cf. Anna Muthesius, 'Essential Processes, Looms, and Technical Aspects of the Production of Silk Textiles', in *The Economic History of Byzantium*, ed. Angeliki E. Laiou (Washington, DC: Dumbarton Oaks Research Library and Collection, 2002), 157.

⁶²Procopius, *Opera Omnia*, Vol 3, part 1, 155.

⁶³Nicolas Oikonomides, 'Silk Trade and Production in Byzantium from the Sixth to the Ninth Century: The Seals of Kommerkiarioi', *Dumbarton Oaks Papers* 40 (1986): 34–8; Muthesius, 'The Byzantine Silk Industry', 23–9.

⁶⁴Koder, *Das Eparchenbuch*, 94–6.

⁶⁵Muthesius, 'The Byzantine Silk Industry', 22–3; Muthesius, 'From Seed to Samite', 121.

⁶⁶Domestic animals in Daqin include horse, donkey, mule, and camel. [The people] bred mulberry silkworms.' See: Chen Shou, *Sanguo Zhi* (Beijing: Zhonghua Shuju, 2000), 638. It should be reiterated here that there are other mulberry-feeding silkworm species. However, in the context of the *Brief History*, it is unlikely that the author had the wild species in mind instead of the dominant one cultivated in China, *Bombyx mori*.

First, after mentioning mulberry silkworms, the same *Brief History* specifies all the textile materials the people of Daqin used in weaving. Aside from sheep wool and vegetable fibre, the book also notes silk from the cocoons of wild silkworms. The silk of mulberry silkworms, referred to in prior sections of the same work as being cultivated locally in Daqin, is not mentioned. Instead, the texts add that they longed for silk from China, which they acquired through maritime trade.⁶⁷ This commentary contradicts the earlier claim that the locals possessed mulberry silkworms. Thus, the description of Daqin as practising mulberry silkworm cultivation was a misrepresentation. The author likely intended to present a general impression of a wealthy country in the far West comparable to China, where the cultivation of mulberry silkworms was a significant portion of the economy and a symbol of wealth.⁶⁸ In contrast, the following details seem to convey a much more reliable picture: the silk used locally in Daqin was derived from wild silkworms, while silk from mulberry silkworms was still imported from China.

Second, accounts of Daqin's sericulture appear in the fourth-century *Annals of the Later Han* (*Hou Hanji*) and the fifth-century *Book of the Later Han* (*Hou Hanshu*). However, they present identical information in the same contradictory manner as the *Brief History* does without providing any new details.⁶⁹ Scholars have advanced the convincing argument that all three similar records are derived from the same lost source that describes what the Chinese diplomat Gan Ying learned from his conversations with Parthian sailors during an unsuccessful mission to Daqin in 97.⁷⁰ Consequently, Chinese sources reports about Daqin were based on second-hand information from the late first century. In this context, Western sources on the sericulture of Daqin/the Roman Empire can be informative for comparison.

In the fourth century BCE, Aristotle mentions that a local silkworm species, probably *Saturnia pyri* or *Pachypasa otus*,⁷¹ was raised for textile production following a practice originating in Kos.⁷² Pliny (23/24–79), a contemporary of Gan Ying, also mentions this silkworm species. Although starting with a straightforward paraphrase of Aristotle's description, Pliny's record continues with some perplexing but new details. For example, he adds that the silkworms fed on cypress, terebinth, ash, and oak, and they were put into a jar and fed with bran at a particular stage. Additionally, Pliny shows a deep contempt for their silk, shaming men who wore textiles made from it.⁷³ These details may represent Pliny's contemporary context. In this vein, Pliny's record could testify to the continuous cultivation of such wild silkworms for textile production in the Roman Empire, a point the above texts from the *Brief History* might have also substantiated. However, the picture remains obscure since textual evidence as the above is few and ambiguous, and there has been no compelling corroboration from archaeological finds.⁷⁴ Nevertheless, it

⁶⁷'Some say that [the people] use not only sheep wool but also vegetable fibre and silk from cocoons of wild silkworms [in weaving] . . . they are anxious to obtain silk from China and unravel it to make textiles of their style. Therefore, they often trade by sea with countries like Parthia.' See: Chen, *Sanguo Zhi*, 638.

⁶⁸Cf. Marta Zuchowska, "'Roman Textiles' in the Hou Han Shu. A Fifth-Century Chinese Vision versus Roman Reality', *Anabasis: studia classica et orientalia* 6 (2015): 218, 235, 238.

⁶⁹Yuan Hong, *Hou Hanji* (Beijing: Zhonghua Shuju, 2002), 301–2; Fan Ye, *Hou Hanshu* (Beijing: Zhonghua Shuju, 1965), 2919.

⁷⁰Yan Shiming and Liu Lanfen, 'Ban Yong Xiyu zhuguo ji, Fan Ye Hou Hanshu: xiyu zhuan, Yu Huan Weilue: Xirong zhuan guanxi kaolun—jian yu Yu Taishan xiansheng shangque' ('The Relationship between Records of the Western Kingdoms, Records of the West in Book of the Later Han and Brief History of Wei — A Discussion with Mr Yu Taishan'), *Yunyang Shifan Gaodeng Zhuanke Xuexiao Xuebao* (2015): 33–8; Zuchowska, "'Roman Textiles'", 234, 236.

⁷¹William T. M. Forbes, 'The Silkworm of Aristotle', *Classical Philology* 25 (1930): 22–6; Robert J. Forbes, *Studies in Ancient Technology*, vol. 4 (Leiden: Brill, 1964), 50–8.

⁷²Aristote, *Histoire des animaux*, ed. and trans. Pierre Louis (Paris: Les Belles Lettres, 1968), 40.

⁷³Pliny, *Naturalis historia*, ed. and trans. H. Rackham, vol. 3 (Cambridge, MA: Harvard University Press, 1967), 478–81.

⁷⁴It is worth noting that wild silk was found among Roman silk finds in Palmyra. However, it has been suggested that they were likely the imported Indian tasar silk rather than yields of local cultivation; see: Andreas Schmidt-Colinet et al., eds., *Die Textilien aus Palmyra: Neue und alte Funde* (Mainz am Rhein: Philipp von Zabern, 2000), 12–13n47; Zuchowska, 'From China to Palmyra', 147; Boyoung Lee et al., 'Species Identification of Silks by Protein Mass Spectrometry Reveals Evidence of Wild Silk Use in Antiquity', *Scientific Reports* 12 (2022): 4579. Nevertheless, the method of identifying silkworm species based on archaeological silk fibre can be debatable, see: Good, 'Silk in Pre-Han Eurasia', 961, 966–7. Lise Bender Jørgensen, 'The Question of Prehistoric Silks in Europe', *Antiquity* 87 (2013): 585–7.

suffices to conclude that the argument favouring the Syrian cultivation of domesticated mulberry silkworms at an early stage remains untenable. If there was any sericulture, it could only have been based on local silkworm species.

Having revisited the sericulture-related evidence of all the proposed provenance regions, it seems that around the mid-sixth century, only the people of the areas around Khotan in the Tarim Basin engaged in a sericulture practice that closely resembled the one imported into Byzantium. The rest regions either did not practice sericulture or adopted somehow different practices. Therefore, from the perspective of sericulture practices, domesticated mulberry silkworms and their cultivation were most likely imported into Byzantium from Khotan or its adjacent zones.

It should be acknowledged here that there is a vast span of land between the Tarim Basin and Byzantium. However, the time interval between the eggs' laying and hatching could be long enough to make the transportation. According to Theophanes' testimony, those eggs rejuvenated at the beginning of spring in Constantinople were most likely laid in the Tarim Basin in the previous spring or autumn. Studies have also shown that by regulating the temperature, the silkworm eggs could be preserved even longer, that is, for two years.⁷⁵ The importer sericulturists must have taken necessary measures to control the environmental conditions, especially the temperature, to preserve the hibernating eggs and to trigger their awakening.⁷⁶ The hollow stem, mentioned in Theophanes' account of storing the silkworm eggs, might have been among the deliberate designs to achieve such an end.

Did the region around Khotan import the cultivation of *Bombyx mori* directly from China? According to the *Great Tang Records on the Western Regions*, the answer hinges on identifying the 'eastern kingdom', from where the sericulture was transferred into Khotan. Later in the *New History of the Tang Dynasty*, which also mentions this transfer, the 'eastern kingdom (*dong guo*)' is worded as the 'neighbouring kingdom (*lin guo*)'. Based on the two records and other contextual information, scholars have argued that the 'eastern kingdom' could have been either China or the Loulan Kingdom, which was in the Tarim Basin east of Khotan.⁷⁷ In other words, without more conclusive evidence, it remains uncertain whether the Loulan Kingdom acted as an intermediary step in transmission.

The appropriations along the transmission route

Having clarified the path of transmission, we can now reconstruct the transmission process along its route using the perspective of appropriation. We will focus on hatching and cocoon processing, the only sericultural procedures documented in all relevant practices. We earlier discussed the features of the Khotanese sericulture when it was imported and those of the surrounding region when it was exported to Byzantium. To determine when sericulture was transferred into Khotan, both the *Prophecy of the Li Country* and archaeological finds suggest a dating before the third century CE.⁷⁸ For the first westward exportation of China's sericulture, we may propose a *terminus*

⁷⁵Tetsuya Iizuka et al., 'Development a Long-Term Storage Method for Diapause Eggs in Some Hybrid Races of *Bombyx Mori*', *Journal of Insect Biotechnology and Sericology* 77 (2008): 69.

⁷⁶Wang San-ming, 'Silkworm Egg Production Volume III', *FAO Agricultural Services Bulletin* 73/3 (1989): 43–52; Tribhuvan Singh, *Principles and Techniques of Silkworm Seed Production* (New Delhi: Discovery Publishing House, 2010), 132–46.

⁷⁷Yin, 'Zhongguo gudai yangcan jishu', 57–8.

⁷⁸Yin, 'Zhongguo gudai yangcan jishu', 60–1; Zhu Lishuang, "'Yutian Guo Shouji" suo zai zaoqi Yutian wangtong yanjiu' ('The Early Imperial Lineage of Khotan According to the *Prophecy of the Li Country*'), in *Tansuo xiyou wenming: Wang Binghua xiansheng bashi huadan zhushou lunwenji* (In Search of the Civilization of the West: Essays Celebrating the Eightieth Birthday of Mr Wang Binghua), ed. Meng Xianshi and Zhu Yulin (Shanghai: Zhongxi Shuju, 2017), 207; Étienne de la Vaissière, 'Silk, Buddhism and Early Khotanese Chronology: A Note on the "Prophecy of the Li Country"', *Bulletin of the Asia Institute* 24 (2010): 86–7.

post quem of the second century BCE when the Silk Road emerged, and technology transfer between China and the kingdoms of the Tarim Basin became possible. In this case, the transfer of this sericulture from China to Khotan, with the possible intermediary of the Loulan Kingdom, must have taken place between the second century BCE and the third century CE. The interval roughly corresponds to China's Han Dynasty (202 BCE–220 CE) and the Three Kingdoms period (220–80). Despite the temporal gap of at least two centuries, the Chinese sericulture practice during this period resembled that of the sixth century described earlier. The cultivation of domesticated mulberry silkworms, consistently mentioned with moriculture in sources, dominated the sericulture. The whole process, including the hatching stage, was already taking place in a designated cocoonery that was expected to be well sealed.⁷⁹ Temperature's effect on the metamorphosis of silkworms was already acknowledged.⁸⁰ Although no specific record of fire-heating cocooneries survives to the present, later commentaries of sources from this period imply that the arrangement was typical.⁸¹ In other words, hatching silkworms were probably already warmed in cocooneries with fire. Concerning cocoon processing, to preserve the integrity of the cocoons, the typical procedure involved killing chrysalides, as in the sixth century. To achieve this, the prevalent method was to cook the cocoons in boiled water,⁸² although exposing them to sunlight was also resorted to.⁸³

With the above information in mind, the appropriations along the transmission route may be reconstructed as follows. Sometime between the second century BCE and the third century CE, Chinese sericulture reached Khotan either with or without the agency of the Loulan Kingdom. On the one hand, the Khotanese appropriated the dominant Chinese practice by eradicating silkworm killing in sericulture, a development possibly attributed to either the Buddhist influence or simply Khotanese ignorance of the advanced sericulture technique that involved killing silkworms.⁸⁴ The appropriated practice of Khotan then spread to cover the whole surrounding region. On the other hand, when sericulture was disseminated in the area, the Chinese heating method for hatching silkworm eggs, which might have included the application of fire in a sealed room, was replaced with dung use. Finally, in the mid-sixth century, the practice incorporating the features above was introduced from the region into Byzantium.

⁷⁹Cui Shi said: during the Qingming Festival in March, instruct the slave woman in charge of raising silkworms to prepare the cocoonery, filling the breaches . . . See: Jia, *Qimin Yaoshu*, 538. Cui Shi, the author of an agricultural manual, flourished in the second century.

⁸⁰Zhong Changtong mentioned in the *Righteous Words*: . . . regarding silkworms, making them cold and hungry would delay their metamorphosis, while warm and satiated would speed it up.' See: Li Fang et al., *Taiping Yulan (Readings of the Taiping Era)* (Beijing: Zhonghua Shuju, 2000), 3677. Zhong Changtong (180–220) was a political author who flourished in the late Eastern Han Dynasty. The *Righteous Words (Changyan)* is his signature piece.

⁸¹For example, Yan Shigu (581–645) comments on the *Book of Han (Hanshu)*: 'Silkworm raisers who wish to speed up the cultivation by adding heat would place them (silkworms) in a cocoonery heated by fire.' See: Ban Gu, *Hanshu* (Beijing: Zhonghua Shuju, 1999), 2011. Li Xian (655–84) comments on the *Book of the Later Han*: ' . . . to satisfy the need for warmth, a cellar heated by fire like a cocoonery was prepared . . . ' See: Fan, *Hou Hanshu*, 80.

⁸²'Cocoons become silk yarns after being reeled in boiled water.' Dong Zhongshu, *Chunqiu Fanlu Yizheng (Evidence on the Meaning of the Abundant Dew on the Spring and Autumn Annals)* (Beijing: Zhonghua Shuju, 1992), 312; 'Cocoon is, in essence, silk yarn, but it cannot convert to silk yarn without being cooked in boiled water and reeled by female artisans.' See: Liu An, *Huainanzi Jishi (Collected Explanations of the Huainanzi)* (Beijing: Zhonghua Shuju, 1998), 1387. A paraphrased version of the sentence also appears in Han Ying, *Hanshi Waizhuan Jishi (Collected Explanations of the Outer Commentary on the Han Poetry)* (Beijing: Zhonghua Shuju, 1980), 185.

⁸³'When a base person is in power, it feels like sleeping by the gate or being in a cocoon exposed to sunlight; not a moment of calmness can be secured.' See: Liu, *Huainanzi*, 710.

⁸⁴Yin, 'Zhongguo gudai yangcan jishu', 59; Tang Changru, 'Tulufan wenshu zhong suo jian sizhi shougongye jishu zai xiyou de chuan bo' ('The Spread of Silk Weaving Techniques in the West as Documented in the Turpan Texts'), *Chutu Wenwu Yanjiu* (1985): 147–8. However, Chinese Buddhists' standpoints on sericulture and silkworm killing could have been highly conflicted, see: Stuart H. Young, 'For a Compassionate Killing: Chinese Buddhism, Sericulture, and the Silkworm God *Aśvaghōṣa*', *Journal of Chinese Religions* 41 (2013): 39–40; Jennifer Eichman, *A Late Sixteenth-Century Chinese Buddhist Fellowship* (Leiden: Brill, 2016), 211.

The appropriated Byzantine sericulture practice

Having reconstructed the transregional phase of the transfer of sericulture into Byzantium, we now turn to the diachronic phase to explore how the imported sericulture was gradually appropriated in Byzantium. As noted earlier, the features Procopius and Theophanes described belonged to the Byzantine sericulture practice in its initial, unappropriated form in the mid-sixth century. Among the surviving records on Byzantine sericulture, two dated between the twelfth and the fourteenth centuries detailed the process: a commentary by Michael of Ephesus (fl. first half of the twelfth century) and two poems by Manuel Philes (c. 1275–1345).⁸⁵ As in the case of Procopius and Theophanes, the accounts of Michael and Manuel probably also reflect the sericulture around Constantinople.⁸⁶ Together, these records form a compelling reference point to show how the initial sericultural features were appropriated half a millennium later. As in our transregional examination, here we will also focus on hatching and cocoon processing procedures to build common grounds for comparison.

The most noteworthy feature of the Byzantine sericulture practice to remain consistent over the centuries may be the non-killing method. It allows the silkworms to naturally complete their life cycle into moths without killing them during the chrysalis stage and processing only the moth-pierced cocoons. As we have shown, the method is already indicated in the record of Theophanes. Later Byzantine authors also imply using the same process, confirming its persistence in Byzantine sericulture. Michael of Ephesus describes the procedures after the cocooning stage of silkworms as follows: '[the silkworms] create a cocoon around each of them . . . then the worm dies. And after some time, a moth comes out of the pierced cocoon, which resembles that which generated the worm, and it goes on like this indefinitely. For again from this moth, a worm is produced and from it a woollen cocoon and a moth, and again from this moth a worm, and in this way forever.'⁸⁷ Manuel Philes also makes the same point clear in one of his poems. He mentions that after the silkworm 'died' in the cocoon it completed, 'the perished one equipped itself with wings [i.e. became a moth] and returned from the burial [i.e. the cocoon] to the light again. For it flies away from the enclosure itself [i.e. the cocoon] and creates new eggs for the raiser after copulating with the other moth from the rump'.⁸⁸ Only the pierced cocoon, described by Manuel as 'the remaining house of resurrection', was used for the subsequent procedures.⁸⁹

In contrast, some sericultural features are no longer attested in the later records. This is most obvious in relation to the procedure of heating silkworm eggs for hatching. Procopius mentions the use of dung for this procedure. However, later authors leave no comparable records. Michael of Ephesus describes the hatching stage as follows: 'The women whose job is to produce the silk collect [the eggs] and warm [them] by putting [them] at their breasts, until [the eggs] acquire sensation and become animals.'⁹⁰ Meanwhile, Manuel Philes states that the silkworm eggs 'were kept warm with fire, in a linen fabric, a leather case, or [women's] breasts'.⁹¹ Both Michael and Manuel mention heating the eggs with women's breasts, suggesting that it may have been the

⁸⁵Michael of Ephesus, *Ioannis Philoponi (Michaelis Ephesii) in libros de generatione animalium commentaria*, ed. Michael Hayduck (Berlin: Reimer, 1903), 153–4; Manuel Philes, *Poetae bucolici et didactici*, ed. Franz S. Lehrs and Friedrich Dübner (Paris: A. Firmin Didot, 1862), 65–7. There are other informative Byzantine textual accounts of sericulture, but they are not detailed enough for our comparative purposes. For example, see: George of Pisidia, *Carmi di Giorgio di Pisidia*, ed. and trans. L. Tartaglia. (Turin: Unione tipografico-editrice torinese, 1998), 386–8; A. Papadopoulos-Kerameus, 'Ioannes Apokaukos kai Niketas Choniates' ('John Apokaukos and Niketas Choniates'), in *Tessarakontaeteris tes kathegesias K. S. Kontou (Fortieth Anniversary of the Professorship of K. S. Kontos)* (Athens: Τύποις Π. Δ. Σακελλαρίου, 1909), 377–9.

⁸⁶Michael of Ephesus and Manuel Philes both pursued their careers in Constantinople, see Alexander Kazhdan et al., eds., *The Oxford Dictionary of Byzantium* (Oxford: Oxford University Press, 1991), s.vv. 'Michael of Ephesus'; 'Philes, Manuel'. For accounts of sericulture from the province, see: Papadopoulos-Kerameus, 'Ioannes Apokaukos', 377–9.

⁸⁷Michael of Ephesus, *Ioannis Philoponi*, 154.

⁸⁸Philes, *Poetae*, 67.

⁸⁹*Ibid.*

⁹⁰Michael of Ephesus, *Ioannis Philoponi*, 154.

⁹¹Philes, *Poetae*, 65.

prevailing method for this procedure in the later period. Those involving fire, linen, and leather clothes also seem to have been common according to Manuel. That the use of dung escapes Manuel's detailed list of heating methods suggests that it might have been abandoned by his time.

This comparison between sericultural features noted in the early and later Byzantine sources completes our reconstruction. It sheds light on how the sericulture practice of Khotan or its adjacent zones was appropriated after reaching Byzantium. Although the local conditions of Byzantium did not seem to affect the adoption of the non-killing method, the methods for warming silkworm eggs were probably transformed by the increasing use of body heat from women's breasts replacing the recourse to dung.

Conclusion

The evidence available for the study of the medieval transfer and development of sericulture is limited, especially in the case of Byzantium where non-textual materials are hardly applicable, and while textual records are patchy in their coverage. This article's analytical framework allows us, nevertheless, to produce a credible account of this history in broad outline. Interpreting the transfer of sericulture into Byzantium as a stadial process of appropriation rather than a one-off event offers a more compelling rationalisation of the available evidence. From a transregional perspective, the original Chinese practice - which involved hatching silkworms in sealed cocooneries (possibly heated by fire) and reeling after having killed them - passed through various intermediaries in its westward dissemination and in that journey incorporated local characteristics at each stage. Before reaching Byzantium, the sericulture practice was appropriated by the residents of the area around Khotan via the use of dung heating in hatching and the non-killing method. Sericulture practice gradually acquired its specifically Byzantine features in a comparable process of appropriation, albeit diachronic, after its transfer into Byzantium. As detailed above, while the non-killing method was retained, heating silkworm eggs using women's breasts became the dominant practice at the hatching stage.

Our reconstruction has broader implications for research. Combining both transregional and diachronic dimensions, the approach of this article provides a template for how to investigate the global transfer of technology in the premodern world for which evidence is generally exiguous. Our approach is governed by the notion that every step of appropriation has to be clarified in order to identify the actual dynamics of the transfer. From the transregional viewpoint, this means that the most significant developments may not have taken place at the two ends of the transmission route but at the intermediary stages. In the Byzantine case, it is most likely on the balance of the evidence that the decisive local appropriation in the transfer happened not in Byzantium, nor in China, but rather in Khotan. The introduction by the Khotanese of the non-killing method, which the Byzantines later embraced, could well have been the decisive step in the whole transfer, profoundly shaping the subsequent nature and course of the Byzantine silk industry. This method substantially increased the cost of silk production, necessitating more investment of time and generating a lower yield. More importantly, the resulting pierced cocoons were unreelable and had to be spun. This procedure was much more labour-intensive and generated rough, uneven silk of inferior quality.⁹² Such limitations inherent to this particular sericulture practice highlight the historical questions unaddressed by any model portraying technological transfer as a one-off event. The high cost and poor output this practice entailed could explain why sericulture seems to have remained poorly developed long after its introduction,⁹³ while the empire continuously

⁹²Ivana Markova, *Textile Fiber Microscopy: A Practical Approach* (Hoboken: Wiley, 2019), 69–71; Datta and Nanavaty, *Global Silk Industry*, 142.

⁹³See note 9.

relied on imported silk.⁹⁴ This observation finds support in a recent study of a collection of Mediterranean and Near East patterned silk textiles manufactured between c. 600–1300, whose percentage of spun silk yarn is very small compared to that of reeled silk.⁹⁵ If that is indicative of high-end silk products from Byzantium, the use of silk from local sericulture must have been extremely limited compared with imported reeled silk in the manufacture of such textiles. In keeping with the narrative presented in this article, it is plausible that the above characteristics of the Byzantine silk industry have their proximate roots in Khotan.

Gang Wu is an assistant professor in the Department of History at Fudan University. He received his doctoral degree in Byzantine Studies from King's College London in 2020. He was a postdoctoral fellow at Koç University's Research Center for Anatolian Civilizations (ANAMED) between 2020 and 2021. His current research interests focus on Byzantine women and the silk industry.

⁹⁴See note 1. Claudio Zanier also notes the possibility that the development of Byzantine sericulture was hindered by the poor quality of its yield, see Zanier, 'The Silk Cycle', 18.

⁹⁵Galliker, 'Middle Byzantine Silk in Context', 178, 254.