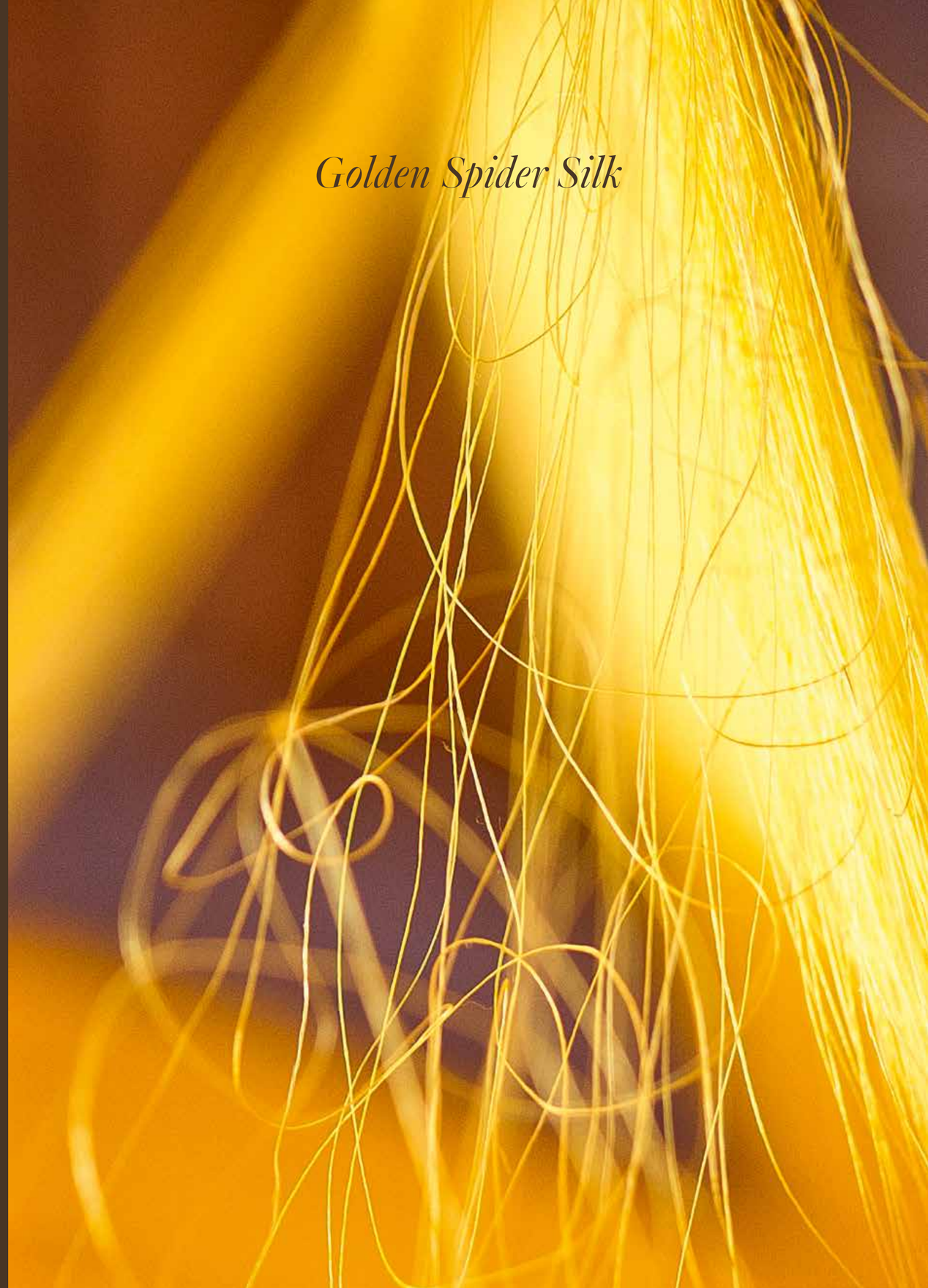
Golden Spider Silk



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Golden Spider Silk

‘The comparison shows evidently how much more brilliant and beautiful the spider’s silk is to the silk of the silkworm; so bright that it appears more like a polished metal or mirror than like silk.’

Raimondo Maria de Termeyer, circa 1796

Published by Oliver Hoare Ltd in 2021
10 Avenue Studios, Sydney Close London SW3 6HW
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Photographs
pp. 28-33 & 46-49 courtesy of the RISD Museum, Providence, RI
pp. 2-5 & 10-25 & 40-43 & 60-61 & 94-96 courtesy of John Brown
pp. 36-39 & 52 & 104-105 courtesy of V&A Museum, London
pp. 55-59 & 62-66 courtesy of David Levene

Design by Anikst Design, London
Printed by Graphicom, Italy

Acknowledgements
Simon Peers and Nicholas Godley would like to express their gratitude to all the many people who have helped in the making of these extraordinary creations. Such an undertaking spread over so many years has inevitably involved talent too numerous to list here. However we would like to mention those who made a particular contribution, above all Norosoa Ravelomahay and her team at the 'spidery', along with the legions of spider collectors; to Nathalie Robert, Martin Rakotoarimanana, the late Antoine Rakotoarinala and all the weavers, and Lanto Razafindraibe and Rondro Faravololona and all the embroiderers. Without their talents and skills the silk would have been spun into webs and dispersed in the wind. We would also like to express our special thanks to Sir David Attenborough for his contagious enthusiasm and allowing us to use the foreword in the present publication. Thanks also to Tom Windross at the V&A who has delved into the archives in pursuit of lost material; and last but not least, thank you Damian and Ann for having the courage and foresight to launch into this adventure with us.

Cover image
Warp threads of golden spider silk,
courtesy of John Brown

pp. 2–3
960 spider silk threads used for the ground relief
in the raised embroidery on the brocaded weave lamba (p.37)

pp. 4–5
Spider silk threads on the warp beam

Contents

Female Nephila madagascariensis

Foreword

Madagascar is an island surrounded by myth. It was once supposed to be the home of a gigantic bird big enough to lift an elephant in its talons and fly off with it. It was also said by some that a dog-headed man roamed its forests and seventeenth-century natural history books contained illustrations of it, standing upright with a shaggy coat, enormous calliper-like hands and the snouted furry face of a dog.

There was material evidence for both stories. Eggs the size of rugby footballs were sometimes found in the islands southern deserts – though we now know that the extinct birds that laid them were flightless, like ostriches. And in the rain forests in the east of the island lives a lemur, the largest of all surviving today, that has hind legs as long as its torso, that stands upright on the ground and has a long-snouted head reminiscent of a dog.

And now we are told that there is a spider living on the island that produces threads of silk that can be woven into a gleaming golden fabric so strong that it can be tailored into stockings fit for a princess.

I am lucky. I have seen the gigantic eggs and the giant lemur. I have also encountered *Nephila,* the huge spider in question, various species of which occur in tropical jungles around the world. I have even, like many other travellers, had to clear the silken threads from my face having carelessly walked into a yard-wide web slung between two trees. So I know how strong it can be. But I did not know, until I went to Madagascar, that anyone had been clever enough to weave those threads into a fabric. And I saw how it was done. Twenty-four female *Nephilas,* each sitting in her own little compartment, industriously spinning silk that is threaded through a tiny hole, wound on to bobbins and then woven to produce what must surely be counted as one of the rarest and most glamorous of fabrics.

Thank goodness the world still holds marvels.

David Attenborough

Introduction

The cape and 3 textiles presented here – which are being offered for sale for the very first time – represent the culmination of centuries of tireless human endeavour and ambition to harvest one of the most beautiful but elusive materials on our planet – spider silk. They also represent the only textiles produced from the silk of golden silk orb-weaver spiders – *Nephila Madagascariensis* (fig.1), native to Madagascar and famous for the colour of their webs, which shimmer with gold.

Spider silk has for centuries been coveted for its promise of riches, particularly by those seeking to compete with the silk which started arriving from China and flooding the wealthy wardrobes and bedchambers of Europe. Its extraordinary history – outlined later in this book – is told through a handful of fascinating and ambitious players determined to push human enterprise into corners of creativity otherwise overlooked, though most soon found their dreams tangled up in a quandary of complications and prohibitive cost.

That is until very recently. Nicholas Godley and Simon Peers spent the best part of two decades working together to produce the cape and three exquisite textiles presented here. Their dream was never one of riches but of the sheer *wonder* of it all; of creating magic, and doing so by turning something otherwise entirely ethereal into a reality.

The results are the product of an effort as heroic as it is quixotic. It took fifteen years of research, drawing what knowledge they could from the efforts which preceded them; designing and re-designing equipment for silk extraction in a tireless process of trial and error, with little more for guidance than images in centuries-old notebooks. A further eight years for production, including five years employing eighty men and women to scour the highlands of Madagascar collecting spiders every morning for 'silking' before returning them, unharmed, to the wild that same evening.

Estimates for the numbers of spiders necessary to produce silk are astonishing: a single ounce (28 grams) of golden spider silk requires 23,000

Fig. 1 Epeira madagascariensis (Nephila madagascariensis). *August Vinson*, Aranéides des iles de la Réunion, Maurice et Madagascar, *Paris 1863, plate VII*

spiders; to produce the cape and brocaded textile alone required drawing the silk from the spinnerets of over 1 million spiders each.

It is little surprise that Sir Richard Burton (British explorer, 1821–1890) chose to describe the attempts that he witnessed in 1883 at this wizardry as like 'gathering moonbeams.' Little surprise too that the extraordinary glow of these textiles hides beneath it a history littered with abandonment and broken dreams, a distinguished list of those who were not able to accomplish what has finally been achieved by Peers and Godley.

For Peers, a highly reputed English textile designer and creator who has lived in and loved Madagascar for over 30 years and whose traditional Malagasy textiles can be found amongst the world's great houses and museums, some of the enticement was towards a fibre whose rarity and beauty could find no equal. Even in the long and illustrious history of fashion houses, whose obsession for luxury has taken them to reap what they can from every corner of the world, they have not come close to producing something so exquisite, so delicate or so refined.

Similarly, Nicholas Godley has held a fascination with Madagascar ever since his arrival to the island in 1993 as a development economist, exploring ways for raising living standards in one of the world's poorest countries. As an entrepreneur he recognised the possibilities for an unexplored natural resource with extraordinary properties of strength and elasticity, whose potential to science remains full of promise.

Together they have spun their colossal efforts into the definitive chapter of an extraordinary story, and by doing so created symbols sure to become beacons for centuries to come for all that is magic and mystical in the natural world.

Damian Hoare

Unthrown silk threads used for the lustrous finishing
of the embroidered spiders on the cape (p.53)

Strands of silk drawn from 24 Nephila madagascariensis

Inspiration & Insight

We are used to thinking of artists as explorers of unchartered conceptual territory. In the physical world, however, it is rare to be exploring the artistic possibilities of an untried and untested material. People have never ceased to borrow from nature, adapting natural processes to their own ends, and few materials have escaped close scrutiny and subsequent use and development. But, occasionally, the effort required to use a new material appears to outweigh the achievement, and an ingenious endeavour is abandoned because the obstacles might appear just too daunting.

Appropriating and transforming spider silk has a long history – and because we are all so familiar with the raw material, the spider web, it is an intriguing history too. The ingenious spider seems to offer abundant possibilities, and the silk of its web is generally known to be a yarn of spectacular strength and elasticity. If we can make silk commercially from silkworm cocoons, why not from spider webs?

But how? Spiders are carnivore and cannibal, and they are not a social animal and cannot be bred like silkworms. Harvesting their silk has been a challenge only an ambitious few have accepted – the extraordinary story of their attempts, beginning over 300 years ago, and outlined later in this book, is a story of efforts abandoned and incomplete.

This has left spider silk trapped in the amber of myth and fairy-tale, but it also might offer that rare opportunity: a rich field of potential just waiting to be explored. Today, spider silk's tensile strength has meant that the pursuit of a material with its special properties for use in medicine and engineering has been the subject of much research.

This research has bypassed the awkward spider itself, and sought to produce what is known as recombinant silk, applying spider DNA in

Spider-silk warp threads passing through the metal eyes of the heddle leashes, 2007

various ways to different carriers, to produce a hybrid silk with spider-silk properties. So far this work has met with limited success.

But we – myself and Nicholas Godley – have not been focused on scientific possibilities. We have been seduced by the creative potential of the silk, by the technical challenges of using such a material, and by the symbolism it holds. Our interest has been further motivated by the empty space that exists in the world of fibres and textiles when considering the material; in a world bursting with innovation and invention, there are few others who have worked with spider silk, or even tried to do so.

Through the years of the Enlightenment, of the industrial revolution and our present digital, computerized age, spider silk has been bypassed, seen as a material too challenging, too demanding. But the creative possibilities, and the conceptual purity of spider silk – so seemingly simple, so naturally appropriate for weaving – were too unusual for us to ignore.

However our objective has not been just conquering the technical challenges, but also to engage people with an emotional and intellectual experience that is entirely new.

Knowing a little of the story of Madagascar's spiders, and having been momentarily attracted by a chance reading in 1989 of an article about experiments undertaken at Wyoming University,[1] I decided to look further at the work of our predecessors (*see 'The Extraordinary History of Spider Silk'*). But it took fifteen years before research was transformed into practical experiment – in 2003 Nicholas Godley and I revived the idea of pursuing the work of the 1890s,[2] drawn irresistibly to the stories from the past, but with an imaginative vision for the future.

From Bon (1678–1761, *see p. 68*) to Camboué (1849–1929, *see p. 88*), the challenges facing production for all of our predecessors were similar; a supply of the necessary numbers of spiders being the most pressing. Having first attempted to farm the spiders, we soon reverted to a more practical method, collecting them on a daily basis. The highlands of Madagascar certainly provide the numbers, but the work is relentless and the yield miniscule.

We recreated and perfected the machines used by the Ecole Professionnelle (*see p. 89*) over 100 years ago, and began collecting in 2005. Our aim has not been to make a pair of gloves or stockings, nor a purse, but to use the exceptional opportunity of working with the rarest of materials to create something that speaks directly to the viewers' senses, to their emotions and intellect.

Over the course of eight years we created the cape and three textiles which are presented here, all made entirely of the undyed silk of the golden silk orb-weaver *Nephila madagascariensis*.

The manner in which light reflects from individual spider-silk threads is unlike the effect of light on the silk of the silkworm, the *Bombyx mori*. This difference probably stems from the fact that the spider silk does not have the gum-like sericin protein that coats the *Bombyx* silk, which needs to be washed and removed before it reveals its lustre. Also, the colour of the spider silk does not result from any added dye. The textile is woven from unadulterated, unaltered silk – the silk taken directly from the spiders' spinnerets as it turns from a liquid crystal in the silk gland to solid thread to make its web is the very same silk we weave with. The resulting optical effect, when threads are grouped in large numbers, shows reflective properties of such delicacy that the cloth, depending on the light, glows

with a range of golden tones that seem to emanate from within the silk itself.[3] Professor Wilder *(see p.85)* described this:

> *'To the admirer of the beautiful and perfect in nature is presented a fibre of absolute smoothness, roundness and finish, the colours of which resemble, and in the sunlight even excel in brilliancy, those of the two precious metals, silver and gold.'*[4]

The resulting work is the fruit of thousands of hours of collecting, 'silking', throwing and weaving the silk of millions of spiders. There is an obvious paradox here, for this lengthy and arduous process is the antithesis of the normal brief, ephemeral life of a web. There is no alchemy that can replace this and we are well placed to appreciate Seneca's sentiment that man's hand cannot imitate the skill of the spider. But we have taken the speculative experiments of the past centuries and applied our imagination and creativity.

Our objective has been to arouse a real sense of wonder in a world that too often admires the facile and meretricious. There is no precedent for spider-silk textiles on this scale, either for the technical complexity, or for the quantity of silk used. Each textile tells a very contemporary story, a confluence of global cultural currents and eclectic borrowings. They are works made after careful consideration and reflection, and with skills acquired after much time and effort. Ultimately they are creations in which the medium is the message.

Simon Peers

Warping through the comb

‘To the admirer of the beautiful and perfect in nature is presented a fibre of absolute smoothness, roundness and finish, the colours of which resemble, and in the sunlight even excel in brilliancy, those of the two precious metals, silver and gold.’

Professor Burt Green Wilder, August 1866

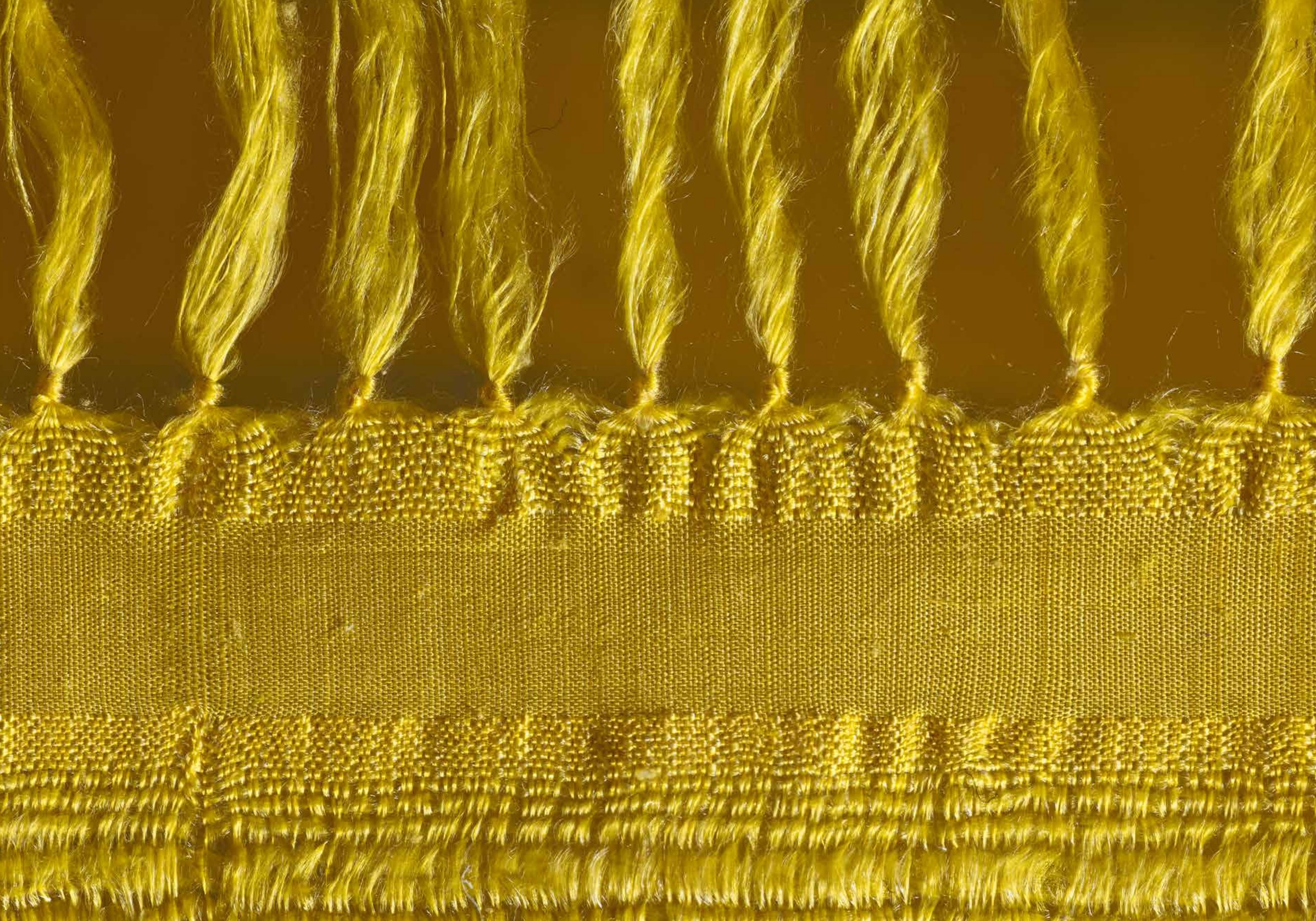
Sheer Taffeta Weave Shawl

Madagascar, 2009
160 × 60.5 cm
Warp: 48 threads, Weft: 24 threads
Weight: 65 grams

Exhibited

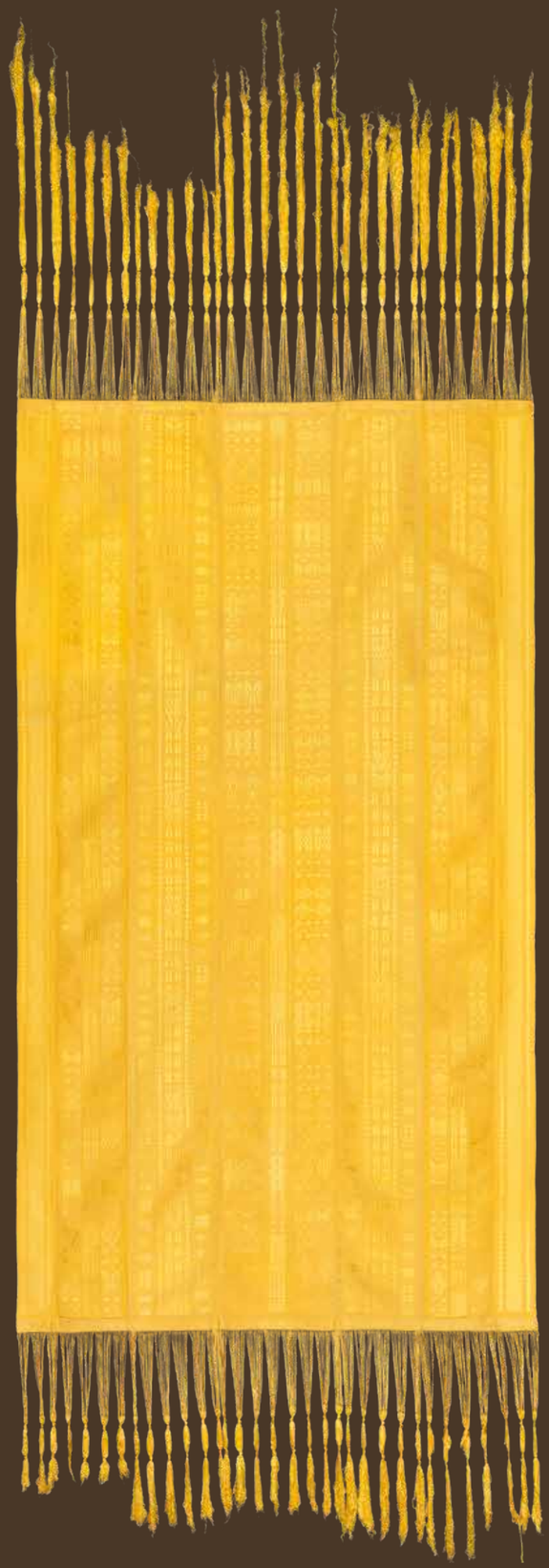
September 2009 – October 2010: Presented at The American Museum of Natural History, New York 'Spider Silk'
June 2011 – September 2011: Fondazione Giorgio Cini, Venice 'Penelope's Labour: Weaving words and images'
September 2012: Musée Bargoin, Clermont Ferrand, France 'Textiles Extraordinaires'
September 2019 – April 2020: Rhode Island School of Design Museum of Art, USA 'The Art and Design of Spider Silk'

Having collected silk from over 500,000 golden orb spiders, it was time to attempt our first proper weave on the loom. This was an exciting and extraordinary moment and nothing could quite prepare us for the experience. All weaving is produced with the warp threads under tension. As the weaving progressed the tension also increased. The elasticity of the threads, so unlike that of Bombyx silk, made us hold our breath as we watched them stretch on the loom. Our apprehension was of course misplaced as not a single thread broke as the weave advanced. We decided to leave a staggered spacing without any weft to add to the airiness and spider silk lightness for this our first weave.



‘…writers talk of ‘spider’s silk’ like gathering moonbeams.’

Richard Francis Burton, 1883



Brocaded Weave Lamba

Madagascar, 2009
310 × 120 cm
Warp: 96 threads, Weft: 148 threads & 960 for the brocade
Weight: 1,280 grams

Exhibited

September 2009 – October 2010: The American Museum of Natural History, New York 'Spider Silk' (where it broke all records for visitor numbers to a single exhibit)
April 2011 – September 2011: The Art Institute, Chicago 'Spinning Gossamer: Golden Spider Silk Textile'
January 2012 – June 2012: The Victoria & Albert Museum, London 'Golden Spider Silk'

Our first major weave was completed in 2009, it took four years to make and used the thread of 1,063,000 spiders.

Lamba is the generic term in Madagascar for a woven fabric of rectangular shape. The design is based on the precious royal silks of the nineteenth-century from the highlands of Madagascar. An endeavour that seemed suitable not just because the silk we use is from the Nephila madagascariensis, nor because we have taken up the task where Nogué left off here in Madagascar (*see p. 89*), but rather because of our familiarity with these textiles and our knowledge of the techniques involved which we have perfected over a period of almost thirty years. For other examples of our work using these traditional designs and techniques with Bombyx silk, please see The Metropolitan Museum of Art, New York, numbers 1999.102 & 2013.23.

Known as a 'lamba akotifahana' in Malagasy, this large rectangular textile is made up of seven panels and two end bands that are all woven using a traditional method of weft brocading with some added warp brocade. This patterned brocading consists of a great wealth of **traditional idiosyncratic geometric motifs, resembling arcane hieroglyphs, which lend themselves to a monochromatic golden textile in which all the subtlety and beauty of the textures and patterns are revealed by the play of light on the surface.**

The cloth of spider silk recalls the robes of Sleeping Beauty. It has a wonderful brilliance and its iridescence sends the rays of the rainbow to astonished eyes. The silk of the spider is a superb golden yellow with reflections that are varied and dazzling'.

Les Annales (politiques et litteraires), 17th June 1900

Satin Weave Shawl

Madagascar, 2011
188 × 27 cm
Warp: 48 threads, Weft: 96 threads
Weight: 82 grams

Exhibited

April 2011 – Presented at the opening of 'Spinning Gossamer: Golden Spider Silk Textile' exhibition at The Art Institute, Chicago
April 2012 – August 2013: Copenhagen Museum of Natural History, Denmark 'Spiders'
September 2019 – April 2020: Rhode Island School of Design Museum of Art, USA 'The Art and Design of Spider Silk'

Our second small weave made in 2011 was undertaken using a satin weave rather than a plain taffeta. We felt this technique would highlight the beauty of the silk, concentrating on its lustre rather than its lightness. We also saw this as an experiment to produce a wearable, if not utilitarian creation, that led on to the making of the cape.

‘It must surely be counted as one of the rarest and most glamorous of fabrics. Thank goodness the world still holds marvels.’

David Attenborough

Cape

Madagascar, 2011
141 × 130 cm
Warp: 96 threads Weft: 192 threads
Lining warp: 48 threads Lining weft: 96 threads
Weight: 1,888.8 grams

Exhibited
January 2012- June 2012:
The Victoria & Albert Museum, London
'Golden Spider Silk'
June 2018 – January 2019:
The Royal Ontario Museum, Toronto
'Spiders, Fear and Fascination'

This cape was our second major creation and used silk from 1,200,000 spiders. In addition to over two years of collecting, silking and weaving of the outer panels and the lining, about 6,000 hours of embroidery and appliqué was required to complete this work.

The waistcoat that Bon supposedly made for King Louis XIV (*see p. 75*) is almost certainly apocryphal, but he did make a pair of stockings for the wife of the Hapsburg Emperor Charles VI, one of the few articles of clothing ever made. We felt the idea of being clothed in spider silk was a potent conceit. The spider's method of entrapping and wrapping its prey in silk is a striking and unforgettable image which in turn imbues any clothing made from this silk with a powerful metaphor.

We wanted to make our own homage to the spider, our own prescriptive code for ritual dress, charged with the talismanic power of the robes of priests. Or to imagine something similar to the attire of the Empress of China as she officiated at the rituals of sericulture. Without forgetting a nod to every self-respecting superhero.

In the embroidered imagery we have hinted at the spider as creator. The hyacinth and floral motifs represent the idea of the enclosed garden as paradise, a garden of Eden. A world made by the spider out of itself. The cape is filled with echoes of myth, poetry and perhaps a distant frisson of nightmare. It is made with a number of different embroidery stitches and fine appliqué effects and with its ground fabric made using a similar technique to the brocaded lamba textile (*p. 37*). The thread used to weave is first composed of 24 single threads drawn from 24 individual spiders. These threads are joined and twisted together in the 'silking' part of the process. They are then removed on to cones before being doubled, and doubled again to make one ground warp thread comprised of 96 individual spider threads. We used this size for the principle weaves in both the cape and brocaded lamba textile, though the lining of the cape is made from a finer 48-strand thread.

The ground weft for both consists of two of the 96-strand threads, so 192 individual threads in total. We used 10 of these threads to make the floating brocaded weft patterns, so that each pass of the brocade shuttle contained 960 individual spider threads.

For the embroidery, the core parts of the raised motifs are made from 96-strand threads, whereas the lustrous covering thread is made from untwisted 24-strand thread with three or four threads in each pass of the needle.

Simon Peers

The Extraordinary History of Spider Silk

The Beginnings: Francois-Xavier Bon

Around 62AD the Roman philosopher Seneca wrote tauntingly, 'Do you not see how the spider weaves a web so subtle that man's hand cannot imitate it.'[5] However, the fact that our hands cannot weave with the skill of the spider has not stopped us from trying to use it through the centuries. People have sought to use not just the webs, but also the pockets and cocoons that different spiders produce. In the West, it has long been known that the web has haemostatic and antiseptic properties, and since ancient Greece it has been used as a wound dressing. In the South-West Pacific Ocean the silk has long been used for making fishing lines and nets.[6] In Vanuatu, the webs are collected on split bamboo frames, accumulating and forming a thick matted material almost like felt, which, when removed from the bamboo, resembles a tube that is then stitched to make bags and purses. In parts of New Guinea the same process produced a type of head covering. In Senegal the strong webs of orb-weaver spiders were sometimes used to make cords.[7] These practical, utilitarian uses are widespread and can be found in many cultures – but the somewhat haphazard borrowings from nature are distinct from the methodical harvesting of spider silk to make textiles.

The first mention of collecting spider silk for use in weaving appears in a work by Dr Epifanio Ferdinando, a professor of medicine and philosophy from Mesagne in the southern Italian province of Brindisi. In 1621 he published *Centum Historiae*, in which he examined different medical cases that he had encountered. One such story was about the bite of the tarantula producing the effect known as tarantism.[8] This was an hysterical condition that became the source of a striking and ancient custom in the region of Calabria, particularly Puglia and Salento, where music accompanied by a dramatic dance was used to drive out the venom from a spider bite. Knowledge of these spiders and this custom was no doubt the reason for Epifanio's interest in the silk the tarantulas produced to make their egg

Fig. 1

sacs, which he realized could be collected and spun into yarn. He describes how his friend and colleague Dr Girolamo Marciano managed to gather 450 grams (16 oz.) of this silk, but Epifanio does not elaborate on what happened to it, stating only that it was more of an ordeal than a profitable idea.[9]

How much credence we can give to this account is not clear, but it precedes the real innovator in this story of spider silk, a Frenchman born in Montpellier in 1678. Francois-Xavier Bon (*Fig. 1*), later the Marquis de Saint-Hilaire came from one of the most influential provincial families in the Languedoc region. A young man of considerable intelligence and ambition, he was one of the founding and honorary members of the Société Royale des Sciences in Montpellier. Established in 1706 as a provincial counter-part to the more powerful Académie Royale des Sciences in Paris, it had certain privileges that reflected the standing of Montpellier as a city of learning and science.

If necessity feeds invention, circumstance and serendipity are rarely far away. The winter of 1708-9 was one of the harshest on record for the whole of France.[10] In the south of the country its severity devastated great swaths of chestnut and olive trees, and it was decided to replace them with mulberry trees, ready for the introduction and propagation of the Chinese silkworm, the *Bombyx mori.* The beginnings of sericulture in the Cévennes region dates from this moment, but the decision also provoked an unusual response

Fig. 1 François-Xavier Bon de Saint-Hilaire (1678-1761)

from the young Francois-Xavier Bon, who attempted something quite different. His reaction may have been partly inspired by the Englishman Martin Lister, described as the first arachnologist and the author of the best-known study of spiders at the time, whom had studied in Montpellier some years before.[11] His work was certainly known to Bon.[12] If spider silk could replace that of the *Bombyx mori*, here was surely a field of study to embrace. Bon began to experiment to see if sufficient quantities of silk could be gathered from the cocoons or silk egg sacs of different native spiders.

Bon was a man driven to experiment, curious about everything. From the spring of 1709 he seems to have devoted all his energies outside his official role as a magistrate to collecting spiders and gathering their cocoons. These he beat, washed and carded with great care before spinning them into thread. These exploits had immediate appeal, for even before he had published his findings, sometime in November of 1709, it was reported that the Duke de Noailles had passed through Lyon with spider-silk stockings Bon had made. These were presented to the Duchess of Bourgogne, the fashionable wife of King Louis XIV's grandson.[13] They were probably made by transferring the spun thread to a stocking-frame, an early form of mechanical knitting that produced stockings; it seems Bon also made some knitted gloves.

On 5 December 1709 Bon presented his *Dissertation sur l' utilité de la soye des araignées* (Fig. 2) at a public meeting of the Société Royale des Sciences in Montpellier, though it was not published in Paris until July 1710. At the meeting, Bon presented both stockings and gloves made from spider silk. He also presented his 'Gouttes d'Araignées', a potion to compete with the popular 'English drops', a famous panacea that countered lethargy – among a host of other illnesses.[14] The ingredients of the drops had remained secret until Martin Lister divulged that raw silk was the principle component. Based on this knowledge, Bon proceeded to work with spider


DISSERTATION
SUR
L'ARAIGNE'E
CONTENANT LA VERTU
& les Proprietés de cet Insecte, avec la qualité &
l'Usage de la Soye qu'il produit & des Goutes
qu'on en tire pour la Guérison de l'Apoplexie, de
la Létargie & de toutes les Maladies Soporeuses,
composée par Monsieur BON, Associé Honoraire
de l'Academie Royale des Sciences à Montpellier,
& Premier Président en Survivance de la Cour des
Comptes, Aydes & Finances de Languedoc.
ON a ajoûté à la Fin de cette Dissertation une Lettre
sur le même Sujet, écrite à Monsieur BON, le
26. Janvier 1710. par le R. P. POUGET,
Prêtre de l'Oratoire, Docteur de Sorbonne &
Abbé Commandataire de Chambon.
A PARIS,
Chez JOSEPH SAUGRAIN, au milieu
du Quay de Gêvres, à la Croix Blanche.
M. DCCX.
Avec Approbation & Privilege du Roy.

Fig. 2

silk, which he found produced an even more potent concoction. His work earned him many admirers, including Louis XIV's physician Guy Crescent Fagon, who discussed Bon's work with the king.[15]

Bon's dissertation opens by stating that the obvious had been overlooked in the story of silk, in large part because of an innate prejudice against 'so common and despicable insect as the humble spider'.[16] Given the demand for the silk of the silkworm, this lack of interest in the spider seemed misplaced, for spiders not only wove webs, but also produced a sort of cocoon or egg sac in which the eggs of the young were protected. These, he noted, could be collected, cleaned, washed and carded before being spun. 'You will be surprised to hear', he wrote, 'that spiders make a silk as beautiful, strong and glossy, as common silk.'[17]

By applying simple logic to the challenge of amassing and transforming a sufficient quantity of cocoons, Bon was looking to establish a sericulture equivalent for spiders. His method was simple: 'I ordered to be brought to me all the large short-legged spiders that could be found in the months of August and September. These I shut up in papers, and put them in pots and covered the pots with the paper pricked full of holes with a pin, as were likewise the several papers that were in it, that the spiders might have air. I fed them with flies, and sometime after found that the greatest part of them had made their bags.'[18] Bon contended that spiders' cocoons, or bags,

Fig. 2 François-Xavier Bon de Saint-Hilaire, *Dissertation sur l'utilité de la soye des araignées*, Paris 1710. Simon Peers Collection

yielded much more silk in proportion to their weight than those of the silkworm of the *Bombyx mori*; they could also take any dyes. His work was sent to the Académie Royale in Paris, where the assembled members looked closely at the wonderful novelty of spider-silk stockings and gloves, and on 15 January 1710 his dissertation was read and his findings discussed:368 grams (13oz.) yield near 113 grams (4oz.) of clean silk, 85 grams (3oz.) of which will make a pair of stockings for the largest sized man.

For those presented to the Académie Royale he wrote, 'these here [the stockings] weigh only 63 grams (2 ¼ oz.), and the gloves about 21 grams (¾ oz.), whereas stockings of common silk weigh around 226 grams (7 or 8 oz.).'[19]

There was some criticism expressed by one member of the Académie, Philippe La Hire, who noted that the stockings lacked the lustre present in the silk of the *Bombyx mori.* In a sense the criticism was justified, because the cocoons had been beaten, washed and boiled before being carded and spun, rather than being drawn as a continuous thread from the cocoon (just as the silk of Cos was inferior to that of Serica). Bon never achieved this single lustrous thread because of the glue that holds the spider cocoon to its support, but his trials did prompt an immediate reaction from the Académie Royale in Paris.

In 1708 the 24-year-old René-Antoine Ferchault de Réaumur (*Fig. 3*) had been appointed as a student of geometry to work with a member of the Académie. After Bon's work was presented – in January 1710 – Réaumur was directed to look into this interesting discovery. His goal was not to see if it could really be done, as Bon had proved that, but to see if it might be developed into a profitable industry. He needed to find out whether spiders could be raised and reared on a grand scale, and, if this could be achieved, he would need to discover if spider silk could be made less expensively than that of the silkworm – and if not to see if this inconvenience could be compensated by some other advantage.[20] This was new ground and nothing had been written on the matter before.

Fig. 3

Réaumur worked during the summer, and on 12 November 1710 he presented his findings, entitled *Examen de la soye des Aaraignées*, in Paris to the Académie Royale des Sciences. He found that it required twelve spiders to produce the same quantity of silk as a single cocoon of the *Bombyx mori.* He also calculated that 27,648 female spiders would be needed to make 448 grams (1lb) of silk. But he noted that as the cocoons are the work of the females, who spin them as a deposit for their eggs, it follows that 55,296 spiders must be needed to yield that quantity of silk. Réaumur went on to distinguish between the different yields of larger and smaller spiders, eventually arriving at the daunting figure of 663, 552 spiders required to furnish his single pound of silk.

Apart from the challenge of collecting the necessary number of spiders, Réaumur had to devise a way to feed them. 'All the flies of the kingdom,' he said, 'would not be sufficient to adequately nourish the spiders, and that, to make an inconsiderable quantity of silk.'[21] To meet this challenge, he decided to experiment with other less orthodox sources of nourishment such as worms and meat, but to no great effect. He had a little more success using the tender, blood- filled feathers of young birds.

He wrote that he had distributed:

Fig. 3 René Antoine Ferchault de Réaumur (1683-1757)
© The Trustees of the British Museum,
by **Johann Martin Bernigeroth** (1713-1767)

in different boxes about four or five thousand spiders which had just left their cocoons: I put two or three hundred, or fifty, or even fewer into others … But their fierce nature broke out at last..the largest and the strongest ate up the smallest and the weakest. Every time I looked upon them, I saw a small one become the prey of a larger one; and sometime after, I had hardly above one or two left in each box … it seems therefore that the only way of breeding spiders, is to lodge them by themselves. One might have several boxes divided into many little cases; and I have done it .. but the charges of feeding each spider separately would not be proportioned to the profit that might arise from it.[22]

And continued:

it appears that this silk would occasion such expenses as would not answer its value; since it would be twenty-four times as dear as that of silkworms … The public will doubtless be concerned for the little success that can be expected from such ingenious discovery; but perhaps there are still some hopes. There may be larger spiders than those that are commonly seen in this country. It appears from the relations of all travellers, that those of America are of a much larger size than ours, and consequently more likely to afford a greater quantity of silk. Our silkworms, though originally come from remote countries, are so prodigiously increased in Europe, that we may reasonably hope the spiders of America might live in this kingdom. However, we must make experiments: T'is the only way of founding out useful things.[23]

From his work that summer Réaumur managed to produce some silk yarn that was woven and transformed into gloves, and subsequently sent to Paris to the Abbé Jean-Paul Bignon, President of the Académie Royale des Sciences.

The rising star of the Paris Académie Royale praised Bon's unusual achievements, but he announced that he was unable to see a profitable

future for the undertaking. Bon's riposte to Réaumur's disappointing findings was not long in coming, however – he circulated a discrete reply, where he held to his belief that there really was a future for spider silk.[24] He was, apparently, bolstered in his view by the enthusiasm and curiosity of all who heard of his work. The Venetian ambassador in Paris, the Marchese Alvise Mocenigo, excited by the discovery, reported that he wanted to make it known to the Venetian republic,[25] and with great speed an Italian edition of Bon's dissertation was published in Siena before the end of 1710.[26]

Bon also received an urgent request for spider-silk gloves to be sent to Elisabeth Christine of Brunswick-Wolfenbüttel, Empress of Germany and Austria, wife of the Holy Roman Emperor Charles VI, and grandmother of Marie Antoinette. In less than 15 days the gloves were completed and sent; the Emperor sent him a gold medal for his troubles.

Early in the spring of 1710, as Réaumur worked on his response, Bon's dissertation was published in the well-known *Journal de Trevoux.* In London, The Royal Society received Bon's paper, and published it in the *Philosophical Transactions* as *Monsieur Bon's Discourse upon the usefulness of the silk of spiders.*[27]

The timing of Bon's dissertation in London was fortuitous for the satirical writer Jonathan Swift, who visited the Royal Society in 1710 and must have taken great pleasure from Bon's exploits. Much later in 1726, basing his description of experiments on those he had read of in the *Philosophical Transactions*, Swift has his hero Gulliver make a visit to the Grand Academy of Lagado, a parody of the Royal Society. Gulliver describes the work being pursued by different 'projectors', which, for all their serious content, border not just on the far-fetched but on the vaguely ludicrous. Here the 'projector' that Gulliver meets is a parody of Bon.

> *I went in to another room, where the walls and ceiling were all hung round with cobwebs, except a narrow passage for the artist to go in and out. At my entrance, he called aloud to me 'not to disturb his webs'. He lamented 'the fatal mistake the world has been so long in, of using silkworms, while we had such plenty of domestic insects, who infinitely excelled the former, because they understood how to weave as well as spin' and he proposed farther, 'That, by employing spiders, the charge of dying silks should be wholly saved;' whereof I was fully convinced when he showed me a vast number of flies most beautifully coloured, wherewith he fed his spiders, assuring us, 'That the webs would take a tincture from them; and as he had them of all hues, he hoped to fit every body's fancy, as soon as he could provide proper food for the flies, of certain gums, oils and other glutinous matter, to give a strength and consistence to the threads.*[28]

Few reading Gulliver's travels might believe that the Grand Academy of Lagado was based on anything but the comic imagination of the writer. The idea that these experiments, except perhaps the coloured flies, were based on real work described by the Royal Society, would stretch the imagination of the most credulous. Voltaire took a view similar to that of Swift. He knew of both Bon and Réaumur's work, but in 1747 implied in his novel *Zadig*, that such an enterprise was akin to such pointless follies as trying to make porcelain from broken bottles, an impossible alchemy doomed to failure.[29]

Back in 1711, however, news of Bon's achievements had spread. In Leipzig a pamphlet was published entitled *Curious information of a new type of silk produced by spiders from which the foolish King Louis XIV wore a waistcoat strewn with other curiosities to amaze the ordinary people*.[30] This is the earliest mention of Bon's supposed creation of a suit of clothes or a waistcoat for the Sun King himself, a story that continued to circulate.[31] It is possible – but unlikely – that Bon accomplished the feat.

Outside Europe, in 1723 Father Dominique Parrenin, a French Jesuit priest working in China, wrote from Peking to the Académie Royal des Sciences in Paris recounting some memories of his work with the recently deceased Emperor Kangxi (1662-1722).[32] One day the Emperor had started

to speak of spider webs, and Parrenin recalled that he had read about the work of Bon and later of Réaumur in the *Journal de Trevoux.* The Emperor asked Parrenin to translate this for him, which interrupted his study of anatomy, but also captured the Emperor's imagination. He passed the translation to three of his sons, and asked them to make remarks about what they had read; the eldest prince said that he had never seen anything like it – research that was so exacting and laborious about a subject that seemed to merit so little. The story left a lasting impression on the Emperor.

Although Bon's work found an audience of sorts, he never found an industrial substitute for the silkworm. A second edition of his work appeared in 1726, and in 1748 at the age of 70 he published revised versions in Latin and French.[33] He was made a member of the Académie Royale des Sciences, and was generally held in great esteem for his many and varied exploits. In 1747 the French philosopher Montesquieu wrote that one of the first publications he saw as a boy was Bon's dissertation on the spider, adding that he thought that Bon 'was one of the most learned personages in France.'[34]

Raimondo Maria de Termeyer: after Bon

Despite Swift's mockery and Réaumur's disenchantment, attempts to create spider silk did not end. In 1761, the year Bon died, a young Spanish Jesuit priest named Raimondo Maria de Termeyer, born of a Dutch merchant father and an Italian mother in Cádiz in 1738, was experimenting. He had been drawn to spider silk without knowledge of either Bon or Réaumur's work.

He began studying sericulture and the *Bombyx mori* silkworm in 1759 – a few years after he entered the Jesuit order. In 1760, curious to apply some of his new-found knowledge of extracting silk from *Bombyx mori*, he experimented with gathering spider cocoons. The following year, taking this a step further, he tried to raise spider cocoons in specially constructed cases 200 × 30 cm (roughly 84 × 12 in), holding 68 cells around 20 cm (8 in) high (*Fig. 10*). With these he had some success, raising cocoons in considerable quantity: from 2,146 spiders he succeeded in gathering 1,714 cocoons. In 1762 he continued these experiments but, in November, he was ordered to travel to join the Jesuit mission in South America. He left with a sealed phial containing *Bombyx* silkworm eggs in his baggage, but it is clear he had not given up on spider silk.

In 1763 Termeyer arrived in the city of Córdoba del Tucumán in the Viceroyalty of the Rio de la Plata, and he is now recognized as the initiator of the sericulture industry in the wider Rio de la Plata region.[35] He discovered the work of Réaumur and Bon in 1764, and became convinced that Réaumur was incorrect, and that there was a real future for spider silk. Réaumur had predicted in his *Examen de la soye des Araignées* that the Americas might have spiders better suited to the task than those of Europe, and perhaps Termeyer had not been disappointed - spiders with large cocoons and huge webs were abundant. He began experimenting again in 1766 and 1767, but this ended abruptly when orders came for the return of all Jesuits to Europe. In 1768 Termeyer found himself back in Cádiz, before moving first to Genoa and on to Faenza in the Papal States. There, between 1775 and 1777 he was again experimenting; in an attempt to change attitudes to the spider he even released thousands among the arcades of the town, but apparently without changing the prejudices of the locals. He published two articles on spider silk in Italian periodicals in 1777 and 1778.[36]

In 1788 Termeyer asked for help from an Italian cousin, Lucrezia Rasponi, to make a pair of stockings from the silk of the *Epeira diadema* spider for King Charles III of Spain. [37] When the stockings, which weighed 70 grams (2½ oz.), became known Termeyer received requests for similar work from Catherine the Great, Empress of Russia, and the Archduchess Maria Elisabeth of Austria – but they were graciously declined as the stockings had been made specifically for the Spanish king. Termeyer,

however, never discovered if King Charles received his gift, as the aging monarch died later that year.

Termeyer later moved to Milan, where he made his most important advance on Bon and Réaumur's efforts. He seems to have been looking to answer the criticism levelled by Phillipe de la Hire and Réaumur – that spider silk lacked lustre and brilliance. This had nothing to do with the silk itself, but resulted from the way it was carded and spun, instead of being drawn out as a single lustrous thread, like the silk of the *Bombyx mori*.

He had already patiently tried to unravel and extract a thread from spider cocoons, but could never get more than 30 cm (12 in) before it broke where the glue held the cocoon to its support. In around 1796, before the arrival of Napoleon's army in Milan, Termeyer resolved to extract the silk directly from the spider rather than from the cocoon. He constructed a small stock from cork and metal, where the spider was fixed with its legs to the front, while a winding machine drew out the silk directly from the spider's spinnerets (*Fig. 4*):

> *I present a fly to him; he takes it quickly with the palpi and turns it over as if he would envelop it. I raise the abdomen, and at the first touch he opens the spinner and permits an abundance of silk to pass out. I then attach the end of the silk to a little reel 11.5 cm (4½ in) in diameter, with a cylindrical arm of glass which I slowly turn and wind the silk of the spider like that of the cocoon… I have wound upon the same small reel a band of spider's silk, and a similar band of the silk of the silkworm. The comparison shows evidently how much more brilliant and beautiful the first is than the second; so bright that it appears more like a polished metal or mirror than like silk.*[38]

Termeyer envisaged this method being adapted to a multiple system of stocks, where several spiders could be attached and silk reeled from them at the same time: 'I am also of the opinion that with a simple contrivance

Fig. 4 The Alpaida latro spider held in place for silk extraction, Raimondo Maria de Termeyer, *Opuscoli Scientifici d'Entomologia di fiscia e d'Agricoltura dell'Abate*, Milan 1807, vol.1, plate VI. Simon Peers collection

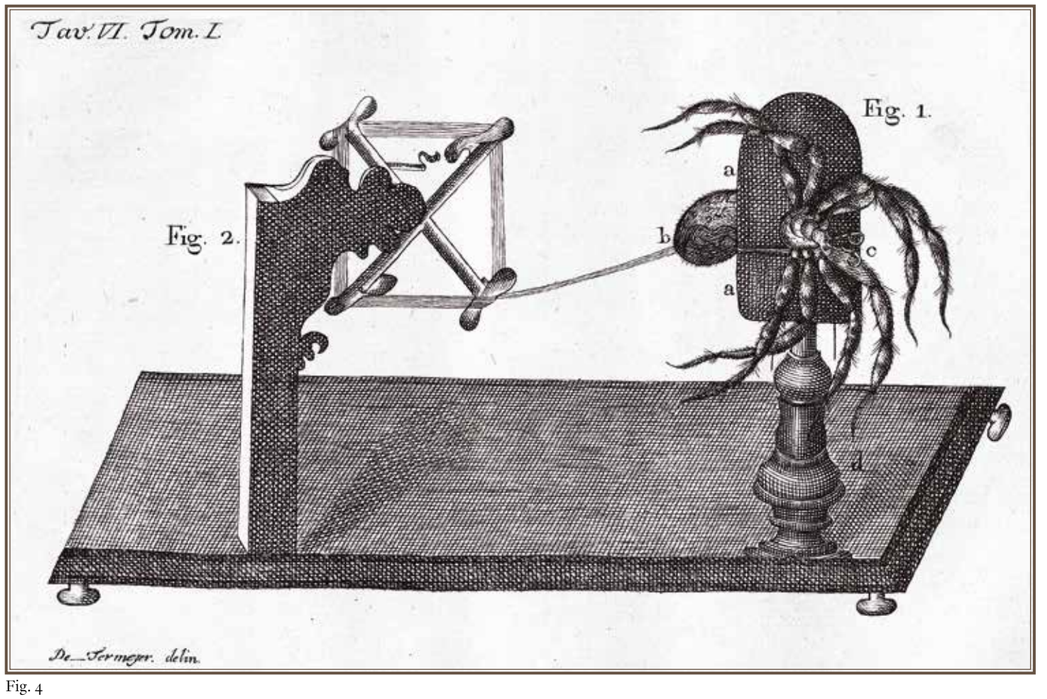


Fig. 4

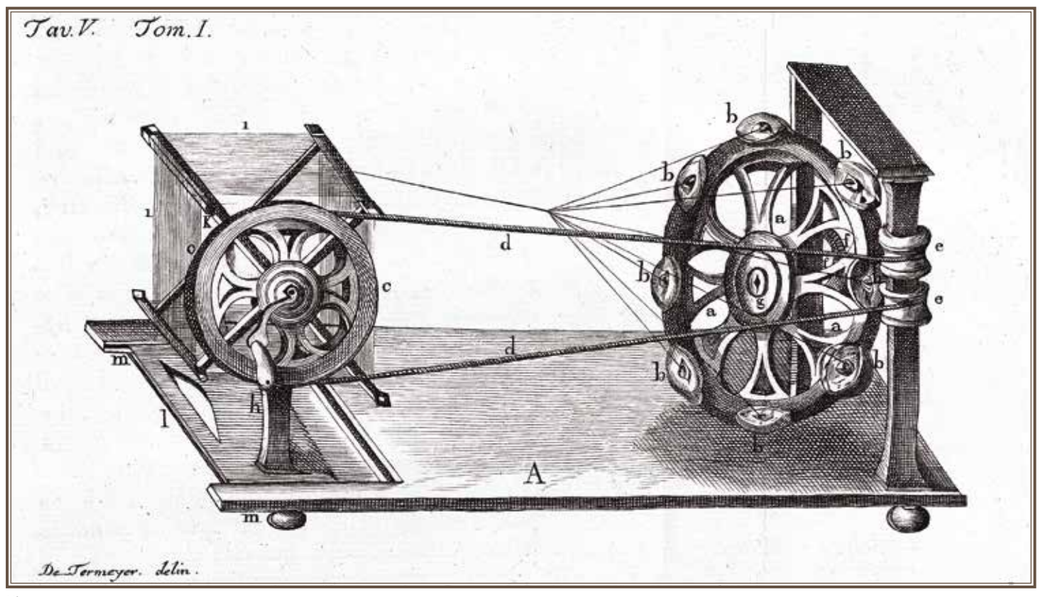


Fig. 5

Fig. 5 Machine for reeling and twisting 8-strand spider-silk thread. Raimondo Maria de Termeyer, *Opuscoli Scientifici*, Milan 1807, plate V

having a few of the arrangements described for holding the spider, it would be possible to draw the silk from all the spiders at once, and to do it so that the threads uniting would twist to form a single thread'[39] (*Fig. 5*).

He never realized this idea (which was not adopted until the end of the nineteenth century in Madagascar). But while in Milan he shared much of his extensive knowledge of spider silk with a talented student, Carlo Sommaschi. To Termeyer's chagrin Sommaschi managed to collect enough spider silk to produce a large tulle shawl for the Empress Josephine, first wife of Napoleon Bonaparte, that in 1806 was exhibited at the Pinacoteca di Brera, Milan, and for which Sommaschi seems to have received all the credit. Sommaschi was also working on stockings for Napoleon himself.

Termeyer published the first of five large volumes on different research he had undertaken, covering everything from the language of the Guarani Indians in Paraguay, to the study of electric eels. The first volume, published in Milan in 1807 (*Figs. 4–10*), was on his extensive work on spiders,[40] in which he opposed Réaumur, making a case for a profitable spider-silk industry.

As to how much silk he was able to collect himself, he says that he made several purses for friends, as well as the stockings for King Charles III of Spain. Otherwise, he managed to amass 624 grams (22 oz.) of silk taken from cocoons of the *Epeira diadema* spider, but that it was all lost or stolen in 1796 when he was caught up in the French siege of the fort in Milan, and with his hurried departure he lost his entire stock of precious silk. There seems to be no record of the amount of silk collected subsequently by Termeyer's student, Carlo Sommaschi, but the younger man's success was achieved without due acknowledgement to Termeyer, leaving him bitter and disappointed.

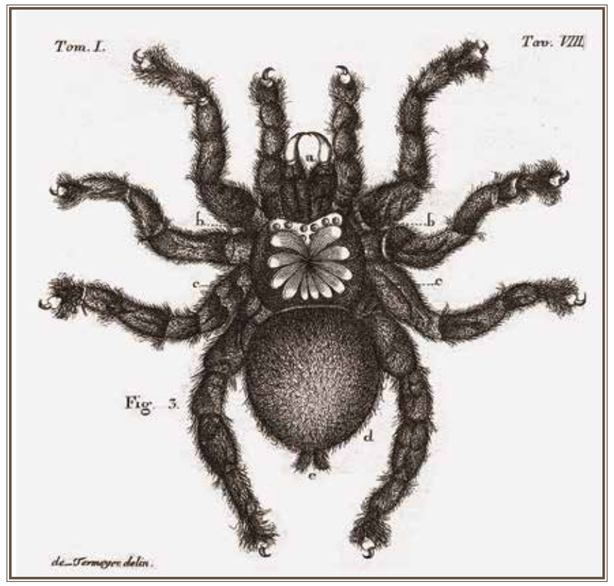


Fig. 6

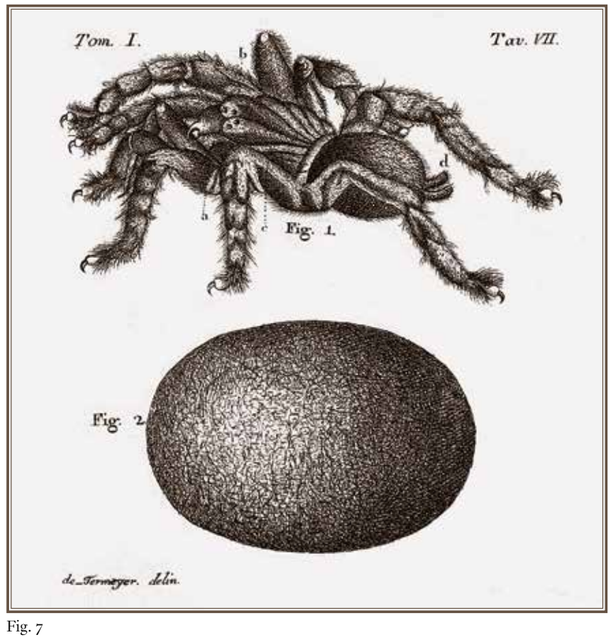


Fig. 7

Fig. 6, 7 Avicularia avicularia and its silk egg sac, Raimondo de Termeyer, *Opuscoli Scientifici*, Milan 1807, Plates VII & VIII

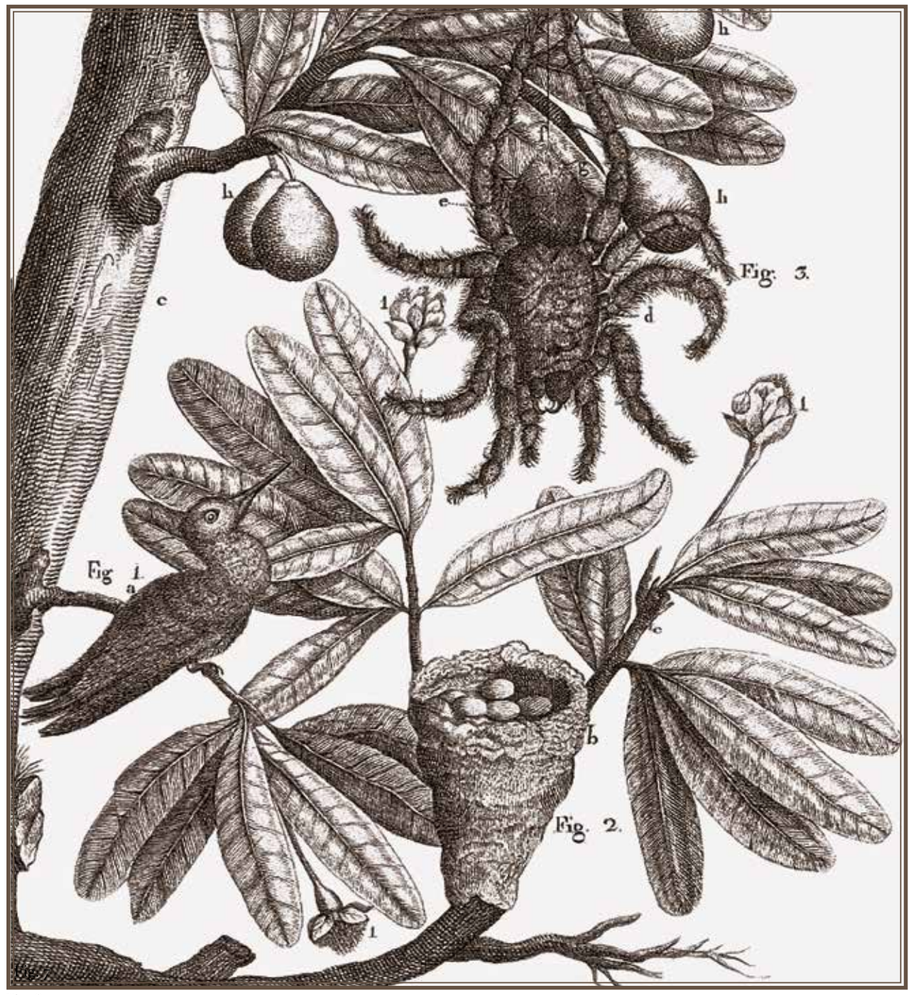


Fig. 8

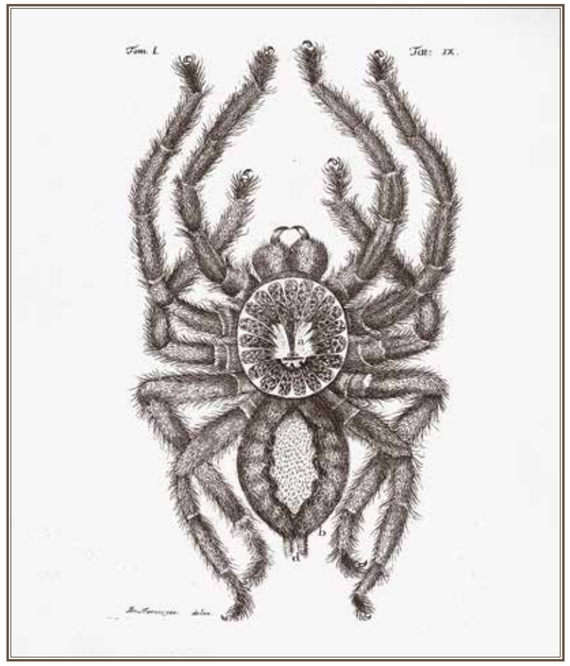


Fig. 9

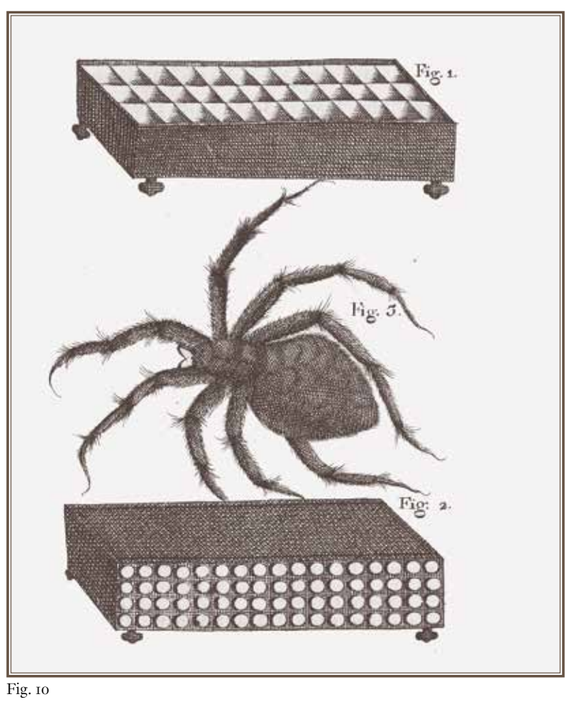


Fig. 10

Fig. 8 Avicularia avicularia, Raimondo Maria de Termeyer, *Opuscoli Scientifici*, Milan 1807, plate XI
Fig. 9 Avicularia avicularia, the pink toe tarantula, sometimes known as the bird-eating spider. Raimondo Maria de Termeyer, *Opuscoli Scientifici*, Milan 1807, plate IX
Fig. 10 Box with compartments to hold the silk egg sacs of the Alpaida latro. Raimondo Maria de Termeyer, *Opuscoli Scientifici*, Milan 1807, plate I

The Americas and other sources: into the 19th century

In 1781 the Spanish military engineer, naturalist, and traveller Don Félix de Azara went to Paraguay, where he remained for two decades. His renowned *Voyage dans l'Amerique méridionale depuis 1781 jusqu'en 1801* was published in 1809. He mentioned the large spider cocoons that were collected and spun by the inhabitants on account of the permanency of the yellow colour, but we do not know much more about this local practice. It was perhaps these same spiders that supplied the material for the clothing of the French naturalist, Alcide d'Orbigny, who while travelling in South America during the 1820s, appears to have had made a pair of trousers woven from spider silk that lasted many years.[41] Who made these trousers and how they were made remains a mystery, for Termeyer's work is proof of the effort required to produce any considerable quantity of silk.

The nineteenth century saw a flurry of interest in spider silk. In 1830 an Englishman by the name of Daniel Rolt managed a small operation using a steam engine. He reeled 5,480 metres (6,000 yards) of silk direct from two dozen *Epeira diademes* spiders in two hours. Although the results appear to be at least somewhat exaggerated he was awarded a silver medal by the Society of Arts in London for the contraption he invented.

There are other references. In 1842 a Mr Mallat presented the Museum National d'Histoire Naturelle in Paris some reeled silk of the orb-weaver *Nephila maculata* from Java. In 1867 Mr Bancal, a French colonial administrator in Saint-Louis in Senegal, was experimenting with samples of the local orb-weaver spider silk.[42] Also in the 1860s the French explorer Francis Garnier wrote of a dyed black cloth he saw in Southern Yunnan province known as *Tong hay touan tse*, or 'satin of the Eastern sea' that he suspected was produced from the silk of a type of spider that he had seen in Talan.[43] But this is unsubstantiated.

In the United States, a young Civil War surgeon, Lieutenant-Doctor Burt Green Wilder (*Fig. 11*), born in 1841, described the moment on 19 August 1863 in the Camp of the Fifty-fifth regiment of Massachusetts

Fig. 11

volunteers, 'on a desolate island a little south from the harbour of Charles ton, South Carolina … I found in a tree a very large and handsome spider, whose web was at least 91 cm (36 in) in diameter.'

Wilder caught the spider and took it to his tent. There he took hold of the thread as it lowered itself down from his sleeve: 'I caught the thread and pulled. The spider was not moved, but the line readily drew out, and, being wound upon my hands, seemed so strong that I attached the end to a little quill, and having placed the spider upon the side of the tent, lay down on my couch and turned the quill between my fingers at such a rate that in one minute 183 cm (72 in) of silk were wound upon it, at the end of an hour and a half … I had 137 m (150 yards) of the most brilliant and beautiful golden silk I had ever seen.'[44]

At this point Wilder assumed that he was the first to have ever achieved the feat. He was sure something would come of his efforts, and he continued to experiment with the help of another officer.

Wilder's experiments did not, however, add up to much in terms of quantity of thread. He stated that he had 'reeled silk from several of these spiders, and made a thread which has been woven in a power-loom as a woof, or filling, upon a warp of common black silk so as to make a bit of ribbon 5 cm (2 in) wide, thereby proving that it is real silk and can be treated as such.'

Fig. 11 Burt Green Wilder (1841-1925)

It was only after much experimenting that Wilder discovered the writings of Bon, and then of Termeyer, some of whose work he later had translated and reprinted after becoming professor of neurology and vertebrate zoology at Cornell University in 1867.

There are other rumours and hearsay concerning spider silk in the years after Wilder's work. It was said that Queen Victoria was presented with a spider-silk shawl by members of the first Chinese embassy sent to England in 1876. But this may be confused with another story, that a dress made of spider webs was presented to Queen Victoria in February 1877 by the Empress of Brazil.[45] A Mr Stillbers was reported to have created a large industry from spider silk somewhere in England to be used for medical applications.[46]

In 1833 the renowned traveller and writer Richard Burton published *To the Gold Coast for Gold*, in which he makes light of such an undertaking – but there is such an air of exaggeration in his account that it is hard to believe a word of it: 'I had sent from Fernando Po several pounds of this fine silk intending to experiment upon it in a veil or lace shawl; and afterwards I learned that the empress Eugénie had a dress made of it, which cost a fabulous amount of francs. Bacon and other old writers talk of 'spider's silk' like gathering moonbeams.'[47]

Madagascar and the Exposition Universelle

It is common in Madagascar to see large golden silk orb-weaver spiders, the *Nephila madagascariensis*, suspended in their webs in trees, or between telephone wires and electricity cables. The spider is large and she sits in the middle of her web, head down, with a black abdomen speckled with grey and a central yellow mark, pointing up. Her thin articulated legs are a dark russet. The web is built on a vertical plane, and sways gently in the breeze – billowing occasionally and catching the sun, which reflects for a moment a brilliant golden sheen.

The *Nephila madagascariensis*, the golden orb-weaver spider of Madagascar, is of the family *Nephilidae* and genus *Nephila*. The *Nephilidae* family can be found throughout the Tropics from the USA to Australia, and the female creates one of the most impressive and largest spiral orb webs in nature. The bigger female sits comfortably in the palm of the hand, with its legs extending from the thumb to little finger. Its web is perhaps 100 cm (36 in) in diameter, with the more prominent threads anchoring it to surrounding branches and leaves. These threads, known as drag-line silk threads, are more obviously gold in colour than the elements that make the central catchment area of the web. The orb web is the most perfectly symmetrical and concentric of all spider webs.

For the Malagasy today the spider is simply called *Halabe*, or great spider, though it has also been known as *Folihala*, or spinning spider. In the highlands, where the people used to build fortified villages with a large ditch around the perimeter, it was known as *Mampitahady*, or ditch crosser, because of the spider's ability to throw its web across the wide channels that circle these ancient villages.

In 1863, around the time of Wilder's experiments in America, Dr Auguste Vinson from Madagascar's tiny neighbouring island of La Réunion published his *Aranéides des Iles de la Réunion, Maurice et Madagascar*. Vinson had been asked to accompany the French delegation sent to the coronation of the Malagasy King Radama II, but his attention seems to have been focused on other – smaller – things. He was intent on discovering and studying the spiders of Madagascar. Vinson gave *Nephila madagascariensis* its name, and he made much of the web that the spider could produce, suggesting that there was a potential for commercial exploitation. He also mentioned that Creole artisans in La Réunion had succeeded in using the silk of another golden *Nephila*, the *Nephila inaurata*, which lives in the dramatic landscape of that island, and had produced a pair of gloves that were presented to the Empress Eugénie.[48] The fate of these gloves, like so much else in this ephemeral world of spider silk, is

Fig. 12

unknown, but Vinson's writings laid foundations on which others in Madagascar could build.

In the 1880s a French Jesuit missionary, Father Paul Camboué (*Fig. 12*), took an interest in Vinson's *Nephila madagascariensis* and, intrigued by the strength and beauty of its orb-spun web, began to consider the possibilities of harnessing the silk. He first tried to card the cocoons of the *Nephila madagascariensis* and spin the resulting thread, but did not have satisfactory results, reporting that it required 50 cocoons to produce a skein of silk weighing 1 gram (½ oz.). Just as Termeyer attempted to extract the silk directly from the spider's spinnerets, Camboué also quickly saw the advantages of the method. He begun by putting the spiders in matchboxes with their abdomens protruding, which achieved the desired result – and he managed to collect from 80 to 700 metres (87-767 yards) of silk from individual spiders.[49]

In 1892 Camboué was in touch with the silk industry in Lyon, particularly the 'Laboratoire d'etude de la Soie'.[50] There they compared the silk of the *Bombyx* silkworm with that of the *Nephila* spider of Madagascar.[51] Camboué slowly acquired a small quantity of silk. 'It is not yet perfection,'

Fig. 12 Father Paul Camboué (1849-1929)

Fig. 13

he wrote, 'nor is it something even approaching it. I leave to others, more skilful and better equipped than a poor missionary in the central highlands of the great African Island, the task to perfect what he has only sketched out.'[52]

In the 1880s Madagascar had become a reluctant French protectorate, and by 1895 the island was conquered entirely; the ensuing French colonial rule lasted for 60 years. One of the first institutions founded by the colonial government was the Ecole Prefessionnelle of Tananarive (the capital of Madagascar, better known as Antananarivo), which was run by Antoine Jully. Knowing of Father Camboué's work with spiders, he decided to turn these experiments into a more formal and organized attempt at producing the silk on a large scale (*Fig. 13*).

The Deputy Director of the Ecole Professionnelle, a man called Mr Nogué, became the driving force of this new attempt. He designed a machine that could hold eight spiders in a guillotine-type trap that was similar, in many ways, to that devised by Termeyer. The threads were then pulled from the spiders on to a bobbin that was then removed. The thread was subsequently

Fig. 13 Students with spiders in the grounds of the Ecole Professionelle in Antananarivo. J.Maroix, ***La soie d'Araignée de Madagascar***, ***Notes, Reconnaissances et Explorations,*** 30 September 1899

twisted and doubled on an ordinary throwing machine. In 1898, Nogué improved this first machine to use twelve spiders. The second machine both pulled and twisted the threads at the same time. This thread was later doubled to produce a thread of 24 strands.

This operation needed a regular supply of spiders, and people would come two or three times a week to deliver them, being paid 40 centimes for 100 spiders. In June 1898 11,708 were collected, in July, 8,650, in August, 9,420.

Alongside Nogué, a Mr Vacher supervised three or four workers. Between 17 November 1898 and 30 April 1899 two of Nogué's machines were made and taken to areas where spiders could easily be found (rather than await deliveries to the school). From June 1898 to June 1899 some 175,000 metres (191,382 yards) of 12-strand thread was produced.

They worked with a specific purpose in mind. In 1900 the *Exposition Universelle* was to be held in Paris, and different colonies vied with each other to produce the most unusual, novel and potentially profitable exhibits. The colonial government of Madagascar chose, among other things, to represent themselves with an extraordinary bed made by local artisans, which was to be adorned with magnificent hangings made from golden spider silk (*Fig. 14*). By the end of 1899 there were three of Nogué's machines working to produce silk for these bed hangings.

The finished bed with its spider-silk hangings did catch the attention of the press, and in an article in *Les Annales politiques et litteraires* for June 1900 the silk was described in excited terms:

> *The cloth of spider silk recalls the robes of Sleeping Beauty. It has a wonderful brilliance and its iridescence sends the rays of the rainbow to astonished eyes. The silk of the spider is a superb golden yellow with reflections that are varied and dazzling.*[53]

In *Le Matin* on 14 December 1900:

> *Few people have noticed at the Madagascar panorama, a dais, or rather a 'ciel de lit', of a lightness and paradoxical subtlety, that one might believe was woven from the 'fils de la vierge' [gossamer threads blown in the wind]. This piece of nebulous cloth, almost unreal, has however been one of the most extraordinary curiosities, the most unexpected? It was silk, but a silk both original and strange, the silk of the spider.*[54]

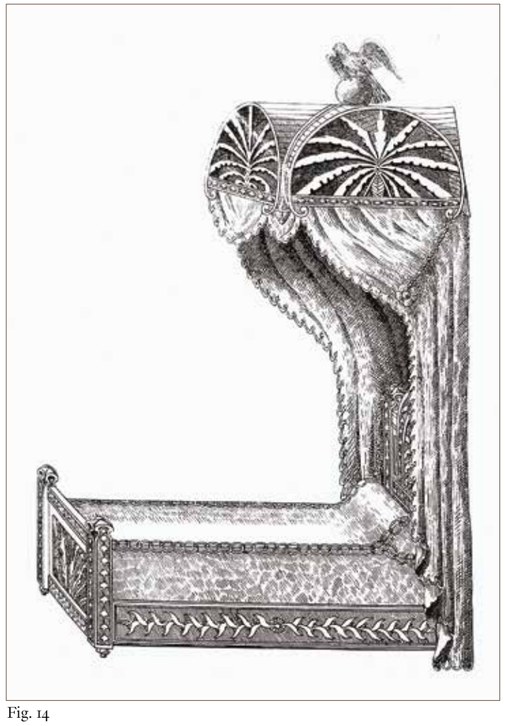


Fig. 14

There is some confusion concerning this bed and its precious hangings. There are various anomalies and inconsistencies in the statistics that have been given for the first cloth that was verifiably woven from spider silk. Certainly the weaving appears to have been a very fine sheer, perhaps in a plain taffeta weave, as mentioned in the *Le Matin* review. How fine the weave might have been, however, is a matter for conjecture – as the bed and its hanging have long disappeared.

The golden yellow woven hanging was a 10 × 0.5 m weave (around 11 × ½ yards). Estimates suggested that 90-100,000 metres of 24- strand silk was needed to make the cloth, which could be supplied by 25,000 spiders. A later report detailed this work as comprising 7.3 m (8 yards) of silk 45 cm (18 in) wide, containing 91,400 metres (100,000 yards) of spun thread of 24 strands, again the product of 25,000 spiders.[55]

Fig. 14 Ciel de lit, or bed canopy, made from silk of the Nephila madagascariensis, exhibited at the Exposition Universelle, Paris 1900

Based on our experience working on the textiles shown here, weaving with 24-strand thread does indeed give a very fine, light cloth, but with a weight that does not correspond to the figures given for the bed hangings in either the prediction or the detailed report.

Also, to claim to have woven anything the size of the hanging with the silk of just 25,000 spiders suggests an error. We have found that it takes 600-1,100 spiders to produce 1 gram of silk, meaning that 25,000 spiders would produce around 22-44 grams. Termeyer's stockings for King Charles III of Spain weighed 70 grams. For a cloth 10 × 0.5 m to weigh just 22 grams (or even 41 grams) is inconceivable, even if it was made as netting. A cloth of 5 m^2 weighing 22 grams is about 4.4 grams per square metre – very nearly as light as the Emperor' new clothes. It would pose fantastical problems even for a fairy weaver. The large brocade textile weighs 1280 grams (or approx. 350 grams per m^2) and required approximately 300,000 spiders for each square metre of cloth.

Nogué mentions a total of 150,000 metres of 12-strand thread produced in a year at the Ecole Professionnelle. He also estimated that between 90-100,000 metres of 24-strand thread were required for these bed hangings (so approximately 200,000 metres of 12- strand thread). As noted, the school seems to have collected about 10,000 spiders per month, and from them seems to have been able to produce 50,000 metres of 12-strand thread monthly, which would mean an average of 60 metres (65 yards) of thread per spider. This is certainly feasible as far as the spiders are concerned, but would not produce enough thread to weave a fabric of the size required for the bed – there is a mystery as to quite what these hangings were and how they were made.

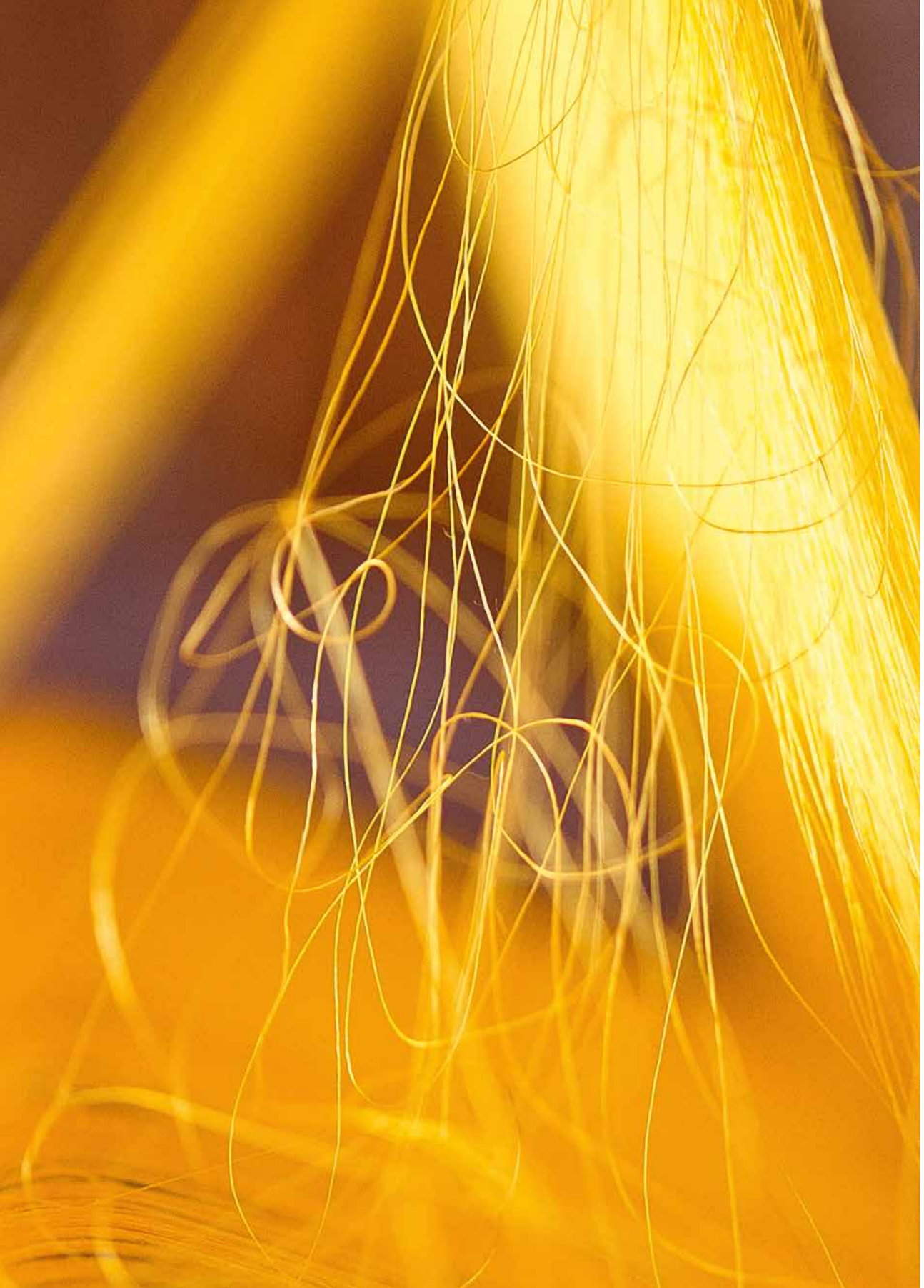
The *Exposition Universelle* closed in December 1900. The bed and its hangings were soon forgotten, and subsequently lost from view. In the *Almanach* Hachette published in 1902, the writer mentions the *ciel de lit* exhibited in 1900, but bemoans the enormous price to pay for such a

fantasy.[56] The spider-silk industry was doomed as an impossible extravagance and, strangely, almost no spider silk now remains in any collection in France. There is a small sample in the Muséum de l'Homme in Paris,[57] and another more substantial woven band in the Muséum d'Histoire naturelle in Lyon.[58] Attempts to raise the *Nephila madagascariensis* in France were tried and abandoned, and little by little the Ecole Professionnelle in Antananarivo moved on to other challenges.

It signalled the final attempt recorded to work with spider silk until Nicholas Godley and I started our research in 2003.

Simon Peers

Detail of spider-silk passementerie,
a trial for the cape fastening (p.53)



Commentary

Spiders – of Myth & Metaphor

The Greek philosopher Democritus suggested that humans learned to weave by watching spiders.[59] Such conjecture is reasonable enough and, although there is no interlacing of warp and weft in a spider web, there is a beauty and geometry that intrigues and pleases in the placement of the threads. A perfect spider web is one of nature's wonders, a work for contemplation and reflection.

Watching the spider create a web to trap and snare its prey has also influenced the development of hunter's nets. In the sixth century the Chinese Buddhist Chih-i wrote a system of sign interpretation signalling that the invention of the fishing net was due to our understanding of the spider web, as the sign for catching things.[60]

The importance of the spider web as a source of inspiration for weaving and hunting (for our clothing and food), seems also to have inspired creation myths, linking the spider's ability to create a web out of itself to the origin of everything. Such ideas can be found in pre-Columbian Peru, ancient Hawaii, among the Hopi, Navajo and Pueblo Indians of America, among the Akan of Ghana in West Africa, and written in the Upanishads of Hindu teaching in India.[61]

The spider has inspired poets as well as philosophers. The image of a sentient spider patiently sitting at the centre of her web waiting, feeling and hunting is powerful. Alexander Pope captured the beauty of this heightened consciousness with:

The spider's touch, how exquisitely fine
Feels at each thread, and lives along the line[62]

The spider and its web is a perfect metaphor of the soul, inspiring writers of the Upanishads as well as poets such as Walt Whitman[63], and John Keats who expanded on the idea in a letter to a friend:

Now it appears to me that almost any Man may like the Spider spin from his own inwards his own airy Citadel – the points of leaves and twigs on which the Spider begins her work are few and she fills the Air with a beautiful circuiting: man should be content with as few points to tip with the Webb of his Soul and weave a tapestry empyrean – full of Symbols for his spiritual eye, of softness for his spiritual touch, of space for his wanderings.[64]

But the spider as the creator, as artist, is just one side of a dichotomy that makes it so compelling. They also inspire acute feelings of repulsion, and are the object of one of the most common phobias. They are both admired and despised in many cultures as an emblem of ruse and deception, of sorcery, associated with fate and foretelling, and mischief and malice. The very term Arachnid for that class of invertebrate with eight legs (Arachnida)[65], differing from insects which have six, derives from a sinister story recounted by Ovid in his *Metamorphoses*, that embodies the strange and perverse view we still have of the spider.

It is a disturbing story, in which the talented but conceited weaver Arachne insults the Gods by depicting their duplicitous ways in a beautiful, flawless tapestry (*Fig. 1*). The incensed Pallas Athena, the goddess of weaving, attacks Arachne and her tapestry, sending her fleeing in shame and fear to hang herself. The moment she is suspended by a cord Athena intervenes to save her from death, but not with forgiveness or grace. Athena takes revenge with a curse, the cord becomes a silken thread, and the suspended Arachne is transformed into a spider, condemned to spin and weave for eternity. The weaver's virtuosity and talent remains, but she is transformed into a creature portrayed as ugly and shameful.

When the English essayist William Hazlitt wrote 'On the pleasure of hating' he included the spider:

Fig. 1

He runs with heedless haste, he hobbles awkwardly towards me … I bear the creature no ill-will, but still I hate the very sight of it … we regard it with a sort of mystic horror and superstitious loathing.[66]

Many writers have used the disgust inexplicably present in so many of us. The cliché is perpetuated. In *Lord of the Rings* J.R.R. Tolkein who, it is said, was bitten by a baboon spider as a baby, depicted Shelob as a terrifying obstacle to the destruction of the ring. J.K. Rowling has Aragog, a gigantic and terrifying spider whom attacks Harry Potter in the dark wood near Hogwarts. The 'mystic horror' that Hazlitt described is as pervasive as ever.

And then there is spider woman, the deadly seductress who devours the male. In Greek mythology weaving is often a sign of deception, and allusions to the spider's web usually signal a deadly entanglement in a web of treachery. This imagery was clearly drawn from direct observation of nature, watching the spider at work pouncing on, binding and devouring its prey, but it has frequently fired imaginative additions to the dark prejudices surrounding the large female spider that weaves the web and

Fig. 1 The Spinners, or the Fable of Arachne by Velázquez, Diego Rodríguez de Silva

very often devours her insignificant male consort. The Black Widow is appropriately named. Sexual cannibalism is widespread in many species, and sexual dimorphism, with the female many times the size of the male, is a striking feature.

It takes little imagination to transform such observations into the duplicitous ensnaring of the male by a spider woman. And it is not just a Graeco-Roman tradition – it can be found in many cultures. In Australian aboriginal stories there is Murgah Muggui,[67] a young woman who seduces her male victims and then paralyses, kills and eats them (eventually the seductress is outwitted by a young man and her spirit becomes a spider spinning her traps and ensnaring her victims for ever more). A similar story can be found in an Edo period legend from Japan, in which a beautiful woman seduces a man with music, and when he is lulled and distracted she binds him in spider silk and devours him.[68] She is Jorōgumo the prostitute spider, with the ensnaring charms of the femme fatale. Another Edo legend concerns the revenge of Princess Wakana, who obtained magical powers from the spider spirit (*Fig. 2*).

The spider's silk also has a rich cultural history, indeed the act of taking and transforming the spider silk might almost seem to come straight from folklore and fairy tale. One might think of Rumpelstiltskin weaving gold from straw, the fairy Queen Mab,[69] or Hans Christian Andersen's *The Emperor's New Clothes*. When the swindlers dress the Emperor, naming each garment, they comment that 'all of them are as light as spider web, one would almost think he had nothing on, but that's what makes them so fine.[70] In fact, if you hold out the palm of your hand and allow thousands of spider-silk threads to descend gently on to your skin there is a most curious sensation … of nothing.

There is a density of imagery and ideas, of analogy and metaphor, that makes spider silk a brilliant repository, a great library of myth, science and art that is incomparable in the world of fibres and the craft

Fig. 2

of textile-making. The woven silk of the spider beguiles, enchants and beckons with a force on our imagination that can be explained only by understanding something of this rich cultural legacy.

The Silkworm & The Spider

Innumerable plant and animal fibres have been collected, spun and then woven. The rarer and more precious fibres, usually coveted either for a luxuriant texture or brilliant sheen, came from the hair of animals, from camel or horse-hair, from fine llama or vicuña fleece from South America or from the shawl goats of Kashmir. These yarns have all helped to satisfy our appetite for the exquisite and beautiful.

Of all these animal sources, the silkworm or *Bombyx mori*, is perhaps the best-known and most remarkable, partly because of its long and detailed history, which remained opaque for so long. Understanding something of its confused origins and enduring fascination has a bearing on the even more arcane and mysterious story of spider silk.

Bombyx mori silk is derived from domesticated *Bombyx mandarina* silkmoths, and was 'discovered' in China almost 5,000 years ago, about the time of the first Emperor Fo Xi. The innovation was truly ingenious, as reeling a single thread from an insect's cocoon was a remarkable undertaking that requires several distinct phases of production. Threads used in weaving wool and cotton yarn are invariably made into a yarn by spinning together short fibres to make a longer continuous thread. These

Fig. 2 Large button netsuke with a design of the Spider-Devil.
Ivory, Japan, circa 1850-1900.
Signed 'Reigyoku'
© Victoria & Albert Museum (564-1904)

short fibres first need to be washed and carded, which is a process of combing and aligning the fibres. The discovery that the silk cocoon of the *Bombyx mori* comprised a single continuous thread of up to 1500 metres long offered considerable advantages over the short, spun fibres.

However, if the chrysalis metamorphoses into the moth and hatches from the cocoon, it breaks the continuous thread. The cocoon is therefore heated to kill the chrysalis, before being put into warm water to loosen the silk. The silk is then drawn up in a process called 'reeling' where several strands of silk are pulled together. These are subsequently 'thrown', whereby different numbers of silk threads are twisted together.

The continuous thread accentuates the lustrous qualities and smooth feel of the silk, which cannot be obtained by spinning short fibres.

The result of what must have been years of trials and experiments was the eventual domestication of a Chinese moth, the *Bombyx mori,* and the invention of sericulture. Such an instance of man's successful manipulation and harnessing of an insect on such an impressive scale, is rare. Only apiculture, bee-keeping, comes close as a comparable achievement.

The word silk derives from the Chinese word *sze* or *szu*, which, in ancient Greek, became *Ser*. In classical antiquity China was thus known as Serica, the country of silk, and the Chinese were called the 'Seres'. Seric cloth was the term used for the woven silk fabric that they produced, and the trade of this wonderful material along the silk routes moved gradually westward, bringing prosperity and wealth to the traders and producers who jealously guarded the secret of its making for thousands of years.

Although the Greeks became aware of the silk in the fifth century BC, and Aristotle even appears to have understood that a caterpillar was involved in its production, confusion and ignorance as to its origins continued until long after even the Romans had begun to use and weave the material, from the time of the Emperor Augustus, 63BC– 14AD. Among the Greeks, Aristotle mentions a woman called Pamphila from the Aegean island of Cos, who first took the already hatched cocoons of a silk moth and washed, carded and spun the resulting yarn for weaving. But as a spun yarn, rather than a continuous thread, the textiles from Cos were always regarded as of a poorer quality than the extraordinary lustrous Chinese Seric cloth.

Notwithstanding Aristotle's information about silk's origins, it was generally thought that Seric cloth was vegetal in origin, and that it was probably made by combing fleeces from leaves, or from a moistened wool from the pods of a tree – there may also have been a suspicion that it was taken from a spider. By the second century AD, however, several chroniclers had clearly heard that an insect was the source. The Greek traveller Pausanias described the insect:

> *Its size is twice that of the largest beetle, but in other respects it is like the spiders that spin under trees, and furthermore, it has, like the spider, eight feet. These creatures are reared by the Seres, who build them houses adapted for winter and for summer. The product of the creatures, a clue of fine thread, is found rolled around their feet.*[71]

It was not until the Emperor Justinian's (526–65AD) reign, when Constantinople became the centre of commerce between the East and West, that the West gained real access to Chinese sericulture. In 532 two Nestorian Persian monks revealed the secrets to Justinian by bringing the eggs of the *Bombyx mori* out of China in a hollow bamboo. The secret that had provoked such jealousy and speculation was finally revealed, and silk from the silkworm – as well as an understanding of the technical process of sericulture – arrived in the West. Any confusion with spiders was forgotten.

Simon Peers

‘Golden Spider Silk’ exhibition
at the Victoria & Albert Museum,
London January – June 2012

Press

A selection of press from the exhibition 'Golden Spider Silk' at the Victoria & Albert Museum, London in 2012:

CNN, 'Arachnophobe Creates Cape Woven from Spider Silk'
The Economist, 'A Tangled and Exquisite Web they Wove'
London Tonight, 'Clothes Spun by Spiders'
BBC News, 'Interview With Simon Peers & Nick Godley'
BBC News, 'Cape of Silk Extracted from Spiders goes on Display at V&A'
BBC Radio 4, 'Enchanting Spider Silk Cloth'
Sky News, 'Gold Cape Spun By Spiders on Display'
Vanity Fair, 'What to See'
The Pick, 'Golden Spider Silk'
The Sunday Times, 'The Stuff That Dreams Are Made Of'
Metro, 'Web Sight'
The Independent, 'Fashionable? A Million Spiders Can't Be Wrong'
The Times, 'Following The Golden Thread'
The Guardian, 'Shimmer of the Spider Woman as Cape Goes on Show at V&A'
Times of India, 'The Real Spider-Men'
The Telegraph, 'Golden Cape Made Of Spiders' Silk To Go On Display'
The Mirror, 'Golden Silk Cape Made From Fabric Spun From A Million Spiders To Go On Display At V&A Museum'
The Sun, 'Cobweb Cape Made By A Million Spiders'
The Daily Telegraph, 'Golden Wonder – The Cape of Spider Silk'
Washington Post, 'Oh, What a Golden Web They Weave'
Victoria & Albert Museum Magazine, 'Golden Spider Silk'
The Telegraph, 'Rare Spider Silk to come to V&A'
Vogue, 'Fashion Web'
Financial Times, 'Amazing Spider-men'

The Observer Magazine, 'Spun by a Million Spiders'
Sunday Express, 'Spiders Get Us In A Spin'

A selection of press from the exhibition 'Spinning Gossamer: Golden Spider Silk Textile' at The Art Insitute, Chicago in 2011:

The New York Times, 'Show Highlights the Return of the Loom'
Nova, 'Making stuff'
Whitewall, 'Golden Spider Silk Textile Exhibit Opens in Chicago'
Huffington Post, 'Art Made of Spider Silk'
Refinery 29, 'This Year's Must-See Exhibit At The Art Insititue'
PinkMemo, 'Spider Silk Textile Makes Appearance at Art Institute Party'

A selection of press from the exhibition 'Spider Silk' at The American Museum of Natural History, New York in 2009:

The Martha Stewart Show, 'Spider Silk Shawl' October
Time Magazine, The 50 Best Inventions of 2009
The New York Times, 'Gossamer Silk, From Spiders Spun'
The Times, September
Wired Magazine, '1 Million Spiders Make Golden Silk For Rare Cloth'
Reuters, 'Golden Tapestry Woven From Spider Silk Goes on Show'
NPR, 'Spider Wranglers Weave One-of-a-Kind Tapestry
Fast Company, 'Creepy, Crawly, Crafty: A Tapestry Woven by Eight-Legged Artists'
StyleCaster, 'Museum of Natural History's Spider Silk Exhibit'
The New York Observer, 'Spider-Silk Glitz'
Times Online, 'Spiders Spin on a Golden Shawl'
FameGame, 'Images of Unveiling of Spider Silk Exhibit'

Notes

1 To reproduce spider's silk transgenically with goats.

2 We were prompted by work undertaken by Christine Athenor from the Musée des Confluences in Lyon.

3 A cross-section of the spider silk compared to the *Bombyx* silk shows the spider silk to be perfectly round in shape, whereas the *Bombyx* silk is triangular.

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18 Ibid.,p.13

19 Ibid.,p.14

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22 Ibid.,p.391

23 Ibid.,p.407

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