Following a Thread

Tracing technology and techniques along the Silk Road

Vol. II/II

Gwendoline M.F. Pepper
PhD
University of York
Archaeology
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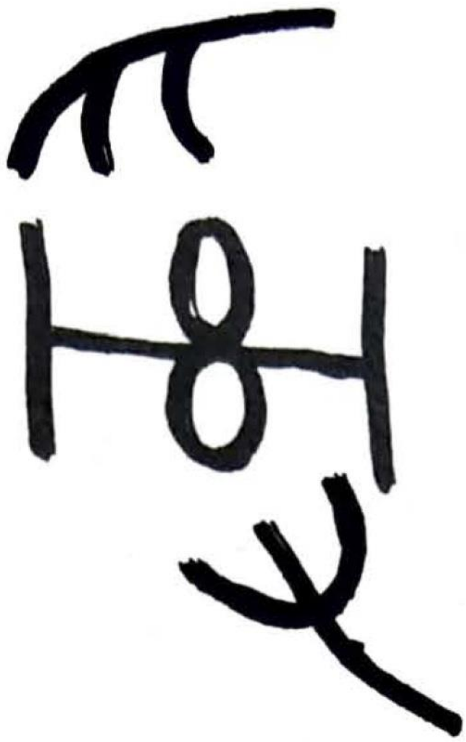
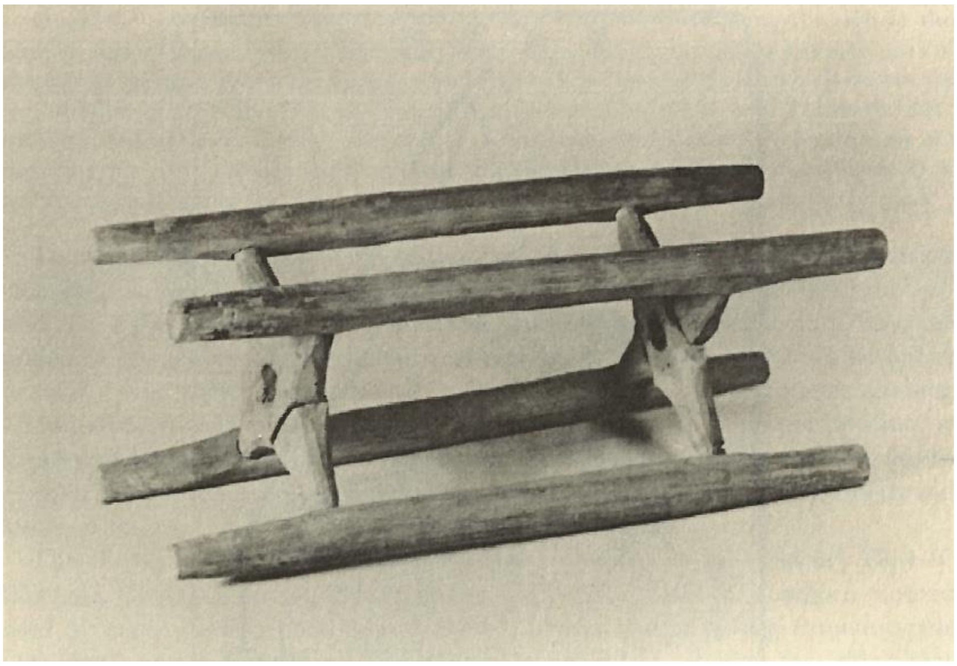
Appendix A Silk Reeling Equipment Catalogue

This catalogue was assembled during a comparative survey of surviving depictions of silk reeling equipment relevant to the mediaeval silk trade. The included images were primarily created in China, Japan, and Europe with a date range of c. 1600 BCE-1820 CE. Extending the scope of the catalogue beyond the European Middle Ages (c. 5th-late 15th centuries CE) has allowed for the inclusion of post-medieval artworks which have been referenced by other authors in relation to the mediaeval silk trade, and images of silk reels that merit comparison with equipment known to date to the Middle Ages. Where appropriate some images have been cropped to highlight the reeling device, or an additional detail view has been included for the sake of clarity.

Images of reeling and throwing equipment were, wherever possible downloaded under a Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International licence (CC BY-NC-SA 4.0) directly from the digital collection of the museum, library, or archive that houses each primary source.



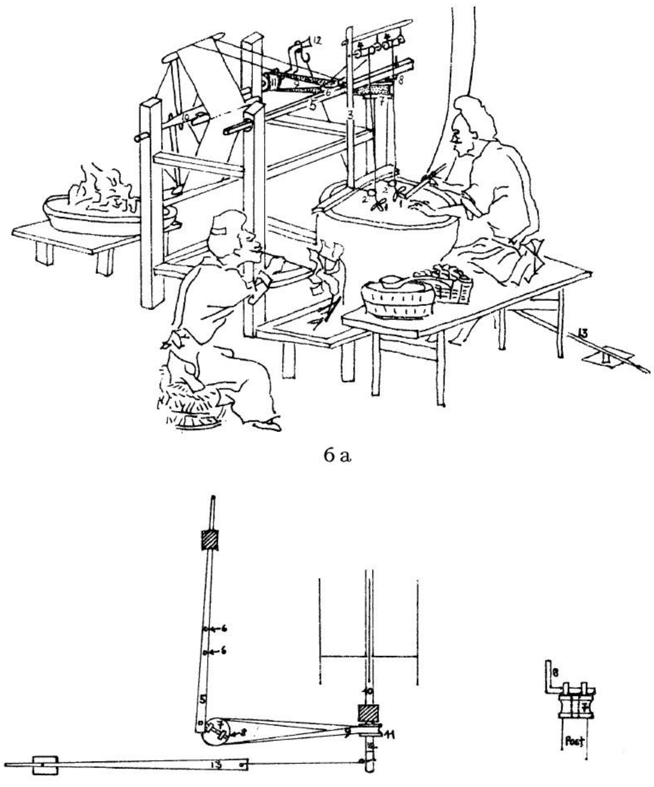
1.
Date: Original: Shang Dynasty (c. 1600 BCE-1046 BCE), Drawing: c. 1925
Medium: Original: Bronze, Copy: Drawing
Artist/area of production: Shang China, region unspecified
Source/collection: Kuhn 1988, p.347 (reproduced from 1959 edition of the *Jinwen Bian* compiled by Rong Geng)



2. **Date:** Jin Dynasty (c. 265-420 CE)
   Medium: Wood
   Artist/area of production: Found in the Xinjiang, specific area unspecified
   Source/collection: Picture in Kuhn 1988, p.173

3. **Date:** Early 1200s (Southern Song Dynasty)
   Medium: Ink and colour on silk
   Artist/area of production: Attributed to Liang Kai, China
   Source/collection: The Cleveland Museum of Art, [https://www.clevelandart.org/art/1977.5]

3a. **Description:** Detail of Cat. 3 depicting cocoon sorting, weighing, storage, and reeling



6 a

6 b   6 c

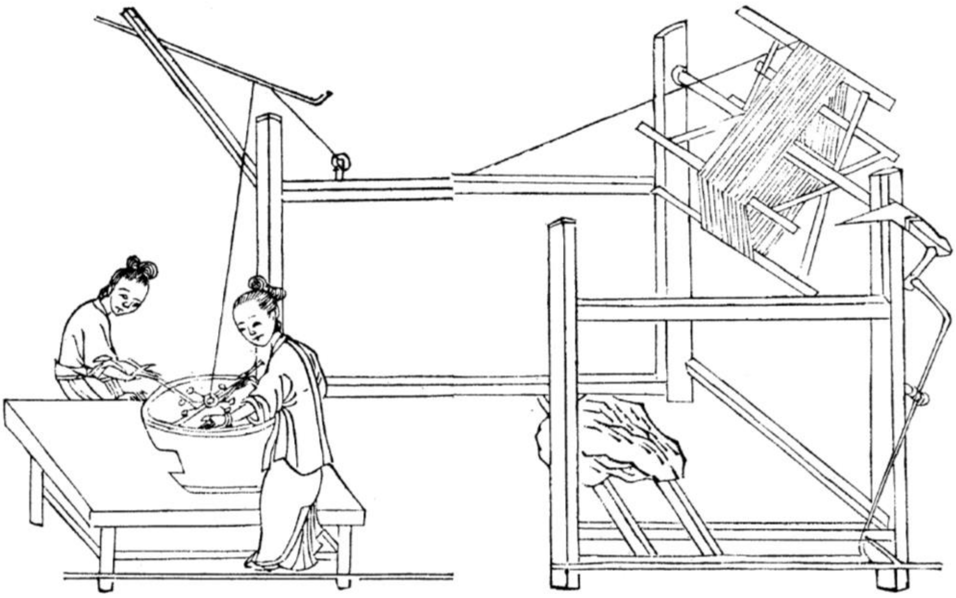
Fig. 6 Reconstruction of the Silk-reeling Machine from Sung Times.
A. The Structural and Functional Parts.
B. The Functional Parts.
C. The Pulley and the Eccentric Lug.
1 Cocoon-assemblies 2 Guiding-eyes 3 Rollerframe 4 Rollers 5 Ramping-board 6 Hooks 7 Pulley 8 Eccentric Lug 9 Driving-belt 10 Axle of the Silk-reel 11 Crank-case 12 Crank 13 Treadle

4. **Date:** c. 1981

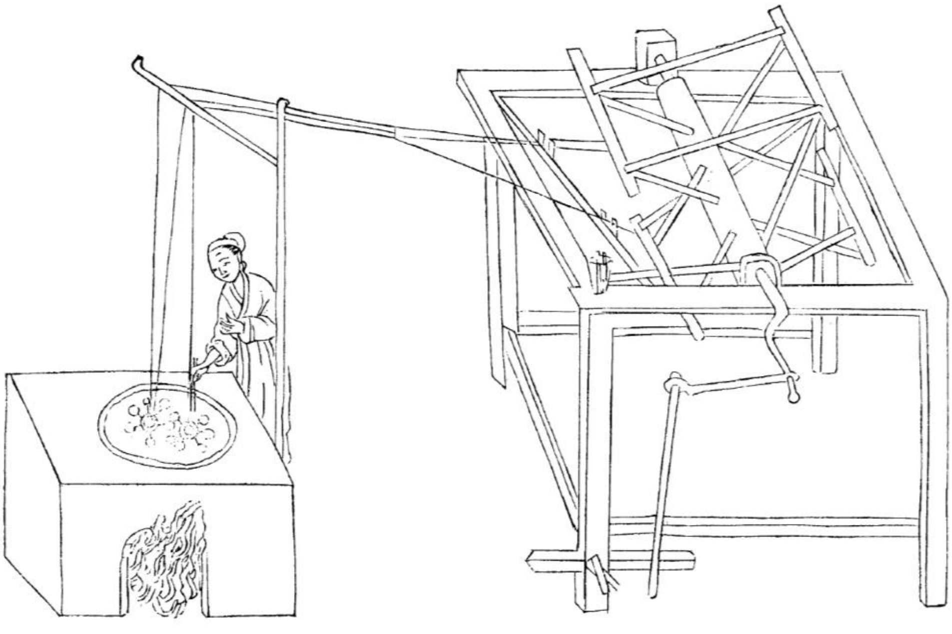
Medium: Drawing
Artist/area of production: (uncredited)
Source/collection: Kuhn 1981, p.73

Fig. 4.6 The silk reeling in *Silkworm Weaving Pictures* (in Empress Wu's annotated edition of the Southern Song Dynasty, Heilongjiang Provincial Museum)

5. **Date:** Southern Song dynasty (1127-1279CE)
   Medium: ?Ink
   Artist/area of production: Empress Wu, China
   Source/collection: Heilongjiang Provincial Museum, imag from Zhao & Liu 2020, 43



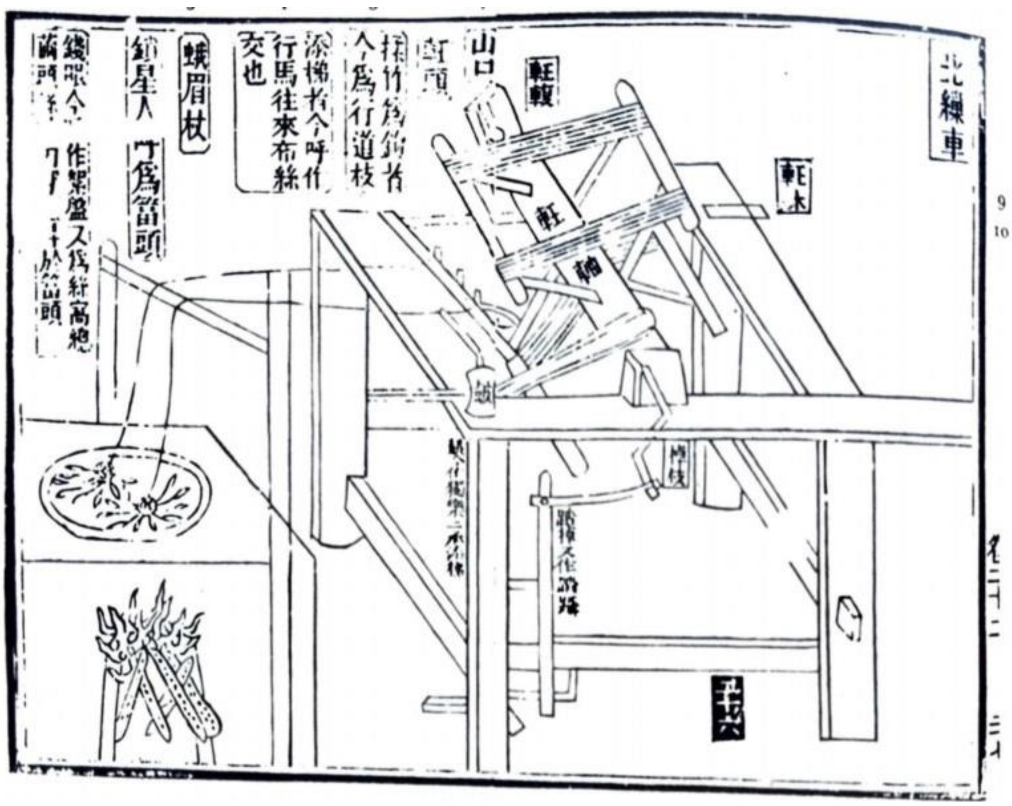
6. **Date:** Unknown (after 1313)
   Medium: Woodblock print
   Artist/area of production: Unknown, China
   Source/collection: From the *Nong Shu* by Wang Zhen (c. 1313), unspecified edition; Kuhn 1981, p.66



7. **Date:** Unknown (after 1313)
   Medium: Woodblock print
   Artist/area of production: Unknown, China
   Source/collection: From the *Nong Shu* by Wang Zhen (c. 1313), unspecified edition; Kuhn 1981, p.66

8. **Date:** c. 1440
   Medium: Miniature detail, illuminated manuscript
   Artist/area of production: The Talbot Master, Rouen, France
   Source/collection: *Le livre de femmes nobles et renomées* (Royal 16 G V f. 54v), The British Library
   Note: This image was downloaded from the British Library's online catalogue in 2020. Following a series of cyber-attacks this online collection is no longer accessible.

9. **Date:** 1530
   Medium: Woodblock print
   Artist/area of production: Unknown, China
   Source/collection: From the 1530 edition of the *Nong Shu*, originally published in 1313 CE; in Kuhn 1988, p.363



10. **Date:** 1530

Medium: Woodblock print

Artist/area of production: Unknown, China

Source/collection: From the 1530 edition of the *Nong Shu*, originally published in 1313 CE; in Kuhn 1988, p.368

11. **Date:** c.1586

Medium: pen and ink/brush and ink drawings

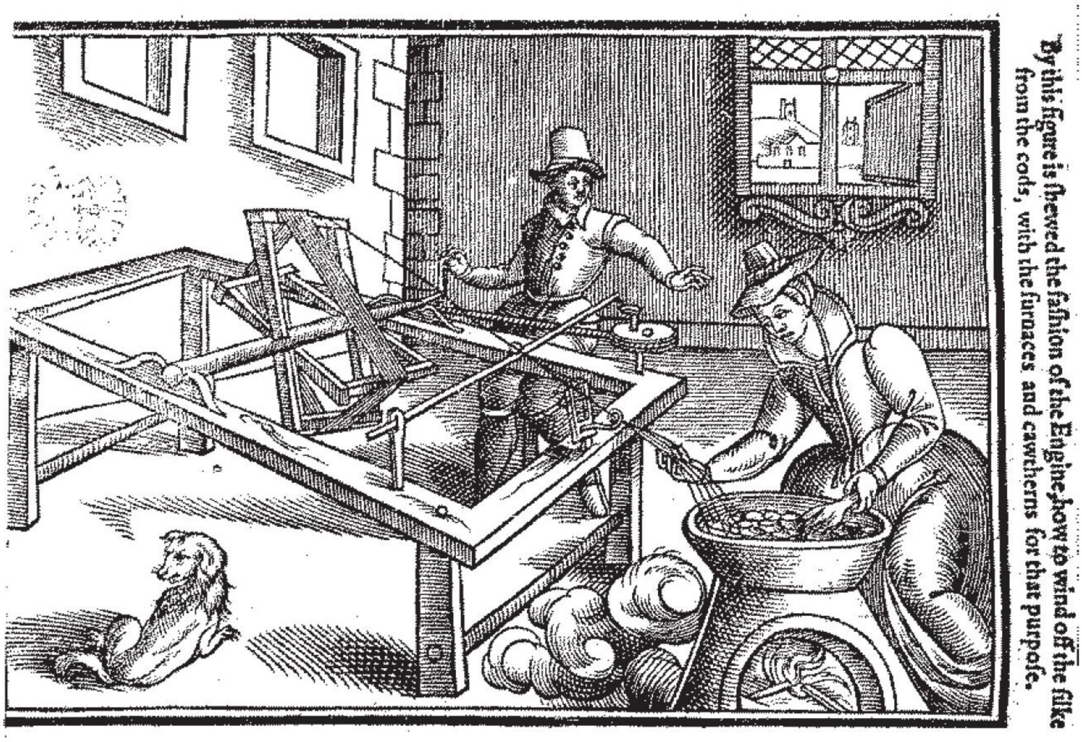
Artist/area of production: Giuseppe Arcimboldo (Italian), Prague, Czech Republic

Source/collection: Museum of Fine Arts, Boston,

Accessed: [https://collections.mfa.org/objects/253925/treatise-on-silk-culture-and-manufacture?ctx=8ef95a3e-3562-4288-80b1-e38f219b6806&idx=2]

12. **Date:** c.1586
Medium: pen and ink/brush and ink drawings
Artist/area of production: Giuseppe Arcimboldo (Italian), Prague, Czech Republic
Source/collection: Museum of Fine Arts, Boston, [https://collections.mfa.org/objects/253925/treatise-on-silk-culture-and-manufacture?ctx=8ef95a3e-3562-4288-80b1-e38f219b6806&idx=2]

13. **Date:** 1595 CE
Medium: Engraving
Artist/area of production: Karel van Mallery, Netherlands
Source/collection: Plate 6 of *Vermis Sericus*, The Metropolitan Museum of Art, New York
[https://www.metmuseum.org/art/collection/search/659745]



14. **Date:** 1607

Medium: Woodblock print

Artist/area of production: Unknown, England or France

Source/collection: *The perfect use of silke-worms and their benefit*, Translated by Nicholas Geffe from the original french by Olivier de Serres

15. **Date:** c. 1607 CE
Medium: woodblock print
Artist/area of production: Anonymous, China
Source/collection: *Bian yong xue hai qun yu*; Needham and Kuhn 1988, p.349

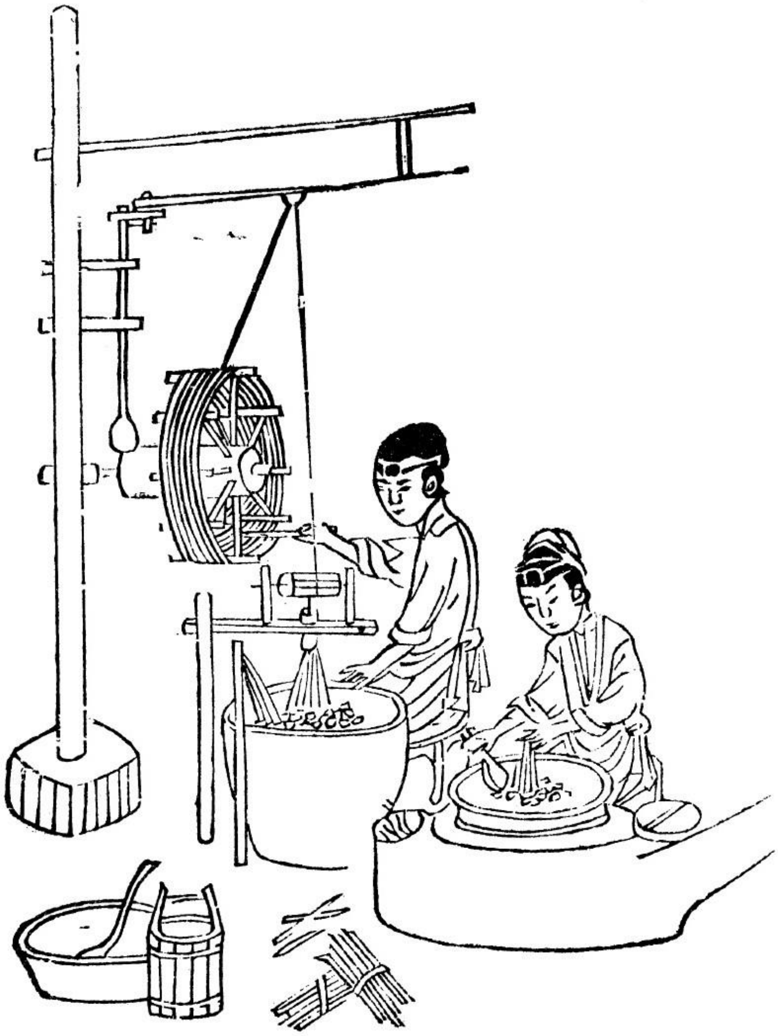
16. **Date:** 1637
Medium: Woodblock print
Artist/area of production: China
Source/collection: *Tiangong Kaiwu* (Also written *T'ien-kung k'ai-wu*); Golas 2015, p.117

17. **Date:**1696

Medium: Woodblock print, painted colour

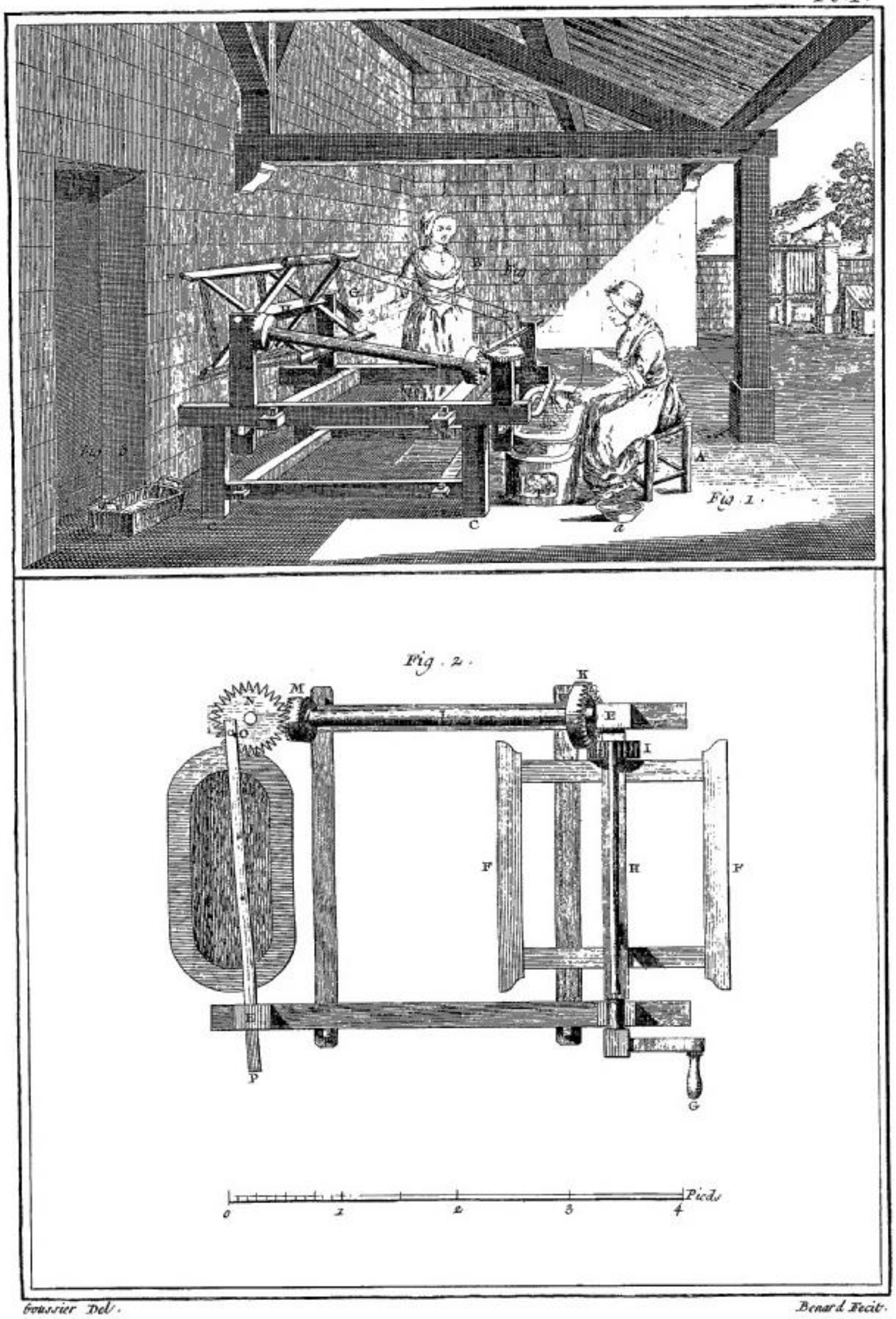
Artist/area of production: Zhu Gui (block cutter, attributed) and Jiao Bingzhen (painter)

Source/collection: *Yuzhi gengzhi tu,* The British Museum, 1949,0709,0.1



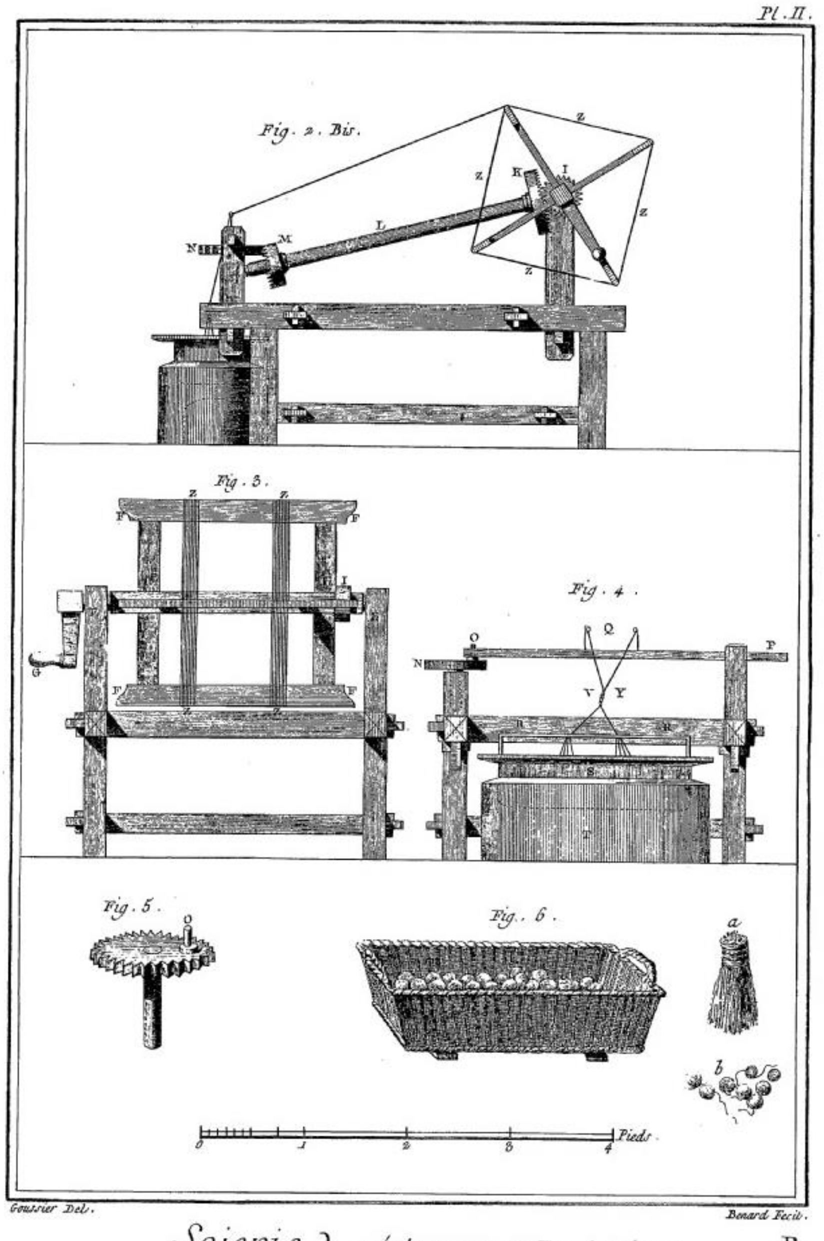
18. **Date:** 1742
Medium: Woodblock print
Artist/area of production: China
Source/collection: *Bin feng guang yi*; in Kuhn 1988, p.380

Pl. I.

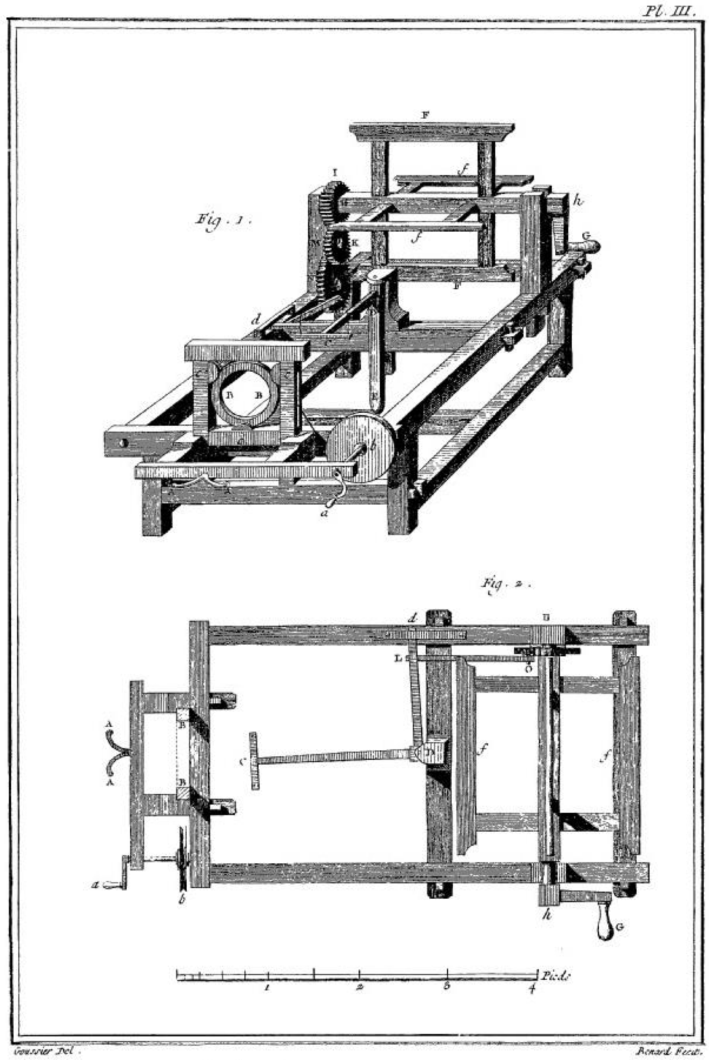


Soierie, Tirage de la Soie et Plan du Tour de Piémont. A

19. a) **Date:** 1751
Medium: Engraving
Artist/area of production: Louis-Jacques Goussier, France
Source/collection: *L'art de la soie*, by Diderot and D'alembert, Plate I

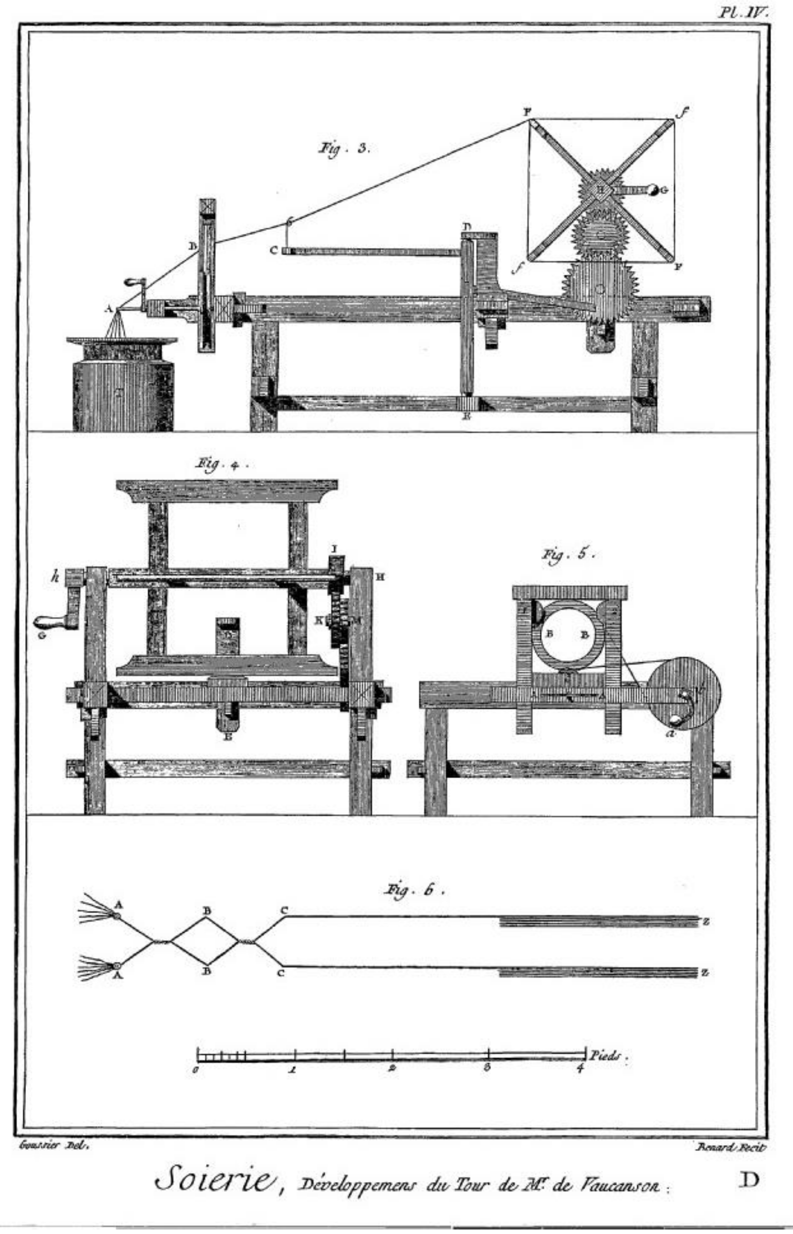


19.b) **Date:** 1751
Medium: Engraving
Artist/area of production: Louis-Jacques Goussier, France
Source/collection: *L'art de la soie*, by Diderot and D'alembert, Plate II

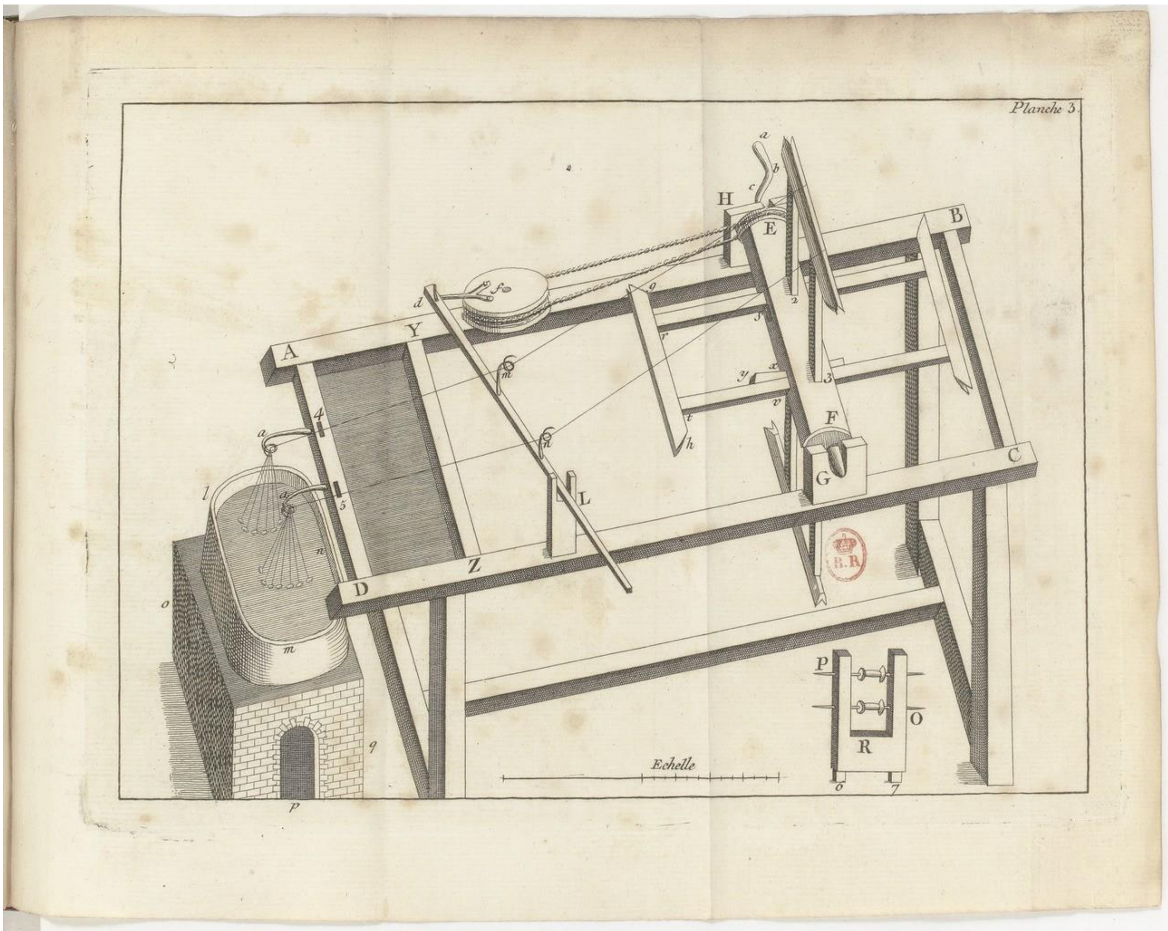


Soierie, *Tour de Mr. de Vaucanson*

20. a) **Date:** 1751
Medium: Engraving
Artist/area of production: Louis-Jacques Goussier, France
Source/collection: *L'encyclopédie Diderot & D'alembert: L'art de la soie,* Plate III

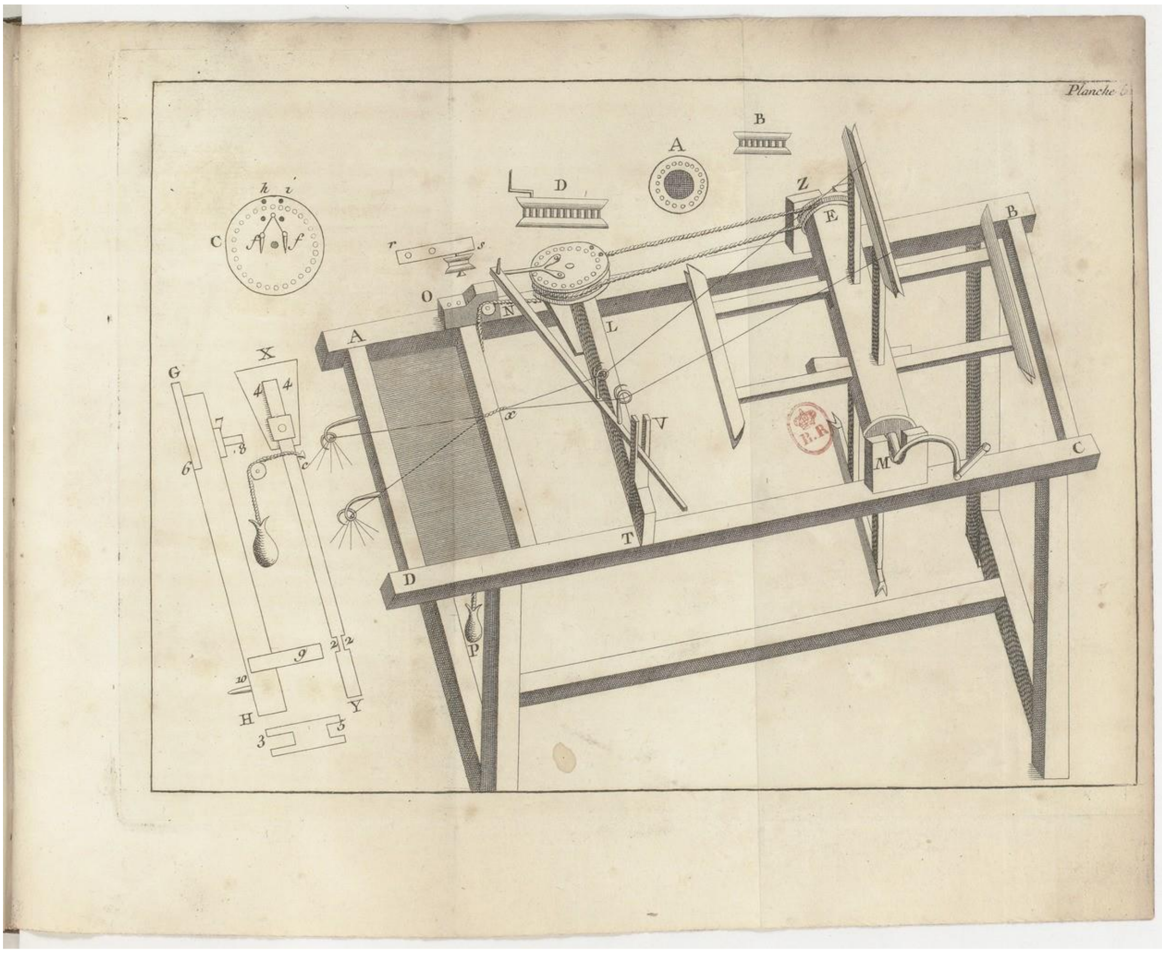


20. b) a) **Date:** 1751
Medium: Engraving
Artist/area of production: Louis-Jacques Goussier, France
Source/collection: *L'encyclopédie Diderot & D'alembert: L'art de la soie*, Plate IV



Source gallica.bnf.fr / Bibliothèque nationale de France

21. **Date:** 1754
Medium: Engraving
Artist/area of production: Unknown, France
Source/collection: Pomier, L (1754). *L'art de cultiver les muriers-blancs, délever les vers a soye et de tirer la soye des cocons avec figures*



Source gallica.bnf.fr / Bibliothèque nationale de France

22. **Date:** 1754

Medium: Engraving

Artist/area of production: Unknown, France

Source/collection: Pomier, L (1754). *L'art de cultiver les muriers-blancs, délever les vers a soye et de tirer la soye des cocons avec figures*

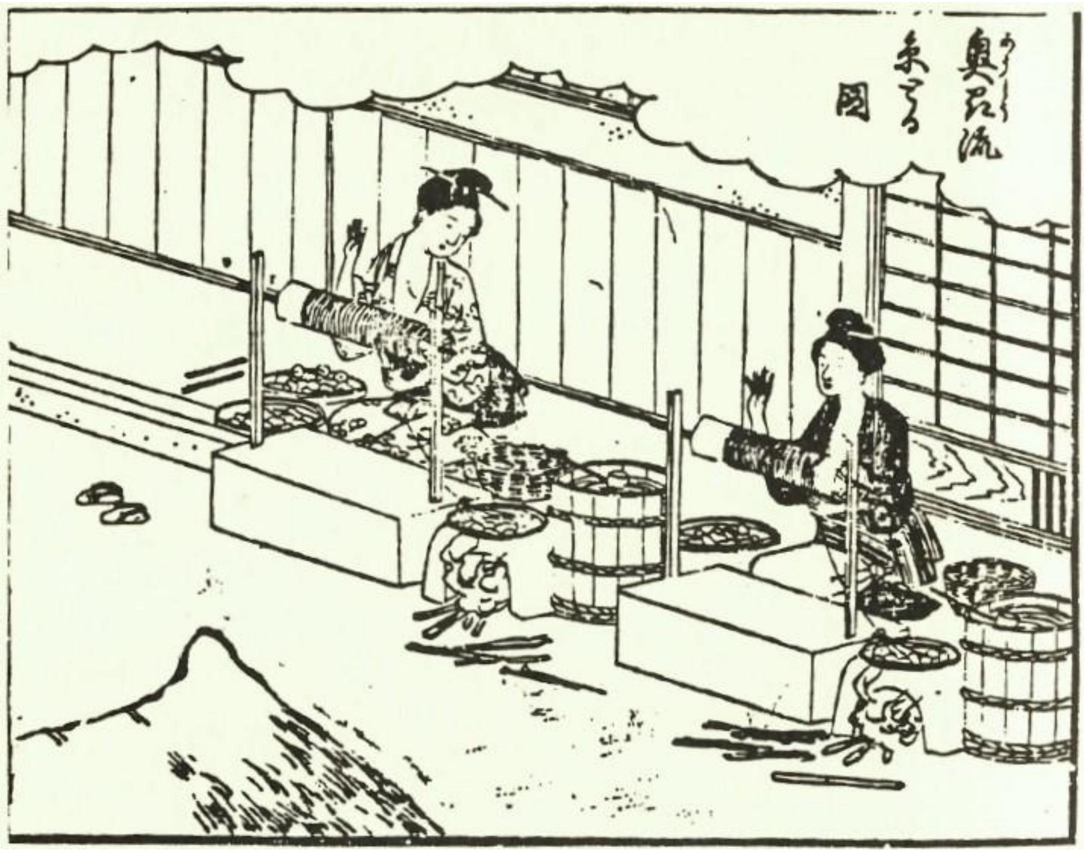
23. **Date:** 1790
Medium: Ink and colour on silk
Artist/area of production: Katsushika Hokusai, Japan (Tokyo)
Source/collection: The Metropolitan Museum of New York [https://www.metmuseum.org/art/collection/search/45822?searchField=All&sortBy=Relevance&ao=on&ft=silk&offset=440&rpp=20&pos=452]

24. **Date:** 1739-1820

Medium: Woodblock print on paper

Artist/area of production: Kitao Shigemasa, Japan

Source/collection: The British Museum [https://www.britishmuseum.org/collection/object/A_1908-0718-0-9]

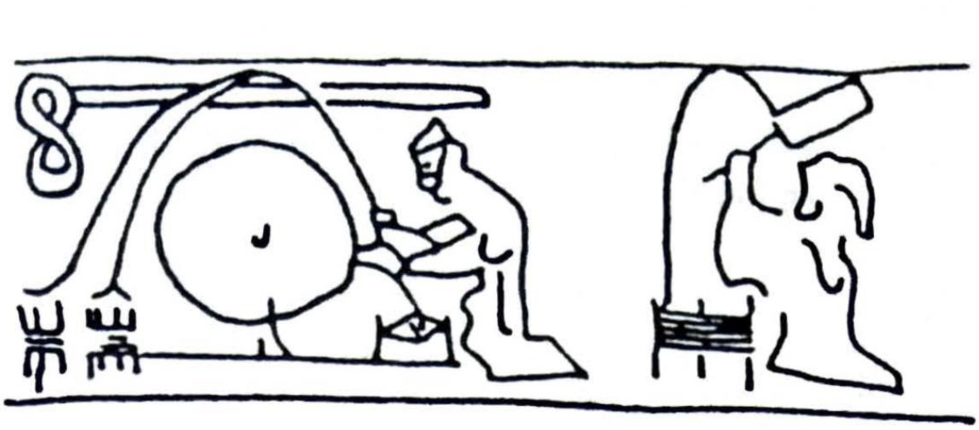


25. **Date:** 1803
Medium: Woodblock print(?)
Artist/area of production: Morikuni Kamigaki, Oshu, Japan
Source/collection: *Yosan Hiroku*; Needham and Kuhn 1988, p.350

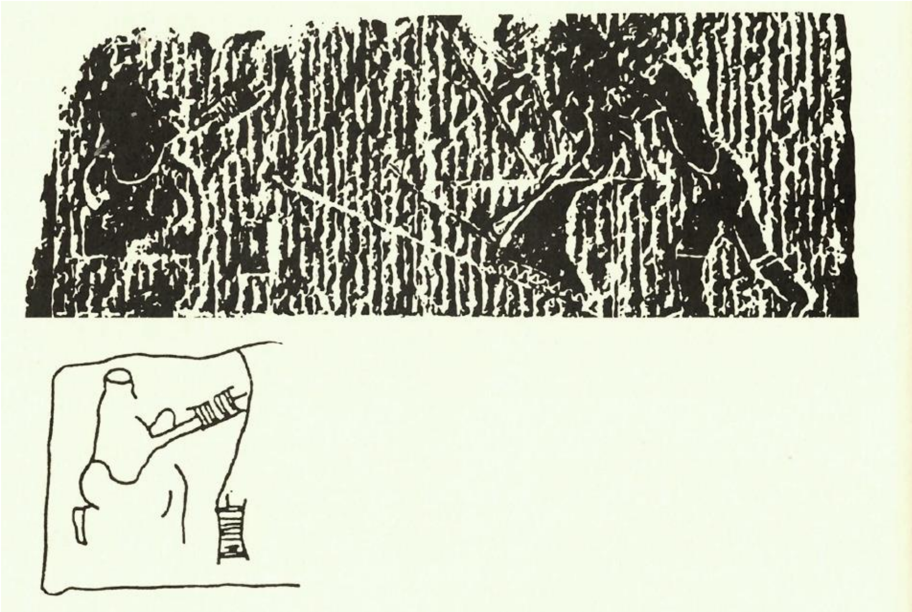
26. **Date:** c. 1815 CE
Medium: Woodblock print(?)
Artist/area of production: Unknown, Japan
Source/collection: *Kogai Kinu Furui Taisei*; Needham and Kuhn 1988, p.351

Appendix B Silk Processing Equipment Catalogue

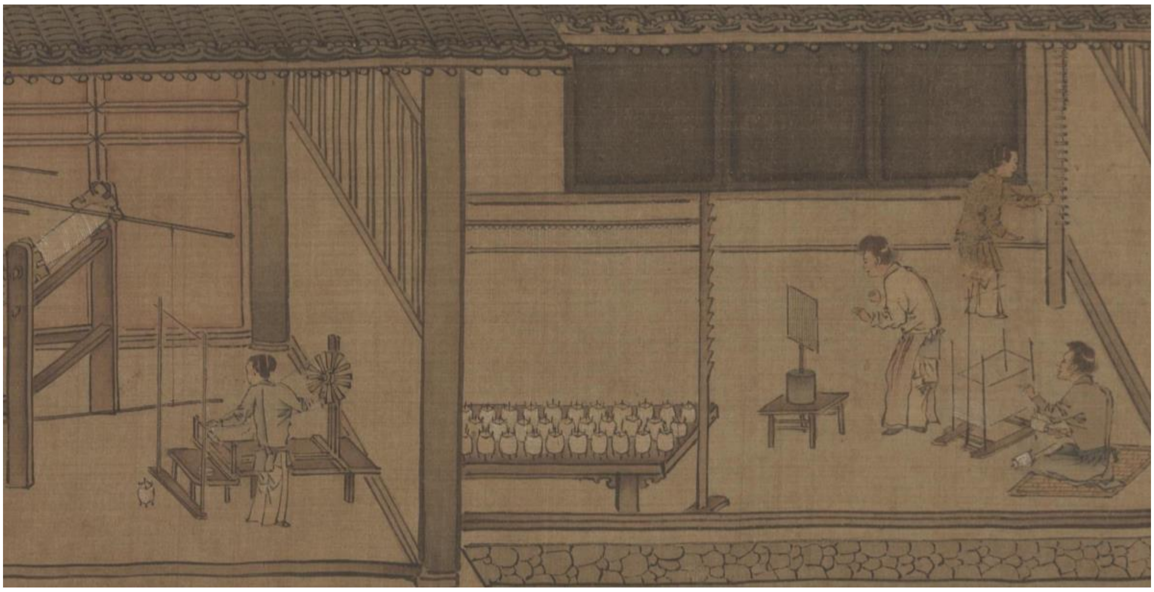
As described in Chapter 2, the process of creating silk yarn and thread is not typically completed at the reeling stage. There are a variety of tools that may be used to process raw reeled silk into yarn or thread, some of these tools appear to only be used in association with silk production, but many are multi-functional tools that are known to have been used in association with other fibres. This catalogue is a collection of images of equipment that is either firmly associated with silk production, or, particularly in the case of mediaeval European examples, which, although commonly used in association with other fibres such as wool, may have been applicable to use in silk production.



1. **Date:** Original: Han dynasty (c. 206 BCE-220CE), Drawing: c. 1979
   Medium: Original: Stone-relief, Copy: Drawing
   Artist/area of production: Tengxian, Shandong, China
   Source/collection: Kuhn 1988, p.161



2. **Date:** Original: Han (c. 206 BCE-220CE) Drawing: c. 1988
   Medium: Original: Stone relief, Copy: Drawing
   Artist/area of production: China (unspecified region)
   Source/collection: Kuhn 1988, p.170



3. **Date:** Early 1200s (Southern Song Dynasty)
   Medium: Ink and colour on silk
   Artist/area of production: Attributed to Liang Kai, China
   Source/collection: The Cleveland Museum of Art, [https://www.clevelandart.org/art/1977.5]
   Description: Detail of Reeling Cat. 3 depicting silk throwing, warp preparation, and (probable) bobbin winding

4. **Date:** 1st quarter of the 14th century
   Medium: Illuminated manuscript
   Artist/area of production: Anonymous, The Netherlands
   Source/collection: British Library Stowe MS 17 f.91v
   Note: This image was downloaded from the British Library's online catalogue in 2020. Following a series of cyber-attacks this online collection is no longer accessible.

5. **Date:** 1st quarter of the 14th century
   Medium: Illuminated manuscript
   Artist/area of production: Anonymous, The Netherlands
   Source/collection: British Library Stowe MS 17 f.92r
   Note: This image was downloaded from the British Library's online catalogue in 2020. Following a series of cyber-attacks this online collection is no longer accessible.

6. **Date:** c.1300-c.1340
   Medium: Illuminated manuscript
   Artist/area of production: London (Historiated Borders)
   Source/collection: British Library, Royal MS 10 E IV, f.137r
   Note: This image was downloaded from the British Library's online catalogue in 2020. Following a series of cyber-attacks this online collection is no longer accessible.

7. **Date:** c.1300-c.1340
   Medium: Illuminated manuscript
   Artist/area of production: London (Historiated Borders)
   Source/collection: British Library, Royal MS 10 E IV, f.139r
   Note: This image was downloaded from the British Library's online catalogue in 2020. Following a series of cyber-attacks this online collection is no longer accessible.

8. **Date:** c.1300-c.1340

Medium: Illuminated manuscript
Artist/area of production: London (Historiated Borders)
Source/collection: British Library, Royal MS 10 E IV, f.139r
Description: Unusual scene of a man spinning with a great wheel. According to the British Library, this is part of a series of scenes along the theme "A housewife sets tasks for her husband or lover." with the note that it may be a variant of The Wright's Chaste Wife.
Note: This image was downloaded from the British Library's online catalogue in 2020. Following a series of cyber-attacks this online collection is no longer accessible.

9. **Date:** 1325-1340
Medium: Illuminated manuscript
Artist/area of production: England
Source/collection: British Library Luttrell Psalter MS 42130 f.193r
Note: This image was downloaded from the British Library's online catalogue in 2020. Following a series of cyber-attacks this online collection is no longer accessible.

10. **Date:** 1409
Medium: oil-egg tempera and gilding on pine
Artist/area of production: Hungary (or Austria?)
Source/collection: Hungarian National Gallery
[https://en.mng.hu/artworks/maria-gravida-fragment-of-a-panel-from-nemetujvar-today-gussing-austria/]

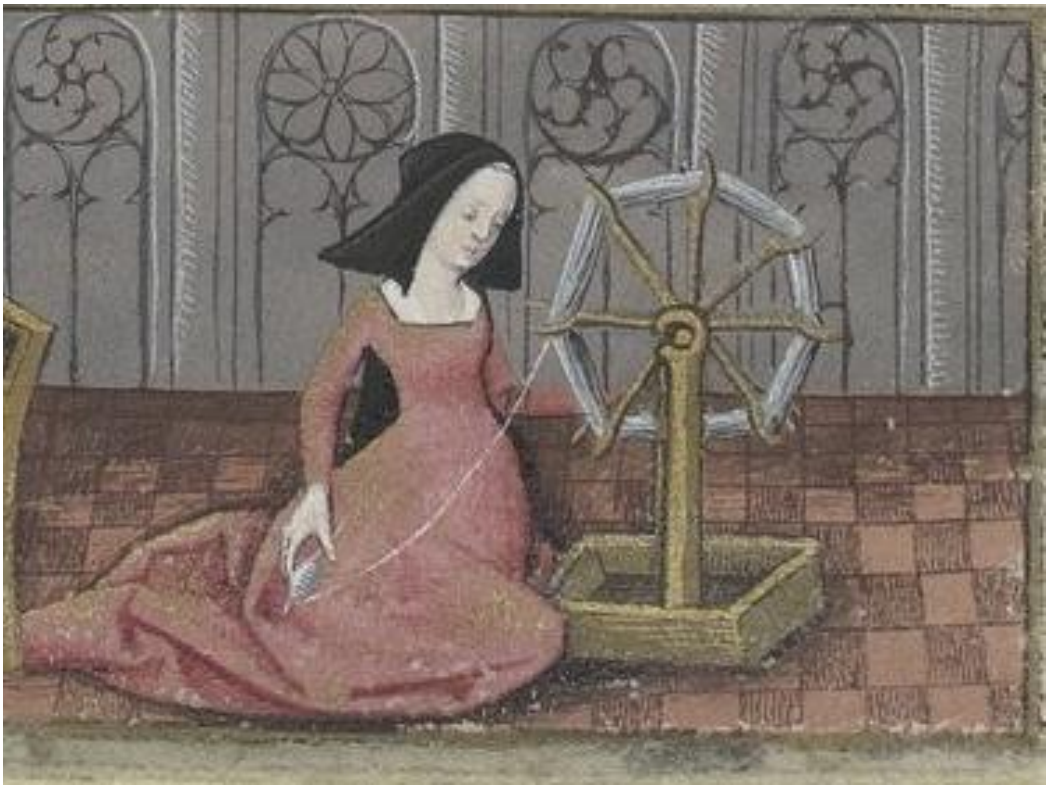
11. **Date:** c. 1475
Medium: Illuminated Manuscript
Artist/area of production: Maïtre François, Paris, France
Source/collection: National Library of the Netherlands [https://manuscripts.kb.nl/search/manuscript/extended/page/1/shelfmark/10+A+11]
Description: 240. The Hague, MMW, 10 A 11 fol. 235r

12. **Date:** 1488-1496

Medium:15th century swift from an anonymous French translation of Giovanni Boccaccio's *De mulieribus claris*

Artist/area of production: Robinet Testard, France

Source/collection: Bibliothèque nationale de France/Gallica [https://gallica.bnf.fr/ark:/12148/btv1b10515437z/f162.item#]

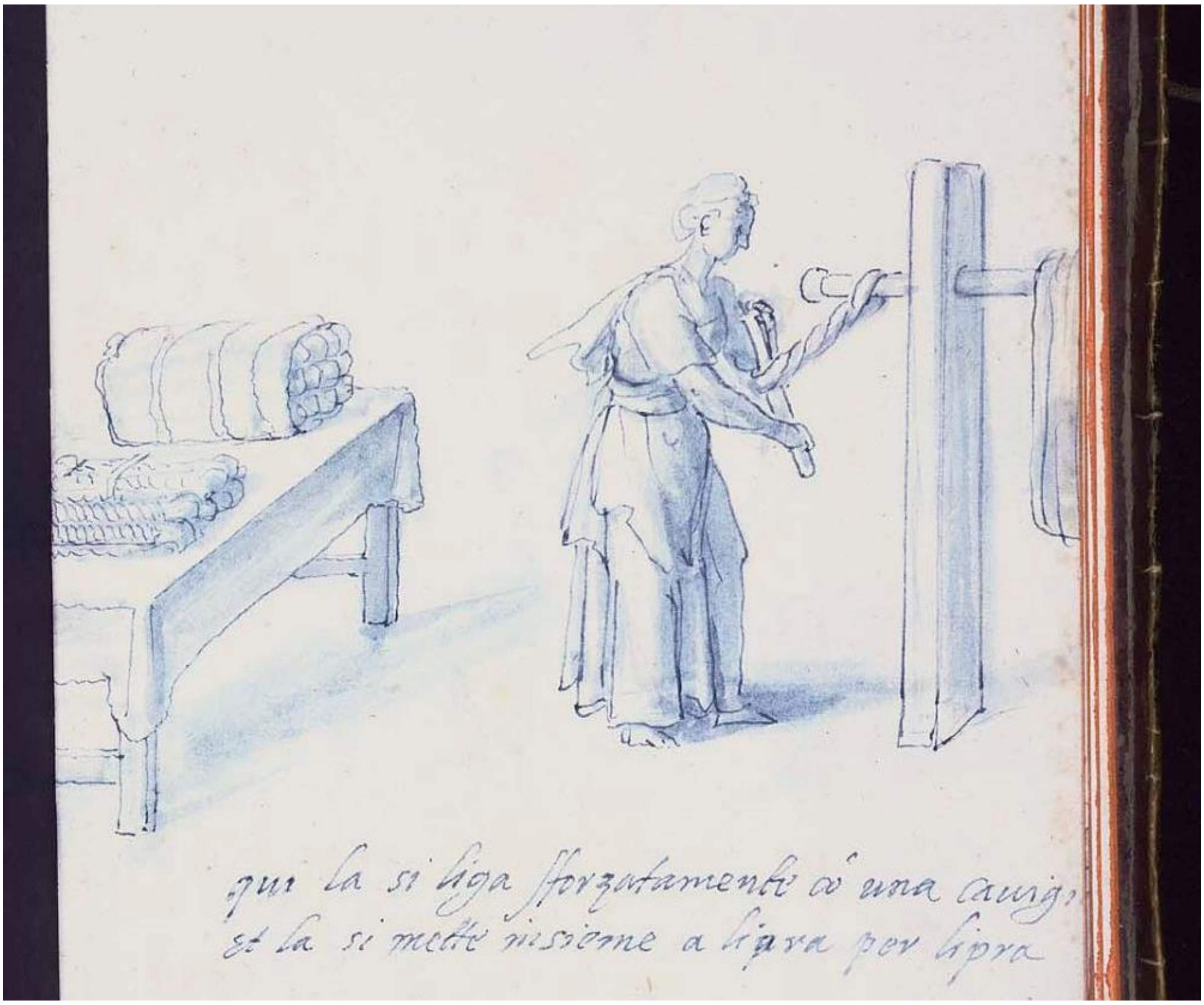


13. **Date:** 15th century
Medium: Illuminated manuscript
Artist/area of production: Jean Bourdichon and/or Robinet Testard, France
Source/collection: Horae ad usum Parisiensem, Bibliothèque nationale de France/ Gallica [https://gallica.bnf.fr/ark:/12148/btv1b8432895r/f12.item#]

14. **Date:** 1401-1500
Medium: Illuminated manuscript
Artist/area of production: France
Source/collection: Le livre appellé Decameron… Bibliothèque nationale de France/Gallica [https://gallica.bnf.fr/ark:/12148/btv1b7100018t/f181.item#]

15. **Date:** 1401-1500
Medium: Illuminated Manuscript
Artist/area of production:
Source/collection: Bibliothèque nationale de France/Gallica [https://gallica.bnf.fr/ark:/12148/btv1b52502614h/f185.item#]

16. **Date:** 15th century
Medium: Illuminated Manuscript
Artist/area of production: ?Anonymous, Holland, probably Windesheim
Source/collection: Edinburgh university library MS 33 f.1r



17. **Date:** c.1586

Medium: pen and ink/brush and ink drawings

Artist/area of production: Giuseppe Arcimboldo (Italian), Prague, Czech Republic

Source/collection: Museum of Fine Arts, Boston, [https://collections.mfa.org/objects/253925/treatise-on-silk-culture-and-manufacture?ctx=8ef95a3e-3562-4288-80b1-e38f219b6806&idx=2]

Description: This image shows skeins of silk being twisted with the help of a large frame and a stick, prior to packaging. Bundles of skeins can be seen on the table to the left of the image. If the order of these images as presented by the Museum of Fine Art, Boston reflect the chronological order of the actions performed, then this stage precedes the process of spooling and throwing the silk, which indicates that the raw reeled silk was transported to a different workshop which carried out the processes of combining and twisting the silk filaments.

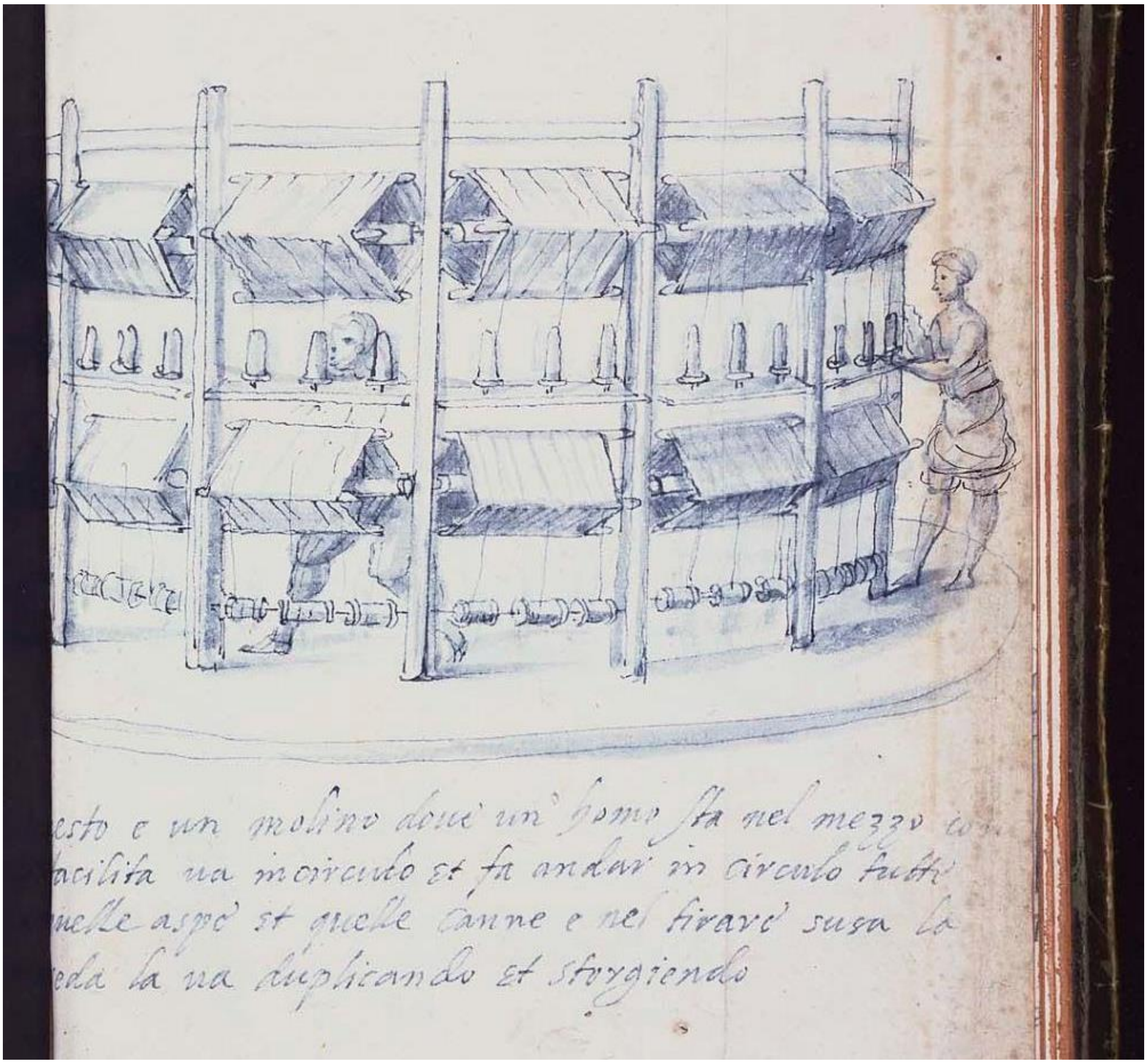
18. **Date:** c.1586

Medium: pen and ink/brush and ink drawings

Artist/area of production: Giuseppe Arcimboldo (Italian), Prague, Czech Republic

Source/collection: Museum of Fine Arts, Boston, [https://collections.mfa.org/objects/253925/treatise-on-silk-culture-and-manufacture?ctx=8ef95a3e-3562-4288-80b1-e38f219b6806&idx=2]

Description: This drawing depicts the process of winding reeled silk onto a style of spool which will be seen in place on a large twisting mill in Cat. 18. The worker on the left is combining two skeins of silk stretched on a set of cage swifts by winding them onto a single bobbin. This indicates that the steps of combining silk filaments and twisting them occurred at separate stages in this context. The silk worker to the right is winding silk from a significantly larger cage swift. At first glance it appeared that the worker was winding a single strand of silk, but on closer inspection, a doubled line both connecting to the silk worker’s hands and on the swift itself may indicate that two skeins of silk may be held on this larger swift. It is possible that the different scales of swift could correlate to different sizes of silk reel, perhaps from different reeling workshops, but there may be some other unknown reason for this size discrepancy.



19. **Date:** c.1586

Medium: pen and ink/brush and ink drawings

Artist/area of production: Giuseppe Arcimboldo (Italian), Prague, Czech Republic

Source/collection: Museum of Fine Arts, Boston, [https://collections.mfa.org/objects/253925/treatise-on-silk-culture-and-manufacture?ctx=8ef95a3e-3562-4288-80b1-e38f219b6806&idx=2]

Description: This image appears to show a silk throwing mill, presumably water-powered, although if that is the case then a number of moving parts have not been included. On the upper tier of the mill, the same style of bobbins seen in Cat. 18 are affixed vertically underneath sets of reels. If the bobbins were rotated as the silk was wound from them onto the reels this would twist the threads in whichever direction the bobbins turned. On the lower tier, a different style of bobbin is affixed horizontally underneath another set of reels. In this case, the silk is unwound from these bobbins onto the reels, would not be twisted as it was transferred so it is possible that this sketch depicts a set up for producing silk both with and without twist simultaneously, or may indicate a different unaccounted for processing step.

Appendix C Experiment Notes: K'NEX Reeling Frame Model Trials

The following text describes the reeling mechanism test carried out using K'NEX brand modular construction toy. The results of these trials and how they informed full-scale reeling equipment construction are discussed in Chapter 3.

Preliminary investigation on 10/08/2020

The first K'NEX constructions were assembled as a casual test of the structural syntheses of silk reeling treadle-crank mechanisms theorised by Hsiao et al. (2010) discussed in chapter 3. This preliminary investigation aimed to assess the treadle-crank mechanism used to rotate the reel in isolation from other moving parts such as the ramping board. The first reconstructions (not pictured), named f1 and f2 after the labelling system used by Hsiao et al. were unsuccessful at rotating the reel. In the case of f1, this was partially due to the length of the connecting rod, which at the length illustrated locked the handle and treadle in place, but at shorter lengths, would not allow the crank to complete a full rotation. In the case of f2, the problem was a result of gravity acting upon the connecting rods, as the hinged connection at both the treadle and at the central joint of the two connecting rods caused the assemblages to fall limply, with the result that depressing the treadle did not transfer motion to the reel crank.

After these two unsuccessful attempts, a modified version of f2 was constructed wherein the lower connecting rod was connected to the treadle without a hinge (Figure C.1). The length of the lower connecting rod was also extended so that it reached past the top of the reeling frame to allow for sufficient range of motion. These modifications resulted in the successful rotation of the reel.

Figure C.1:Final iteration of treadle mechanism from the preliminary investigation

Second set of investigations 14/08/2020

The second round of investigations were carried out in order to further test Hsiao et al. 's proposed mechanism structures, with an additional aim of testing the mechanics of the silk reel depicted in the 13th century handscroll attributed to Liang Kai. This series of investigations was divided into 8 trials. During these trials, a decision was made to focus on the treadle-crank mechanism, rather than testing the mechanism syntheses of the ramping board as theorised by Hsiao et al. because their proposed reconstructions do not match the ramping boards illustrated in both Chinese and European sources. The ramping board therefore remained unmodified after Trial 1. Prior to these trials, a K’NEX two-way connector was modified by removing the rounded central cross-pieces to create a slotted centre (Figure C.2). This helped to create the best chance of success in replicating treadle-crank designs f3-f6 from Hsiao et al.

Figure C.2:An unmodified K'NEX two-way connector (left), next to a modified K'NEX two-way connector (right)

The Trials

Trial 1 (Figure C.3)

This trial attempted to reconstruct the 13th century ramping board driven by the reel, independent from the treadle-crank mechanism. This trial ran into difficulty which can be attributed to the mechanical properties of K'NEX. The primary issue was a lack of the friction necessary to consistently transfer motion from the rotating reel to the cam driving the ramping board. After multiple tension readjustments and mixed success, it was concluded that the mechanism structure is sound but would likely perform better when constructed from wood. The drive band material may also be a factor, and further experimentation could be necessary. It should also be noted that the way in which the cam shaft is connected to the frame replicates the mobility it would be afforded but has been modified from the reference material to accommodate the way that K'NEX pieces interlock.

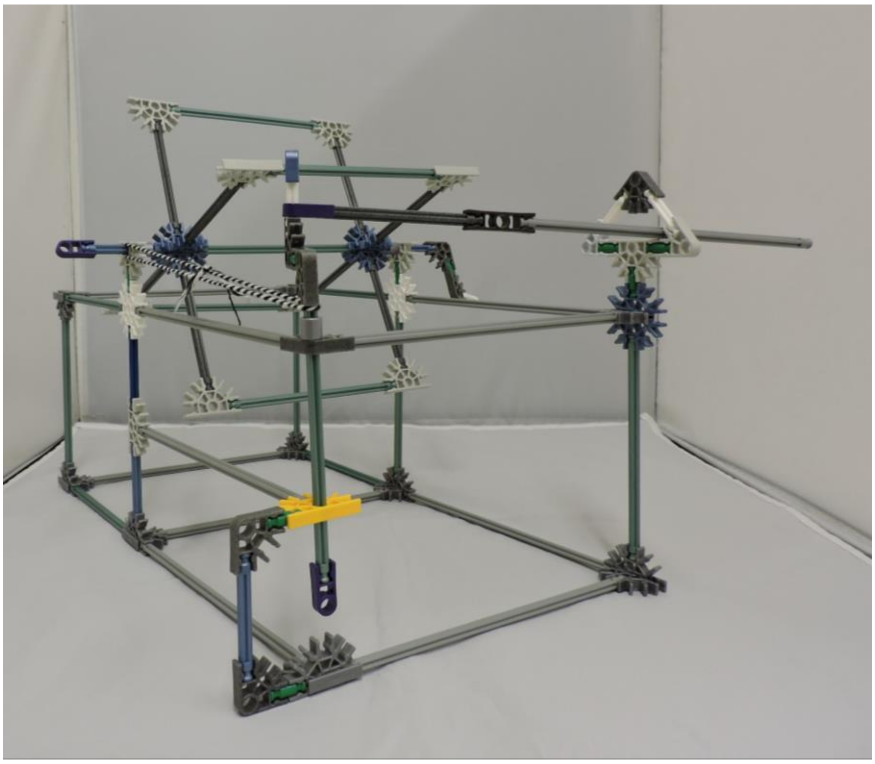


Figure C.3:K'NEX model of silk reeling device designed to replicate the mechanical elements of a 13th century ramping board

Trial 2 (Figure C.4 & Figure C.5)

This trial attempted to replicate the 13th century ramping board in combination with the 13th century treadle mechanism. The treadle in the original image is partially obscured, but the end of the treadle where it appears to be affixed to a plate on the floor, and the hook around the crank and attached cord are visible and allow for a reasonable estimate of how this treadle functioned. The first version of the reeling frame in this trial (2a), was immediately determined not to be functional, and therefore two quick adjustments were made to improve the device's function before the more functional version from trial 2c) was documented photographically. The features and modifications of stages a) to d) of trial 2 are summarised as follows:

2a) The cord was tied loosely to the crank, resulting in limited success in rotating the reel, as the cord wound around the crank, binding it and inhibiting motion

2b) The cord was tied instead to a K'NEX 2-way connector which was affixed to the crank, in an attempt to replicate the presumed effect of the hook on the crank handle. This prevented the cord from binding the crank, but movement was still stilted and it was concluded that the treadle was likely too short, while the cord was too long. While not a complete success, this stage of the trial clarified the functional importance of the hook depicted in the 13th century hand scroll.

2c) (Figure C.4) The treadle was lengthened, extending it closer to the crank, and the cord was shortened to achieve the necessary tension. This transferred motion successfully, but there was still difficulty in gathering momentum. It was concluded that this was at least partly due to a tendency for the K’NEX pieces to slip at their connection points when under tension, in a way that a wooden structure would not.

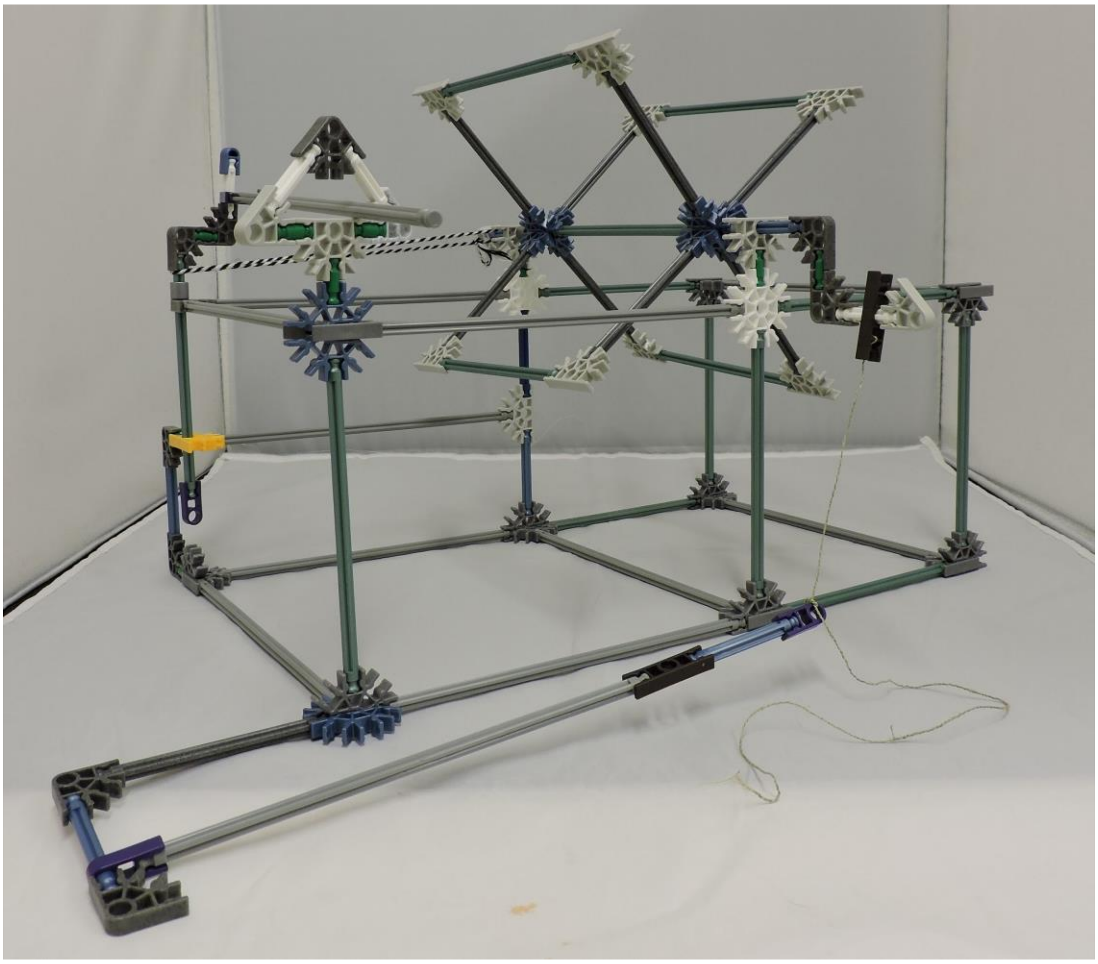


Figure C.4: Silk reeling frame constructed during Trial 2, using a treadle mechanism based on the 13th century handscroll attributed to Kai Liang

2d) (Figure C.5) The crank was reinforced to reduce slipping, this lengthened the crank which then required the treadle to be lengthened further, and the cord to be shortened in compensation. The moving parts still slipped at the connectors, which prevented the reel from gathering enough momentum to turn continuously. It was concluded that weight could also be a factor, and that this treadle-crank mechanism would be likely to function when replicated as a wooden structure to resolve both the weight and slipping problems.

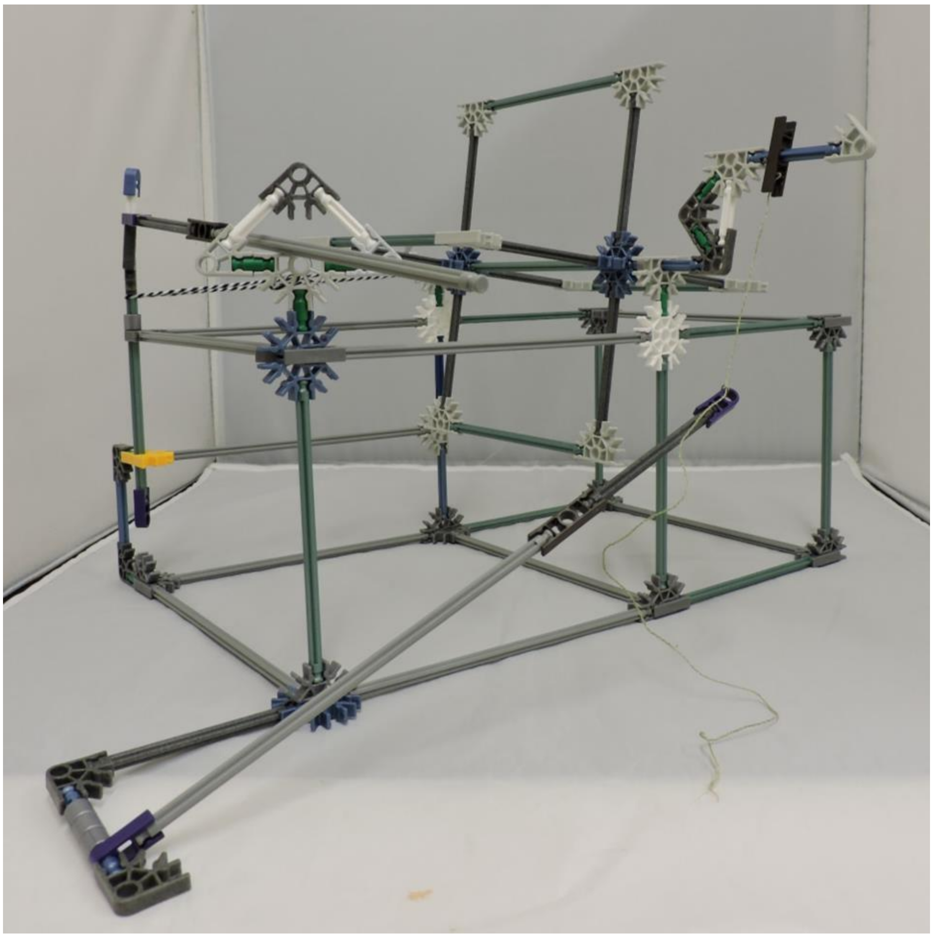


Figure C.5:Silk reeling mechanism after modification of reinforced crank during Trial 2

Trial 3 (Figure C.6)

Repetition of reconstruction of treadle-crank (f1). Affirming the findings of the preliminary tests, this trial was unsuccessful as the connecting rod was too long to allow the crank to swing downwards, while also being too short to allow the crank to reach its apex of rotation.

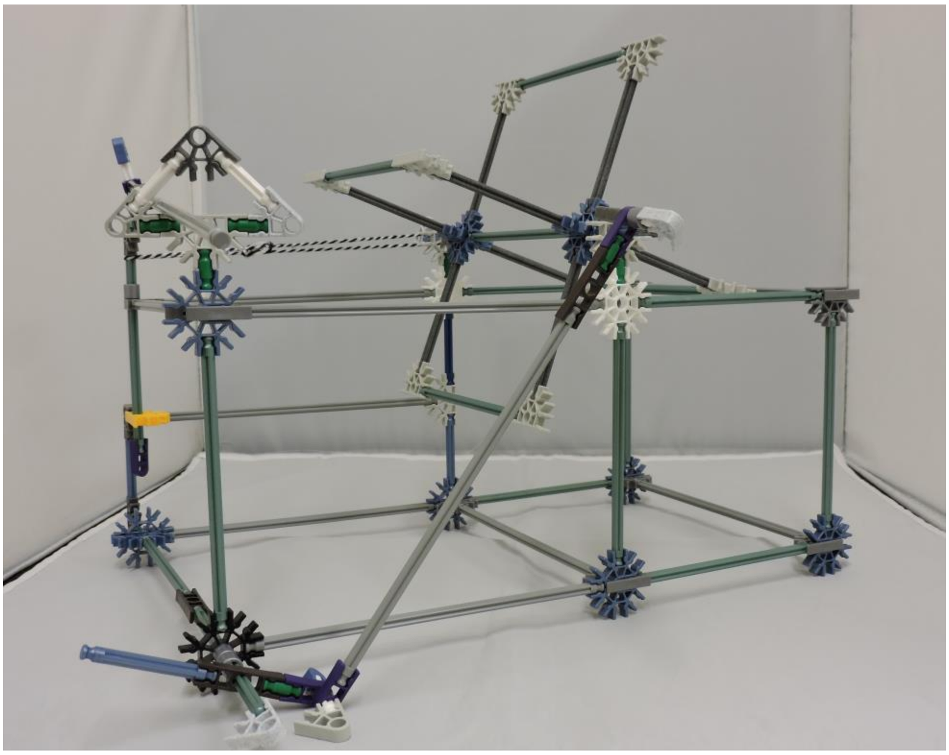


Figure C.6: Silk reeling mechanism constructed during trial 3, testing treadle design (f1) from Hsiao et al 2010

Trial 4 (Figure C.7)

Repetition of reconstruction of treadle-crank f2. Drawing on experience from the preliminary trial, this mechanism was intentionally reconstructed with longer pieces than depicted in the diagram, because the pieces as illustrated would have been too short to allow the crank to make a full rotation. Even with this pre-emptive modification, this reconstruction was unsuccessful because, while the use of longer connecting rods in comparison to the preliminary trial meant that these parts did not fall limply, the number of hinged joints still prevented the motion from being successfully transferred from the treadle to the crank.

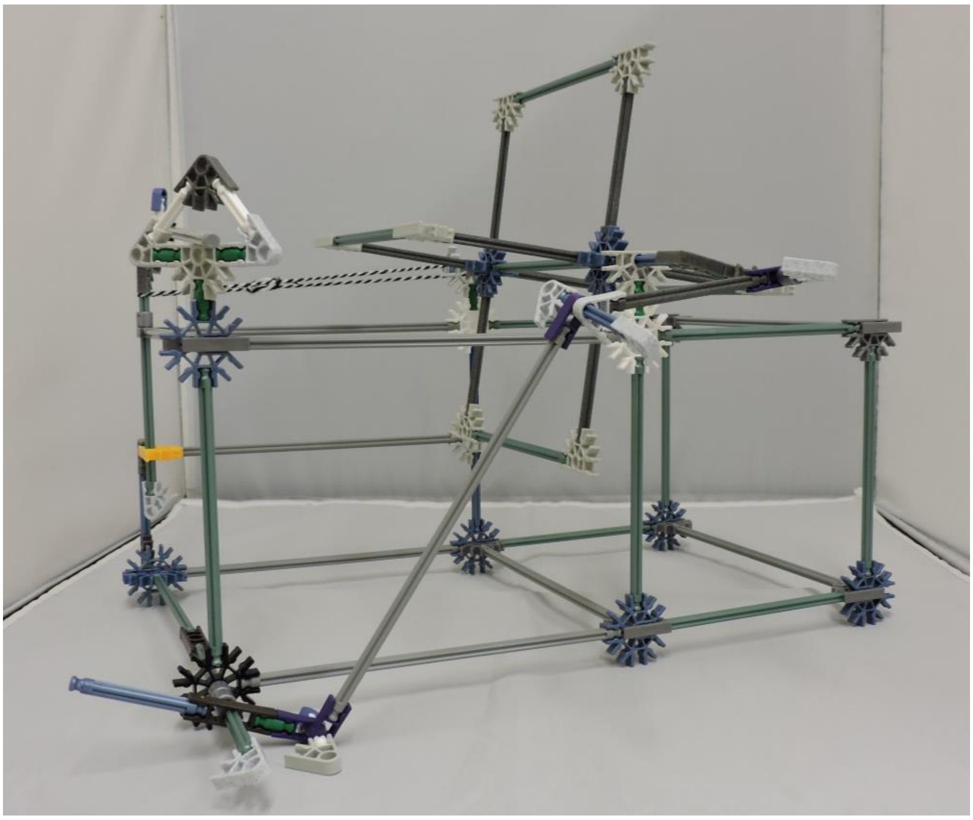


Figure C.7: Silk reeling mechanism constructed during trial 4, testing treadle design (f2) from Hsiao et al 2010

Trial 5 (Figure C.8)

Reconstruction of treadle-crank f3. The parts of this mechanism were from the start reconfigured to be longer than depicted in the diagram. This was partly necessary to accommodate the standardised lengths of K'NEX pieces, but was also required in order to provide a suitable range of motion enabling the crank to complete a full rotation. This trial was ultimately unsuccessful, as affixing the centre of the lower connecting rod to the reeling frame prevented transfer of motion from treadle to crank which was required in order to rotate the reel. Further investigation resulted in the discovery that with the slight modification of disconnecting the treadle from the frame and manually propelling it in a back-and-forth, rather than up-and-down motion, the reel was successfully rotated. This demonstrated that there was a way in which a version of this design would function, possibly with the incorporation of some sort of piston, but it was not conducive for use with a treadle activated by pressure from the foot. There is a possibility that the limited length of the treadle connector was a factor in this, and that a modified wooden model could perform better, but this seems unlikely.

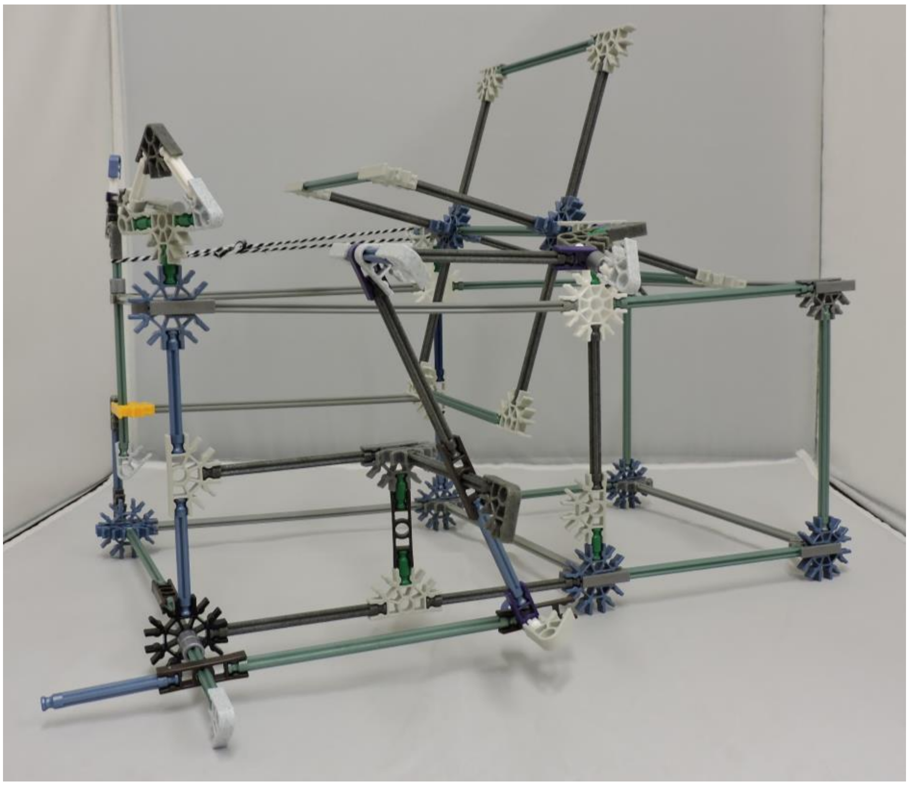


Figure C.8: Silk reeling mechanism constructed during trial 5, testing treadle design f3 from Hsiao et al. (2010)

Trial 6 (Figure C.9)

Reconstruction of f4. A slight modification to the reeling frame was made to strengthen the point where the lower connecting rod ws attached. Like the last trial, the movement was too restricted by the point where the lower connecting rod hinged on the frame. In this case it seems even more likely that part of the issue was the short length of the slotted section on the connecting rod and it is possible that a longer slot would allow for enough movement to rotate the reel, but even so the movement would be restricted and it seems unlikely that this would be the most effective design. As with trial 5, more success was had when the treadle was detached from the frame and manipulated into a back-and-forth motion, which further emphasises that this model is less suitable for treadle-operation.

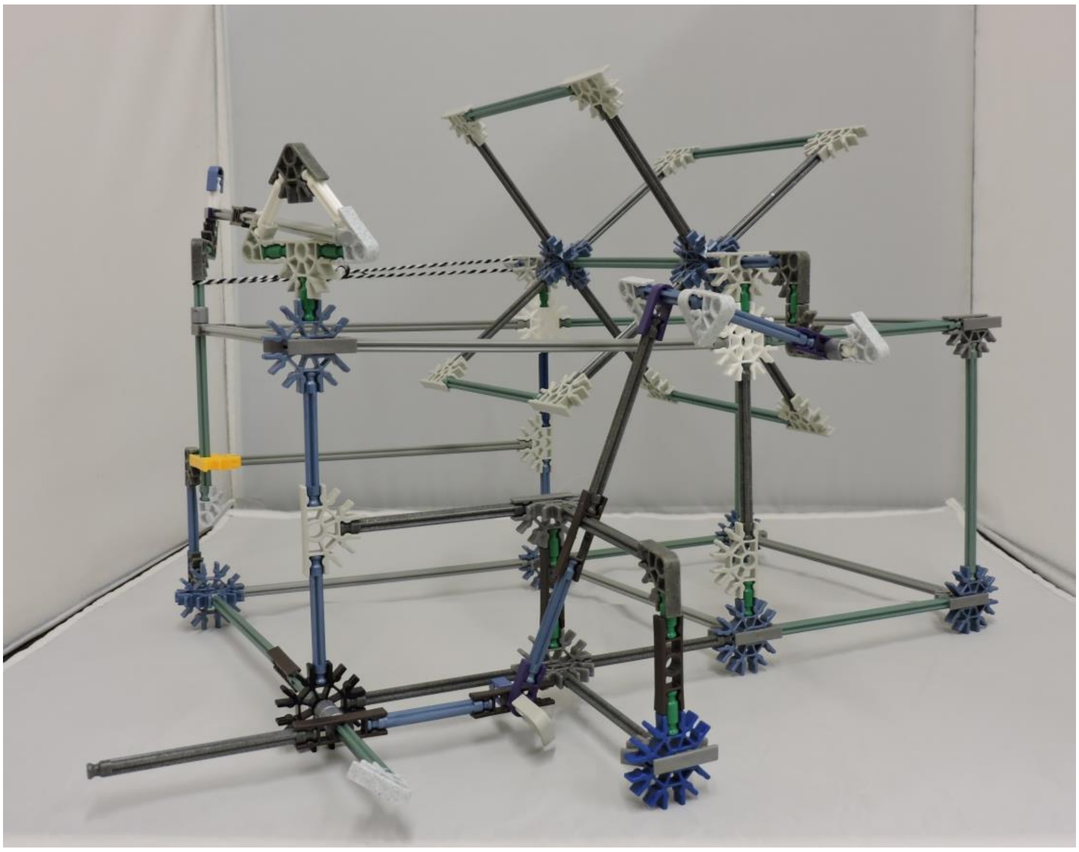


Figure C.9: Silk reeling mechanism constructed during trial 6, testing treadle design (f4) from Hsiao et al 2010

Trial 7 (Figure C.10)

Reconstruction of (f5). This model completely restricted the movement of both the upper and lower connecting rods by affixing the upper connecting rod to the frame. Further trials would reveal whether extending the slotted reel crank connection would improve motion, but further exploration was deemed impractical for this set of trials.

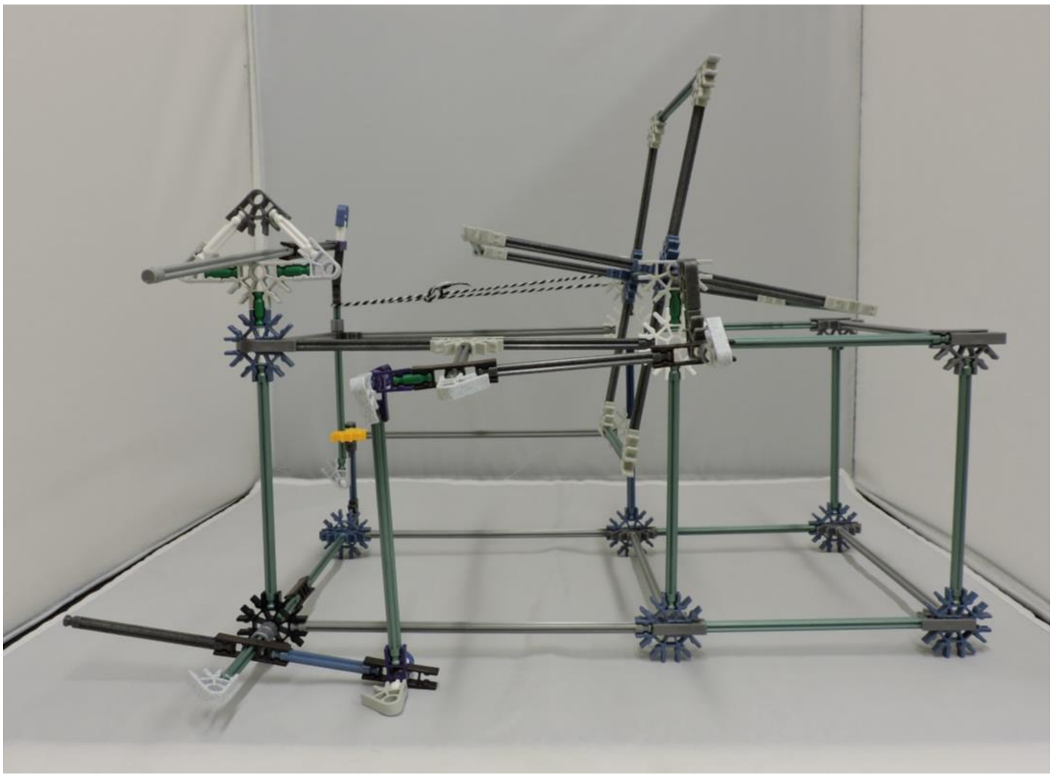


Figure C.10: Silk reeling mechanism constructed during trial 7, testing treadle design (f5) from Hsiao et al 2010

Trial 8 (Figure C.11)

Reconstruction of f6. This trial was also unsuccessful as, although the connection point was slotted, the decision to affix the upper connecting rod to the reeling frame still prevented the transfer of motion from the treadle to the reel. Further trials would reveal whether extending the slotted connection would improve motion, but as with Trial 7, this was deemed impractical for this set of trials.

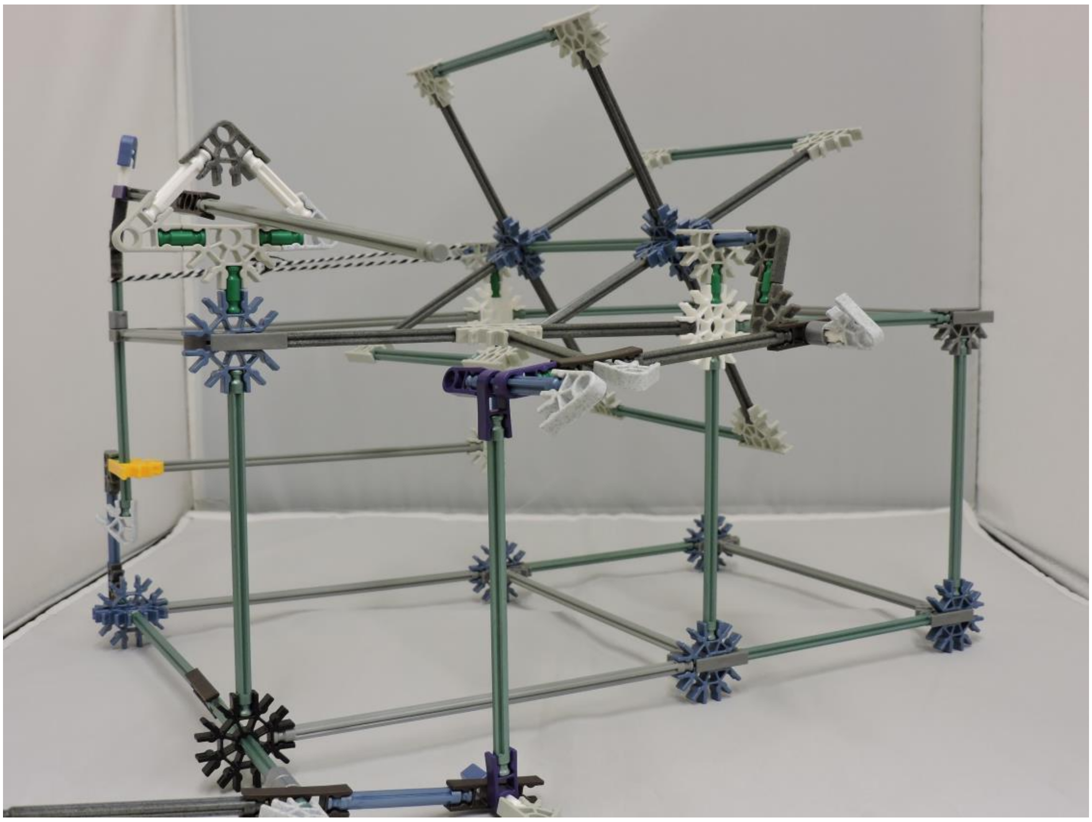


Figure C.11: Silk reeling mechanism constructed during trial 8, testing treadle design (f6) from Hsiao et al 2010

Trial 9 (Figure C.12)

This final trial was a revision of the modification of f2 from the 10/08/2020 preliminary trials. The frame constructed for the second series of trials was larger than the frame used for the preliminary tests, meaning that in this trial, the upper and lower connecting rods were modified to be longer than in the previous version. Even with these modifications, this treadle-crank variant was successful in rotating the reel, however, with the addition of the ramping board connected to the reel with a drive band, building momentum and consistently turning the reel was more difficult due to increased slipping at the connection points because of the increased resistance from the drive band. This was confirmed when the drive band was removed, and the treadle was successful in driving the reel more quickly and consistently.

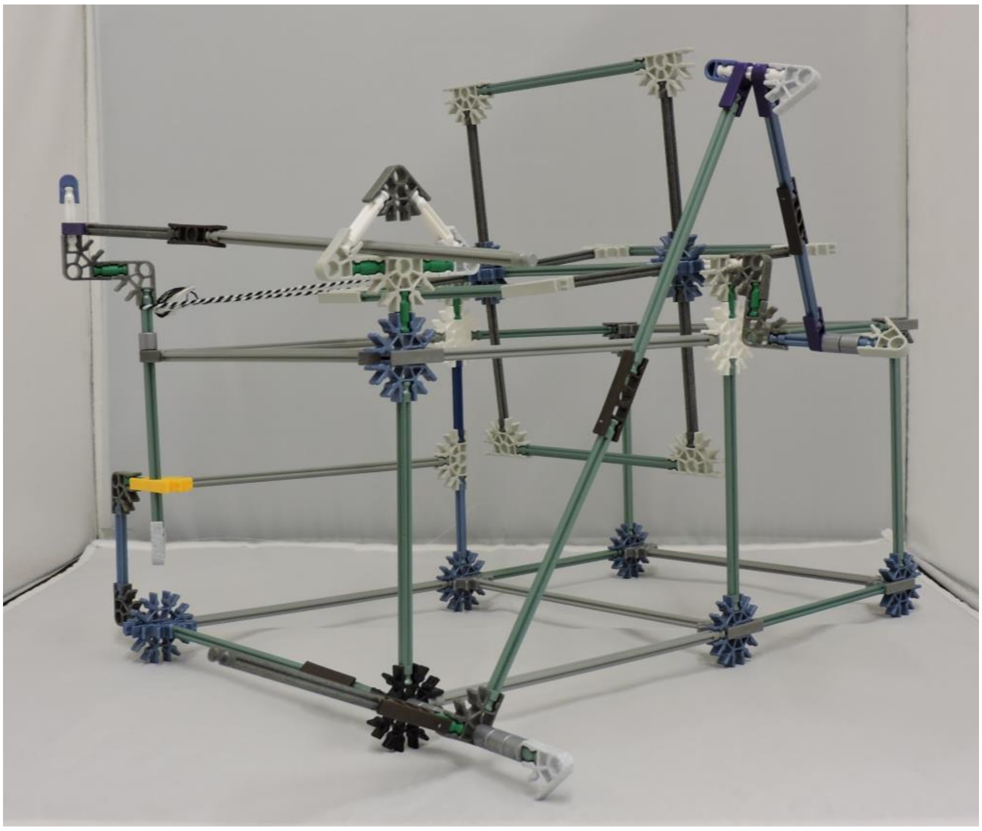
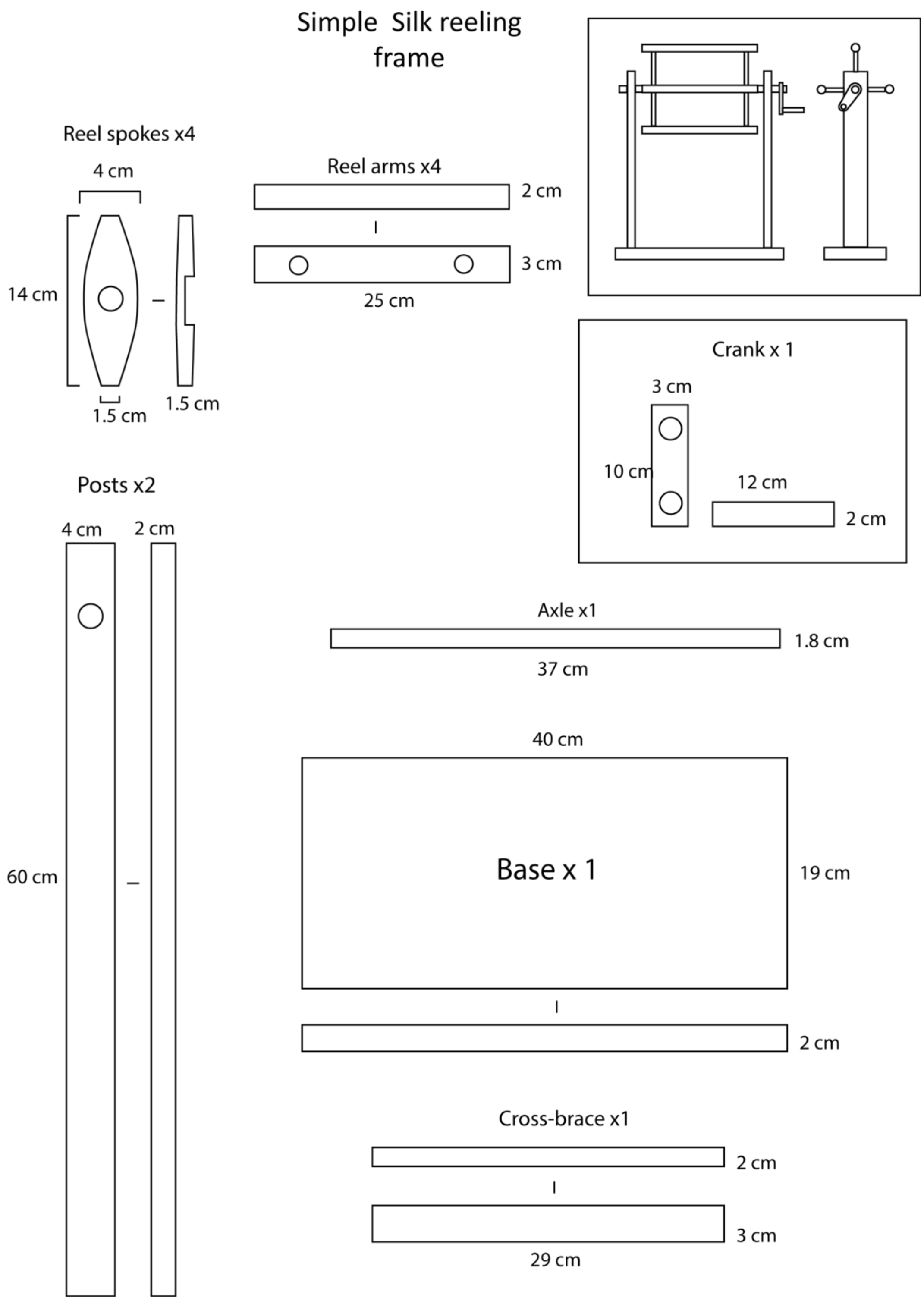


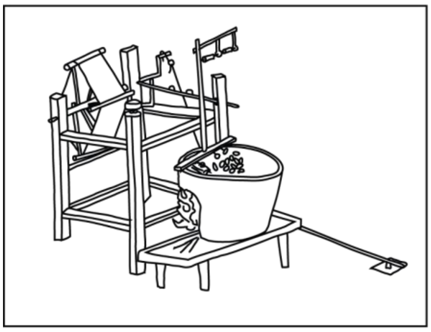
Figure C.12: Silk reeling mechanism constructed during trial 9, testing a variant of treadle design f2 from Hsiao et al 2010, which has been modified to have a fixed joint at the treadle connection

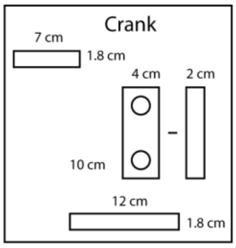
Appendix D Reeling Equipment Measured Plans

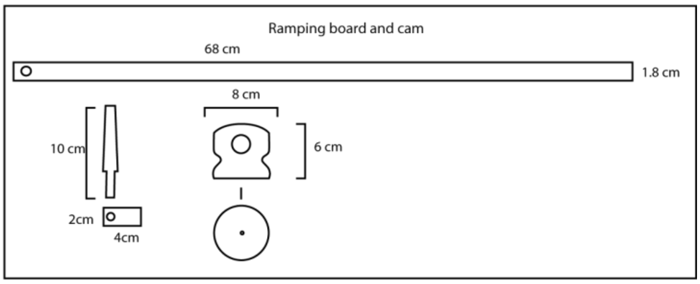
These measured plans were produced prior to the construction of the silk processing equipment and served as guides for timber-cutting.



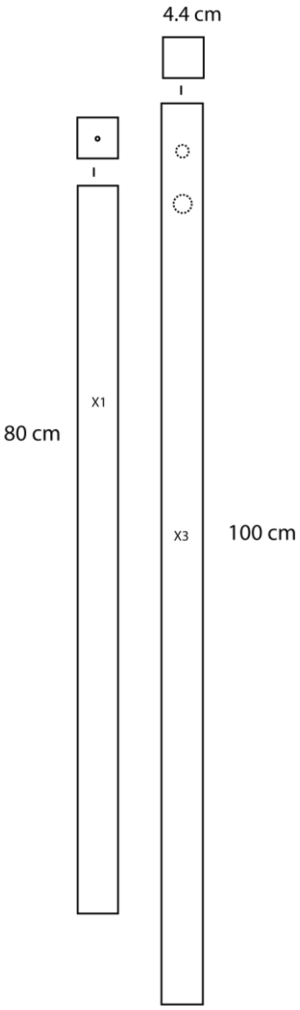
13th century Chinese silk reeling device

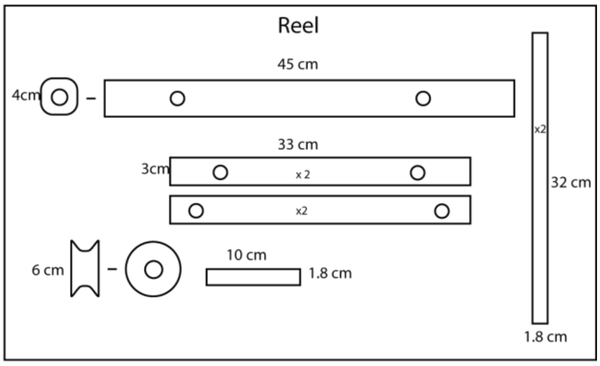




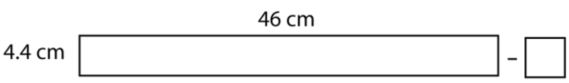


Reeling frame posts (4 total)

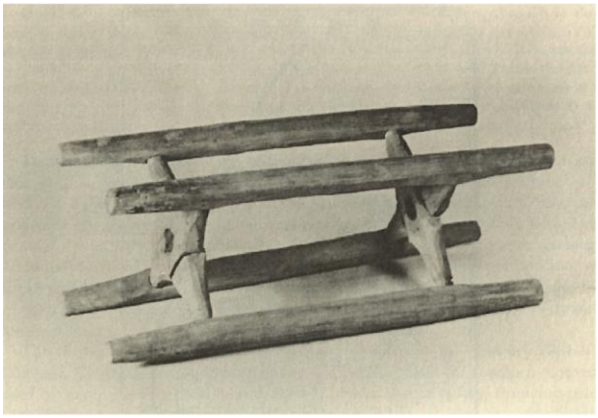


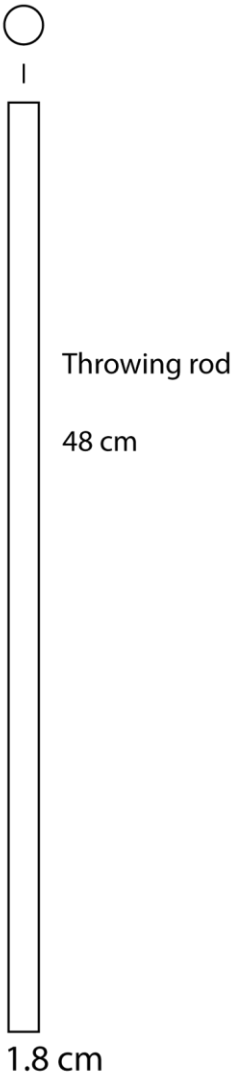


Reeling frame cross-beams x8

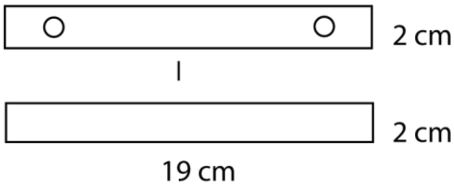


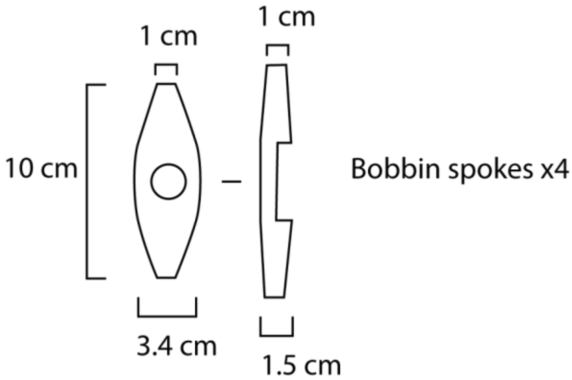
Bobbin/Throwing rod



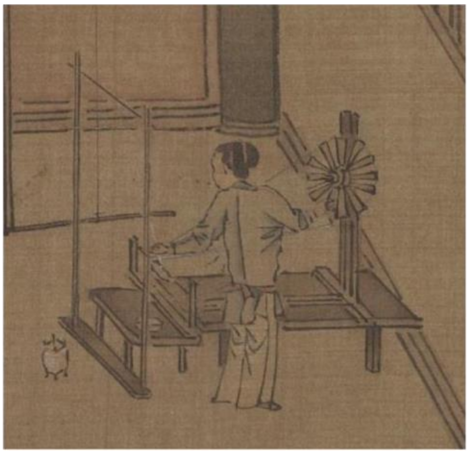


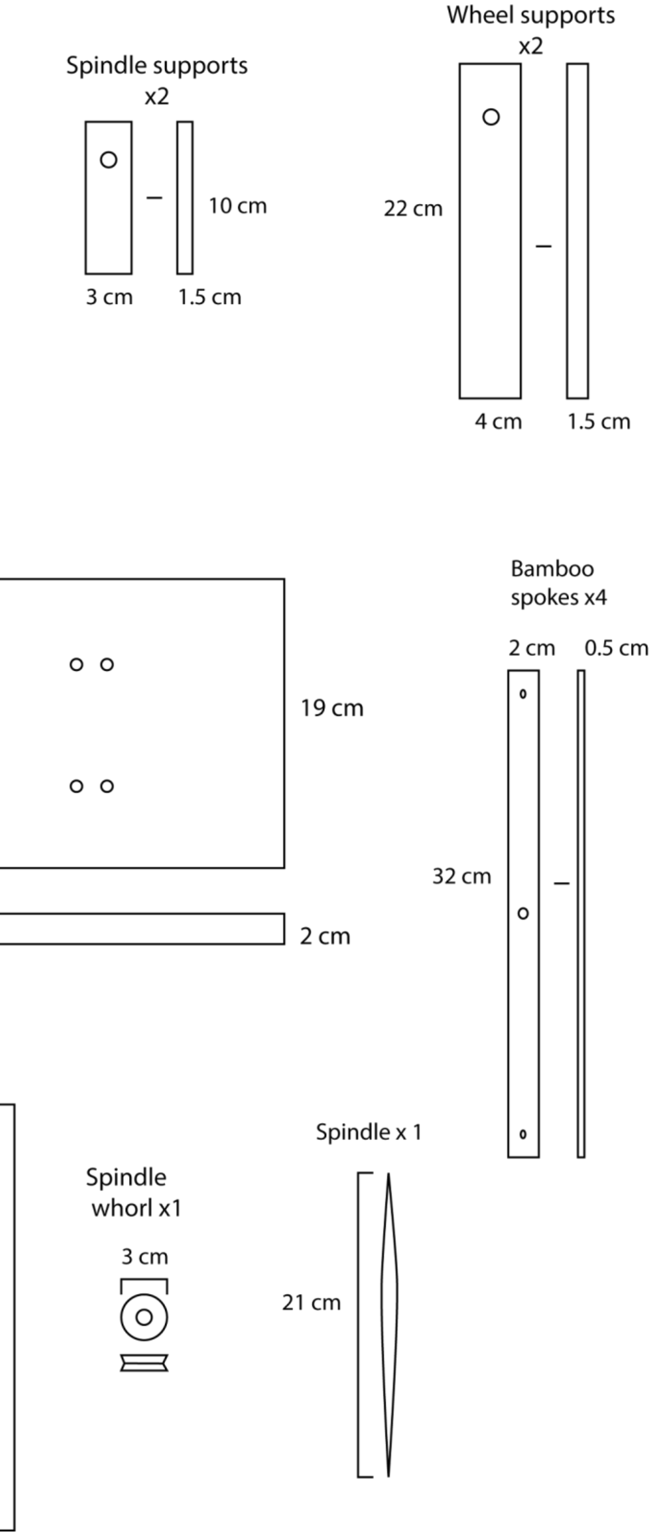
Bobbin arms x 4



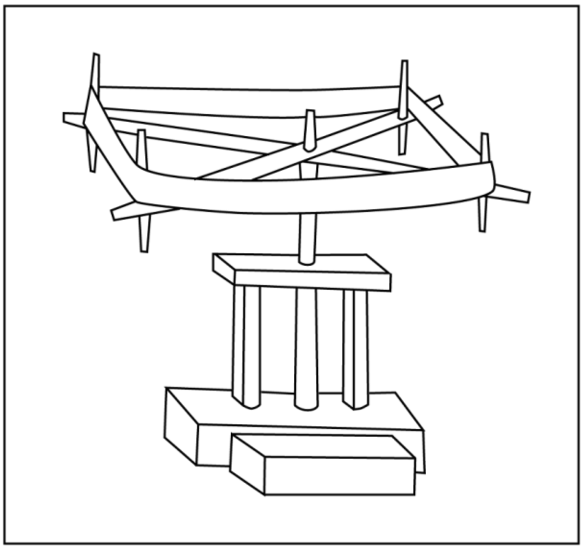


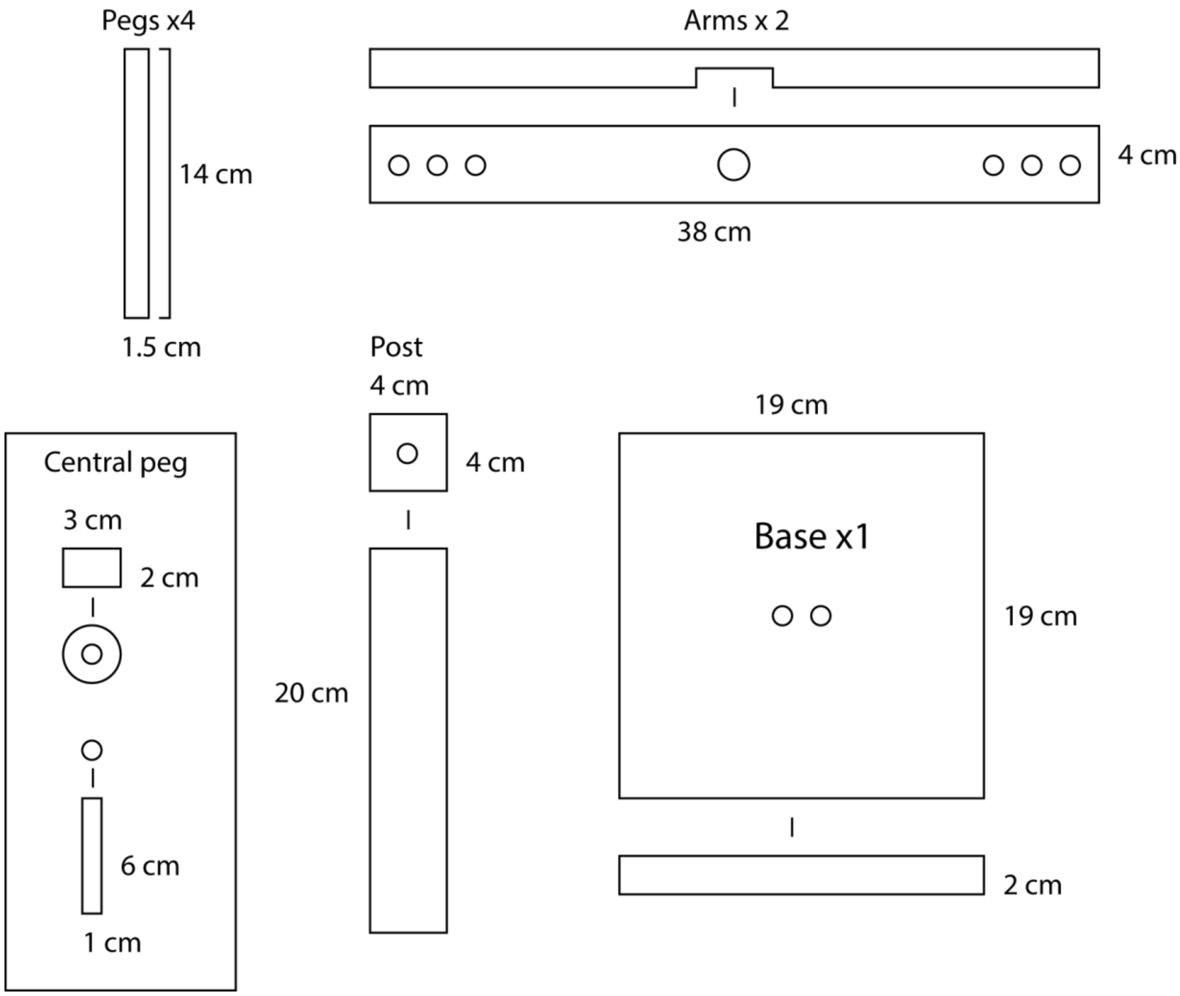
Spindle Wheel





Swift (skein frame)





Appendix E Experiment Notes: Constructing a Heat Source

To build a heat source which would serve as a reasonable facsimile to medieval reeling stoves, the construction of two clay stoves was planned in consultation with Dr Gareth Perry who also assisted throughout the process, and hand-built the stoves.

Materials

- Sculptural Terracotta Clay*
- Cardboard
- Black bin liners

*The type of clay used was suggested by Dr Perry because it contained a high quantity of large inclusions of coarse quartz grains, which would provide more stability than a finer clay such as a red studio terracotta. These inclusions would also modify the thermal properties of the clay, making it less susceptible to thermal shock both during firing and during use as a stove

Methods

Measurements for the stoves were noted from written descriptions, however, as was the case with images and descriptions of the reeling frames, the measurements varied considerably, and the stove measurements were finalised based on the dimensions of the constructed reeling equipment. Initially the plan was to construct stoves with a height of 55cm. A slightly conical design was agreed upon with a base diameter of 36cm, and a rim diameter of c. 28cm, which would support the carbon steel woks initially intended for use as reeling pans.

To determine the appropriate dimensions for the arched opening of the stoves, the ratio of the size of cutout compared to the size of the stove was calculated based on measurements taken directly from printed copies of illustrations of silk reeling stoves.
To aid in determining the height of the archway, three references were selected which clearly showed the height of archway and the height of the stove:

I. 13th century handscroll by Kai Liang;
II. 1607 illustration from *Bian yong xue hai qun yu;*
III. 1803 illustration from *Yosan Hiroku* by Morikuni Kamigaki ;
IV. 1607 illustration from *The perfect use of silke-worms and their benefit* by Nicholas Geffe.

The following measurements were then taken from the printed images:

I. Total height of stove: 14mm Height of doorway: 9mm;
II. Total height of stove: 11mm Height of doorway: 9mm;
III. Total height of stove: 6mm Height of doorway: 4mm;
IV. Total height of stove: 10mm Height of doorway: 7mm.

The doorways were then calculated to occupy the following percentages of the total height of the stoves:

I. 64.29%;
II. 81.2%;
III. 66.7%;
IV. 70%.

An average of these percentages was calculated to be used for the constructed stoves, but due to a minor omission, only percentages II.-IV. were averaged, resulting in a calculation of 72.6%.

The width of the arches was also calculated based on measurements taken from illustrations of silk reeling stoves.
Only three of the illustrations consulted provided a view of the stoves from the angle required to make these calculations:

I. 1607 Illustration from the *Bian yong xue hai qun yu;*
II. 1803 illustration from *Yosan Hiroku* by Morikuni Kamigaki;
III. 1607 illustration from *The perfect use of silke-worms and their benefit* by Nicholas Geffe.

The following measurements were taken:

I. Diameter of stove: 7mm Width of arch (at base): 4mm;
II. Diameter of stove: 11mm Width of arch (at base): 4mm;
III. Diameter of stove: 22mm Width of arch (at base): 11mm.

The width of the doorways therefore took up the following percentages of the diameter of the stove

I. 57%;
II. 36%;
III. 50%.

The average of these percentages was calculated to be 46%. This percentage was then used to calculate the width of the arches for the built stoves.

Stove construction

1. A circular template 36cm in diameter was cut out of cardboard to be used as a guide when forming the stove base.
1. A 12.5kg bag of Valentine's Sculptural Terracotta clay was divided into three, approximately equal sections.

2. Each lump of clay was wedged and then shaped into coils c. 1 metre long, each weighing approximately 4kg (Figure E.1).
    a. This length was based on the calculated circumference of the base of the stove, while allowing some room for overlap.
3. The stoves were hand-built from the coils forming a solid cylinder into which an arched opening would later be cut.
4. Each coil was joined with overlapping ends in the same vertical region of the stove, creating a potential weak point which was to be oriented on the opposite side to the arched opening (Figure E.2Figure E.3).
5. Each coil was pinched together at the join where it was added, and the clay was then smoothed with potter's ribs, one with a flat edge on the exterior of the stove, one with a curved convex edge on the interior of the stove to ensure uniform wall thickness
6. When each stove had been built to roughly the desired height, the interior was scraped smooth.
7. A carbon steel wok intended for use during the reeling was then tested against the rim of the stove for fit
8. The rim was then cut level and any necessary shape adjustments were made.
9. A trimmed piece of sponge was then dampened and run along the exterior and interior of the stove to smooth the surface, seal coil joins, and remove excess lumps of clay

The resulting stoves (Figure E.4) were similar but not identical in dimensions, partly due to some reshaping of the first stove following initial buckling at the base. Following their construction, the stoves were left to slowly dry for 5 days. To ensure that the stoves did not dry too quickly and crack, they were covered over with plastic bin liners.

Figure E.1:The clay being formed into coils

Figure E.2:Clay coils being stacked and pinched together

Figure E.3:Rough joining of two clay coils

Figure E.4:The fully-built clay stoves

Cutting the Arched openings

After 5 days of drying, the stoves had reached the desired leather-hard state and were structurally sound yet pliable enough to be cut. The bin liners were removed at this stage and top and base diameter and height measurements were taken for each stove (Table E.1).

	Stove 1	Stove 2
Top Diameter	29.5cm	28.5cm
Base Diameter	44cm	41cm
Height	38.5cm	41.5cm

Table E.1: Measurements of Stoves 1 and 2, used to calculate the size of the arched opening for each.

Based on the averaged archway height of 72.6% of the total stove height, the following archway heights were calculated:

Stove 1: 27.7cm
Stove 2: 29.8cm

Similarly, the width of the arched stove openings were calculated based on the averaged archway width of 46% of the stove diameter:

Stove 1: 20.24cm
Stove 2: 18.8cm

Based on the calculated dimensions, the arches were traced on the surface of the stoves and sliced with a metal stylus (Figure E.5). The stoves were then left uncovered (Figure E.6) for 2 weeks to fully dry prior to firing.

Figure E.5:cutting the arch with a metal stylus.

Figure E.6:One of the completed stoves with archway removed.

Clay Stove firing

The clay stoves were fired using a bonfire method at the York Experimental Archaeological Research (YEAR) Centre.

1. Prior to firing the stoves a bonfire was lit to dry and heat the ground in the area where firing was to take place
2. The stoves were placed near the fire to gradually heat them and avoid thermal shock during firing (Figure E.7)
3. The temperature of the stoves was monitored with an Infra-red thermometer
4. During preheating one spall of clay broke off of one of the stoves
5. After the fire had burned down, the coals were raked down, and two platforms of dry wood were built over top (Figure E.8)
6. The furnaces were placed vertically on the platforms and long pieces of wood were laid overtop in a conical formation (Figure E.9)

Figure E.7: The stoves preheating by the fire

Figure E.8:Wooden platforms built over hot coals

Figure E.9: The outer conical wooden structure being built around the stoves.

The intention had been to then relight the fire from the edge of the platform, which would allow the fire to slowly burn inwards, firing the clay while avoiding thermal shock. Unfortunately, in an unforeseen complication, the stoves funnelled heat from the coals upward before the external fire was light, causing the fire to reignite from the interior of the conical structure (the beginnings of this can be seen in Figure E.9). This resulted in severe temperature shock and cracking. Within 10 minutes one stove had completely collapsed (Figure E.10). The second stove was removed from the fire with heat protective gloves, but the temperature shock had already caused a large fracture (Figure E.11).

Figure E.10: Collapsed remains of clay stove

Figure E.11: The second fractured stove, removed from fire.

A quick decision was made to continue firing the second stove with the modification of angling it on its side (Figure E.12) to prevent the heat from funnelled up through the centre again. Additional precautions were taken by blocking the top and bottom of the stove with broken clay from the other collapsed stove. This second attempt was more successful, and the stove lasted an additional 10-15 minutes before the heat was again drawn through the centre and the rest of the stove collapsed (Figure E.13).

Figure E.12: The second attempt at firing the fractured stove, now oriented on its side.

Figure E.13: Fragments of the second stove.

Appendix F Experiment Data

Experiment recording methods

Photographs and videos were taken using a Nikon Coolpix P530 digital camera. Photographs were saved as large format JPEG files. Additional photos and videos were also taken using a smartphone with a 48MP 4-lens camera. A notebook log was kept for each experiment, in which I recorded the date, experiment location, weather conditions, equipment and variables tested, the corresponding sample numbers for each experiment, and any additional relevant observations. The notebook log entries were typed into a word document on a weekly basis; this served as a means of data back-up and created a digitally searchable document for ease of use. As the handwritten log entries were typed, any additional thoughts and observations from the experiments were included following each entry under the heading “Post-experiment Reflections”. A spreadsheet was also used to track information on the silk samples created and their corresponding experiment date and experiment variables. This spreadsheet was updated after each experiment was conducted.

Sample Labelling

After considering several label format options including sequential numbering and letter-coding, a hybrid system was established which used a sequence of letters (Table F.1) to indicate the reeling equipment used, whether the samples had gone through the throwing degumming processes, followed by sequential numbers. This allowed for easy identification of broad categories of samples, while facilitating easy sequential organisation of specific samples.

Sr	Simple Reel
Tr	Treadled Reel
T	Thrown silk
D	Degummed
Sp	Spun silk

Table F.1: Label code key

The labels took the following format:
[Type of reeling equipment]_[Indication that silk has been thrown]_[Indication that silk has been degummed]_###

For example:
Sr_001 = Simple Reel sample 001
Sr_T_001= Simple Reel, Thrown sample 001
Sr_ T_D_001= Simple Reel, Thrown, Degummed sample 001

Labels made from acid-free cardstock were used to indicate the number and production date for each sample. Cotton yarn was used to secure the centre of reeled skeins and attach sample labels. Except for the experiment conducted on 30-08-2021, all silk was reeled using tap water.

Silk reeling equipment

The following equipment was used in different combinations according to throwing method (See Table F.2):

- Spindle wheel
- Cylindrical bamboo bobbins
- 3 four-armed bobbins
- Throwing rod
- 3 drop spindle sticks
- 1 fired-clay, glazed spindle whorl weighing 35g
- 4-armed skein frame
- Modern umbrella swift
- Simple reel
- Electric Eel Wheel Nano e-spinner

Thrown Sample	Date	Equipment
Sr_T_001	04/08/2021	Spindle wheel, 4-armed bobbins, bamboo bobbins
Sr_T_002-Sr_T_006	06/08/2021	Spindle wheel, 4-armed bobbins, bamboo bobbins
Sr_T_007-Sr_T_012	31/08/2021	Spindle wheel, 4-armed bobbins, bamboo bobbins
Sr_T_013-Sr_T_022	07/09/2021	Spindle wheel, 4-armed bobbins, bamboo bobbins, Drop Spindle
Sr_T_023-Sr_T_029	08/10/2021	Spindle wheel, 4-armed bobbins, bamboo bobbins
Sr_T_030-Sr_T_037	28/10/2021	Spindle wheel, 4-armed bobbins, bamboo bobbins, e-spinner, simple reel, Drop spindle
Sr_T_038-Sr_T_039	18/11/2021	e-spinner, simple reel, 4-armed bobbins, spindle wheel, bamboo bobbins
Tr_T_001-Tr_T_005	18/11/2021	e-spinner, simple reel, 4-armed bobbins, spindle wheel, bamboo bobbins
Tr_T_006-Tr_T_007	11/01/2022	Drop spindle, 4-armed bobbin, modern umbrella swift

Table F.2: Equipment used for each set of silk throwing experiments, with the date of the experiments.

The Spindle-wheel: Determining Number of Twists per Metre

Prior to the first throwing trial, the ratio of spindle rotations to wheel rotations was calculated to estimate the number of times the yarn was twisted per metre.

To calculate this ratio, a mark was drawn on the whorl of the spindle, and the number of times that the mark reached its original position while the crank of the spindle wheel made one full rotation was counted. This process was repeated 10 times in the clockwise direction (Z) and in the anti-clockwise direction (S) (Table F.3). In cases where the spindle did not finish on its starting position following a full crank rotation, the rotation was noted approximately using 1/10th increments and written as a decimal. This process showed some variation in the number of rotations each time, but allowed for the calculation of an average that could be used to estimate the number of twists added to each metre of silk yarn.

	Z	S
1	26	27.5
2	27	26.75
3	27.5	27.5
4	27.75	27.75
5	27.25	27.75
6	27.75	27.8
7	27.8	25.5
8	27.75	27.75
9	27.8	28
10	27.75	27.5
Mean	**27.435**	**27.38**

Table F.3: Results of counting the number of rotations made by the spindle of the spindle-wheel per full crank rotation, in both Z and S directions, repeated 10 times with the mean for each direction.

The number of twists per half-metre for each experiment were determined by the desired level of twist (low, moderate, or high level twist), with lower levels of twist being set at 3 cranks per 0.5 metre (c. 165 twists per metre), a moderate level of twist being set at 4 cranks per 0.5metre (c. 219 twists per metre), and a high level of twist being set at 6 cranks per 0.5 metre (c. 329 twists per metre). The actual degree of twist achieved from these methods will be discussed in a later chapter, but in the interim it is important to note that the designation of low, moderate, and high levels of twist in relation to the spindle-wheel should be considered relative to the spindle-wheel's context of use, and is not necessarily reflective of what may be considered low vs. high levels of twist overall.

Summary of Silk Reeling Experiment Conditions: Simple Reeling Frame

Sample #	Date produced	Cocoons	Intended number of Cocoons	Water Temp	Intended Water temp	Crossing/wrapping	Position in Cocoon
Sr_001	04-08-2021	4	6	70	80C	None	Interior
Sr_002	04-08-2021	4	6	70	80C	None	Exterior
Sr_003	04-08-2021	4	6	70	80C	None	Middle
Sr_004	30-08-2021	6	6	80	80C	None	Interior
Sr_005	30-08-2021	6	6	80	80C	None	Middle
Sr_006	30-08-2021	6	6	80	80C	None	Exterior
Sr_007	06-09-2021	6	6	82	80C	None	Interior
Sr_008	06-09-2021	6	6	82	80C	None	Middle
Sr_009	06-09-2021	6	6	82	80C	None	Exterior
Sr_010	08-09-2021	8	6	80	80C	Self cross	Exterior
Sr_011	08-09-2021	8	6	80	80C	Self cross	N/A
Sr_012	08-09-2021	8	6	80	80C	Self cross	N/A
Sr_013	08-09-2021	8	6	80	80C	Self cross	N/A
Sr_014	08-09-2021	8	6	80	80C	Self cross	M (but mixed)
Sr_015	21-09-2021	3	3	80	80C	None	Interior
Sr_016	21-09-2021	3	3	80	80C	None	Exterior
Sr_017	21-09-2021	3	3	80	80C	None	Middle
Sr_018	12-10-2021	c.13	15	80	80C	None	Exterior
Sr_019	12-10-2021	c.13	15	80	80C	None	Interior
Sr_020	12-10-2021	c.13	15	80	80C	None	Middle
Sr_021	13-10-2021	8	6	Boiling	Boiling	None	Interior
Sr_022	13-10-2021	8	6	Boiling	Boiling	None	Middle
Sr_023	13-10-2021	8	6	Boiling	Boiling	None	Exterior

Summary of Silk Reeling Experiment Conditions: Treadled Reeling Frame

Sample #	Date produced	Cocoons	Intended number of Cocoons	Water temp	Intended Water Temp	Crossing / wrapping	Skein	Section of cocoon
Tr_001	14-09-2021	6	6	80	80	Single	Both	Interior
Tr_002	14-09-2021	6	6	80	80	Single	Both	Exterior
Tr_003	14-09-2021	6	6	80	80	Single	Both	Middle
Tr_004	14-09-2021	6	6	80	80	Double	Right	Interior
Tr_005	14-09-2021	6	6	80	80	Double	Right	Exterior
Tr_006	14-09-2021	6	6	80	80	Double	Right	Middle
Tr_007	14-09-2021	6	6	80	80	Double	Left	Exterior
Tr_008	14-09-2021	6	6	80	80	Double	Left	Middle
Tr_009	16-09-2021	6	6	80	80	Double (again)	Left	?Exterior
Tr_010	16-09-2021	6	6	80	80	Double (again)	Left	?Interior
Tr_011	16-09-2021	6	6	80	80	Double (again)	Left	?Middle
Tr_012	16-09-2021	6	6	80	80	Double (again)	Right	Exterior
Tr_013	16-09-2021	6	6	80	80	Double (again)	Right	Interior
Tr_014	16-09-2021	6	6	80	80	Double (again)	Right	Middle
Tr_015	17-09-2021	15	15	80	100	Single	Left	Interior
Tr_016	17-09-2021	15	15	80	100	Single	Left	Exterior
Tr_017	17-09-2021	15	15	80	100	Single	Left	Middle
Tr_018	17-09-2021	15	15	80	100	Single	Right	Interior
Tr_019	17-09-2021	15	15	80	100	Single	Right	Exterior
Tr_020	17-09-2021	15	15	80	100	Single	Right	Middle
Tr_021	22-09-2021	3	3	70	80	Single	Left	Interior
Tr_022	22-09-2021	3	3	70	80	Single	Left	Exterior
Tr_023	22-09-2021	3	3	70	80	Single	Left	Middle
Tr_024	22-09-2021	3	3	70	80	Single	Right	Interior
Tr_025	22-09-2021	3	3	70	80	Single	Right	Exterior
Tr_026	22-09-2021	3	3	70	80	Single	Right	Middle
Tr_027	24-09-2021	15	15	68	80	Piedmont	Left	?Interior
Tr_028	24-09-2021	15	15	68	80	Piedmont	Left	?Exterior

Tr_029	24-09-2021	15	15	68	80	Piedmont	Left	Middle
Tr_030	24-09-2021	15	15	68	80	Piedmont	Right	?Interior
Tr_031	24-09-2021	15	15	68	80	Piedmont	Right	?Exterior
Tr_032	24-09-2021	15	15	68	80	Piedmont	Right	Middle
Tr_033	24-09-2021	6	6	80	80	Piedmont	Left	Interior
Tr_034	24-09-2021	6	6	80	80	Piedmont	Left	Exterior
Tr_035	24-09-2021	6	6	80	80	Piedmont	Left	Middle
Tr_036	24-09-2021	6	6	80	80	Piedmont	Right	Middle
Tr_037	24-09-2021	6	6	80	80	Piedmont	Right	Interior
Tr_038	24-09-2021	6	6	80	80	Piedmont	Right	Exterior
Tr_039	29-09-2021	30	30	Boiling	Boiling	Piedmont	Left	Interior
Tr_040	29-09-2021	30	30	Boiling	Boiling	Piedmont	Left	Exterior
Tr_041	29-09-2021	30	30	Boiling	Boiling	Piedmont	Left	Middle
Tr_042	29-09-2021	30	30	Boiling	Boiling	Piedmont	Right	Interior
Tr_043	29-09-2021	30	30	Boiling	Boiling	Piedmont	Right	Exterior
Tr_044	29-09-2021	30	30	Boiling	Boiling	Piedmont	Right	Middle
Tr_045	06-10-2021	6	6	Boiling	Boiling	Single	Left	Interior
Tr_046	06-10-2021	6	6	Boiling	Boiling	Single	Left	Exterior
Tr_047	06-10-2021	6	6	Boiling	Boiling	Single	Left	Middle
Tr_048	06-10-2021	6	6	Boiling	Boiling	Single	Right	Interior
Tr_049	06-10-2021	6	6	Boiling	Boiling	Single	Right	Exterior
Tr_050	06-10-2021	6	6	Boiling	Boiling	Single	Right	Middle

Summary of Silk throwing Experiment variables

ID	Date created	Equipment	Method	Reeled Filament ID
Sr_T_001	04-08-2021	Spindle Wheel	2 strands Z twisted	Sr_001-Sr_003
Sr_T_002	06-08-2021	Spindle Wheel	2 strands of Sr_T_001 S twisted	Sr_001-Sr_003
Sr_T_003	06-08-2021	Spindle Wheel	2 strands combined without twist	Sr_001-Sr_003
Sr_T_004	06-08-2021	Spindle Wheel	2 strands of Sr_T_004 combined without twist	Sr_001-Sr_003
Sr_T_005	06-08-2021	Spindle Wheel	2 strands S twisted	Sr_001-Sr_003
Sr_T_006	06-08-2021	Spindle Wheel	2 strands of Sr_T_005 Z twisted	Sr_001-Sr_003
Sr_T_007	31-08-2021	Spindle Wheel	Burnham weft method	Sr_004-Sr_006
Sr_T_008	31-08-2021	Spindle Wheel	Burnham warp method	Sr_004-Sr_006
Sr_T_009	31-08-2021	Spindle Wheel	Kuhn method ?2Z2S variation	Sr_004-Sr_006
Sr_T_010	31-08-2021	Spindle Wheel	Desrosiers' method	Sr_004-Sr_006
Sr_T_011	31-08-2021	Spindle Wheel	Kuhn method	Sr_004-Sr_006
Sr_T_012	31-08-2021	Spindle Wheel	3 strands combined without twist	Sr_004-Sr_006
Sr_T_013	07-09-2021	Spindle Wheel	Burnham weft method	Sr_007-Sr_009
Sr_T_014	07-09-2021	Spindle Wheel	Burnham warp method	Sr_007-Sr_009
Sr_T_015	07-09-2021	Spindle Wheel	Kuhn method ?2Z2S variation	Sr_007-Sr_009
Sr_T_016	07-09-2021	Spindle Wheel	Desrosiers' method wound clockwise, then anticlockwise	Sr_007-Sr_009
Sr_T_017	07-09-2021	Spindle Wheel	Desrosiers' method wound anticlockwise, then clockwise	Sr_007-Sr_009
Sr_T_018	07-09-2021	Spindle Wheel	Kuhn method	Sr_007-Sr_009
Sr_T_019	07-09-2021	Drop Spindle	2 strands Z twisted	Sr_007-Sr_009
Sr_T_020	07-09-2021	Spindle Wheel	2 strands combined without twist	Sr_007-Sr_009
Sr_T_021	07-09-2021	Spindle Wheel	3 strands combined without twist	Sr_007-Sr_009
Sr_T_022	07-09-2021	Drop Spindle	2 strands of Sr_T_020 S twisted	Sr_007-Sr_009
Sr_T_023	08-10-2021	Spindle Wheel	Desrosiers method, clockwise then counterclockwise	Sr_015-Sr_017
Sr_T_024	08-10-2021	Spindle Wheel	Desrosiers method, counterclockwise, then clockwise	Sr_015-Sr_017
Sr_T_025	08-10-2021	Spindle Wheel	Burnham warp method	Sr_015-Sr_017
Sr_T_026	08-10-2021	Spindle Wheel	Kuhn method I2Z2S variation	Sr_015-Sr_017
Sr_T_027	08-10-2021	Spindle Wheel	Burnham weft method	Sr_015-Sr_017
Sr_T_028	08-10-2021	Spindle Wheel	3 strands combined without twist	Sr_015-Sr_017

Sr_T_029	08-10-2021	Spindle Wheel	Unintentional s twisted variation of Burnham weft method	Sr_015-Sr_017
Sr_T_030	28-10-2021	Spindle Wheel	Burnham warp method	Sr_021-Sr_023
Sr_T_031	28-10-2021	Spindle Wheel	Kuhn method I2Z2S variation	Sr_021-Sr_023
Sr_T_032	28-10-2021	Spindle Wheel	Burnham weft method	Sr_021-Sr_023
Sr_T_033	28-10-2021	Spindle Wheel	2 strands combined without twist	Sr_021-Sr_023
Sr_T_034	28-10-2021	Mock Silk Mill	Mock silk mill I2Z	Sr_021-Sr_023
Sr_T_035	28-10-2021	Drop Spindle	2 strands of Sr_T_036 twisted S	Sr_021-Sr_023
Sr_T_036	28-10-2021	Drop Spindle	2 strands twisted Z	Sr_021-Sr_023
Sr_T_037	28-10-2021	Spindle Wheel	Single strand wound clockwise onto a bamboo bobbin	Sr_021-Sr_023
Sr_T_038	18-11-2021	Mock Silk Mill	Mock silk mill I3S	Sr_021-Sr_023
Sr_T_039	18-11-2021	Mock Silk Mill	Mock silk mill I2Z	Sr_021-Sr_023
Tr_T_001	18/11/2021	Mock Silk Mill	Mock silk mill I3S	Tr_001-Tr_003
Tr_T_002	18/11/2021	Mock Silk Mill	Mock silk mill I2Z	Tr_001-Tr_003
Tr_T_003	18/11/2021	Spindle Wheel	Burnham warp method	Tr_001-Tr_003
Tr_T_004	18/11/2021	Spindle Wheel	Burnham weft method	Tr_001-Tr_003
Tr_T_005	18/11/2021	Spindle Wheel	3 strands combined without twist	Tr_001-Tr_003
Tr_T_006	11/01/2022	Drop Spindle	2 strands of Tr_T_007 twisted S	Tr_001-Tr_003
Tr_T_007	11/01/2022	Drop Spindle	2 strands twisted Z	Tr_001-Tr_003

Summary of Silk Degumming Experiment Variables

ID	Date	Degumming Agent	Rinse Additive	Method	Simmering time	Water Temp	Original Thrown Sample
Sr_T_D_001	24-11-2021	Soda Ash	None	Weight of Fibres	30 minutes	75	Sr_T_013
Sr_T_D_002	24-11-2021	Soda Ash	None	Weight of Fibres	1 hour	75	Sr_T_013
Sr_T_D_003	24-11-2021	Soda Ash	None	Weight of Fibres	2 hours	75	Sr_T_013
Sr_T_D_004	24-11-2021	Soda Ash	Citric Acid	Weight of Fibres	2 hours	75	Sr_T_013
Sr_T_D_005	10-1-2022	Soda Ash	None	Weight of Fibres	30 minutes	80	Sr_T_021
Sr_T_D_006	10-1-2022	Soda Ash	None	Weight of Fibres	1 hour	80	Sr_T_021
Sr_T_D_007	10-1-2022	Soda Ash	None	Weight of Fibres	2 hours	80	Sr_T_021
Sr_T_D_008	10-1-2022	Soda Ash	Citric Acid	Weight of Fibres	2 hours	80	Sr_T_021
Sr_T_D_009	21-10-2022	Soap Flakes	None	Ratio to water	2 hours	80	Sr_T_013
Tr_T_D_001	08-01-2023	Soda Ash	None	Quantity by pH	30 minutes	80	Tr_T_006
Tr_T_D_002	08-01-2023	Soda Ash	None	Quantity by pH	1 hour	80	Tr_T_006
Tr_T_D_003	08-01-2023	Soda Ash	None	Quantity by pH	2 hours	80	Tr_T_006
Tr_T_D_004	08-01-2023	Soda Ash	Citric Acid	Quantity by pH	2 hours	80	Tr_T_006

Appendix G Silk Production Experiment Logs

04/08/2021

Assistance provided/photographs taken by Andy Needham

Equipment: Simple Reel, Hot Plate, Carbon Steel wok (oiled), Probe thermometer, small natural bristle dish brush, spiral ladle, 3 Pine bobbins & hardwood throwing rod, additional dowel with bamboo thread guide, spindle wheel

Cocoons: Grade A, Supplier 2
8 cocoons were soaked to reel an average of 6 strands at a time

Setting: Material Culture Lab (DS/008) Palaeohub, windows open
Weather: Sunny and hot, then overcast with intermittent rain

Water Temperature: 68-70°C, Goal had been 80°C

Samples created:

Sr_001	Silk from the interior of the cocoon/end of reeling
Sr_002	Silk from the exterior of the cocoon/beginning of reeling
Sr_003	Silk from the middle of the cocoon/middle of reeling
Sr_T_001	Filaments from the middle and interior of the cocoon, twisted I2Z @ 2 crank turns/0.5metres

Method:

- Day began @ 9:30
- The oiled wok was degreased with dish soap and filled with water.
- The wok was set on the hotplate which was set to 3, and then 4 after a few minutes
- The water heated very slowly so the hotplate was turned up to 8 and by 10:27, the water had only reached a temperature of 35°C
- As the water heated it went cloudy at the steel oxidised
- The water was emptied and the wok scrubbed, refilled, and set back on the hotplate
- The water temperature was 34°C @ 11:17 so the hotplate was set to maximum heat (10)

- As the water temperature reached 34°C the pan once again oxidised and it was concluded that an alternative method or pan would need to be use in future experiments, but that reeling should proceed for this session
- By 12:19, the water temperature plateaued, holding at between 67 and 70°C
- 8 cocoons were placed in the water at 12:21
- Within t3 minutes the exteriors of the cocoons took on a reddish stain from the rust in the water
- Cocoons were checked with brush @12:35, and again @ 12:42, no ends came loose either time
- By 13:42 some ends were gathered, but the filaments broke frequently and it took several more minutes to get 6 strands reeling steadily
    - It was concluded that in future, all 8 cocoons should be used initially in reeling to compensate for the fact that 1-2 cocoons usually break away
    - This issue of gathering ends may be related to the lower temperature, since 80°C is supposed to be the ideal
- Reeling was completed at 14:18, overall thickness varied from 4-7 cocoons, but remained at 6 for the majority
- A sample of silk was taken prior to spooling (Sr_001)
- The reel was removed from its frame and placed on the floor
    - The dowel with thread guide was placed in the reel, which remained on the table where reeling took place
    - The silk filament was fed through the guiding eye and the end was tied to a pine bobbin affixed to the throwing rod
- While spooling, it was observed that the end of the silk (the section which would have been on the interior of the cocoons) was separating into 3 separate ends
- Air humidity increased during spooling as it began to rain
- The plan was to spool half of the reeled silk onto one bobbin, then take a sample from the middle of reeling, before spooling the rest onto a second bobbin, but the filament broke during spooling before half of the silk had been wound on to the first bobbin.
    - This caused difficulty because the end of the filament became lost
    - After several minutes of unsuccessful searching, the skein of silk was pulled from the end of the reel and placed loosely over a pine bobbin to reduce tangling

- The opposite end of the silk was located from this point and another sample (Sr_002) was taken
- Spooling continued until enough had been wound to find the middle section and the silk became too tangled to continue
  - A third sample was taken (Sr_003)
- Throwing the silk was attempted at this point, the two bobbins were placed on the floor end-on and the ends were tied together to a bamboo bobbin fixed on the spindle-wheel's quill
- The silk was twisted together at c. 2 clockwise crank turns/0.5metres
  - This should have produced Z twist silk with c. 109.76 twists/metre
  - This can be verified during analysis
- There were problems with the filaments breaking as the appeared to catch on the bobbins, it's also possible that how fine the silk on the first spooled bobbin was was a factor
- After several time breaking the throwing was discontinued to be carried on later

Post-experiment Reflections:

- The reason for the wok oxidizing was determined to be because it had not been properly seasoned (Gareth Perry, pers comm), this can be rectified prior to next experiment
- The reason the goal temperature could not be reached was likely because the wok was losing heat faster than the water could be heated by the hotplate (Gareth Perry, pers comm)
- It was concluded that a camp stove would be needed to effectively heat the water
- Something that became clear during spooling was that the weight of the pine bobbins when used in the way depicted historical and described by many authors was likely to lead to serious wrist strain, and I needed to rest the end of the throwing rod on my leg to avoid this
  - The dimensions of the bobbins were based roughly on a piece found in Xinjiang dated to the Jin dynasty which was described as either a reel or a bobbin
  - Based on this it seems probable that this find was a reel rather than a bobbin used with a throwing rod, and it is clear that further tests need to be conducted with lighter bobbins
- The silk was observed to have a reddish hue at the start of reeling, becoming more white in the interior layers of the cocoons

- It also seems likely that part of the difficulty with unwinding from the ends of the bobbins was a result of the guiding eye not being suspended high enough from the ground (according to Burham should be more than 2 metres from the ground)

06/08/2021 (Throwing)

Equipment: spindle wheel, 3 Pine bobbins & hardwood throwing rod, Reel frame and dowel with bamboo thread guide, modern umbrella swift

Setting: Material Culture Lab (DS/008) Palaeohub, windows open

Weather: Overcast, intermittent heavy rain

Samples created:

Sr_T_002	I2Z2S: Two strands of I2Z (Sr_T_001), twisted in the S direction @ 2 crank turns/0.5 metres
Sr_T_003	I2I: Two untwisted strands wound together using a spindle wheel
Sr_T_004	I2I2I: Two strands to I2I (Sr_T_003_) wound together using a spindle wheel
Sr_T_005	Filaments from the middle and interior of the cocoon, twisted I2S @ 2 crank turns/0.5metres
Sr_T_006	I2S2Z: Two strands of I2S (Sr_T_005), twisted in the Z direction @ 2 crank turns/0.5 metres

Method:

- A modern umbrella swift was used to tension the tangled skein of raw silk
- Finding loose ends proved to be difficult, and a strand needed to be cut
- Eventually it became clear that the silk was too tangled to continue spooling efficiently and I continued twisting/throwing the previously spooled silk
- 5 additional samples were produced containing 2 and 4 strand twisted (both S and Z) and untwisted samples
- Leftover raw silk was stored separately in a sample bag

23/08/2021 (Side experiment)

- Four (4) new lighter bobbins were constructed from bamboo and c. 3mm dowelling, along with a bamboo throwing rod, and a thin bamboo ring for guiding threads
- Winding silk onto the new bobbins proved to be significantly easier and faster than the heavier pine bobbins
    - The new bobbins are light enough that the bamboo cross-pieces warp inwards slightly under the tension of the silk, but this is subtle and bobbins are still sturdy enough to withstand this moderate tension
- The bamboo ring was suspended c. 195cm from the ground and this proved more effective for guiding the silk smoothly from the bobbins
- The silk, which in this case was degummed and untwisted caught somewhat on the bobbins, which were sanded with 3000 grit paper afterward to prevent this in future
    - The light weight of the new bobbins did mean that they were easily lifted off the ground when the silk snagged, so it is possible that these bobbins are too light, but the lifting issue was solved with the addition of some weight by means of adding a clamp to the bottom of each bobbin
    - One downside of this was discovered, as when one of the bobbins did drop with the weight attached, it broke
    - Also because of the method of construction, the spokes of the bobbin gradually pushed through the cross-pieces
    - It was concluded that while a little too heavy, the pine bobbins were the best option for spooling during the experiments

30/08/2021

Assistance provided/photographs taken by Eleanor Green
Equipment: Simple Reel, camp stove, Carbon Steel wok (seasoned), Probe thermometer, small natural bristle dish brush, small broom, spiral ladle, 3 Pine bobbins & hardwood throwing rod, bamboo ring.

Cocoons: Grade A, Supplier 2
8 cocoons were soaked to reel an average of 6 strands at a time

Setting: YEAR centre
Weather: Overcast with intermittent rain

Water Temperature: Goal of 80°C, actual range between 75°C and 86°C

Samples created:

Sr_004	Silk from the interior of the cocoon/end of reeling
Sr_005	Silk from the exterior of the cocoon/beginning of reeling
Sr_006	Silk from the middle of the cocoon/middle of reeling

Method:

- Transporting equipment to YEAR Centre and set up took 1 hour
- Water temperature taken at 10:07 was 45°C
- Water had noticeably evaporated byt 10:30 so more water was added
  - Water temp. dropped from 75°C to 65°C at this point
  - Prior to addition of water lots of little bubbles approaching "crab's eye" in appearance were visible
  - With addition of water some of the "coating" from seasoning the wok had clearly flaked off and was floating on water surface
    - It was difficult to skim this off
    - Despite flaking no rust was visible in water at this time
- The water temperature reached 80°C at 10:38
- The cocoons were placed in the water at 10:41
  - The temperature read 84°C at this point
  - The cocoons were checked periodically at this point, but it took some time for all of the ends to be found and to be unravelled continuously
- At 11:00 the temperature had dropped to 73°C so flame was adjusted to bring temperature back up to 80°C
- All ends found and reeling proper began at 11:40
  - Two cocoons dropped right away leaving 6 total, when one of the six came near to its end, one of the other cocoons was added back in
- Reeling finished at 12:00, when more cocoons started dropping off
- Spooling was carried out by clipping a bamboo ring on a cord to the edge of the roof of one of the Henson huts

    - The filament was passed through the ring and the reel placed on its end in a basket underneath
    - The free end of the silk was tied to one of the bobbins, mounted on the throwing rod, and the bobbin was turned clockwise to wind the silk on to the bobbin.
    - The silk was split across the three bobbins in this way, each one marked interior, exterior, and middle depending on where in the cocoon the silk on the bobbin was from
    - Samples were taken of the exterior, interior and middle silk and labelled accordingly
- Spooling concluded at 13:10

Post-experiment Reflections:
- The sample of silk taken from the exterior of the cocoon was rusty orange in colour, indicating that oxidation has occurred in areas where the coating had flaked away from the wok
- Inspection of wok post-reeling showed multiple small areas of pitting on the interior surface of the wok
- It was concluded that a copper reeling basin was needed for future experiments
    - Two have been purchased, one is a round bottomed bowl 20cm in diameter one is a flat-bottomed jam pan 36cm in diameter at rim
- The importance of tacit knowledge in silk reeling became really clear during this experiment: The need to know when a subtle tug means that the silk is not unravelling/unwinding properly, understanding when one cocoon isn't unravelling along with the others, etc.

31/08/2021 (Throwing)

Solo work, throwing silk reeled on 30/08/2021.

Setting: Material Culture Lab (DS/008) Palaeohub, windows open
Weather: Partially cloudy

Samples Created:

Sr_T_0 07	S3Z, Burnham weft method (3 filaments: interior, exterior, and middle), approx. 3 cranks/0.5 metres
Sr_T_0 08	S2Z Burnham warp method (2 filaments: interior and exterior), approx. 6 cranks/0.5metres

Sr_T_0 09	S2Z2S, (interior and exterior bobbins) converted from Kuhn's method, approx. 4 cranks/0.5 metres
Sr_T_0 10	Desrosiers' method, either Z2S, I2I or some other variant, to be determined via analysis (middle bobbin)
Sr_T_0 11	Kuhn's method, more or less as written ?2S2Z (interior and middle bobbins) approx. 4 cranks/0.5 metres
Sr_T_0 12	I3I, 3 filaments (interior, middle, and exterior) wound together without twist

Method:

- Samples were created according to three proposed methods of throwing silk with twist ranging from minimal, to high level of twist (none to the extreme of crepe twist)
- All samples were thrown from 1-3 bobbins, with the filament(s) passed through a bamboo ring suspended from an easel c. 1.5 metres off the ground
- Sr_T_010 did not appear to produce much visible twist, so Sr_T_010 was created intentionally with no twist added for comparison
- The process of creating the 6 samples (with extra skeins for degumming experiments) began at 12:42 and was completed at 15:56, some breaks were taken in between
- After samples were created a significant amount of raw silk was left on each bobbin
    - This remaining silk was processed using Burnham's weft method which was then wound into a skein and bagged and labelled separately
    - This took approximately 1.5 hours (from 16:00-17:30)
    - The amount of "weft" produced is uncertain but likely exceeds 100 metres
    - Extra sections of raw filament were wound into skeins and included in the corresponding sample bags

Post-experiment reflections:

- No obvious twist observed in samples from Desrosiers samples- will be useful to analyse both gum and degummed samples under a microscope
- Bamboo ring made a significant difference in ease of throwing

- Looking at images of silk textiles from a number of museum collections, I'm observing more silk warps that appear single-twisted than I had expected, this has me wondering if Burnham's method is most likely, but it's too soon to tell.

06/09/2021

Assistance provided/photographs taken by Skye and George (photos primarily taken by Skye)

Equipment: Simple Reel, camp stove, Copper Jam pan, Probe thermometer, small natural bristle dish brush, small broom, spiral ladle, 3 Pine bobbins & hardwood throwing rod, bamboo ring.

Cocoons: Grade A, Supplier 2
8 cocoons were soaked to reel an average of 6 strands at a time

Setting: YEAR centre
Weather: high humidity, sunny, no breeze

Water Temperature: Goal of 80°C, mostly sat at 82°C

Samples created:

Sr_007	Silk from the interior of the cocoon/end of reeling
Sr_008	Silk from the exterior of the cocoon/beginning of reeling
Sr_009	Silk from the middle of the cocoon/middle of reeling

Method:
Same methodology as previous reeling experiments

- Water temperature at 11:17 was 35°C
- 11:24 - 59°C
- 80°C at 11:35, cocoons were placed in pan
- The "crab eye" appearance observed in the carbon steel wok was not visible in flat-bottomed copper jam pan at 80°C, it is unclear whether this is because of the change in material or pan shape
- Reeling finished at 12:30, at least half of the time was soaking the cocoons and finding the ends

  - Water temperature held consistently at 82°C during reeling, with the stove on the lowest possible setting, demonstrating how effective copper is a conducting heat
  - Uncertain whether the more constant temperature is a result of the lack of breeze, the copper, or a combination of both
  - The cocoons were not stained during the process

Post-experiment reflections:

- Finding the silk ends appeared to occur much more quickly this time, uncertain whether this is improved method, the result of a more consistent temperature, or also connected to the change in pan material

07/09/2021 (Throwing)

Throwing silk reeled on 06/09/2021. Photos by Andy Needham.

Setting: YEAR centre, sunny, very mild breeze, warm

Samples Created:

Sr_T_013	S3Z, Burnham weft method (3 filaments: interior, exterior, and middle), approx. 3 cranks/0.5 metres
Sr_T_014	S2Z Burnham warp method (2 filaments: interior and exterior), approx. 6 cranks/0.5metres
Sr_T_015	S2Z2S, (interior and exterior bobbins) converted from Kuhn's method, approx. 4 cranks/0.5 metres
Sr_T_016	Desrosiers' method, wound clockwise, then counterclockwise (middle bobbin)
Sr_T_017	Desrosiers' method, wound counterclockwise, then clockwise (middle bobbin)
Sr_T_018	Kuhn's method ?2S2Z, approx. 4 cranks/0.5 metres
Sr_T_019	Drop spindle with 35g clay whorl, ?I2Z, 1 flick/length of drop, spindle was gradually lowered over course of c. 5 seconds, and allowed to continue twisting for an additional 3 seconds when nearly touching the ground (Interior and exterior filaments)
Sr_T_0	2 strands combined, no intentional twist (I2I) (Interior and

20	exterior filaments)
Sr_T_0 21	3 strands combined, no intentional twist (I3I) (Interior and exterior filaments)
Sr_T_0 22	Drop spindle with 35g clay whorl, ?I2Z2S, gauged to result in visible twist on the ply, meaning silk was probably slightly over-spun in the ply directions

Method:

- All samples were initially twisted/wound directly from spooling bobbins, with the filament passing through a bamboo ring suspended from roof of Henson Hut
- Filaments were plied directly from bobbins which were either allowed to roll freely in a basket, or were organised on a stand in the case of the Desrosiers method, in both cases the filaments were not passed through the bamboo loop during plying
    - The exception being when plying with drop spindle, in which case two spindle sticks holding the twisted ?I2Z filaments were placed in a basket and the filaments were passed up through the ring before being plied with a third spindle stick- the same whorl was used for all three sticks

Post-experiment Reflections:

- The issue of twist is tricky- Kuhn and other authors including Burnham insist that twist is required in silk to be used for a warp thread, Desrosiers also argues along these lines, but at least acknowledges that there is evidence for silks woven with warp threads with no apparent twist
- The relevant issue with twist here is Desrosiers' claim that all silk has at least some incidental twist- this might be true, for any method which involves pulling silk from the end of a bobbin at least
    - The real question is whether this minor incidental twist is at all visible in finished yarn, AND, whether such an unobservable degree of twist lends any strength
    - This connects importantly to Desrosiers' (2019; 2021 ETSG conference) argument that reeled silk with absolutely no twist will fall apart/ will be too weak to weave with
        - My theory is that Desrosiers is confusing strength with resistance to abrasion, as the two are connected but different, and I also think Desrosiers is not account for

the fact that, when slack the filaments of an untwisted thread will separate and become weaker, but under tension will behave more like a cohesive unit and retain strength- this needs testing but I would argue that to some extent untwisted thread would be easier to manage as a warp during weaving than it would be to manage if used in embroidery

- The issue of incidental twist is also important because if not intentionally incorporated into the throwing process, there is a question of whether a) the incidental twist somewhat undoes intentional twist, reducing the degree of twist, or b) the incidental twist has little impact on intentional twist in which case it is less relevant than has been argued

08/09/2021

Assistance provided/photographs taken by Skye and George (photos primarily taken by Skye)

Equipment: Simple Reel, “Silent Roller”, camp stove, Copper Jam pan, Probe thermometer, small natural bristle dish brush, spiral ladle, 3 Pine bobbins & hardwood throwing rod, bamboo ring.

Cocoons: Grade A, Supplier 2
8 cocoons were soaked to reel an average of 6 strands at a time

Setting: YEAR centre
Weather: Hot, sunny, no breeze

Water Temperature: Goal of 80°C, Heat fairly consistent, 79-81°C, tap water was used

Samples created:

Sr_010	Small sample from exterior of cocoon
Sr_011	Longer sample, possibly from middle of cocoon
Sr_012	Short samples from throughout skein
Sr_013	Further short samples
Sr_014	Remainder of silk, cut from reel

Method:

- Water began heating at 11:00
- 79°C at 11:24
- Began reeling at 11:56
    - To do this silk filament was pulled through Bamboo tube at base of soundless roller, then brought up and around roller, wrapping 4 times around itself before being tied to the reel
        - This method was based on images from silk reeling using a similar frame in Thailand and Laos
    - Reeling then proceeded as normal, with the right hand guiding the silk back and forth across the reel
- Reeling progressed smoothly, finishing around 12:30
    - 1 breakage occurred
- Reeling was carried further slightly longer than usual so filament became quite thin
    - Possibly because of this, the filament snapped just before spooling could commence and then, apparently because it had become tucked under another thread, could not be found
- A modern swift was collected from the Palaeohub so that the silk could be pulled off the reel and then spooled
    - This took c. 15 minutes
- Most likely because the silk began to dry and shrink against the reel in the time it took to collect the swift, it proved impossible to pull the silk from the reel and as more time passed the silk began breaking under tension
- After c. 30 minutes of struggling, it became clear the silk could not be removed, small samples of silk were gathered for fibre analysis and labelled accordingly
- Finally the silk was cut from the reel, twisted into a loop and stored in a labelled sample bag
- Because of this complication it will be impossible to produce a thrown sample of this silk without repeating the experiment, but it will at least be possible to carry out fibre analysis, and possibly degumming

Post-experiment Reflections:

- The results of this experiment were disappointing and largely due to human error, it's fortunate that enough samples were collected that fibre analysis will be possible, but disappointing that thrown samples cannot be produced

    - This experiment will be repeated if there is enough time, and remaining cocoons to do so after the other variables have been tested
- The broader shape of the silk reel arms may also have put additional strain on the silk. The reel will not be modified in the interest of keeping the experiments consistent, but this is a possible factor
- Ways to avoid this problem in future experiments:
    - Stop reeling when the silk becomes noticeably thin, to prevent easy breakage
    - If silk is to be tied off and pulled from reel this should be done right away, before fetching additional equipment
        - Back-up equipment kept on-hand would also solve this problem

14/09/2021

Assistance provided/photographs taken by Skye and Abbie, most photographs taken by Abbie

Equipment: Treadled reel, roller frame, camp stove, Copper Jam pan, Copper bowl, Probe thermometer, small natural bristle dish brush, spiral ladle, Cotton yarn.

Cocoons: Grade A, Supplier 2
8 cocoons to reel an average of 6 strands at a time x 2

Setting: YEAR centre
Weather: Overcast, Rainy, very humid

Water Temperature: Goal of 80°C, Heat not consistent, tap water was used

Samples created:

Tr_001-003	2 Skeins from first session of reeling, using single winding on roller frame and the treadle, will need to be subdivided
Tr_004-006	Successful skein from second reeling session using double winding method on roller frame, and hand-cranking, will need to be subdivided

Tr_007-008	Less successful (kept breaking) skein from second reeling session using double winding method on roller frame and hand-cranking

Method:
I struggled to keep track of time during this set of experiments, but safe to say reeling process was longer than with simple reel

- The Jam pan was too large to fit on the stove next to the copper bowl
- It was decided that all cocoons to be used for the session (32 total) would be heated ahead of time in the bowl
    - This took longer than expected, partly due to the cold damp weather, and partly due to some difficulty regulating the gas flow, which was resolved
    - I estimate it took an hour to heat the water to c. 74°C at which point the coons were added
    - Shortly after this the gas flow was increased and the temperature quickly shot up to 91°C, before being lowered again to 81°C
    - The round shape of the bowl may also have affected the consistency of the temperature, as temp. is much more even when the flat-bottomed copper pan is used
    - Another important thing to note is that the "crab eye" bubbles formed in the round copper bowl around 80°C but not in the flat-bottomed pan, this suggests this shape is more in line with what was used in the Song Dynasty
- After the ends had been gathered, the required number of cocoons for the first session (16) were transferred from the bowl to the (cold) water in the jam pan
- The bowl was removed from the burner and set aside so the remaining cocoons could continue soaking
- The Jam pan was then placed on the stove and the flame raised to heat the cocoons quickly
- The ends were re-found and divided into two assemblages while the pan heated and the reel was threaded while the pan finished heating
- Because of the humidity, the reel drive band had become loose so a new one was tied, which worked well
- Reeling went fairly smoothly with the single wrap
    - Treadling took a fair bit of concentration, so there was some starting-and-stopping

    - It was difficult to tend cocoons and treadle, fortunately they mostly watched themselves
- When reeling was finished the ends of the skeins were tied with cotton, and cotton was tied around the skeins to save the centre before they were pulled from the reel and labelled Tr_001-Tr_003
- The cocoons which had been soaking for the duration of reeling were transferred to the now heated jam pan and sizzled upon addition
- In the interim time, the friction with the drive band had reduced and the ramping board was not moving properly
    - Some pitch or similar was found on a tree stump and added to the pulley which mostly fixed this problem
- It took roughly half an hour to find the ends of the cocoons again and they were then divided in half
- The two filaments were then threaded double, using Kuhn's theory which involved two rollers
- There were immediately problems with the threads breaking, and it was impossible to get them to reel
- At this point we switched to the double wrap method using just the top rollers. This immediately worked better but again the threads snapped when I started using the treadle
- We agreed to hand crank the reel instead, noting that Kuhn does describe this method as slower and wondering if this was a possible reason
- The reeling progressed more smoothly with hand-cranking, but the thread on the left repeatedly snapped and needed to be re-tied until it was finally abandoned
    - Upon investigation the top left rolled had become coated in a layer of silk and it was clear the silk was catching on the roller somehow
- After proceeding with reeling the single right filament, the ramping board stopped running smoothly, repeatedly sticking at one point in the rotation
    - It therefore became necessary for me to stand to the side of the reel instead of tending the cocoons so that I could manually rotate the ramping board which we theorised was sticking because the wood had expanded due to the moisture
- Finally, with the right skain complete the ends of this skein was tied off and labelled Tr_004-Tr_006, while the smaller left-hand skein was labelled 007-008 (Because there was no interior cocoon silk to collect from this skein)

- At the end of the process the skeins were all very damp so they were brought inside to completely dry before being placed into sample bags while awaiting throwing
- It was noted that the skeins from the second reeling session were stained a light brown in contrast to the brighter skeins from the first session, this may be due to the longer soaking time

Post-experiment Reflections:

- Humidity had a negative impact on the wooden equipment, but may have helped in making the skeins easier to pull from the reel
- Some equipment maintenance is necessary before next reeling session:
    - Rough patch on cam needs to be sanded and whole section will be oiled
    - There may be rough patches on rollers (especially top left) which need to be smoothed
        - Upon inspection, the top left rolled still somewhat jams so the ends need to be shaved and smoothed as well
    - Need to bring rosin and beeswax to next session
- The prolonged soaking did not improve the efficiency of the reeling, unless two stoves can be operated simultaneously, I will abandon pre-soaking and reel one set of cocoons at a time
- I need to do a better job of recording reeling times moving forward, have prepared a format to help with this
- Space was cramped under Henson hut, so it would be preferable to work in the open

16/09/2021

Assistance from Abbie and Caroline, Photographs primarily taken by Caroline
Equipment: Treadled Reel, Roller frame, copper jam pan, camp stove, thermometer, brush, wire ladle

Setting: YEAR centre
Weather: Sunny and warm

Cocoons: Supplier 2, Grade A c.6 x2

Water Temperature: Goal of 80°C, Heat relatively consistent, turned off in middle of reeling, to save butane, tap water was used

Samples created:

Tr_009-Tr_011	Double-wrapped silk, left roller-will need to be divided
Tr_012-Tr_014	Double-wrapped silk, right roller-will need to be divided

Method:

- Water was put on burner at 10:36
- Water 70°C at 11:06
- 80°C at 11:13-cocoons in
- Started to reel at 12:13 (approx. 1 hour, 5 min. to find all cocoon ends)
- Cocoons in both assemblages wrapped according to Kuhn's "complete wrapping" diagram, immediately clear that rollers would not turn sufficiently to use this method on both sides
    - Tested a variation of this method with fewer wraps around rollers but the bottom left roller would not turn to allow this either
- Decided to split experiment, so left side would be used to re-do double-wrap method, while the right would used my variation of the complete wrapping method
- Once reeling began, the complete wrap on the right caused problems, both rollers would not turn sufficiently and the strand repeatedly broke
- Decision was made to proceed with both roller double wrapped, thereby repeating the previously not-very-successful attempt
- This method went fairly smoothly, but could not be treadled without snapping
    - A few breakages occurred even when hand-cranked and a noticeable amount of silk was deposited on rollers
    - The silk was less inclined to shred when wound more quickly-which is consistent with Kuhn's writing
- The heat was turned off at 13:09 at which point the reeling had begun properly
- Finished reeling c. 14:10
- The goal was to continue with a second round of 6 cocoons in boiling water but the canister of butane ran out before the water could be boiled

Post-experiment Reflections:

- There are a few possible reasons that the complete winding method was unsuccessful:
    - The hollow diameter of the bamboo tubes may be too large in relation to diameter of the axle, meaning that they don't roll smoothly
    - The tubes are not all perfectly circular in cross-section, which could prevent them from rotating properly
    - The tubes may be slightly too rough, causing the breakages (additionally this could be contributing to the silk shredding during double-wrapping)
    - 6 cocoons may be too few for the complete-winding method, it's possible that 15 would be strong enough to withstand the added tension
- The quality of the double wrapped silk seemed better than last time, but still showed some uneven discolouration, this may be a result of the length of time the cocoons soaked, or could be the result of some intrusive dirt in the water
- The silk shredding was at least partly a result of slow, over-cautious reeling, as the filaments were more likely to separate as they dried
- Not for the first time, observations were made on the sometimes subtle gestures involved in the process. On this occasion it related to my interactions with Abbie and as I found the loose ends of the cocoons and transferred them from my hand to hers. These movements are gentle and almost intimate as we crouch over the basin coaxing the cocoons to unravel smoothly, and I one by one wrap one, or two new threads around her hand
    - It has also struck me that a pseudo-apprenticeship relationship is forming between myself and the volunteers- most of them are anxious about harming the experiments, or breaking the delicate silk, but they understand the process more and more as time goes on and as I've become more comfortable having them interact more directly with the fibres, they gain confidence and offer their own insights on what is and isn't working in the experiments
        - Sometimes this needs to be reined in-like when Caroline was convinced the fibres were shredding and about to break because of the way they vibrated from the transferred motion of the ramping board, but this is also a part of them learning about the process and gaining a

        - more sophisticated understanding of the properties of silk fibres
        - The ongoing theme is amazement at how strong the silk fibres are when grouped together or wrapped round and round and object (or someone's hand)
        - One of many things that distinguishes this from a formal apprenticeship is that I am not a master, and am still gaining confidence and knowledge myself throughout this process- I'm quite happy with this of course, but the fact that this makes the process a little more collaborative is an important distinction to make

17/09/2021

Assistance from Caroline and Nevan, Photographs primarily taken by Nevan (camera died part way through)

Equipment: Treadled Reel, Roller frame, copper jam pan, camp stove, thermometer, brush, wire ladle

Setting: YEAR centre
Weather: Partly cloudy, c. 11°C, mild breeze to moderate wind

Cocoons: Supplier 2, Grade A c.15 x2

Water Temperature: Goal of 80°C, Heat relatively consistent, tap water was used

Samples created:

Tr_015-Tr_017	Single-wrapped silk, c. 15 cocoons, left roller-will need to be divided
Tr_018-Tr_020	Single-wrapped silk, c. 15 cocoons, right roller-will need to be divided

Method:

- Aim of this experiment was to reel 6 cocoons x2 in boiling water
    - Began heating water at 11:00
    - By 12:08 the water temp. could not be raised above 87°C
    - By 12:20, the wind had picked up and the temperature had dropped to 12:20

    - At this point it was concluded it would be more productive to drop the temperature to 80°C and test reeling 15 cocoons per assemblage
- Heat was lowered to 80°C and the cocoons were added at 12:26
- Most ends were found by 13:15 and reeling commenced
- It was possible to treadle smoothly with this session although some cocoons were inclined to drop away so some stopping-and-starting occurred
    - Eventually we adjusted to having Caroline slowly but steadily turning the reel while I added ends back in, and then switching back to reeling in between, this reduced the degree to which the filaments were inclined to separate during reeling
- Reeling was completed at 14:00

Post-experiment Reflections:

- Few breakages occurred during this process and while the filament may not have appeared visibly thicker, it was noticeably stronger and the reeled skeins were more substantial than those reeled from 6 cocoons
- We had a few instances of the drive-band popping off of the reel, pulley (not a new problem) Nevan observed that this occurred every time the know hit the pulley and he was able to prevent this by manually holding tension
    - This problem can be resolved by making another knotless drive band at the correct tension- it may also be worth making a drive band out of cotton rather than flax
- There was still some noticeable staining on the silk, which was streaky in nature, this could have resulted from dirt contaminating the water

21/09/2021

Assistance from Eleanor J

Equipment: Simple reel, copper jam pan, camp stove, thermometer, brush, wire ladle, tap water

Setting: YEAR centre
Weather: Partly cloudy,dry

Cocoons: Supplier 2, Grade A 3

Water Temperature: Goal of 80°C, Heat relatively consistent, tap water was used

Samples created:

Sr_015	Interior of cocoon
Sr_016	Exterior of Cocoon
Sr_017	Middle of cocoon

Method:

- Water set on stove at 10:55
- Reached 80°C at 11:33, 5 cocoons were then added to the water
- It took 11 minutes to find the ends of 3 cocoons and ge the unravelling consistently, reeling proper began at 11:44
- Reeling finished at 12:09 (25 min. reeling time)
    - This time while reeling, I guided the silk with my right hand back and forth across the reel more rapidly, which was more tiring, but meant that the silk was (theoretically) less likely to snag during later unwinding
    - When one of the cocoons became noticeably transparent I added in one of the other 2 cocoons, and did the same when the next one became thin and the first one had nearly dropped away
        - By the end the filament was made up of 4-5 cocoons then, three of which were extremely thin
- Spooling started out fairly well (was actually slowed down slightly by the shaft of the throwing rod snagging on my clothing) but the thread did snap after several metres had been wound onto the first spool and the end was lost
    - This break, strangely, occurred right as the filament was becoming noticeably thicker and was therefore getting closer to the middle
    - The skein was then removed from the reel and transferred to a modern umbrella swift (I don’t know how this situation would have been handled historically, but it’s possible 3 cocoons were only reeled on the treadled reel in which case the skein would be transferred to a swift or other frame anyway)

    - From the swift the beginning of the thread was located and wound onto a paper sample bobbin
    - The middle of the thread was then located and wound onto one of the bobbins, which had been mounted onto the reel axle so that it could be turned while simultaneously turning the swift (with Eleanor's help)
        - After a few metres were wound on the thread broke again and I struggled to find it in the lighting conditions
        - At this point I tied off the skein with cotton and bagged it for later processing
        - I was able to transfer the several metres of middle filament from the bobbin to a sample bobbin, thereby collecting the three filament samples I needed

Post-experiment Reflections:

- It was important to have the silk pass between my nearly closed thumb and forefingers so that the 3 cocoons strands didn't separate as they dried
    - this was effective but meant I had to be careful to let the silk pass smoothly through my fingers as too much tension resulted in breakages (unsurprising, since the silk was extremely fine)
- Although the criss-cross winding did not prevent the silk from snagging and breaking, this pattern of laying the silk on the reel meant that it was significantly easier to pull the thread from the end of the reel in order to transfer it onto an umbrella swift and find the end more easily
- The silk was relatively strong for its fineness but definitely more vulnerable to breaking than the 6 cocoon silk
- Unsurprisingly the small number of cocoons meant that it took very little time to find the ends and begin reeling
- Despite the break which occurred, it seems that unravelling from above would be the better method since it puts less strain on this silk than unwinding from the umbrella swift which requires more pulling or manually unwinding, which slows the process down significantly

22/09/2021

Assistance from Skye

Equipment: Treadled Reel, without the treadle, Roller frame, copper jam pan, camp stove, thermometer, brush, wire ladle, tap water

Setting: YEAR centre
Weather: Partly cloudy, mild breeze to noticable wind (strong enough to extinguish the stove at one point)

Cocoons: Supplier 2, Grade A 3 x2

Water Temperature: Goal of 80°C, Heat very inconsistent due to wind

Samples created:

Tr_021-Tr_23	Single-wrapped silk, 3 cocoons, left roller-will need to be divided
Tr_024-Tr_026	Single-wrapped silk, 3 cocoons, right roller-will need to be divided

Method:
- Set up took c. 40 minutes
- Water on at 13:44
    - After a few minutes the flame went out and we constructed a wind barrier with equipment and scrap board to prevent this happening again
        - Despite the wind break the wind still slowed down the heating of the water
    - At 14:53, the water had only reached 65°C
        - We changed the fuel canister which was nearly empty, and put a wooden board over top of the jam pan to speed heating, leaving a small gap so the temperature could be monitored
    - The water temperature reached 80°C at 15:00
        - We removed the lid and added the cocoons (10 total)
        - With the lid off, the water quickly lost temperature, hitting 70°C before we replaced the lid and allowed the cocoons to soak until the water reached 80°C again (c. 15-20 mins)
    - By 15:30 the ends were found and we began reeling
        - Reeling went very smoothly and the threads did not break at all until the right one snapped at the very end

        - To spare extra tension or jerking, Skye hand-cranked the reel the entire time while I tended the cocoons, this allowed me to add in new ones near the end and kept the process going for longer
        - During reeling there was a temperature low of 63°C
    - Reeling finished at 15:57 when the right thread snapped
        - The skeins were tied, tagged and bagged
            - A couple of breaks appear to have occurred while removing the left skein, and it appeared the something had gone strange with the ramping board so that it laid just one thread off of the end of the reeling, which meant it was not in line with the other threads and snapped under tension

Post-experiment Reflections:

- This silk was a brighter white than any other reeled with the big reel
    - This might be the shorter cocoon soaking time, the (unintentional) lower temperature during reeling, or an unplanned difference in cocoons quality
        - I want to assess the 3-strand silk from the simple reel as well to see if this one is also brighter than the other silks which would suggest it is a result of shorter soaking time
- I replaced the drive band this experiment, switching the waxed linen for heavily twisted cotton, stitch-joined and this resulting in much smoother motion from the ramping board (it only got stuck once) and a much better pattern of laid silk on the reel
    - I attribute this partially to the elasticity of the cotton cord, and partly to it not being as inclined to slacken in moist conditions
- The smoothness of this trial makes me think that the treadled (well, cranked) big reel is a better machine for silks this fine

24/09/2021

Assistance from Nevan, Abbie, and George (photos by Nevan), Abbie assisted with logbook, temp. Monitoring and other organisations tasks, George assisted with cocoons and reel cranking

Equipment: Treadled Reel, without the treadle, copper wire thread guide, copper jam pan, camp stove, thermometer, brush, wire ladle, tap water

Setting: YEAR centre
Weather: Cloudy, cool, mild breeze, to noticeable wind (not as bas as previous trial)

Cocoons: Supplier 2, Grade A 15 x2 and 6x2

Water Temperature: Goal of 80°C, Heat inconsistent due to wind

Samples created:

Tr_027-Tr_029	Piedmont crossing, 10-17 cocoons, left skein-will need to be divided
Tr_030-Tr_032	Piedmont crossing, 10-17 cocoons, right skein-will need to be divided
Tr_033-Tr_035	Piedmont crossing, 6 cocoons, left skein-will need to be divided
Tr_036-Tr_038	Piedmont crossing, 6 cocoons, right skein-will need to be divided

Method:

- Water on at 10:55, immediately constructed wind break
- Slow heating due to wind
- 80°C at 11:43, cocoons (approx 36) were added
- Temperature lowered more as cocoons were stirred in effort to find ends
- The temp hit 68°C at 12:02, fuel canister was changed to new one at this point as it was getting low (was not as low as we thought though)
- At 12:36, enough ends had been found to set up Piedmont crossing, with 10 twists
    - George cranked reel and I tended cocoons
    - Cocoons quickly dropped to 10 and I spent much of the time adding them back in, therefore the silk ranged from 10-17 cocoons in each assemblage
    - George cranks slightly more slowly than Skye but the process still progressed smoothly with no breaks
    - Temp. low during reeling was 63°C
- First reeling finished at 13:16, skeins were tied and tagged and set in basket

- The water was then changed and replaced on stove at 13:33
- Wind had died down a little by this point
- Water heated to 80°C at 14:45, 16 cocoons were added
- Reeling began at 15:12, also with 10 twist piedmont crossing
    - Mostly consistent temperature at 78-80°C
- Did not record end time but was c. 15:50
- Skeins were removed, tied, tagged, and allowed to dry slightly before all 4 were bagged

Post-experiment Reflections:
- This silk was brighter than some other samples but not as white as 3 cocoon silk
- Ramping board continued to operate mostly smoothly, with only a few stalls
    - On second round of reeling, the laying pattern was strange and a little uneven, uncertain if this was due to reeling speed or friction issue with drive band
- Whole process was very smooth
    - I chose not to use the treadle since most of the Italian samples show hand cranking, but the process was smooth enough that I think it would have run fine with the treadle
        - This could be investigated further in future

29/09/2021

Assistance from Skye and George, some photos by Skye, assistance with cocoons from George, Skye cranked reel, George kept drive-band tension

Equipment: Treadled Reel, without the treadle, copper wire thread guide, copper jam pan, camp stove, thermometer, large brush, modified to be tight at end with copper wire, wire ladle, tap water

Setting: YEAR centre
Weather: Cloudy, cool, mild breeze

Cocoons: Supplier 2, Grade B 30 x2 (72 cocoons in)

Water Temperature: Boiling, Heat inconsistent due to wind

Samples created:

Tr_039-Tr_041	Piedmont crossing, boiling water, c. 30 cocoons, left skein-will need to be divided
Tr_042-Tr_044	Piedmont crossing, boiling, c. 30 cocoons, right skein-will need to be divided

Method:

- Spent a fair bit of time, sanding reel parts to make ramping board run smoothly, ultimately tension was issue with drive band, tightened several times
- Water on at noon
- 55°C at 12:45
- Changed fuel canister at 13:13
- Added wooden lid at 13:30
- 75°C at 13:36
- 84°C at 13:41
- Temperature was stuck on 89°C at 14:17
    - Cocoons were placed in water to soak and lid was replaced
    - A wind break was set up
- 91°C at 14:26 (windbreak effective)
- Water boiling at 14:36
    - Removed lid, began finding ends, and temperature dropped relatively quickly (Temp. low of 88°C)
- Began reeling with Piedmont crossing (10 twists) at 15:00
    - Hand-cranked to replicate most Italian imagery & Mola description
- Finished reeling at 15:26
- The silk was consistent and smooth to the naked eye, and (unsurprisingly) the thickest so far
- The left side filament broke right at the end of reeling because I put pressure on it while trying to add in more cocoons

Post-experiment Reflections:

- Problems with ramping board stalling have been ongoing
    - The previously effective cotton cord, has been having tension problems since heavy rain on 28/09/2021
    - Elasticity had previously been a positive, may be detrimental now
    - May need to try new materials or drastically adjust tension
- The boiling water significantly sped the process of finding the cocoon ends, more silk coming off immediately

    - No noticeable difference in quality to the naked eye at first, may be slightly more dull- will be very important to assess under microscope

06/10/2021

Assistance from Caroline, Eleanor J, Leon, and Finn, photos by Leon, assistance with reel from Caroline and Eleanor

Equipment: Treadled Reel, Roller frame, copper jam pan, camp stove, thermometer, small brush, wire ladle, tap water

Setting: YEAR centre
Weather: Cold, clear skies, still

Cocoons: Supplier 2, Grade A 6 x2 (16 in)

Water Temperature: Boiling, Heat inconsistent due to cold

Samples created:

Tr_045-Tr_047	Single wrap on roller frame, boiling water, c. 6 cocoons, left skein-will need to be divided
Tr_048-Tr_050	Single wrap on roller frame, boiling water, c. 6 cocoons, right skein-will need to be divided

Method:

- Water on at 10:40
- 65°C at 11:16
- 69°C at 11:35
- Changed canister at 12:00
- Lid on at 12:05
- 91°C at 12:16
- 98°C at 12:20
    - Cocoons in at 12:29, left in until water boiled
- Started reeling at 12:53
    - treadle was used
    - Caroline had to pull on drive band to keep tension
    - Temperature low of 79°C
- Finished reeling at 13:00

Post-experiment Reflections:

- Once the water was boiled the process was incredibly fast
    - Don't have exact time for gathering ends but it was quick
    - Reeling was fastest yet (7 minutes!)

07/10/2021 (Spooling)

Spooling silk reeled on 21/09/2021

Equipment: Blue umbrella swift, spools, throwing rod, spindle wheel, bamboo bobbins

Setting: Home office

Cocoons: S2A3 (From 21/09/2021)

Method:

- Tensioned skein from 21/09/2021 on umbrella swift
- Very slowly spooled silk onto bobbins, fragile nature led to multiple breaks during process
    - Would have been faster top-feeding from a bobbin or spool
    - Painfully slow
- Didn't completely fill bobbins, just wound enough to throw basic samples
    - Spooled silk for Desrosiers method directly onto bamboo bobbins from main skein
    - Once this was done remainder of skein was tied off and stored in sample bag

08/10/2021 (Throwing)

Throwing silk reeled on 21/09/2021

Equipment: Blue umbrella swift, spools, throwing rod, spindle wheel, bamboo bobbins

Setting: Home office

Cocoons: S2A3 (From 21/09/2021)

Samples created:

Sr_T_023	Desrosiers method, clockwise then counterclockwise
Sr_T_024	Desrosiers method, counterclockwise, then clockwise
Sr_T_025	Burnham warp method, 6 cranks/0.5 metres
Sr_T_026	Kuhn Method, Z then S, 4 cranks/0.5 metres
Sr_T_027	Burnham weft method, 3 cranks/0.5 metres
Sr_T_028	3 filaments, untwisted
Sr_T_029	Burnham weft method with final S twist, 3 cranks/0.5 metres (accidental, skein only)

12/10/2021

Assisted by Wren
Equipment: Simple reel, copper jam pan, camp stove, thermometer, small brush, wire ladle, green umbrella swift, tap water

Setting: YEAR centre
Weather: Cloudy, cold, slight breeze

Cocoons: Supplier 2, Grade A 15

Water Temperature: 80 C

Samples created:

Sr_018	Exterior of cocoon
Sr_019	Interior of Cocoon
Sr_020	Middle of cocoon-To be collected

Method:

- Water was put on heat at 12:29
- Reached 80 C at 13:00

    - Cocoons were put in water
- Reeling began at 13:35
    - Ends dropped off easily, and continual rejoining was necessary, all told, for most of reeling only c. 13 cocoon ends were reeled at a time
- Reeling was finished at 14:10
    - Silk had begun to shrink/dry by this time and had to be immediately pulled from reel to avoid breaking
    - Silk was placed on modern swift (green) and interior and exterior samples were gathered,
    - The ends of the skein were tied together and skein was tied with cotton string to preserve for later processing
    - Middle sample to be gathered during throwing process

Post-experiment Reflections:
- The silk likely dried quickly because more time was spent gathering ends of cocoons during reelin, slowing the process somewhat.

13/10/2021

Assisted by Wren and Leon
Equipment: Simple reel, copper jam pan, camp stove, thermometer, small brush, wire ladle, green umbrella swift, tap water

Setting: YEAR centre
Weather: Mild, still, cloudy

Cocoons: Supplier 2, Grade A, 6 (actually 8)

Water Temperature: Boiling

Samples created:

Sr_021	Interior of Cocoon
Sr_022	Middle of Cocoon
Sr_023	Exterior of cocoon

Method:

- Water put on heat c. 12:00
- Water boiling at 12:46
    - Cocoons put in water
    - Soaked for c. 5 min.
    - Ends gathered quickly, all 8 gathered and did not drop
- Reeling began at 12:58
- Reeling finished at 13:11
- Silk was fairly wet
    - Was pulled off reel, put onto swift
    - Silk was spooled off swift
    - Thread broke twice during spooling
        - Skein was tied and brought home to air dry prior to later spooling/throwing

Post-Experiment Reflections:

- Boiling significantly speed reeling process, and appears to brighten colour of silk
    - It may, however slightly weaken silk, should look out for fibrils, narrower diameters, and flaking gum during microscopic analysis

28/10/2021 (Throwing)

Assisted by George
Equipment: Spindle wheel, bobbins, throwing rod, bamboo spools, espinner, 3D printed quills/spools, umbrella swift (green)

Setting: YEAR centre
Weather: Breezy, cloudy, dry

Reeled silk from 13/10/2021

Samples created:

Sr_T_030	Burnham warp method (interior and exterior filaments) 6 cranks/0.5 m
Sr_T_031	Kuhn (?2Z2S), 4 cranks/0.5 m
Sr_T_032	Burnham weft (3 filaments) 3 cranks/0.5 m
Sr_T_033	No twist- 2 strands

Sr_T_034	“Silk mill” test, 2 strands wound on quill, Z twisted at medium speed setting, reel turned c. 17.6 rpm
Sr_T_035	Drop Spindle I2Z2S
Sr_T_036	Drop spindle I2Z
Sr_T_037	Single-wound clockwise on bamboo bobbin using spindle wheel (to be checked for twist)

Method:

- First spooled onto bobbins from umbrella swift
    - Frequent silk breaks, could be silk was weakened from boiling, could be pressure from swift
- Couldn’t find interior cocoon end
- Wound 1 strand of silk onto a quill, then wound that plus end from swift onto a second quill (counterclockwise)
    - Observed more silk splitting (uncertain if this is a result of boiling, hand-cranked reel with no rollers, or both)
- Quill was inserted into espinner, turned on its end, spinner was set at medium speed (need to find how many rpm)
    - Silk was wound from turning quill onto simple hand-cranked reel which was turned by hand
        - 30 cranks in 102 seconds = approximately 1 full rotation every 3.4 seconds
        - 17.6 rpm (this was calculated by George)

Post-Experiment Reflections:

- There may be issues with consistency of hand cranking reel
- Time pressure led to somewhat haphazard sample protocol

04/11/2021 (Sampling and documentation)

Assisted by George

Equipment: Cross-piece swift, baskets

Setting: YEAR centre
Weather: Cold, breeze

Samples created:

Tr_001	Interior of cocoon
Tr_002	Exterior of cocoon
Tr_003	Middle of cocon

Method:

- Started with documentation of all Tr skeins under different outdoor lighting conditions to accurately capture colour and sheen discrepancies between experimental samples prior to further sampling/throwing
    - In photos samples appear in the following order from left to right: Tr_001-Tr_003; Tr_004-Tr_006; Tr_009-Tr_011; Tr_015-Tr_017; Tr_024-Tr_026; Tr_027-Tr_029; Tr_033-Tr_035; Tr_039-Tr_041; Tr_045-Tr_047
- For sampling, Skein Tr_001-Tr_003 was placed on cross-piece swift, ties were left on, but silk ends were untied and samples were collected of each end
    - Ends were re-tied and marked with cotton string, skein was broken in middle (single strand) and a sample was taken from this middle section
    - All samples were labelled and stored in bags

Post-Experiment Reflections:

- Tis method works but is slow and needs to be revised to improve efficiency

17/11/2021 (Sampling)

Equipment: Modern green swift, paper bobbins

Setting: Home office

Samples created:

Tr_004	Probable cocoon interior
Tr_005	Probable cocoon exterior
Tr_006	Cocoon middle

Method:

- Same as previous sampling method but using modern swift
    - Silk broke during collection of sample Tr_004

Post-Experiment Reflections:

- Faster sampling method definitely required
- Resolved to pre-type all labels and make spreadsheet of samples to be collected which can be manually filled in with I (interior) M (middle) and E (exterior) for appropriate sample numbers

18/11/2021 (Throwing)

Equipment: Spindle wheel, 3D printed quills, espinner, simple reel, wooden bobbins

Setting: YEAR centre
Weather: Relatively warm, overcast

Throwing silk from: 14/09/2021 (Tr_001-003) and 13/10/2021

Samples created:

Tr_T_001	Mock silk mill, 3 strands, S twist, espinner on half speed, 16 cranks in 40 seconds
Tr_T_002	Mock silk mill, 2 strands Z twist, espinner full speed, 18 cranks in 20 seconds
Tr_T_003	Burnham warp method, 6 cranks/0.5 metres
Tr_T_004	Burnham weft method, 3 cranks/0.5 metres
Tr_T_005	3 strands, no twist
Sr_T_038	Mock silk mill, 3 strands, S twist, espinner at half speed, 70 cranks in 3 minutes, 3 seconds
Sr_T_039	Mock silk mill, 2 strands, Z twist, espinner full speed, 21 cranks in 41.5 seconds

Method:

- Not all silk was wound onto wooden bobbins so that remainder of raw silk could be saved for future experiments
- Same method as previous mock silk mill experiments but with varied speeds

Post-Experiment Reflections:

- Tr_T_001 seemed more tightly twisted than previous experiment with espinner at half speed
- Sr_T_038 semed to exhibit little twist

04/01/2022

Equipment: Brifit professional scale, sealable plastic containers, small scoops
Materials: Soda Ash, citric Acid, Soap flakes

Setting: Indoors, well-ventilated

Method:

- 4 skeins of silk were weighed totalling 0.356g
    - 0.119g of soda ash weighted out to equal approx. ⅓ of weight of silk
        - Actual weight of soda ash was 0.122g as such fine quantities are difficult to match
- Measurements for soap flakes given to correspond to quantity of water rather than weight of silk (8g per 1 litre of water)
    - 8 grams of soap flakes were pre-weighed
    - Silk skein to be degummed with soap flakes weighs 0.221g
- Citric acid for rinsing was weighed out at 3 grams and dissolved in roughly 75 ml of water, resulting in solution with a Ph of 3
- All pre-measured ingredients were stored in plastic bottles with inner seal, all clearly labelled with contents

05/01/2022 (Degumming)

Equipment: Camp stove, Stainless steel jam pan, Thermometer, dowels, camp stove wind break
Materials: 4 Skeins of Sr_T_013, pre-measured soda ash
Setting: Outdoors
Weather: Overcast, temperature of 3 C

Samples created:

Sr_T_D_001	Sr_T_013 simmered for 30 minutes
Sr_T_D_002	Sr_T_013 simmered for 1 hour
Sr_T_D_003	Sr_T_013 simmered for 2 hours
Sr_T_D_004	Sr_T_013 simmered for 2 hours with a citric acid rinse

Method:

- Skeins of silk were tied with "code strings" to differentiate them during degumming
    - 1 Knot= simmered for 30 minutes
    - 2 knots= simmered for 1 hour
    - 3 knots= simmered for 2 hours
    - 4 knots = simmered for 2 hours and rinsed with citric acid
- The code strings were used to suspend silk skeins from a dowel so they could hang freely in the water
    - Skeins were first soaked in warm water with Ph of 6
- 3 litres of water were added ot jam pan which was placed on the camp stove to heat to 80C
- Water could not break 75C so Soda Ash was added
    - No clear shift in Ph was noted so an additional 0.130g of soda ash was added which just shifted the Ph to 7 (may be lower than needed)
- Water was holding steadily at 71 C when skeins were added
    - Over the course of process water temperature dipped to 68 C
- After 30 minutes, the first skein of silk (Sr_T_D_001) was removed and rinsed twice in pyrex bowl of tap water with Ph of 5-6
    - Skein was hung to dry
- After another 30 minutes, the second skein of silk (Sr_T_D_002) was removed and rinsed twice in in pyrex bowl of tap water with Ph of 5-6
- After another hour, the final two skeins were removed
    - Sr_T_D_003 was rinsed twice in pyrex bowl of tap water with Ph of 5-6
    - Sr_T_D_004 was rinsed once in a pyrex bowl of tap water with Ph of 5-6, a second time in water shifted to Ph 4-5 with citric acid solution, and finally rinsed once more in unaltered tap water

Post-Experiment Reflections:

- None of the skeins appear to be thoroughly degummed after drying although they may be slightly softer and shinier
    - It's possible that the Ph of the water is more important to degumming than the soda ash additive measuring ⅓ of the weight of silk
    - That said, temperature may have also been an issue as the water temp was not steady and a minimum of 10 degrees below goal temperature at any given time
- More control tests are needed, one which establishes proper temperature, and one which measures Soda Ash according to Ph rather than percentage of weight of silk.

10/01/2022 (Degumming)

Equipment: Electric element, stainless steel jam pan, thermometer, dowel
Setting: Indoors
Materials: 4 Skeins of Sr_T_021, pre-measured soda ash, citric acid

Samples created:

Sr_T_D_005	Sr_T_021 simmered for 30 minutes
Sr_T_D_006	Sr_T_021 simmered for 1 hour
Sr_T_D_007	Sr_T_021 simmered for 2 hours
Sr_T_D_008	Sr_T_021 simmered for 2 hours with a citric acid rinse

Method:

- 0.252g of Soda Ash was measured to match quantity used in previous experiment
- Water was heated to 80
- Skeins tied with code string and then left to soak in water
    - 1 Knot= simmered for 30 minutes
    - 2 knots= simmered for 1 hour
    - 3 knots= simmered for 2 hours
    - 4 knots = simmered for 2 hours and rinsed with citric acid
- The Ph of the water at 80C was 6-7 prior to the addition of Soda Ash, and 7-8 after the addition of Soda Ash
- The skeins were added to the jam pan, code strings suspended from dowel
- Water for the most part held steady between 79 and 81 C, but there was a dip in temperature roughly 50 minutes in, when element was

turned down to prevent water temperature rising too much, and temperature briefly dipped to 74 degrees

- After 30 minutes, the first skein of silk (Sr_T_D_005) was removed and rinsed twice in pyrex bowl of tap water with Ph of 5-6
    - Skein was hung to dry
- After another 30 minutes, the second skein of silk (Sr_T_D_006) was removed and rinsed twice in in pyrex bowl of tap water with Ph of 5-6
- After another hour, the final two skeins were removed
    - Sr_T_D_007 was rinsed twice in pyrex bowl of tap water with Ph of 5-6
    - Sr_T_D_008 was rinsed once in a pyrex bowl of tap water with Ph of 5-6, a second time in water shifted to Ph 4 with citric acid solution, and finally rinsed once more in unaltered tap water

Post-Experiment Reflections:

- Seems like it may have been more effective
- I forgot to weigh skeins of silk prior to degumming which will mess with the data a bit
- While winding dry samples onto bobbins I observed that longer degumming time does seem to remove more sericin, but this quantity of soda Ash does not fully remove gum even with 2 hours of simmering

Citric acid rinse after 2 hours of simmering seems to have removed considerably more sericin (as evidenced by the amount of tangling which occurred between rinsing and winding onto a bobbin.)

Appendix H Analysis Recording Methods

Labelling

The identification codes used in the labelling of all images of the Coppergate Silk textiles are based on the Catalogue number given for each textile in Walton(1989), but in two cases the assigned catalogue number has been subdivided to more efficiently refer to textiles which comprise two pieces of cloth stitched together. Textile 1351 is composed of two small textile fragments, one woven from yarn without twist (I) in both systems, the other woven from Z twisted yarn in both systems. To distinguish between these two fragments the codes 1351_IxI and 1351_ZxZ were used. Data collected from 1355 was divided into 1355_R1 and 1355_R2 to reflect the two pieces of ribbon that have been stitched together to form this textile. The Coppergate textiles were also assigned Small Finds numbers by York Archaeology (Table H.1). The SF numbers were used during the early stages of recording and analysis.

Small Finds #	Catalogue #	Period
SF13789	1342	4B (c. 930-975)
SF10528	1343	4B (c. 930-975)
SF8324	1347	4B (c. 930-975)
SF14011	1349	4B (c. 930-975)
SF10487	1281	4A (c.900-30/5)
SF14513	1351	4B (c. 930-975)
SF12973	1352	4B (c. 930-975)
SF12597	1355	4B (c. 930-975)
SF12754	1371	5A (c. 975)

Table H.1: The Small Finds numbers and corresponding catalogue numbers of the Coppergate textiles selected for analysis

Data Formats

Three key types of data were collected for analysis

1) Image files
2) Quantitative measurements
3) Qualitative Descriptors (textual data)

Image files were saved as either TIFF or JPEG formats. TIFF was the preferred image format as it does not risk loss of image resolution through compression and preserves Metadata (such as scale calibration). High resolution JPEG files were used when taking digital photographs in favour of RAW image files to avoid the need for further reformatting. JPEG formats were also used in cases where smaller image sizes were required for efficient file transfer, or where a higher resolution image was not essential.

All photographs and micrographs were labelled using a similar format that incorporated the identifying code for each sample being recorded, a summary of relevant information, and a sequential number.

Quantitative measurements were recorded in spreadsheets which were saved in Google Sheets documents for online access, or as either Microsoft Excel (.xls) or .csv files for offline preservation. Qualitative Descriptors were either handwritten on recording sheets or were typed in Word or Google Doc files. Summaries of qualitative data were compiled using Google Sheets.

All micrographs were saved in TIFF format with duplicates showing a scale. The file-naming format followed the that established for the experimental silk micrographs with a slight modification in sequential numbering, which treated polarised and brightfield images of the same view as sharing the same number in a sequence, for example: 1347-a_10x_001; 1347-a_10x_001-Pol.

Recording sheets

The following recording sheets were created to streamline the recording of observations during analysis.

Date: Analyst: ID #:

Archaeological Textile Analysis Sheet

Collection/owner:

Time Period:

Culture:

Woven structure:

Density:

Direction of twist:

Degree of twist:

Texture, overall appearance:

Supplementary Threads/ Other elements:

Image Capture:
Macro Camera:
Microscope/Stereoscope:
Camera:
Light: Reflected

Fibre Sampling:

Other Notes:

Date: Analyst:

Sample #:

Fibre whole mount analysis sheet

Microscope: Olympus BX53M
Camera: Olympus SC50
Software: Stream Essentials (Olympus)
Slide:
Coverslip:
Mounting Medium:

Fibre Characteristics

Number of Filaments:

Fibres/Filament:

Fibre Spread:

Presence of fibrils:

Texture/Sericin (cracks, clumping, flaking):

Additional Notes:

Date: Analyst: **Sample #:**

SEM Fibre/Yarn analysis sheet

Microscope: Hitachi TM4000 II Plus Tabletop SEM

Coating:

Fibre Characteristics

Number of Filaments:

Fibres/Filament:

Fibre Spread:

Presence of fibrils/Damage:

Texture/Sericin (cracks, clumping, flaking):

Fibre in situ (in yarn)?: Y / N

Direction of twist:

Ply?:

Degree of twist?:

Yarn texture:

Other characteristics:

Additional Notes:

SEM settings

The charge reduction setting was utilised, and the most successful charge reduction during topographic imaging resulted from a setting of 5kV mode 1 (Figure H.1), with the compromise of reduced resolution. Higher resolution was obtained at 10kV mode 3 and 15kV mode 3 (Figure H.3), with the trade-off of obscured detail in charged areas. The resolution of images captured at 5kV were somewhat improved at higher levels of magnification (Figure H.4).

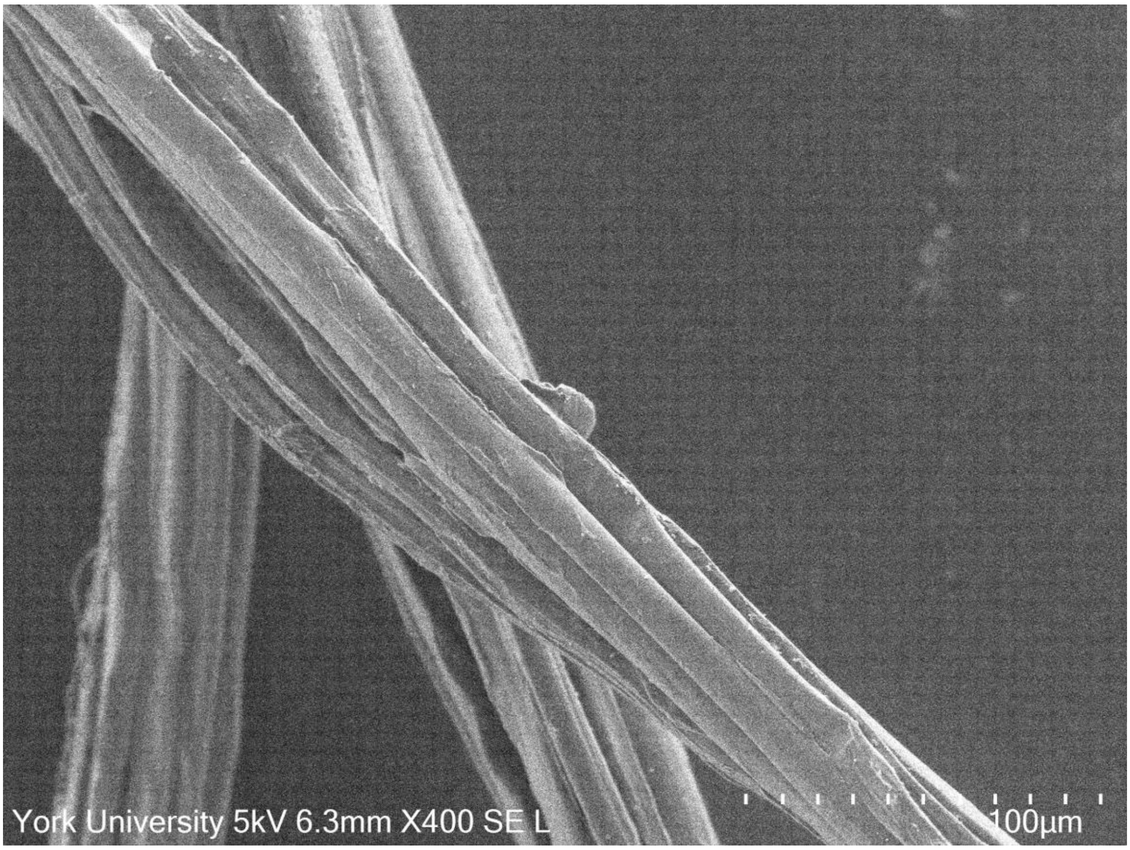


Figure H.1:SEM image of sample Sr_022 at 400x magnification showing reduced resolution and significant reduction of charging resulting from imaging at 5kV (mode 1)

Photography

Photographs were taken with a Nikon D3300 digital single-lens reflex (DSLR) camera. A copy stand was used to position the camera securely above and parallel to each textile (**Error! Reference source not found.**). The textiles were photographed with a scale bar. Photographs were taken on automatic settings at varying levels of zoom and were saved as large format JPEGs.

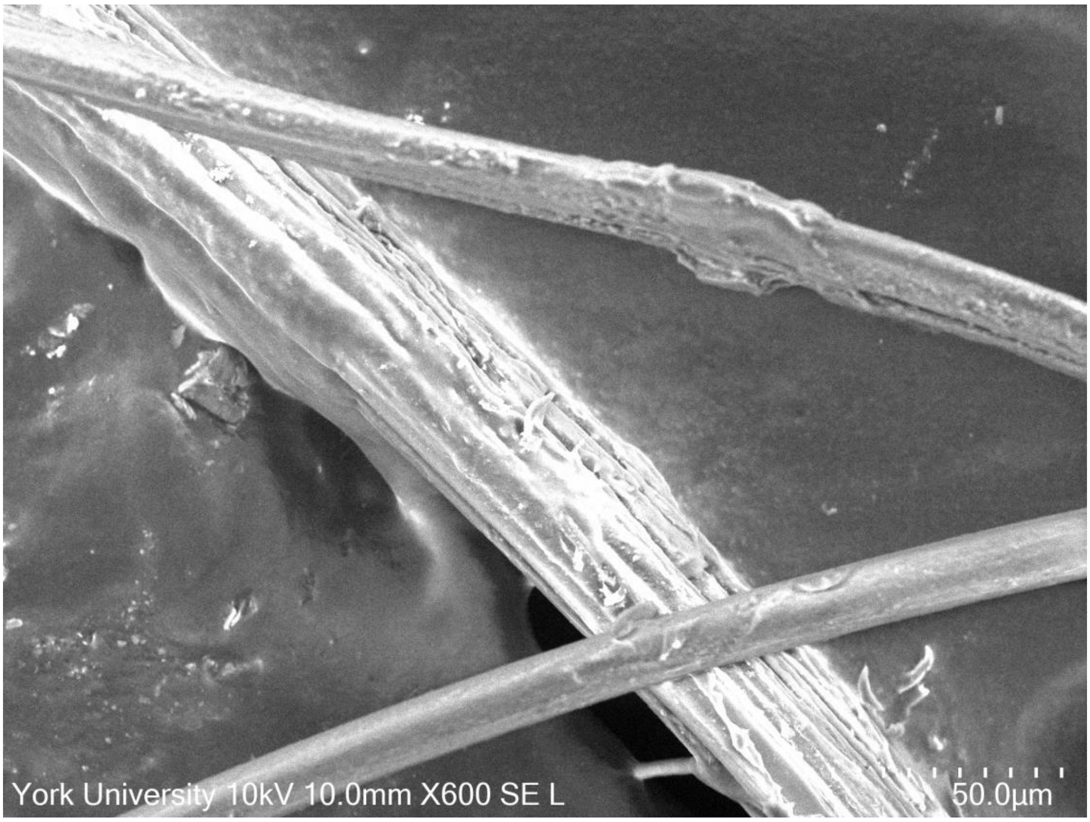


Figure H.2: SEM image of Sample Sr_002 at 600x magnification. The bright white areas are a result of charge buildup, a consequence of imaging an uncoated sample at 10kV (mode 3)

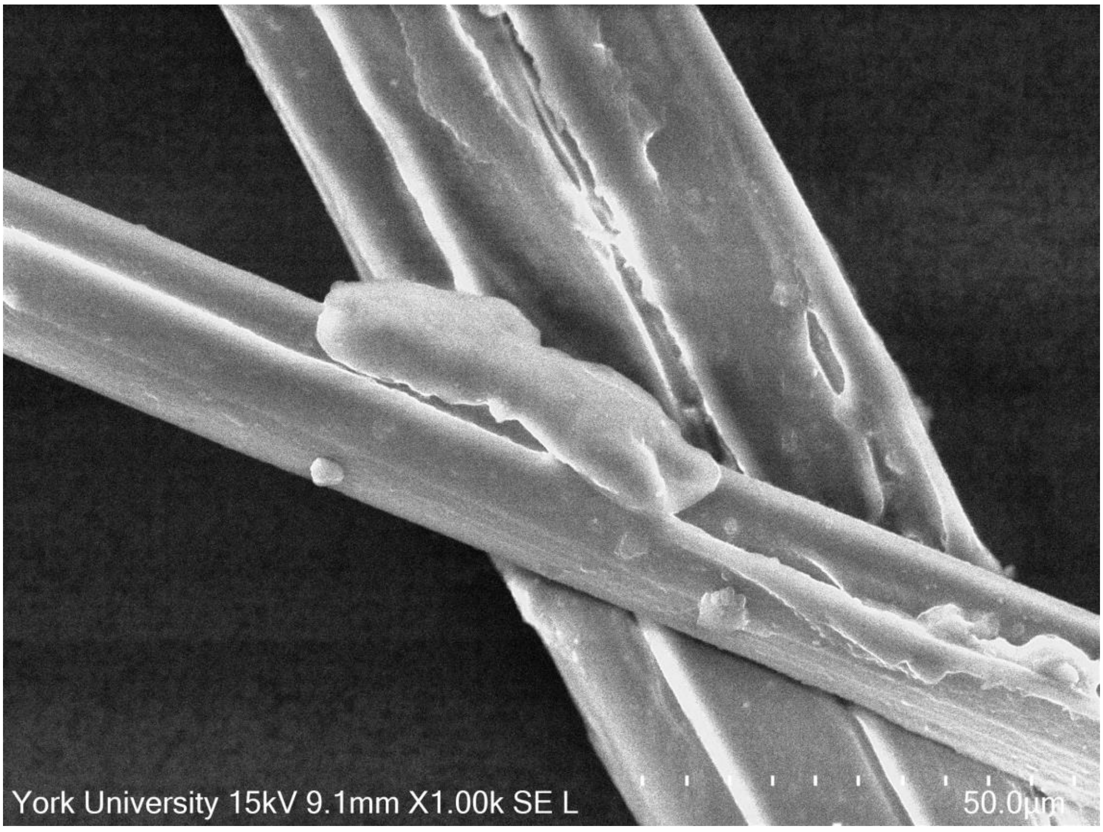


Figure H.3:SEM image of Sr_003, 1000x magnification, imaged at 15kv (mode 3).

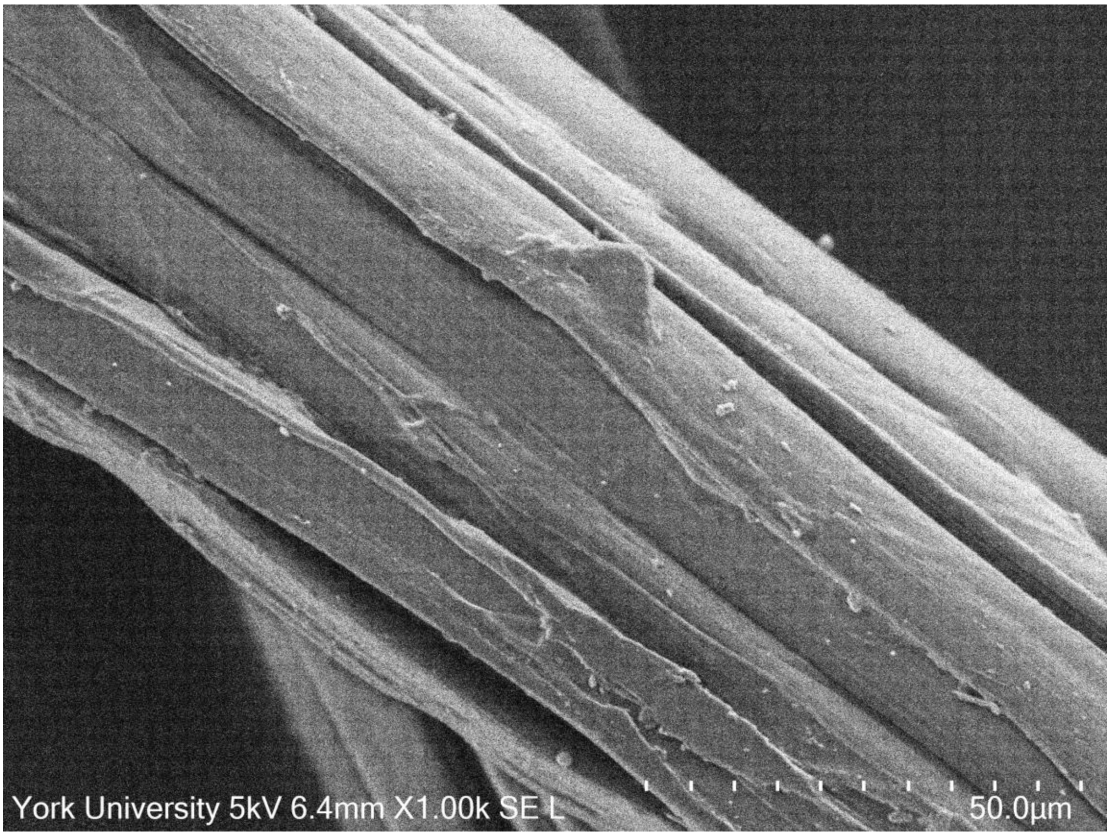


Figure H.4:SEM image of sample Sr_022 captured at 5kV (mode 1).

Using the back-Scattered electron (BSE) setting, it was also possible to view the chemical composition of the fibres, sericin, and inclusions at a glance (Figure H.5). BSE imaging also allowed for higher resolution without the same build-up of charge, but while this method is useful for highlighting chemically distinct elements in a sample, it was not as well suited for detailed topographic imaging, and did not eliminate the build-up of charging over time.

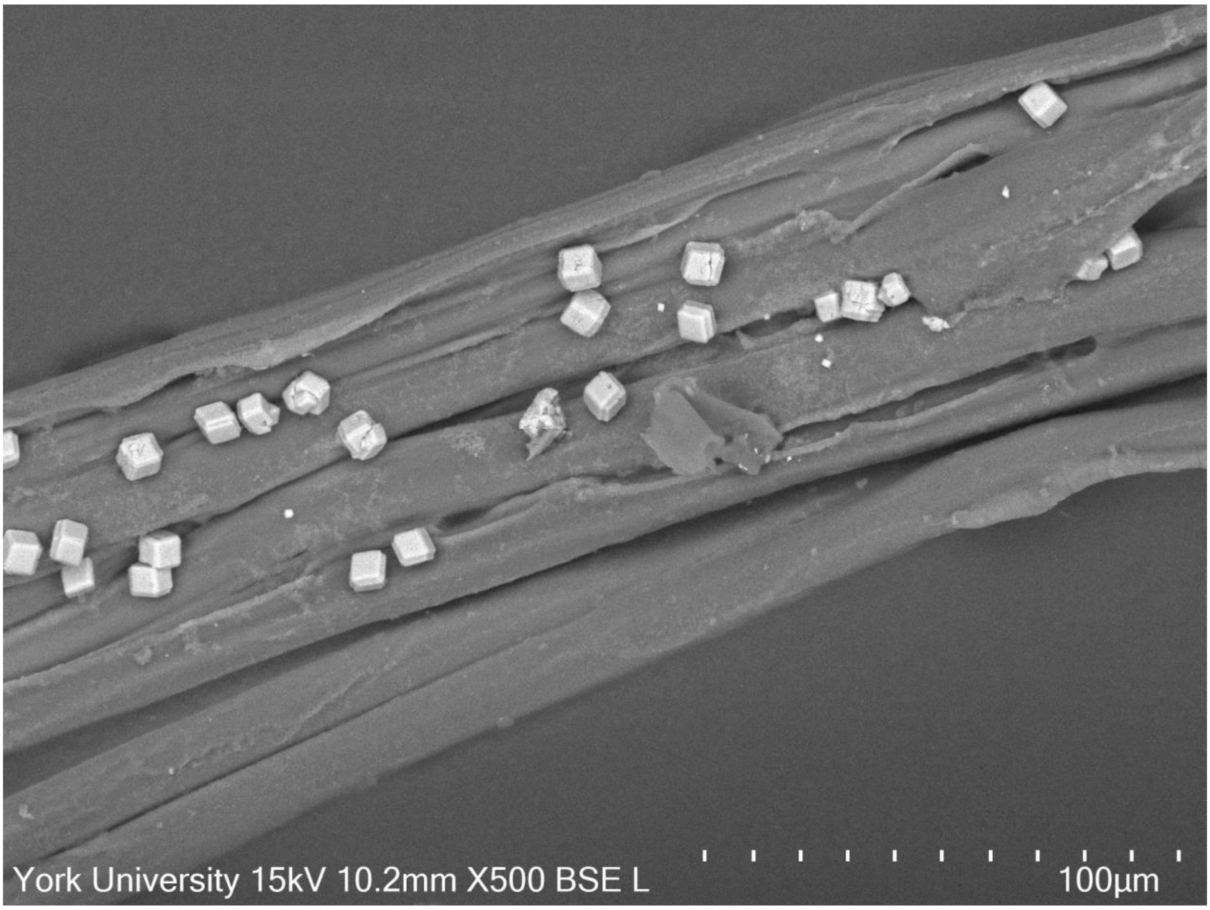


Figure H.5: SEM image of Sr_T_D_001 showing Calcium crystals affixed to partially degummed sericin, 500x magnification, BSE imaging at 15kV (mode 3)

The captured micrographs were saved in TIFF format with key data overlaid, including magnification, kV and a scale bar. The files were named with the following format: Sample-name_SEM_type of detection_###_kV-mode(magnification)
For example: CT24-b_SEM_SE_008_10kV-4(x600).

Appendix I Experimental Silk Data

The following data was foundational to the results presented in Chapter 7 of this thesis.

Fibre Diameter Distribution

The experimental silk fibre diameters when plotted individually showed a mixture of normal and non-normal distributions, and a non-normal distribution when all measurements were plotted together (Figure I.1; Table I.1)

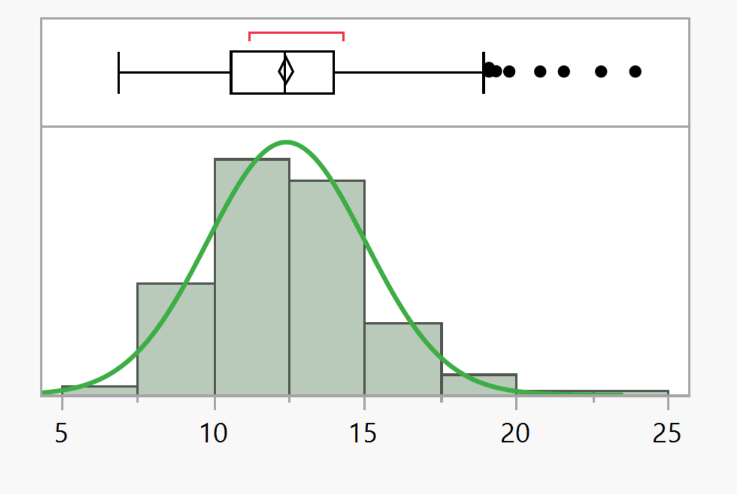


Figure I.1: Histogram showing distribution of all Experimental fibre diameter measurements in relation to a normal distribution line of fit.

	W	Prob<W
Shapiro-Wilk	0.9806636	<.0001*

Table I.1: Results of Shapiro-Wilk test on all Experimental fibre diameters, rejecting a normal distribution.

Experimental Silk Fibre Diameter Measurements

Sample#	Measurement Count	Minimum (µm)	Maximum (µm)	Mean (µm)	Median (µm)	Standard Deviation (µm)
Sr_001	20	8.513420995	17.65326101	12.84880096	12.7294676	1.877387231
Sr_002	20	10.42215815	16.66738083	13.37067212	13.18590157	1.673723367
Sr_003	20	8.272912557	18.42068559	13.4048639	13.37133157	2.528034247
Sr_004	20	7.070011317	13.54277373	10.40182924	10.3711815	1.93499833
Sr_005	20	9.705803064	19.33718436	14.1191378	13.83973162	2.555467728
Sr_006	20	10.60501698	22.80010141	14.42456328	13.68024379	2.7866591
Sr_007	20	8.513420995	15.51442197	11.46695815	11.04284437	1.738891718
Sr_008	20	7.569053362	20.7935271	14.1887145	14.19747529	3.388123334
Sr_009	20	9.039156383	18.91501202	13.37405455	13.1134247	2.541665846
Sr_011	20	7.940911517	18.87431264	13.23901628	13.47798657	2.439831811
Sr_013	20	7.50528598	13.03645673	10.33055959	10.90871659	1.602373122
Sr_015	20	7.191335905	13.13928108	10.33967755	10.46620787	1.943108827
Sr_016	20	9.804341662	16.80522505	13.29199768	13.19036046	2.112588199
Sr_017	20	6.84901864	18.43633391	11.00661062	10.9651291	2.938040515
Sr_018	20	10.17008477	16.78805642	12.97206384	12.74886794	1.86629119
Sr_019	20	7.657435629	16.37060847	10.82775496	10.5731971	2.025259668
Sr_020	20	8.001207838	16.22907318	12.34696978	12.48297823	2.073003209
Sr_021	20	7.669978529	15.8393987	11.63145645	11.84502997	2.015711458
Sr_022	20	9.039156383	19.10211868	12.13742436	11.73641841	2.460758072
Sr_023	20	9.249397425	14.27533694	11.38048182	11.44615941	1.546529794
Tr_001	20	8.434013601	14.46265021	12.13321269	12.19349675	1.788359333
Tr_006	20	7.892342795	13.86543295	10.68956539	10.35573099	1.902462584
Tr_017	20	10.42215815	18.23712969	13.43959308	13.04347637	2.020912854
Tr_026	20	8.468136519	18.32126914	14.52526048	14.34845897	2.285395258
Tr_029	20	7.657435629	14.03083164	11.33372379	11.00529077	1.762097412
Tr_036	20	11.09234636	23.92741498	15.29139626	14.61750086	3.370521438
Tr_041	20	7.569053362	15.80902591	11.41456001	11.72372546	2.10415158
Tr_050	20	8.191173943	15.74199948	12.00990072	12.17860505	2.447044895

Experimental Silk Filament Diameter Measurements

Sample #	Measurement Count	Minimum (μm)	Maximum (μm)	Mean (μm)	Standard Deviation
Sr_001	N/A	N/A	N/A	N/A	N/A
Sr_002	14	68.91958883	121.7253295	99.47347093	16.97234377
Sr_003	15	60.70987123	127.1398972	88.71340727	20.27158305
Sr_004	20	47.51522944	113.0621014	68.13701887	16.71126048
Sr_005	15	66.60666775	131.379252	98.73755518	17.76214152
Sr_006	15	83.05240346	189.353061	133.1808096	31.34585019
Sr_007	15	47.37656999	110.7380911	73.6063833	19.41620786
Sr_008	16	74.53085258	146.9937906	115.0663553	20.6971617
Sr_009	N/A	N/A	N/A	N/A	N/A
Sr_011	17	51.03371106	101.4017372	80.14955636	15.26589443
Sr_013	16	34.70319116	87.71616848	49.86163291	14.97086494
Sr_015	17	36.10236559	83.58190796	56.81169451	13.33558822
Sr_016	15	44.12857816	91.30883223	77.05681853	15.14173691
Sr_017	20	36.45438398	68.71714834	50.59551559	9.373232614
Sr_018	15	115.2520251	307.6220545	199.1400343	62.20515784
Sr_019	15	82.04919374	151.7300506	110.3356971	20.44251477
Sr_020	15	97.76434872	226.0009483	148.4412001	34.85868829
Sr_021	15	42.97341187	71.06485498	59.44955319	7.79805243
Sr_022	20	52.64616937	129.969588	87.09793587	19.69039979
Sr_023	15	67.21395684	118.8328601	85.25637565	14.29614942
Tr_001	15	58.60158067	96.01895133	77.47791425	11.50916496
Tr_006	15	53.34717559	109.9841776	75.36924572	15.44934728
Tr_017	15	194.6081838	286.2685468	232.9665161	29.53201185
Tr_026	15	42.84715183	82.35050003	61.14376674	11.33815862
Tr_029	15	85.3367994	137.7184003	110.330219	16.33826317
Tr_036	15	55.6757244	99.88288428	73.16710245	11.84683535
Tr_041	15	90.61536431	175.7871312	128.8325153	18.7042569
Tr_050	15	42.32006182	101.1533671	79.35773717	16.24619156

Experimental Silk Fibre and Filament Visual Analysis Data

ID	Place within Cocoon	Filament Cohesion	Filament Shape	Fibre Spacing (Raw silk only)	"Rippled" Fibres	Fibre Pairs	Fibre Groups	Sericin Integrity	Sericin spread	Fibre Damage	Fibre Shape Variability
Sr_001	Interior	Low	N/A	Wide	No	Yes	Yes	High	Moderate	Low	Moderate
Sr_002	Exterior	Low	Flat	Wide	No	N/A	N/A	Moderate	Moderate	Low	Low
Sr_003	Middle	Low	Flat	Wide	No	Yes	Yes	Moderate	Moderate	Low	Moderate
Sr_004	Interior	Moderate	Mixed	Moderate	No	N/A	N/A	High	Low	None	Low
Sr_005	Middle	Moderate	Flat	Moderate	No	N/A	N/A	High	Moderate	Low	Moderate
Sr_006	Exterior	High	Flat	Moderate-Wide	No	N/A	N/A	High	High	None	Low
Sr_007	Interior	Moderate	Mixed	Variable	No	N/A	N/A	High	Moderate	Low	Moderate
Sr_008	Middle	High	Flat	Moderate	No	N/A	N/A	High	Moderate	None	Low
Sr_009	Exterior	None	Flat	Wide	No	Yes	Yes	High	Moderate	Low	Low
Sr_011	N/A	High	Mixed	Compact	No	N/A	N/A	Moderate	Low	Moderate	Low
Sr_013	N/A	High	Round	Compact	No	N/A	N/A	High	Low	Moderate	Low
Sr_014	N/A	High	Round	Compact	No	N/A	N/A	High	Low	None	Unclear
Sr_015	Interior	Moderate	Flat	Moderate	No	N/A	N/A	Moderate	Moderate	None	Low
Sr_016	Exterior	Low	Flat	Wide	No	Yes	Yes	Moderate	High	Low	Moderate
Sr_017	Middle	Low	Flat	Moderate	No	N/A	N/A	Moderate	Moderate	Low	Moderate
Sr_018	Exterior	Moderate	Mixed	Compact	No	N/A	N/A	Moderate	Moderate	None	Moderate
Sr_019	Interior	High	Flat	Compact	No	N/A	N/A	Moderate	Moderate	None	Low
Sr_020	Middle	Moderate	Flat	Compact	No	N/A	N/A	Moderate	Moderate	Moderate	Low
Sr_021	Interior	Moderate	Mixed	Compact	Yes	N/A	N/A	Moderate	Low	Low	Moderate

Sr_022	Middle	Moderate	Mixed	Moderate	Yes	N/A	N/A	Moderate	Moderate	Low	Moderate
Sr_023	Exterior	High	Mixed	Compact	Partly	N/A	N/A	Moderate	Low	Low	Low
Sr_T_D_001	N/A	Low	N/A	Wide	N/A	Yes	Yes	Moderate	Moderate	Low	High
Sr_T_D_005	N/A	Low	N/A	Wide	N/A	Yes	Yes	Moderate	Moderate	None	Moderate
Sr_T_D_006	N/A	None	N/A	N/A	N/A	Yes	Yes	Low	N/A	None	Moderate
Sr_T_D_007	N/A	Low	N/A	N/A	N/A	Yes	Yes	Low	N/A	None	Moderate
Sr_T_D_008	N/A	None	N/A	N/A	N/A	Yes	Yes	Low	N/A	Low	Moderate
Tr_001	Interior	Moderate	Flat	Wide	No	N/A	N/A	Moderate	High	Moderate	Low
Tr_006	Middle	High	Mixed	Compact	No	N/A	N/A	Moderate	Low	Low	Low
Tr_011	?Middle	Moderate	Round	Compact	Yes?	N/A	N/A	Moderate	Moderate	None	Low
Tr_017	Middle	Moderate	Flat	Moderate	No	N/A	N/A	High	Moderate	None	High
Tr_026	Middle	Low	Mixed	Wide	No	Yes	Yes	Moderate	Moderate	Low	Moderate
Tr_029	Middle	High	Flat	Moderate	No	N/A	N/A	High	Moderate	Low	Low
Tr_032	Middle	Moderate	Round	Moderate	Maybe	N/A	N/A	Moderate	High	Moderate	Low
Tr_035	Middle	High	Round	Moderate	No	N/A	N/A	Moderate	High	Low	Low
Tr_036	Middle	Moderate	Round	Moderate	No	N/A	N/A	Moderate	Low	None	High
Tr_041	Middle	High	Round	Compact	Yes	N/A	N/A	Moderate	Moderate	None	Low
Tr_047	Middle	High	Round	Moderate	No	N/A	N/A	High	Moderate	None	Low
Tr_050	Middle	Moderate	Flat	Moderate	No	N/A	N/A	Moderate	Moderate	Low	Moderate
Tr_T_D_003	N/A	None	N/A	N/A	No	Yes	No	None	N/A	Low	Low

Appendix J Archaeological Silk Data

The following data was foundational to the results presented in chapter 8.

Fibre Diameter Distribution

Measurement distributions were first plotted to determine which tests of variance would be best suited to each data set.

The fibre diameters for Winchester returned slightly different results in that it showed normally distributed measurements for most samples with a few exceptions, and the measurements across the entire sample set were determined to be normally distributed (Figure J.1; Table J.1).

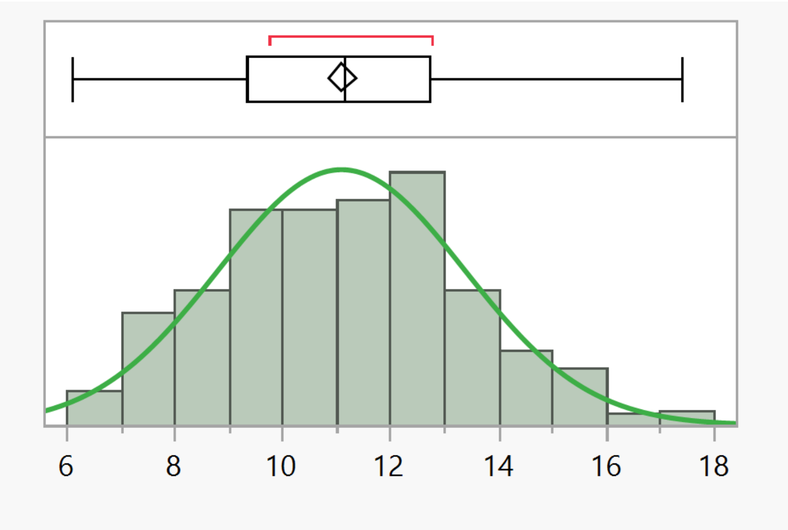


Figure J.1:Histogram showing distribution of all Winchester fibre diameter measurements in relation to a normal distribution line of fit.

	W	Prob<W
Shapiro-Wilk	0.9922858	0.0960

Table J.1: Results of Shapiro-Wilk test on all Winchester fibre diameters, confirming normal distribution.

The Coppergate fibre diameter measurements showed a mixture of normal and non-normal distributions by sample and were not normally distributed overall (Figure J.2; Table J.2).

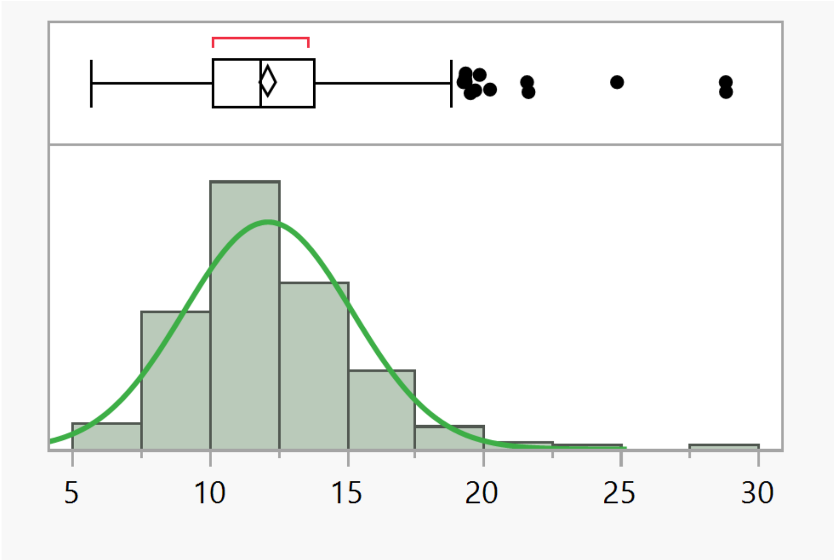


Figure J.2: Histogram showing distribution of all Coppergate fibre diameter measurements in relation to a normal distribution line of fit.

	W	Prob<W
Shapiro-Wilk	0.9463478	<.0001*

Table J.2: Results of Shapiro-Wilk test on all Coppergate fibre diameters, confirming normal distribution.

Kruskal-Wallis (Table J.3 & Table J.4) and Median tests were then used to determine that the differences between the measurements gathered was statistically significant.

ChiSquare	DF	Prob>ChiSq
160.8194	27	<.0001*

Table J.3: Experimental Silk Fibre Diameters Kruskal-Wallis Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
114.3045	27	<.0001*

Table J.4:Experimental Fibre Diameters 1-Way Test, ChiSquare Approximation

Statistically significant differences in the fibre diameters recorded for the Winchester (Table J.5; Figure J.3) and Coppergate (Table J.6:

Coppergate Fibre Diameters Kruskal-Wallis Test, ChiSquare Approximation) silk textiles were confirmed by one-way tests of variance, appropriate to their distributions. The results of these tests confirmed statistically significant variation in the fibre diameters recorded from both groups of samples, based on the rejection of a null hypothesis.

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
ID	15	373.9934	24.9329	5.8744	<.0001*
Error	304	1290.2683	4.2443		
C. Total	319	1664.2617			

Table J.5: Results of One-way ANOVA of Winchester fibre diameter measurements

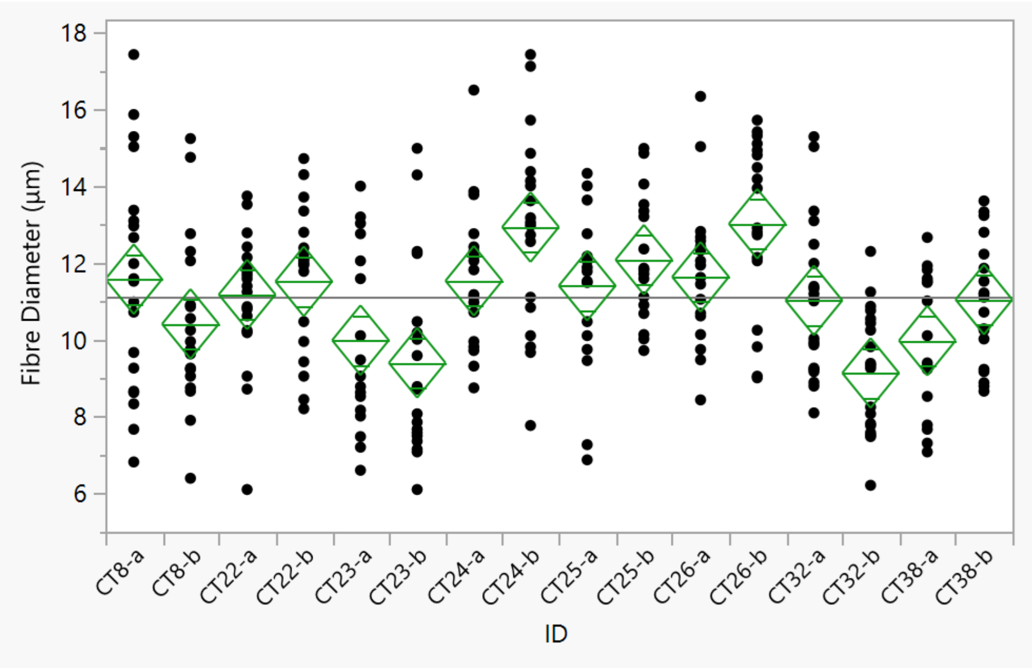


Figure J.3: Visualisation of One-way ANOVA of Winchester fibre diameter measurements

ChiSquare	DF	Prob>ChiSq
69.3246	23	<.0001*

Table J.6: Coppergate Fibre Diameters Kruskal-Wallis Test, ChiSquare Approximation

Winchester Textile Fibre Diameters

ID	Measurement Count	Min. (µm)	Max. (µm)	Mean (µm)	Standard Dev.
CT8-a	20	6.806783795	17.40650349	11.56222284	2.925097526
CT8-b	20	6.384124759	15.22043127	10.39696562	2.158743783
CT22-a	20	6.091329457	13.72607833	11.16406309	1.773789017
CT22-b	20	8.191173943	14.69997481	11.50492281	1.937789549
CT23-a	20	6.591551575	13.98279245	9.973953354	2.307041284
CT23-b	20	6.091329457	14.96567803	9.386110446	2.453578129
CT24-a	20	8.736323119	16.4817953	11.52005572	1.87341292
CT24-b	20	7.757210984	17.40650349	12.91882232	2.487719786
CT25-a	20	6.863039163	14.31568182	11.39233449	1.951288369
CT25-b	20	9.705803064	14.96567803	12.06855904	1.574040332
CT26-a	20	8.422608574	16.3176766	11.62198168	1.823085225
CT26-b	20	8.996518615	15.6991973	13.00323475	2.119562842
CT32-a	20	8.084867252	15.27087195	11.01042527	2.032741375
CT32-b	20	6.200810122	12.28480489	9.121677877	1.609738642
CT38-a	20	7.070011317	12.64722073	9.964679592	1.819686537
CT38-b	20	8.647851745	13.5994383	11.03091918	1.616895576

Coppergate Textile Fibre Diameters

ID	Measurement Count	Min. (µm)	Max. (µm)	Mean (µm)	Standard Dev.
1281-a	20	6.591551575	13.62062674	11.13524583	1.781901793
1281-b	20	8.084867252	20.24543139	12.1298711	2.666147319
1342-a	20	9.414210345	18.27398837	14.19956603	2.483288595
1342-b	20	7.904512953	17.97700303	13.37420257	2.76401057
1343-a	20	8.376833188	16.63851954	12.56695724	2.303796958
1343-b	20	9.155386428	19.35705814	13.46292016	2.806352288
1347-a	20	7.02	19.36	13.1	3.092412952
1347-b	20	7.492467378	19.53501237	11.78638165	2.974020738
1347-c	20	7.137668469	28.8354339	12.60426603	5.459604288
1347-d	20	7.904512953	28.82543144	14.29237092	4.477546498
1349-a	20	6.84901864	24.86903683	13.25129645	4.370151441
1349-b	20	9.321861635	19.70648285	13.59006948	2.974654943
1351-a	20	8.614440731	18.5455025	12.45046264	2.694853663
1351-b	20	5.700025352	13.93458766	10.61132706	1.989231606
1351-c	20	7.50528598	13.76104928	10.49139252	2.007704193
1351-d	20	7.892342795	15.9603119	11.17647393	2.265196963
1352-a	20	6.707201653	18.76705685	11.74123313	2.862205056
1352-b	20	7.84347333	17.19537307	11.96305345	2.575641262
1355-R1-a	20	8.342336817	14.03768096	11.1378409	1.630644711
1355-R1-b	20	6.473835828	14.96567803	10.96960353	2.058323322
1355-R2-a	20	5.882604997	13.98279245	10.24441016	1.991974971
1355-R2-b	20	6.518228365	19.86679954	11.71502042	2.996846438
1371-a	20	7.466764155	18.11018757	12.23145908	3.237786815
1371-b	20	6.576952329	15.53918563	11.7105848	2.288086818

Winchester Textile Yarn Diameters

ID	System A diameter (µm)	System A diameter (mm)	System B diameter (µm)	System B diameter (mm)
CT8	183.062045	0.18	239.909945	0.24
CT22	225.23654	0.23	251.42727	0.25
CT23	197.507845	0.2	227.50881	0.23
CT24	217.65735	0.22	239.647815	0.24
CT25	259.51793	0.26	243.26001	0.24
CT26	201.064025	0.2	202.39918	0.2
CT32	284.086745	0.28	282.40449	0.28
CT38	194.881145	0.19	265.211225	0.27

Coppergate Textile Yarn Diameters

ID	System A diameter (µm)	System A diameter (mm)	System B diameter (µm)	System B diameter (mm)
1281	159.46	0.16	326.03	0.33
1342	141.3	0.14	497.25	0.5
1343	188.98	0.19	397.64	0.4
1347	214.01	0.21	332.79	0.33
1349	204.3	0.21	174.89	0.17
1352	N/A	N/A	215.48	0.22
1371	215.58	0.22	188.7	0.19
1351_IxI	214.49	0.21	304.23	0.3
1351_ZxZ	172.56	0.17	189.04	0.19
1355_R1	272.98	0.27	273.17	0.27
1355_R2	255.11	0.26	219.067	0.21

Winchester Textile thread Counts

ID	Min Count A	Min Count B	Max Count A	Max Count B	Median Count A	Median Count B	Std Dev A	Std Dev B
CT8	26	42	32	50	29	44	1.89	2.23
CT22	35	34	45	42	39	37	2.90	2.17
CT23	36	32	40	38	40	36	1.63	1.86
CT24	32	31	37	38	35	34	1.77	2.04
CT25	29	29.5	38	41.5	32	33	2.69	3.14
CT26	56	33	67	39	62	37	2.99	1.78
CT32	33	21	42	25	39	24	2.28	1.12
CT38	36	29	39	32.5	37.5	30.5	0.79	0.97

Coppergate Textile Thread Counts

ID	Min Count A	Min Count B	Max Count A	Max Count B	Median Count A	Median Count B	Std Dev A	Std Dev B
1281	16	20	22	46	20	30	1.81	7.38
1342	17	17	27	23	19	20	2.77	1.96
1343	15	20	27	22	24	20.75	3.25	0.63
1347	22	27.5	24	39	23	32	0.61	3.03
1349	14	12	30	29	25	15	4.53	5.02
1351_IxI	32	20	38	28	36	22	1.75	2.16

1351_ZxZ	36	28	44	32	39	30	3.35	2.19
1355_R1	40	22	50	30	46	27	2.70	2.56
1355_R2	48	34	56	39	50	37	2.85	1.73
1371	29	15	45	23	33	18	4.86	2.26

Degree of twist of yarn from Winchester textiles

ID	Max	Min	Mean	Median	Std Dev
1281-a	162.4381	132.0595	149.8248	151.4107	8.849739
1342-a	166.1162	146.8542	156.3223	156.2958	5.88305
1343-a	165.3031	138.4391	152.9559	152.9103	6.897535
1347-a	172.1302	110.6514	151.7409	154.8609	15.37531
1349-a	158.7962	135.4313	148.4549	150.1773	6.965716
1349-b	168.0553	136.9076	151.5066	151.1595	7.323177
1351_ZxZ-a	168.0112	129.5597	150.9577	150.9044	11.23703
1351_ZxZ-b	169.0252	136.3937	154.3928	154.1924	7.365241
1352-a	168.5433	138.8141	155.217	153.4117	7.874353
1355-R1-a	39.93772	7.539411	17.34308	15.51709	8.20362
1355_R1-b	38.37642	9.734831	22.27062	24.47366	7.737425
1355_R2-a	46.05199	15.16298	22.46292	20.26483	8.080219

1355_R2-b	30.33332	5.520971	17.4511	15.83583	6.45264
1371-a	174.8018	130.6892	153.5853	155.5429	12.84595
1371-b	166.6949	132.2326	153.1388	153.1134	7.992974

Degree of twist of yarn from Coppergate textiles

ID	Max	Min	Mean	Median	Std Dev
CT22-a	38.5608	10.6197	25.21444	25.6383	6.251727
CT22-b	29.6872	12.4396	20.81176	21.586	4.442008
CT23-a	174.7099	141.5819	156.4517	156.5991	8.518532
CT24-a	55.4478	21.4253	35.58715	35.61075	8.019381
CT24-b	36.7406	17.3762	25.57601	25.64945	5.418629
CT25-a	33.4654	9.6312	22.67716	23.63445	6.899916
CT25-b	45.4341	12.6302	32.31346	30.9511	8.728884
CT26-a	41.4105	10.7843	24.10018	23.89435	7.307058
CT32-a	34.8753	11.9006	21.93302	20.57855	6.068305
CT32-b	36.8699	13.3034	24.15353	24.3956	7.086948
CT38-a	170.4449	136.1573	151.3296	148.706	9.080262

Physical Characteristics of Fibres from the Winchester Textiles

ID	Filament Cohesion	Fibre Pairs	Fibre Groups	Sericin Integrity	Fibre Damage	Fibre Shape Variability	Fibre Compression	Areas where the fibre bulges	Paired Dents
CT8-a	Low	Yes	Yes	Low	High	Low	No	No	No
CT8-b	None	Yes	Yes	Low	Very High	Low	Yes	No	No
CT22-a	None	Yes	No	Very Low	High	Low	No	No	No
CT22-b	Low	Yes	Yes	Moderate	High	Low	Yes	No	No
CT23-a	None	Yes	Yes	Moderate	Very High	Moderate	Yes	No	No
CT23-b	Low	Yes	Yes	Moderate	High	None	No	No	No
CT24-a	None	Yes	No	Low	High	Low	No	Yes	No
CT24-b	None	Yes	No	Low	Moderate	Moderate	Yes	Yes	No
CT25-a	None	Yes	Yes	Low	High	Moderate	Yes	Yes	No
CT25-b	None	Yes	No	Moderate	High	Low	Yes	No	No
CT26-a	None	Yes	No	Low	Moderate	Low	Yes	No	No
CT26-b	None	Yes	No	Low	Moderate	Moderate	Yes	Yes	No
CT32-a	None	Yes	Yes	Moderate	High	None	No	No	No
CT32-b	None	Yes	Yes	Moderate	High	Low	Yes	Yes	No
CT38-a	None	Yes	Yes	Moderate	Moderate	None	No	No	No
CT38-b	None	Yes	Yes	Moderate	High	Low	No	Yes	No

Physical Characteristics of Fibres from the Coppergate Textiles

ID	Filament Cohesion	Fibre Pairs	Fibre Groups	Sericin Integrity	Fibre Damage	Fibre Shape Variability	Fibre Compression	Areas where the fibre bulges	Paired Dents
1281-a	None	No	No	None	High	Low	Yes	Yes	No
1281-b	None	Yes	Yes	Low	High	Moderate	Yes	Yes	No
1342-a	None	Yes	No	Low	Moderate	Low	No	Yes	No
1342-b	None	Yes	No	Moderate	Moderate	Moderate	Yes	Yes	Yes
1343-a	None	Yes	No	Moderate	Moderate	Low	Yes	Yes	No
1343-b	None	Yes	No	Low	Moderate	Moderate	Yes	Yes	No
1347-a	None	Yes	No	Low	Moderate	High	Yes	Yes	Yes
1347-b	None	Yes	No	Low	Moderate	High	Yes	Yes	Yes
1347-c	None	Yes	No	Moderate	Moderate	High	Yes	Yes	Yes
1347-d	None	No	No	Moderate	Moderate	High	Yes	Yes	Yes
1349-a	None	Yes	No	Low	Moderate	Moderate	Yes	Yes	Yes
1349-b	None	No	No	None	Moderate	Moderate	Yes	Yes	No
1351-a	Low	Yes	Yes	Moderate	High	Low	No	Yes	No
1351-b	None	Yes	Yes	Low	Moderate	Low	No	Yes	No
1351-c	None	Yes	Yes	None	Moderate	Low	Yes	Yes	No

1351-d	None	Yes	Yes	Moderate	Moderate	None	No	No	No
1352-a	None	Yes	No	None	High	Low	Yes	Yes	No
1352-b	None	Yes	No	Low	High	Low	No	Yes	No
1355-R1-a	None	Yes	No	None	Moderate	Moderate	Yes	Yes	Yes
1355-R1-b	None	Yes	No	Low	Moderate	High	Yes	Yes	Yes
1355-R2-a	None	No	No	Moderate	Moderate	Moderate	Yes	Yes	Yes
1355-R2-b	None	No	No	None	Moderate	Moderate	Yes	Yes	Yes
1371-a	None	No	No	None	Moderate	Low	Yes	No	No
1371-b	None	No	No	None	Moderate	Low	Yes	Yes	No

Physical Characteristics of the Winchester Textiles

ID	Selvedge	Paired warp threads in Selvedge	Twist	Surface Texture	Density	Balance	Yarn Movement	Deterioration
CT8	No	N/A	IxI	Flat	Balanced	System B Dominant	Moderate	Moderate
CT22	No	N/A	SxS	Crow's feet	Balanced	Balanced	Moderate	High
CT23	No	N/A	ZxI	Flat	Balanced	Balanced	Moderate	Moderate
CT24	No	N/A	SxS	Crow's feet	Balanced	Balanced	Moderate	High
CT25	No	N/A	SxS	Crow's feet	Balanced	Balanced	Moderate	Very High
CT26	Yes	No	SxS	Flat	Dense	System A Dominant	Low	Low
CT32	Yes	No	SxS	Crow's feet	Balanced	System A Dominant	Low	Moderate
CT38	No	N/A	ZxI	Flat	Open	System A Dominant	Moderate	Moderate

Physical Characteristics of the Coppergate Textiles

ID	Selvedge	Paired warps in Selvedge	Twist	SurfaceTexture	Density	Balance	Yarn Movement	Deterioration
1281	No	N/A	ZxI	Crow's Feet	Open	System B Dominant	High	High
1342	No	N/A	ZxI	Crepe	Variable	System B Dominant	High	High
1343	Yes	Yes	ZxI	Ribbed	Open	System B Dominant	High	Very High
1347	Yes	Yes	ZxI	Crow's Feet	Balanced	System B Dominant	Moderate	Low
1349	Yes	Yes	ZxZ	Crepe	Very Open	Variable	Very High	High
1351_IxI	Yes	No	IxI	Flat	Open	Balanced	Low	Moderate
1351_ZxZ	No	N/A	ZxZ	Crow's Feet	Open	Balanced	Low	Moderate
1352	Only Selvedge	Yes	ZxZ	Ribbed	Very Dense	System A-Faced	Low	Very High
1355_R1	Yes	No	SxS	Ribbed	Dense	System A Dominant	Low	Moderate

1355_R2	Yes	No	SxS	Flat	Dense	System A Dominant	Low	Moderate
1371	No	N/A	ZxZ	Crepe	Open	System A Dominant	High	High

Glossary

Bave: The twin, sericin coated silk fibres extruded by the silkworm.

Bobbin: A typically cylindrical object on which silk thread is wound.

Bombyx mori: The species of domesticated silkworm which produces the most common variety of silk used in textile production.

Brin: An individual silk fibre, two of which form a bave.

Compound weave: A woven structure comprising two warp and/or weft units, one of which is visible on the front of the cloth. Variants on this structure are often used to create cloth with woven-in patterns.

Damask: A reversible cloth structure wherein designs in the silk are created through contrasting binding systems, ie. alternating the warp and weft faces of an unbalanced woven structure. Damasks are often monochrome.

Degree of twist: How tightly or loosely a yarn or thread is twisted.

Degum: To remove the sericin from silk. Silk which has been degummed is also called "soft silk" or "cooked silk"

Figured silk: Silk cloth with a woven-in design.

Grège: Raw silk yarn, typically without twist.

Ground fabric: The base structure in any textile which incorporates additional warp and/or weft systems.

I twist: Technical descriptor of yarn that has not been twisted (see also STA)

Lampas: A figured textile wherein a pattern is formed by weft threads which float over a ground structure. According to CIETA (Monnas et al., 2021, p.39), the ground structure of lampas can vary, as can the means of causing the warp threads to float.

Moriculture: The practice of growing mulberry trees, often associated with silk production.

Ply: The act of combining two or more spun or twisted yarns, usually by twisting in the opposite direction to form a thicker and/or more stable yarn.

Raw silk: Silk which has not been degummed (therefore the sericin remains intact), also called "gummed silk" or "hard silk".
Reel: The part of a reeling frame upon which silk is wound.
Reeling Frame: the entire apparatus used to reel silk.
Reeled (silk): Silk which has been unravelled continuously from multiple cocoons.
Samite: A type of weft-faced compound twill, typically silk or half-silk. The term originates from Byzantine Greek.
Selvedge: the edge of a piece of woven cloth often formed by the weft changing direction and wrapping around the outer warp thread(s).
Sericulture: The practice of raising silkworms for their silk.
Sizing: A coating historically composed of starch, fat, or wax applied to either protect, stiffen or add weight to yarn or cloth before or after weaving.
Skein: Yarn or thread which has been wound into a loop for compact storage.
Slub: A lump or short uneven section appearing along a length of yarn.
Spin: To form a yarn by twisting together discontinuous fibres. The act of spinning involved the continuous addition or "drafting" of new fibres while twisting.
Spindle: A tool used to spindle or twist yarn by hand. Spindles typically comprise two parts, a whorl, which add weight, and a stick.
STA: Abbreviation of "*Sans Torsion Appreciable*" or "Without appreciable twist", describing yarn which has no apparent twist. This term is similar to the term I twist but bears some implication that there may be subtle twist which has gone unnoticed.
S Twist: Term used to describe yarn which has been twisted or spun in a counterclockwise direction
Swift: A frame for holding a skein of yarn in tension so that it can be used, or wound onto a bobbin etc. without tangling.
Umbrella Swift: A modern style of swift, so named because it folds out like an umbrella.

Tabby: A basic cloth structure composed of alternating warp and weft threads (also called plain weave)

Compound tabby: A figured tabby structure comprising two or more warp or weft systems which form a pattern. If comprising multiple warp systems, the pattern is formed by different coloured warp threads dominating the front of the textile (Warp-faced compound tabby). If comprising multiple weft systems, the pattern is formed by different coloured weft threads dominating the front of the textile (weft-faced compound tabby or taqueté).

Taqueté: A compound weave in tabby structure comprising two warp systems and two or more weft systems which form a pattern.

Tasar: The most encountered form of wild silk which comes from the *Antheraea* genus of the *Saturniidae* family of moths. The term tasar (also Tussar and the archaic Tussah) typically refers to species of *Antheraea* moths found across Asia.

Thread: A strand composed of fibres, usually used in textile manufacture. The term thread may be used interchangeably with the term yarn, but is frequently used in relation to sewing or embroidery, or to refer to yarn in-situ within a woven structure. Thread may also carry the connotation of a fine strand.

Throwing: The act of combining multiple silk filaments with or without twist to form a yarn.

Throwster: A person whose profession is to throw silk.

Twill: A cloth structure wherein warp, and/or weft threads float over two or more threads in the opposite system, aligning diagonally. Common twill structures are 2/2 (Figure J.4) and 1/2 (Figure J.5).

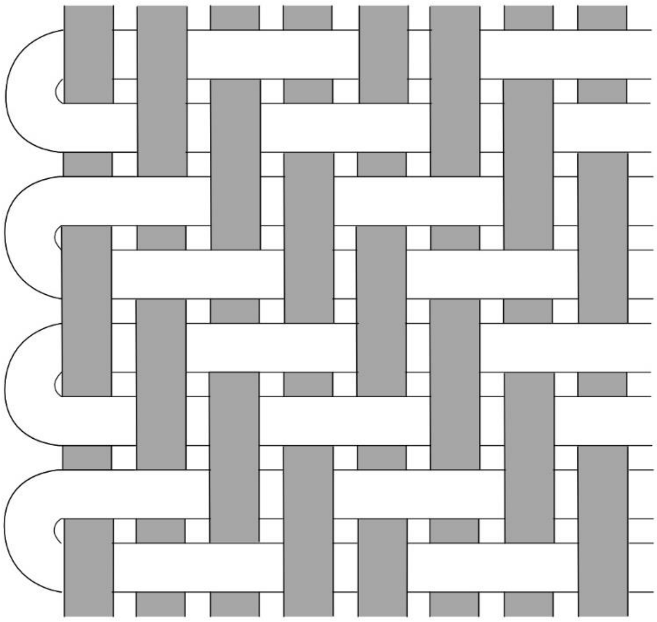


Figure J.4: Diagram of a 2/2 twill structure with selvedge visible on left edge

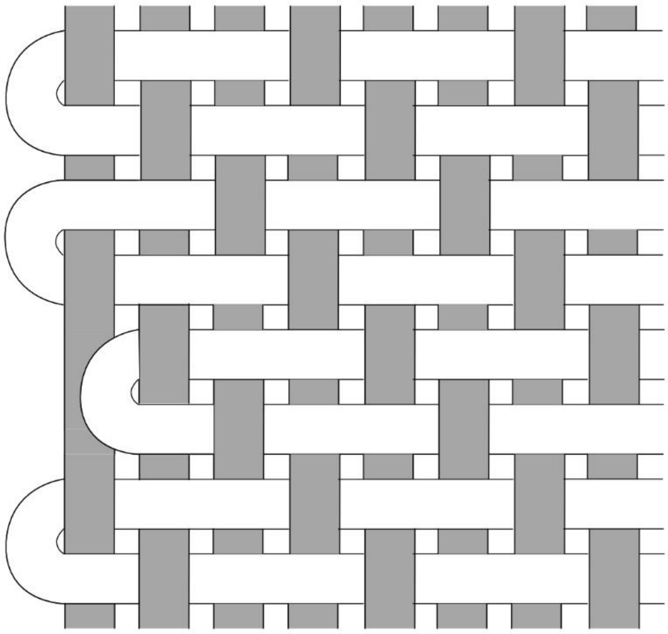


Figure J.5: Diagram of a 1/2 twill structure with selvedge visible at left edge

Compound Twill: A cloth formed of multiple, interlocking twill systems, typically to form a pattern.

Warp: The system of threads in a woven structure which stretch longitudinally across a loom and are moved up or down to facilitate weaving.

Warp-dominant: A textile wherein the warp covers more of the weft but the weft is still visible.

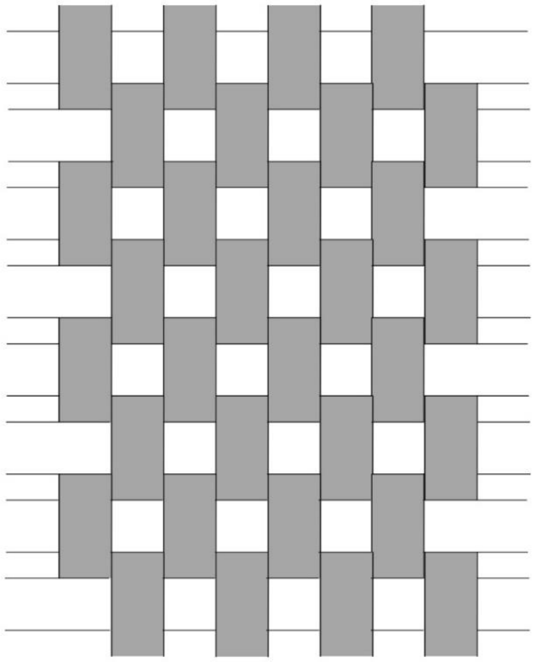


Figure J.6: Diagram of a warp-dominant tabby structure

Warp-faced: A textile wherein the warp completely covers the weft.

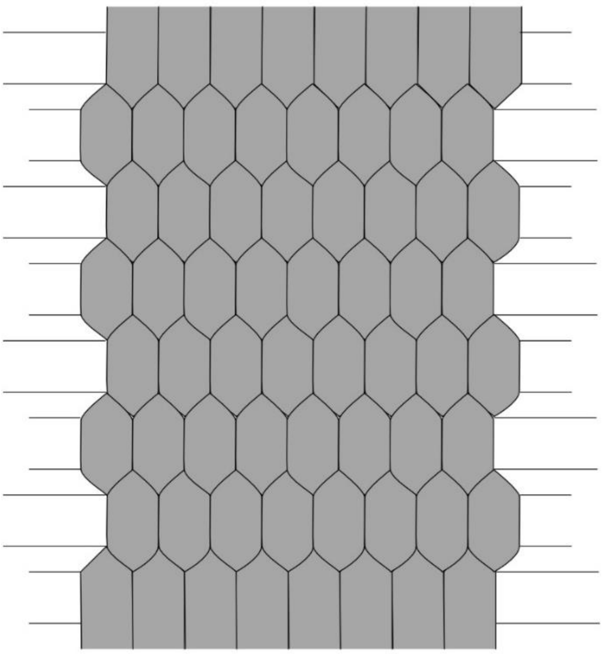


Figure J.7; Diagram of a warp-faced tabby structure

Weave/Woven structure: A manner of interlacing threads at 90° angles to form a cloth.
Weft: The system of threads which traverse across the warp threads, forming a woven structure.
Weft-dominant: A textile wherein the weft covers more of the warp but the warp is still visible.

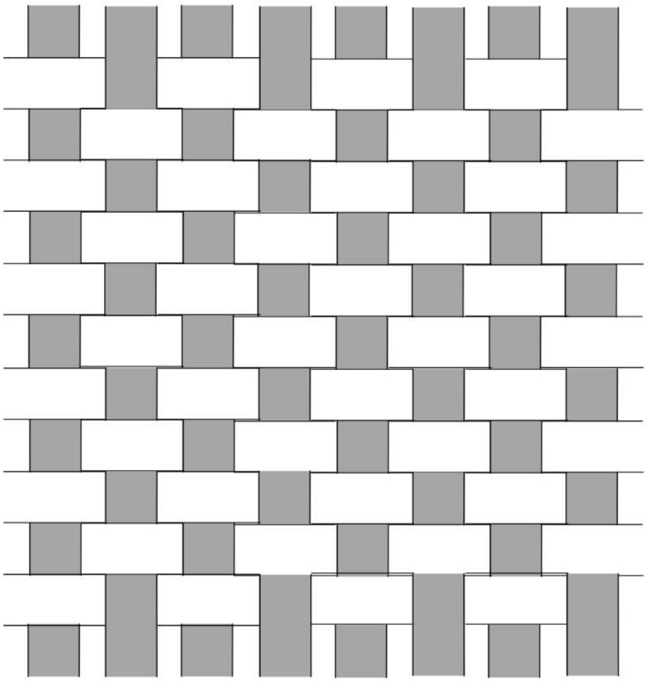


Figure J.8: Diagram of a weft-dominant tabby structure

Weft-faced: A textile wherein the weft completely covers the warp

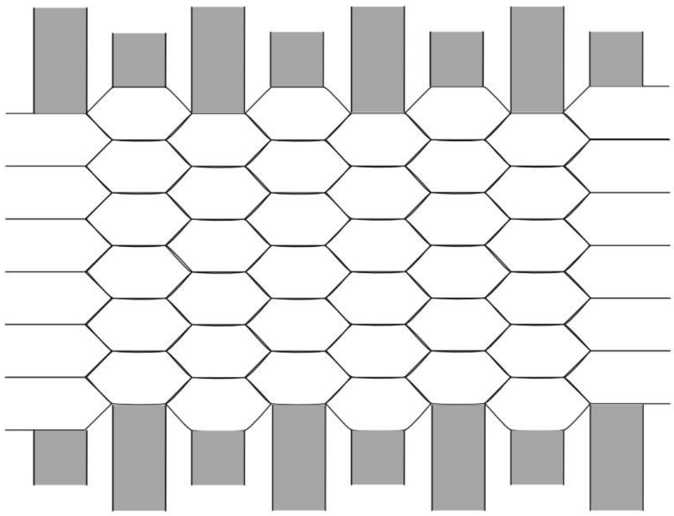


Figure J.9: Diagram of a Weft-faced tabby structure

Wild Silk: Silk produced from species of silk moth which have not been domesticated. It is common for wild silk to be spun rather than reeled.

Yarn: See thread. Yarn is often used to describe a raw material used in weaving, knitting, etc. the term yarn can carry connotations of a more coarse or rough stand in contrast to a fine thread.

Z twist: Yarn which has been twisted or spun in a clockwise direction

Bibliography

Adamson, G. (2007). *Thinking through craft*. New York : Berg.

Albers, A. (2017). *On Weaving*. REV-Revised. Weber, N. F., Cirauqui, M. and Smith, T. (Eds). Princeton University Press.

Arcimboldo, G. (c. 1586). *Treatise on Silk Culture and Manufacture*. [Online]. Museum of Fine Arts Boston. Available at: https://collections.mfa.org/objects/253925/treatise-on-silk-culture-and-manufacture?ctx=8ef95a3e-3562-4288-80b1-e38f219b6806&idx=2 [Accessed 22 June 2020].

Bartolomei, C. and Ippolito, A. (2016). The Silk Mill "alla Bolognese." In: López-Cajún, C. and Ceccarelli, M. (Eds). *Explorations in the History of Machines and Mechanisms*. History of Mechanism and Machine Science. 32. Springer International Publishing. pp.31–38.

Battistini, F. (1998). Gelsi, bozzoli e caldaie. *L'industria della seta in Toscana tra città, borghi e campagne (sec. XVI-XVIII)*, pp.393–400.

Bender Jørgensen, L. (1992). *North European textiles until AD. 1000*. Aarhus University Press.

Boccaccio, G. (1488). *Boccace, Des cleres et nobles femmes, traduction française anonyme*. [Accessed 10 September 2020].

Bongers, J. L., O'Shea, C. and Farahani, A. (2018). Communities of weavers: A methodology for analyzing textile and cloth production. *Journal of Archaeological Science: Reports*, 22, Elsevier., pp.223–236.

Bratchel, M. E. (1995). *Lucca 1430-1494 : the reconstruction of an Italian city-republic*. Oxford : Clarendon Press.

Bray, F. (1995). Textile Production and Gender Roles in China, 1000-1700. *Chinese science*, (12), International Society of East Asian Science, Technology, and Medicine., pp.115–137.

Bunn, S. (2022). Technology as Skill in Handwork and Craft: Basketwork and Handweaving. In: Bruun, M. H. et al. (Eds). *The Palgrave Handbook of the Anthropology of Technology*. Singapore : Springer Nature Singapore. pp.61–83.

Burnham, H. B. (1968). The preparation of silk yarns in Ancient China. *Bulletin du CIETA*, (27), pp.49–53.

Burns, E. J. (2009). *Sea of Silk [electronic resource] : A Textile Geography of Women's Work in Medieval French Literature*, Middle Ages series. Philadelphia : University of Pennsylvania Press.

Chen, S. et al. (2019). Mechanical properties of Bombyx mori silkworm silk fibre and its corresponding silk fibroin filament: A comparative study. *Materials & design*, 181, Elsevier., p.108077.

Chung, D. E. et al. (2015). Effects of different Bombyx mori silkworm varieties on the structural characteristics and properties of silk. *International journal of biological macromolecules*, 79, Elsevier., pp.943–951.

Cook, M. (2004). *Degumming*. [Online]. Available at: http://www.wormspit.com/degumming.htm [Accessed 28 February 2023].

Cork, C. R., Cooke, W. D. and Wild, J. P. (1996). The use of image analysis to determine yarn twist level in archaeological textiles. *Archaeometry*, 38 (2), Wiley Online Library., pp.337–345.

Crook, J. (2022). Medieval Royal and Episcopal Burials in Winchester Cathedral. *The Antiquaries Journal*, 102, Cambridge University Press., pp.134–162. [Accessed 7 May 2024].

Crowfoot, E., Pritchard, F. and Staniland, K. (2006). *Textiles and Clothing, C.1150-c.1450*. Woodbridge : Boydell Press.

Crowfoot, G. M. (1937). Of the Warp-weighted Loom. *Annual of the British School at Athens*, 37, Cambridge University Press., pp.36–47. [Accessed 24 June 2024].

Daryaee, T. (2010). Bazaars, merchants, and trade in late antique Iran. *Comparative Studies of South Asia, Africa and the Middle East*, 30 (3), read.dukeupress.edu., pp.401–409. [Accessed 21 February 2020].

Day, G. W. (1981). The Impact of the Third Crusade upon Trade with the Levant. *The International history review*, 3 (2), Routledge., pp.159–168.

Desrosiers, S. (2004). *Soieries et autres textiles de l’Antiquité au XVIe siècle*. Paris : Réunion des musées nationaux.

Desrosiers, S. (2015). *Au plus près de la matière, entre Orient et Occident. Les différentes filières de transformation de la soie du Bombyx mori*. [Online]. Available at: https://hal.archives-ouvertes.fr/hal-01213712/document [Accessed 15 August 2021].

Desrosiers, S. (2018). Sendal-cendal-zendado, a category of silk cloth in the development of the silk industry in Italy (twelfth–fifteenth centuries). *Crusading and Trading between West and East*, taylorfrancis.com. [Online]. Available at: doi:10.4324/9781315142753-23/sendal-cendal-zendado-category-silk-cloth-development-silk-industry-italy-twelfthâ□‟ fifteenth-centuries-sophie-desrosiers.

Desrosiers, S. (2019). Scrutinizing Raw Material between China and Italy: the Various Processing Sequences of Bombyx mori Silk. *L'Atelier du CRH*, (20), journals.openedition.org. [Online]. Available at: doi:10.4000/acrh.10323 [Accessed 17 January 2020].

Desrosiers, S. and Debaine-Francfort, C. (2016). *On Textile Fragments Found at Karadong, a 3rd to early 4th Century Oasis in the Taklamakan Desert (Xinjiang, China)*. digitalcommons.unl.edu. [Online]. Available at: https://digitalcommons.unl.edu/tsaconf/958/ [Accessed 21 January 2020].

Diderot, D. and D'Alembert, J.-B. le R. (1751). *L'Encyclopédie; L'art de la soie*. [Accessed 12 February 2020].

Dixon, E. (1895). Craftswomen in the Livre Des Métiers. *The Economic Journal*, 5 (18), Oxford University Press on behalf of the Royal Economic Society., pp.209–228.

Dobres, M.-A. (2000). *Technology and Social Agency: Outlining a Practice Framework for Archaeology*. Malden, Mass. : Blackwell.

Emery, I. (1980). *The primary structures of fabrics, an illustrated classification*. bcin.ca. [Online]. Available at: https://www.bcin.ca/bcin/detail.app?id=86325&wbdisable=true.

Ertl, T. (2006). Silkworms, Capital and Merchant Ships: European Silk Industry in the Medieval World Economy. *The Medieval History Journal*, 9 (2), SAGE Publications India., pp.243–270.

Fang, S. et al. (2014). A study of Tung-oil–lime putty—A traditional lime based mortar. *International Journal of Adhesion and Adhesives*, 48, pp.224–230.

Farmer, S. (2014). Medieval Paris and the Mediterranean: The Evidence from the Silk Industry. *French historical studies*, 37 (3), Duke University Press., pp.383–419. [Accessed 22 December 2017].

Farmer, S. (2016). *The Silk Industries of Medieval Paris: Artisanal Migration, Technological Innovation, and Gendered Experience*. Philadelphia : University of Pennsylvania Press.

Feltwell, J. (1990). *The story of silk*. Sutton.

Flanagan, J. F. (1936). Early Figured Silks.-The Effect of the Use of the Scale Harness on Early Islamic Silks. *The Burlington Magazine for Connoisseurs*, 68 (396), The Burlington Magazine Publications Ltd., pp.145–147.

Fleming, R. (2007). Acquiring, flaunting and destroying silk in late Anglo-Saxon England. *Early Medieval Europe*, 15 (2), Wiley Online Library., pp.127–158.

Ford, J. E. and Simmens, S. C. (1959). Fibre Section Cutting by the Plate Method. *Journal of the Textile Institute Proceedings*, 50 (3), Taylor & Francis., pp.P148–P158.

François, M. (c. 1475). *The Hague, MMW, 10 A 11, fol. 235r*. [Online]. National Library of the Netherlands. Available at: https://manuscripts.kb.nl/search/manuscript/extended/page/1/shelfmark/10+A+11 [Accessed 28 June 2024].

Galliker, J. (2017). Terminology associated with silk in the middle Byzantine period (AD 843-1204). *Textile Terminologies from the Orient to the Mediterranean and Europe, 1000 BC to 1000 AD*, Lulu. com., p.346.

Galliker, J. L. (2015). *Middle Byzantine silk in context: integrating the textual and material evidence*. PhD, University of Birmingham. [Online]. Available at: http://etheses.bham.ac.uk/id/eprint/5560/ [Accessed 2 October 2020].

Geffe, N. and de Serres, O. (1607). *The Perfect Use of Silke-Worms and Their Benefit*. Kingston.

Geijer, A. (1938). *Birka III: die Textilfunde aus den Gräbern*. Almquist Wiksells Bokthyckeri.

Geminiani, L. et al. (2023). Historical Silk: A Novel Method to Evaluate Degumming with Non-Invasive Infrared Spectroscopy and Spectral Deconvolution. *Materials*, 16 (5), mdpi.com. [Online]. Available at: doi:10.3390/ma16051819.

Goitein, S. D. (1967a). *A Mediterranean Society: The Jewish Communities of the Arab World as Portrayed in the Documents of the Cairo Geniza, Vol. I: Economic Foundations*. University of California Press.

Goitein, S. D. (1967b). *A Mediterranean Society: The Jewish Communities of the Arab World as Portrayed in the Documents of the Cairo Geniza, Vol. IV: Daily Life*. University of California Press.

Golas, P. J. (2015). *Picturing Technology in China: From Earliest Times to the Nineteenth Century*. Hong Kong : Hong Kong University Press.

Goodway, M. (1987). Fiber Identification in Practice. *Journal of the American Institute for Conservation*, 26 (1), Maney Publishing., p.27.

Hall, R. A. (1989). Archaeological Introduction. In: Walton, P. (Ed). *Textiles, Cordage and Raw Fibre from 16-22 Coppergate*. The Archaeology of York. 17. Council for British Archaeology. pp.285–297.

Hammarlund, L. (2005a). Handicraft knowledge applied to archaeological textiles. *The Nordic Textile Journal*, University College of Borås. The Swedish School of Textiles., pp.87–119. [Accessed 25 February 2020].

Hammarlund, L. (2005b). Handicraft knowledge applied to archaeological textiles—Visual groups and the pentagon. *Archaeological textiles newsletter*.

Hammarlund, L. et al. (2008). Visual textiles: a study of appearance and visual impression in archaeological textiles. In: Netherton, R. and Owen-Crocker, G. R. (Eds). *Medieval Clothing and Textiles*. 4. Woodbridge : The Boydell Press. pp.69–98.

Hammarlund, L. and Pedersen, K. V. (2010). Textile appearance and visual impression – Craft knowledge applied to archaeological textiles. In: *NESAT Symposium, North European Symposium for Archaeological Textiles X*. unknown. pp.1–7. [Accessed 15 March 2023].

Hao, P. (2012). Sericulture and silk weaving from antiquity to the Zhou dynasty. In: Kuhn, D. (Ed). *Chinese Silks*. Yale University Press. pp.65–113.

Harris, S. (2019). The sensory archaeology of textiles. In: Skeates, R. and Day, J. (Eds). *The Routledge Handbook of Sensory Archaeology*. Routledge. pp.210–232.

Hearle, J. W. S., Lomas, B. and Cooke, W. D. (1998). *Atlas of Fibre Fracture and Damage to Textiles*. Elsevier.

Hernanz, A. et al. (2012). Spectroscopy of Historic Textiles: a Unique 17th Century Bodice. In: *Analytical Archaeometry*. academia.edu. pp.468–480.

Hills, R. L. (1992). From Cocoon to Cloth. The Technology of Silk Production. In: Cavaciocchi, S. (Ed). *La seta in Europa secc. XIII-XX*. Atti delle "Settimane di Studi" e altri Convegni. Le Monnier. pp.60–90.

Høgseth, H. B. (2012). Knowledge Transfer: The Craftsmen's Abstraction. In: Wendrich, W. (Ed). *Archaeology and Apprenticeship*. University of Arizona Press. pp.61–78.

Holland, A. (2015). How to Degum Reeled Silk. *George Weil*. [Online]. Available at: https://www.georgeweil.com/blog/how-to-degum-reeled-silk/ [Accessed 28 February 2023].

Hooper, L. (1900). *Silk: its production and manufacture*, Pitman's common commodities and industries . Pitman.

Hsiao, K., Chen, Y. and Yan, H. (2010). Structural synthesis of ancient Chinese foot-operated silk-reeling mechanism. *Frontiers of Mechanical Engineering in China*, 5 (3), pp.279–288.

Hsiao, K.-H. and Yan, H.-S. (2014). *Mechanisms in Ancient Chinese Books with Illustrations*, History of Mechanism and Machine Science. Springer. [Accessed 6 December 2019].

Hsieh, C.-M. and Falkenheim, V. C. (2021). Xinjiang. *Encyclopedia Britannica*. [Online]. Available at: https://www.britannica.com/place/Xinjiang.

Ingold, T. (2007). Materials against materiality. *Archaeological Dialogues*, 14 (1), Cambridge University Press., pp.1–16. [Accessed 5 July 2023].

Islam, A., Akhter, S. and Mursalin, T. E. (2008). Automated textile defect recognition system using computer vision and artificial neural networks. *World Academy of Science, Engineering and Technology, International Journal of Mechanical, Aerospace, Industrial, Mechatronic and Manufacturing Engineering*, 2, academia.edu., pp.110–115.

Jacoby, D. (1994). Italian privileges and trade in Byzantium before the Fourth Crusade: a reconsideration. *Anuario de estudios medievales*, 24, Instituto de Historia Medieval de España., p.349.

Jacoby, D. (2004). Silk Economics and Cross-Cultural Artistic Interaction: Byzantium, the Muslim World, and the Christian West. *Dumbarton Oaks Papers*, 58, Dumbarton Oaks, Trustees for Harvard University., pp.197–240.

Jiang, P. et al. (2006). Tensile behavior and morphology of differently degummed silkworm (Bombyx mori) cocoon silk fibres. *Materials letters*, 60 (7), pp.919–925.

Jirousek, C. A. (1998). The End of the Silk Road: Implications of the Decline of Turkish Sericulture. *Textile history*, 29 (2), Routledge., pp.201–225.

Joy, J. (2009). Reinvigorating object biography: reproducing the drama of object lives. *World archaeology*, 41 (4), Routledge., pp.540–556.

Kai, L. (c.1200). *Sericulture (The Process of Making Silk)*. [Online]. The Cleveland Museum of Art. Available at: http://www.clevelandart.org/art/1977.5 [Accessed 7 May 2020].

Kania, K. (2021). The story of twist: Handspinning as a medieval craft. *Crafting Textiles: Tablet Weaving, Sprang, Lace and Other Techniques from the Bronze Age to the Early 17th Century*, Oxbow Books., p.207.

Karatzani, A. and Rehren, T. (2006). Clothes of gold: metal threads in Byzantine-Greek orthodox ecclesiastical textiles. *Proceedings ISA*, academia.edu., pp.444–409.

Karatzani, A., Rehren, T. and Zhiyong, L. (2009). The metal threads from the silk garments of the Famen Temple. *Restaurierung und Archäologie*, 2, academia.edu., pp.99–109.

Karuno, H. (2013). *Kigami and Kami-ito: Japanese handmade paper and paper threads*. Library and Archives Canada Cataloguing in Publication.

Kennedy, H. (2016). *Caliphate: The history of an idea*. Basic Books.

Khan, A. M. (1996). Science and technology in early medieval India. *Erdem*, 9 (26), Erdem., pp.717–728.

King, D. (1968). A chasuble of the later middle ages. *Bulletin du cancer*.

Knaller, R. and Ströbele, F. (2014). The heritage of Tang dynasty textiles from the Famen Temple, Shaanxi, China: Technological and stable isotope studies. *Studies in Conservation*, 59 (sup1), Routledge., pp.S62–S65.

Kostajnšek, K. and Dimitrovski, K. (2021). Use of Extended Cover Factor Theory in UV Protection of Woven Fabric. *Polymers*, 13 (8). [Online]. Available at: doi:10.3390/polym13081188.

Kuhn, D. (1979). The Spindle-Wheel: A Chou Chinese Invention. *Early China*, 5, Cambridge University Press., pp.14–24. [Accessed 28 July 2018].

Kuhn, D. (1981). Silk Technology in the Sung Period (960-1278 A.D.). *T'ung pao. T'oung pao*, 67 (1/2), Brill., pp.48–90.

Kuhn, D. (1988). *Chemistry and Chemical Technology, Part 9, Textile Technology: Spinning and Reeling*, Science and Civilisation in China. Cambridge University Press.

Kuhn, D. (2012). Reading the Magnificence of Ancient and Medieval Chinese Silks. In: Kuhn, D. (Ed). *Chinese Silks*. Yale University Press. pp.1–64.

Kumar, F. (2018). *Degumming of Silk*. [Online]. Available at: https://textilestudycenter.com/degumming-of-silk/ [Accessed 28 February 2023].

Lacey, K. (1987). The production of 'Narrow Ware'by silkwomen in fourteenth and fifteenth century England. *Textile history*, 18 (2), Taylor & Francis., pp.187–204.

Lardner, D. (1831). *The Cabinet Cyclopaedia: A Treatise on the Origin, Progressive Improvement, and Present State of the Silk Manufacture*. Longman, Rees, Orme, Brown, and Green.

Lee, B. et al. (2022). Species identification of silks by protein mass spectrometry reveals evidence of wild silk use in antiquity. *Scientific reports*, 12 (1), nature.com., p.4579.

Lemon, H. (1968). The Development of Hand Spinning Wheels. *Textile history*, 1 (1), Routledge., pp.83–91.

Lemonnier, P. (2004). Introduction to technological choices. *Material culture: critical concepts in the social sciences. Vol. 3: Pt. 1*, 1, Taylor & Francis., p.339.

Li, L. M. (1981). *China's Silk Trade: Traditional Industry in the Modern World, 1842-1937*. Harvard Univ Asia Center.

Lopez, R. S. (1945). Silk Industry in the Byzantine Empire. *Speculum*, 20 (1), [Medieval Academy of America, Cambridge University Press, University of Chicago Press]., pp.1–42.

Luxford, N. (2009). *Reducing the risk of open display: optimising the preventive conservation of historic silks*. phd, University of Southampton. [Online]. Available at: https://eprints.soton.ac.uk/162153 [Accessed 30 May 2023].

Ma, D. (2002). The great silk exchange: how the world was connected and developed. In: *Pacific Centuries*. Routledge. pp.48–79.

Mair, V. H. (2014). Introduction: Reconceptualising the silk roads. In: Victor H. Mair, Jane Hickman, Colin Renfrew (Ed). *Reconfiguring the Silk Road*. University of Pennsylvania Press. pp.1–4.

Malcolm-Davies, J. A., Gilbert, R. and Lervad, S. (2018). Unravelling the confusions: Defining concepts to record archaeological and historical evidence for knitting. *Archaeological Textiles Review*, 60, forskningsdatabasen.dk., pp.10–24.

van Mallery, K. (c. 1595). *The Reeling of Silk, Plate 6 from Vermis Sericus*. [Online]. New York : The Metropolitan Museum of Art. Available at: https://www.metmuseum.org/art/collection/search/659745?searchField=All&sortBy=Relevance&ft=vermis+sericus&offset=0&rpp=20&pos=5 [Accessed 26 May 2020].

Manning, J. G. (2014). At the limits: long-distance trade in the time of Alexander the Great and the Hellenistic kings. *Reconfiguring the Silk Road: new research on east--west exchange in antiquity*, pp.5–14.

May, F. L. (1957). *Silk textiles of Spain: eighth to fifteenth century*. Hispanic Society of America.

Millson, D. C. E., Theoretical Archaeology Group and ebrary, Inc. (2010). *Experimentation and interpretation [electronic resource] : the use of experimental archaeology in the study of the past*. Oxford ; Oakville, Conn. : Oxbow Books.

Molà, L. (2000). *The Silk Industry of Renaissance Venice*. London : The Johns Hopkins University Press.

Molà, L. (2016). A luxury industry: The production of Italian silks 1400-1600. In: Lambert, B. and Wilson, K. A. (Eds). *Europe's Rich Fabric*. Abingdon : Routledge. pp.237–266.

Monnas, L. (2008). *Merchants, princes and painters: Silk fabrics in Italian and northern paintings, 1300-1550*. Yale university Press.

Monnas, L. et al. (2021). *Vocabulary of Technical Terms: English*. CIETA. [Online]. Available at: https://cieta.fr/wp-content/uploads/2021/10/English-Vocabulary_6August2021.pdf.

Muthesius, A. (1989). From Seed to Samite: Aspects of Byzantine Silk Production. *Textile history*, 20 (2), Routledge., pp.135–149.

Muthesius, A. (1997). *Byzantine silk weaving: AD 400 to AD 1200*. Verlag Fassbaender.

Muthesius, A. (2001). The "Cult" of Imperial and Ecclesiastical Silks in Byzantium. *Textile history*, 32 (1), Routledge., pp.36–47.

Muthesius, A. (2008). *Studies in Byzantine, Islamic and Near Eastern Silk Weaving*. Pindar.

Muthesius, A. M. (1992). *Silk, Power And Diplomacy In Byzantium*. digitalcommons.unl.edu. [Online]. Available at: https://digitalcommons.unl.edu/tsaconf/580/ [Accessed 11 July 2023].

Nunome, J. (1989). Archaeology of Silk. *Sen'i Gakkaishi*, 45 (6), The Society of Fiber Science and Technology, Japan., pp.P277–P282.

Oikonomidès, N. (1986). Silk Trade and Production in Byzantium from the Sixth to the Ninth Century: The Seals of Kommerkiarioi. *Dumbarton Oaks Papers*, 40, Dumbarton Oaks, Trustees for Harvard University., pp.33–53.

Owen-Crocker, G. R. (2004). *Dress in Anglo-Saxon England*. Boydell Press.

Øye, I. (2016). When did weaving become a male profession? *Danish Journal of Archaeology*, 5 (1–2), Routledge., pp.34–51.

Ozkaya, Y. A., Acar, M. and Jackson, M. (2010). *Yarn twist measurement using digital imaging*. Loughborough University. [Online]. Available at: https://repository.lboro.ac.uk/articles/Yarn_twist_measurement_using_digital_imaging/9569387 [Accessed 17 February 2020].

Patel, N. et al. (2013). Automatic Binding Point and Surface Helix Angle Measurement in Historic Weft-Faced Compound Weave Figured Silks. In: *2013 12th International Conference on Machine Learning and Applications*. 2. December 2013. pp.529–534.

Pomier, L. (1754). *L'art de cultiver les muriers-blancs, délever les vers à soye, et de tirer la soye des cocons*. [Accessed 8 May 2020].

Pritchard, F. (1984). Late Saxon Textiles from the City of London. *Medieval archaeology*, 28 (1), Routledge., pp.46–76.

Pritchard, F. (1988). Silk braids and textiles of the Viking Age from Dublin. *Archaeological Textiles*, 1988, pp.149–161.

Rasheed, A. et al. (2020). Fabric Defect Detection Using Computer Vision Techniques: A Comprehensive Review. *Mathematical Problems in Engineering*, 2020, Hindawi. [Online]. Available at: doi:10.1155/2020/8189403 [Accessed 19 March 2024].

Rayner, H. (1903). *Silk throwing and waste silk spinning*. Scott, Greenwood.

Ribble, M. (2018). *Electric Eel Wheel Mini 2 Press Release*. [Online]. Available at: https://www.dreamingrobots.com/2018/11/20/electric-eel-wheel-mini-2-press-release/ [Accessed 28 June 2024].

Riboud, K. (1972). Some Remarks on Strikingly Similar Han Figured Silks Found in Recent Years in Diverse Sites. *Archives of Asian Art*, 26, University of Hawai'i Press., pp.12–25.

Riboud, K. (1977). A closer view of early Chinese silks. In: Gervers, V. (Ed). *Studies in Textile history*. Toronto: Royal Ontario Museum. pp.252–280.

Saunier, I. et al. (2022). Making clothes, dressing the deceased: Analysis of 2nd century AD silk clothing from the child mummy of Burgast (Altai Mountains, Mongolia). *Archaeological Research in Asia*, 29, Elsevier., p.100343.

Schäfer, D., Riello, G. and Molà, A. L. (Eds). (2020). *Seri-Technics: Historical Silk Technologies*, Studies. Max Planck Research Library for the History and Development of Knowledge. [Accessed 1 September 2020].

Serjeant, R. B. (1972). *Islamic Textiles: Material for a History up to the Mongol Conquest*. Beirut : Librairie du Liban.

Shen, Y., Johnson, M. A. and Martin, D. C. (1998). Microstructural Characterization of Bombyx mori Silk Fibers. *Macromolecules*, 31 (25), American Chemical Society., pp.8857–8864.

Simmons, P. (1950). Crosscurrents in Chinese silk history. *The Metropolitan Museum of Art Bulletin*, 9 (3), JSTOR., pp.87–96.

Solazzo, C. et al. (2012). Proteomic Profiling of the Photo-Oxidation of Silk Fibroin: Implications for Historic Tin-Weighted Silk. *Photochemistry and photobiology*, 88 (5), Wiley Online Library., pp.1217–1226.

Swire, E. (2024).Email to Gwendoline Pepper, 21 June.

The Talbot Master. (c.1440). *Royal 16 G V f. 54v*. [Online]. British Library. Available at: http://www.bl.uk/catalogues/illuminatedmanuscripts/ILLUMIN.ASP?Size=mid&IllID=43181 [Accessed 26 May 2020].

Vollmer, J., Keall, E. J. and Nagai-Berthrong, E. (1983). *Silk roads, China ships*. Toronto : Royal Ontario Museum.

Vornicu, N., Bibire, C. and Zaltariov, M. F. (2021). Characterisation of metal threads from archaelogical textiles religious by methods of archaeometry. *Annals of the University of Oradea*, ibn.idsi.md. [Online]. Available at: https://ibn.idsi.md/vizualizare_articol/186751.

Wåhlander, L. (2016). The Value of Textiles. In: Andersson, G. (Ed). *We Call Them Vikings*. The Swedish History Museum. pp.142–147.

Walton, P. (1989). *Textiles, cordage and raw fibre from 16-22 Coppergate*. York Archaeological Trust.

Walton, P. and Eastwood, G. (1988). *A brief guide to the cataloguing of archaeological textiles*. bcin.ca.

Walton Rogers, P. (2007). *Cloth and clothing in early Anglo-Saxon England, AD 450-700*. Council for British Archeology.

Walton Rogers, P. (2020a). Textile networks in Viking-Age towns of Britain and Ireland. In: Ashby, S. P. and Sindbaek, S. (Eds). *Crafts and Social Networks in Viking Towns*. Oxford : Oxbow Books. pp.83–122.

Walton Rogers, P. (2020b). Zoom meeting with Gwendoline Pepper, 29 June.

Walton Rogers, P. (2023). *Two silks from the mortuary chests: dates and dyes*. Internal Project Archangel Report. Unpublished.

Wang, X., Georganas, N. D. and Petriu, E. M. (2011). Fabric Texture Analysis Using Computer Vision Techniques. *IEEE transactions on instrumentation and measurement*, 60 (1), IEEE., pp.44–56.

Wenying, L. (2012). Silk artistry of the Qin, Han, Wei, and Jin Dynasties. In: Kuhn, D. (Ed). *Chinese Silks*. Yale University Press. pp.115–165.

Whitfield, S. (2019). *Silk Roads: Peoples, Cultures, Landscapes*. Whitfield, S. (Ed). London : Thames & Hudson., p.480. [Accessed 29 March 2024].

Wincott Heckett, E. (2003). *Viking age headcoverings from Dublin*. Royal Irish Academy.

Woodward Wendelken, R. (2014). Wefts and worms: The spread of sericulture and silk weaving in the west before 1300. In: Netherton, R. and Owen-Crocker, G. R. (Eds). *Medieval Clothing and Textiles*. 10. Woodbridge : Boydell & Brewer. pp.59–78.

Yorke, B. (2021). Royal Burial in Winchester: Context and Significance. *Early Medieval Winchester: Communities, Authority and Power in an Urban Space, c. 800-c. 1200*, Oxbow Books., p.59.

Yukseloglu, S. M. and Canoglu, S. (2016). Silk Fibre Degradation and Analysis by Proteomics. *Annals of the University of Bucharest. Mathematical Series*. [Online]. Available at: https://search.ebscohost.com/login.aspx?direct=true&profile=ehost&scope=site&authtype=crawler&jrnl=1843813X&AN=116581866&h=l9NhllkfFav8rXuOZd5IPj%2BQ4wMWHlPG15yIbgEuvxRyRxMk4gtxk4tXhzqvqGW54SIZfuTh3ey8%2F3IkNil8oA%3D%3D&crl=c.

Zanier, C. (2020). The Silk Cycle in China and its Migration. In: Dagmar Schäfer, Giorgio Riello, and Luca Molà (Ed). *Seri-Technics: Historical Silk Technologies*. Studies. 13. Max Planck Research Library for the History and Development of Knowledge. pp.13–31.

Zhang, X., Berghe, I. V. and Wyeth, P. (2011). Heat and moisture promoted deterioration of raw silk estimated by amino acid analysis. *Journal of cultural heritage*, 12 (4), pp.408–411.

Zhang, X. and Wyeth, P. (2010). Using FTIR spectroscopy to detect sericin on historic silk. *Science China. Chemistry*, 53 (3), Springer Science and Business Media LLC., pp.626–631.

Zhao, F. (2012). Silks in the Sui, Tang, and Five Dynasties. In: Kuhn, D. (Ed). *Chinese Silks*. London : Yale University Press. pp.203–257.

Zhao, F. (2020). The Ever-Changing Technology and Significance of Silk on the Silk Road. In: Carter, I. G. A. S. (Ed). *The Oxford Handbook of History and Material Culture*. Oxford University Press. [Accessed 28 June 2021].

Zhao, F. (2021). Domestic, wild or unraveled? A study on tabby, taquete and jin with spun silk from Yingpan, Xinjiang, third-fourth centuries. In: Hildebrandt, B. and Gillis, C. (Eds). *Silk: Trade and Exchange along the Silk Roads between Rome and China in Antiquity*. Oxbow. pp.95–103.

Zhao, F. and Liu, H. (2020). Sericulture and Silk Production. In: Hua, J. and Feng, L. (Eds). *Thirty Great Inventions of China: From Millet Agriculture to Artemisinin*. Singapore : Springer Singapore. pp.37–62.

Zhao, F. and Wang, L. E. (2013). Glossary of Textile Terminology (Based on the Documents from Dunhuang and Turfan). *Journal of the Royal Asiatic Society of Great Britain & Ireland. Royal Asiatic Society of Great Britain and Ireland*, 23 (2), Cambridge University Press., pp.349–387. [Accessed 31 January 2020].

Zhao, H.-P., Feng, X.-Q. and Shi, H.-J. (2007). Variability in mechanical properties of Bombyx mori silk. *Materials Science and Engineering: C*, 27 (4), pp.675–683.

Zheng, H. et al. (2021). Rapid Enrichment and Detection of Silk Residues from Tombs by Double-Antibody Sandwich ELISA Based on Immunomagnetic Beads. *Analytical chemistry*, 93 (43), ACS Publications., pp.14440–14447.

Zimliki, D. A. et al. (2000). Determining Mechanical Properties of Yarns and Two-Ply Cords from Single-Filament Data: Part I: Model Development and Predictions. *Textile Research Journal*, 70 (11), SAGE Publications Ltd STM., pp.991–1004.

(2007). *C55000-garnvinne*. *Museum of Cultural History* [Online]. Available at: https://www.unimus.no/portal/#/photos/d3086956-20c9-4954-b46e-c9a7e9a0a4f1 [Accessed 3 September 2022].

(2022). *Textile MA S.861*. [Online]. Available at: https://www.britishmuseum.org/collection/object/A_MAS-861 [Accessed 7 January 2023].

(c.1300-1340). *Royal MS 10 E IV, f.137r*. *British Library*.