



# Human History Through Fiber

How Fiber Changed the World

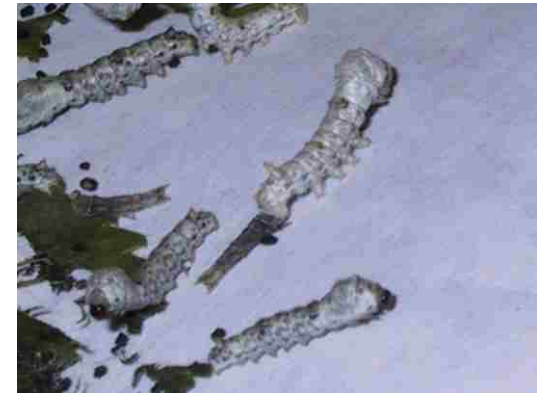
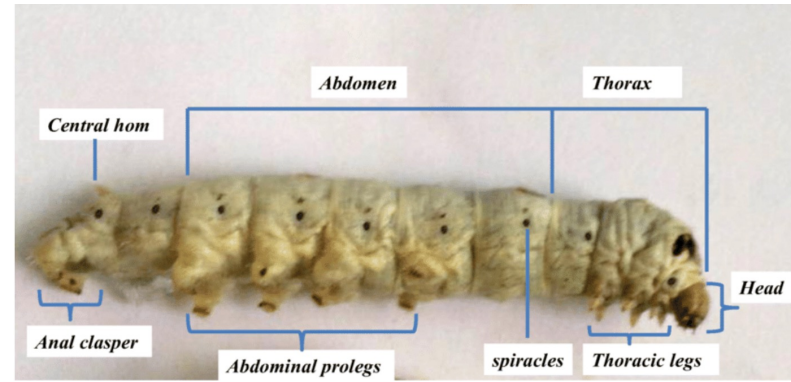
Howard Seltman and Kathy McIntyre-Seltman

# Course Overview

- Week 1
  - Prehistory and early history
  - Process overviews of spinning and weaving
- Week 2
  - Hemp and flax and other bast fibers
  - Cotton
- **Week 3: Silk**
  - **Silkworms and silk properties**
  - **Sericulture and silk in China**
  - **Silk Road and silk outside of China**
- Week 4: Woolly mammals
- Week 5
  - Dyeing
  - Synthetics
  - Fiber hobbies

# Silkworm Life Cycle

- Egg (ova): 1mm, dark purple
- Worm (larva): five instars and 4 molts (700x weight ↑ to ~1¼ oz in 35 days)
- Cocoon (pupa): wrapped in silk (2-3 days), emerges 10-14 days later
- Male and female moths (imago): quickly mate and lay eggs

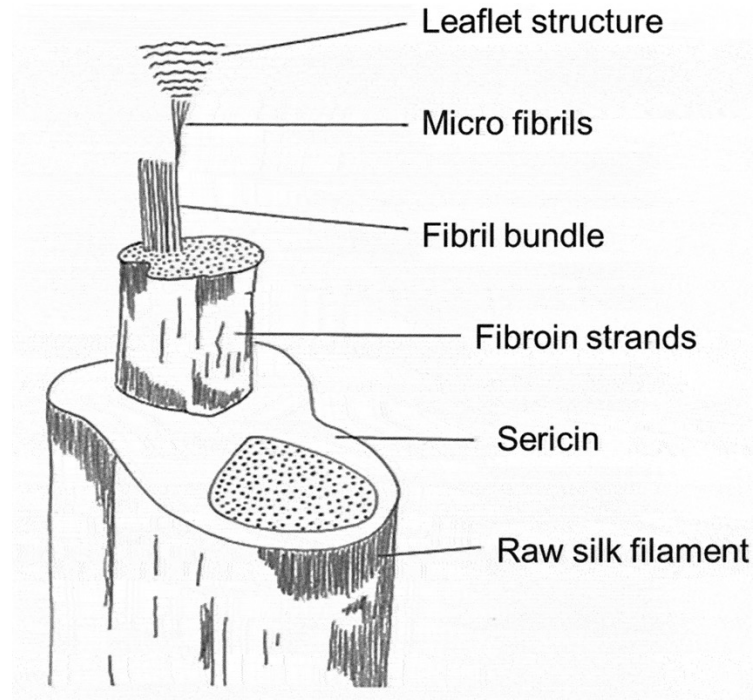


**Spinning a cocoon 12 hours  $\Rightarrow$  1 minute [B. Stevenson]**

# Silk properties

- Each cocoon is a single long fiber with a triangular cross-section
- Produced by silk glands in the mouth
- Only 0.01 mm (1/2500 in.) wide, but about half a mile long
- Strong, shiny, pliable, resistant to degradation
- Made of fibroin and sericin proteins
- Five times the tensile strength of an equivalent sized steel fiber
- Loses 20% of its strength when wet, moderate to poor elasticity
- In addition to cloth, used for fishing line, bowstrings, paper, and musical instrument strings

# Silk Formation



# Sericulture is the art and science of growing cocoons

- Oral history traces sericulture to Léi Zǔ (嫫祖), wife of the Yellow Emperor, who discovered sericulture and invented the silk loom in circa 2650 BCE

From the *Nóng Shū*  
(1313) by Wáng Zhēn:  
“Silkworm Deity”



# Sericulture details

- Worms (*Bombyx mori*) are a domesticated species
- Mulberry (*Morus alba*) leaves are the main diet
- Mostly a cottage industry for first few thousand years
- Kept a Chinese secret until about 50 CE
- First developed in the Huáng Hé (Yellow River) valley in the north of China, then moved southward
- Mulberry cultivation is discussed in many ancient texts
- Domestication
  - cocoons have very long silk filaments
  - larvae don't roam
  - moths don't fly
  - (bivoltine and trivoltine varieties)



# **Sericulture details (varies by region and era)**

- Hatch the eggs on paper at the correct time
- Selecting hatchlings
- Feeding while maintaining temperature, humidity and cleanliness
- Transferring from tray to tray
- Providing a good place to produce a cocoon
- Sexing and grading cocoons, killing the pupa
- Selecting some to go to the moth stage
- Selecting moths allowed to mate and reproduce
- Treating and maintaining the eggs until the subsequent year

# Sericulture math and next steps

- One pound of silk: 2500 worms, 30 pounds of mulberry leaves
- The larvae eat around 30,000 times their initial weight
- When undamaged a single cocoon can be unwound as a single thread
- The sticky sericin “gum” must be removed using an alkaline or hot water bath
- Reeling is the process of combining several individual cocoon threads in to one usable thread
- A skilled worker can reel 20-30 ounces or 1 mile per day
- The reeled threads can be plied to make thicker threads
- Damaged cocoons can be used to make spun or stretched silk
- Several wild moth species, e.g., tussah and muga, are also used in some parts of China and in India

# Reeling in the Song Dynasty (1200s)



# Processing after reeling

- Diet affects color, e.g., adding some wild mulberry changes the silk from white to yellow
- Washing removes the remaining sericin and dirt
- Dyes included:
  - red: madder root or safflower
  - dark blue: indigo
  - black: iron sulfate
  - yellow: ginzi root
  - dark red: ochre

# Silk from the earliest times

- Yellow Emperor (2697-2597 BCE): Léi Zǔ's discoveries
- Silk threads, a braided silk belt and a woven silk cloth fragment dated to circa 2570 BCE were excavated from the Liángzhǔ culture site in Zhèjiāng Province
- Shāng Dynasty (~1600-1050 BCE)
  - The oldest known written reference to silk is on a bronze fragment found at Ānyàng
  - Systematic unisex clothing styles developed
  - *yīcháng*: Combined jacket and wrap-around skirt
  - *bìxī*: decorative knee covering
  - Only red, blue, yellow, and green
  - Silk for upper classes & ceremonially; hemp or ramie otherwise



A standing dignitary wearing *yīcháng* and *bìxī*, Shang dynasty, 12th-11th century BC

# Silk before the Qín Dynasty

- Western Zhōu Dynasty (~1050-771 BCE): tops and bottoms separated; strict hierarchical society with more ornate clothing for higher ranks; strict regulations on the clothing of the emperor, feudal dukes, senior officials, soldiers, ancestor worshippers, brides, and mourners
- Spring and Autumn Period / Warring States (770-221 BCE): Dress codes broke down; earliest known silk paintings
- 5<sup>th</sup> century philosophers: "men till and women weave"



Reconstruction of one of the shēnyī with a straight front, unearthed from the Mashan tomb, ca 300 BCE



Jade silkworms from Warring States burials

# Silk in the Qín Dynasty (221-206 BCE)

- Time of the terra cotta soldiers, connection of the Great Wall
- Implemented the shēnyī system
  - The emperor wore a black shēnyī
  - Higher official wore green
  - Lower officials and commoners wore white
  - Laid the foundations of dress codes for subsequent dynasties



Drawing of the first Qín emperor

# Hàn Dynasty (202 BCE – 220 CE)

- Silk was used for paying taxes in the Hàn Dynasty)
- The Hàn officially opened western trade in 130 BCE after the conquest of Xīnjiāng (to the northwest)
- Three tombs of a Hàn Chinese family at Mǎwángduī contain thousands of artifacts, including some of the world's oldest preserved silk paintings, clothing, and textiles
- Textile analysis suggests that the drawloom was invented in the late Hàn Dynasty
- Printing on silk was also invented at this time

Western Hàn painting on silk was found draped over the coffin in the grave of Lady Dǎi (c. 168 BCE) at Mǎwángduī near Chángshā in Húnán province.





# Summary of Silk in China

- Silk was highly valued by the Chinese elite
- It was developed in China, and kept a secret for a long time
- Even after other countries developed silk technologies, Chinese silk was a high-quality luxury good around the world
- Export of silk was a major factor in the Chinese economy

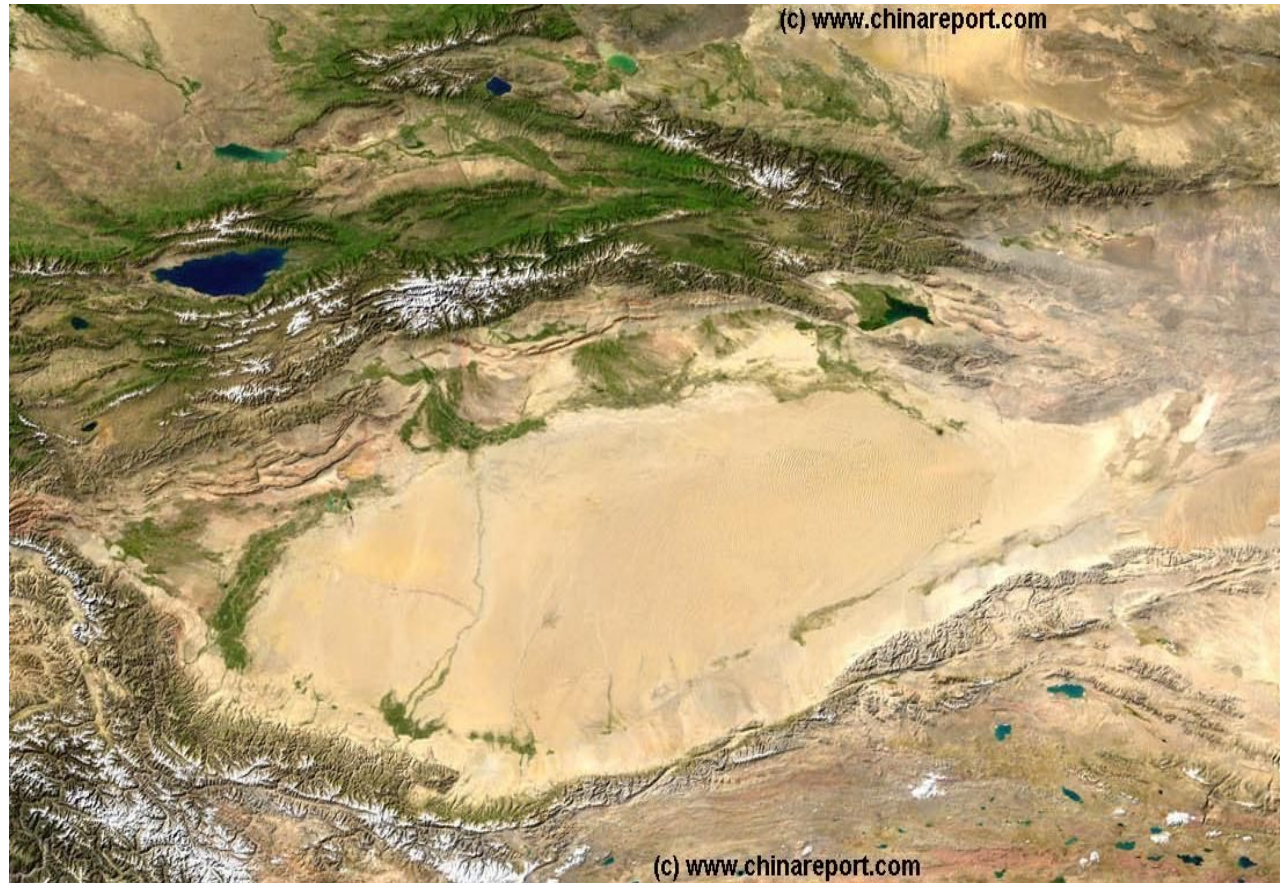
# Questions and Comments

# Silk in the rest of the world



# Trade Routes Before Silk Road

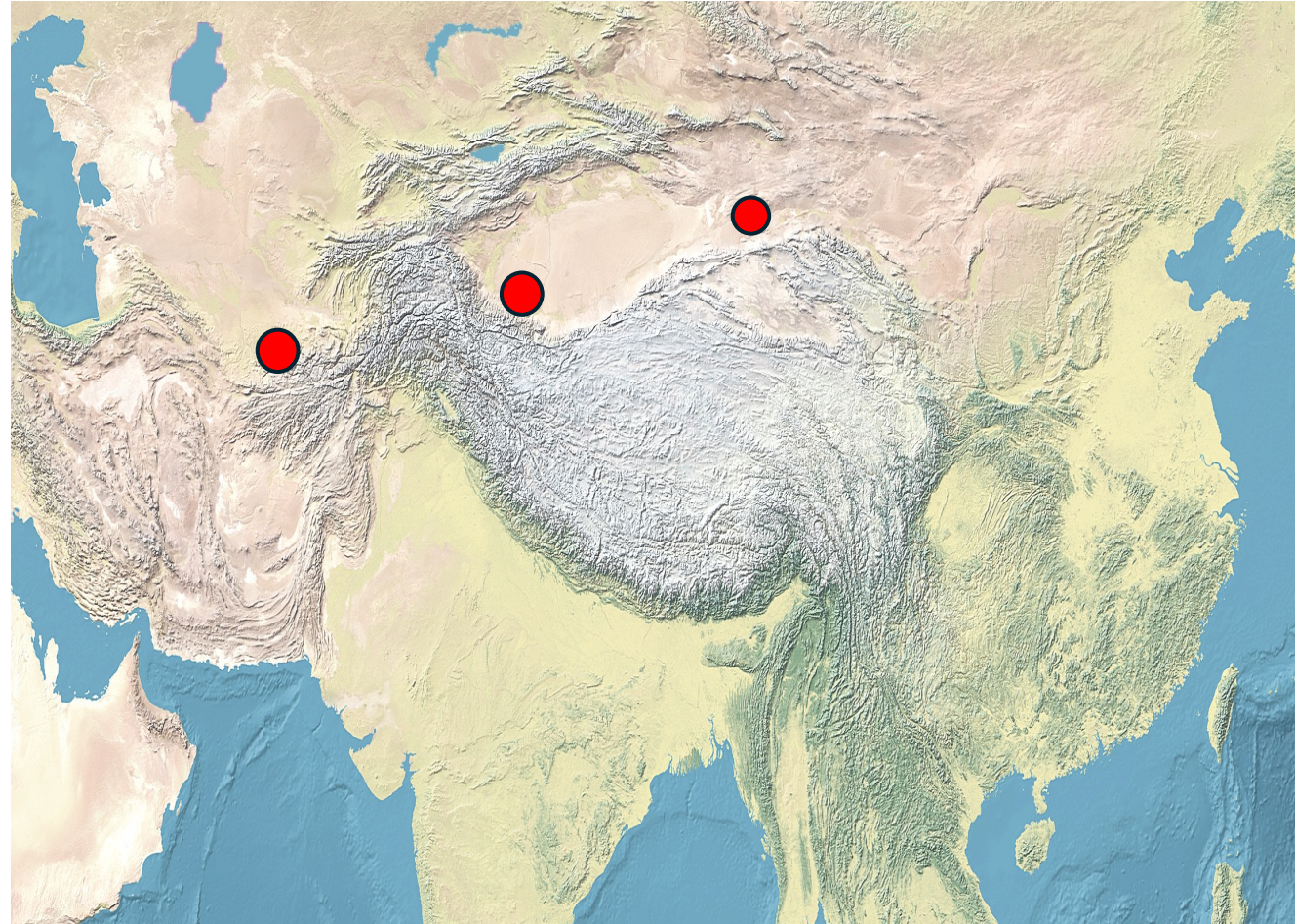




# Earliest Chinese Trade

## Goods found going TO China

- 2<sup>nd</sup> millennium BCE – nephrite and lapis from Khotan
- 1600 BCE goods from Loutan
- 8<sup>th</sup> – 6<sup>th</sup> c BCE – gold from central Asia



# Earliest Chinese Trade

## Goods found going FROM China

- 1070 BCE Chinese silk found in Egyptian tombs
- 6<sup>th</sup> C BCE Chinese silk found near present Stuttgart
- 5<sup>th</sup> C BCE Siberian Ice Maiden



# Siberian Ice maiden – Ukok Princess

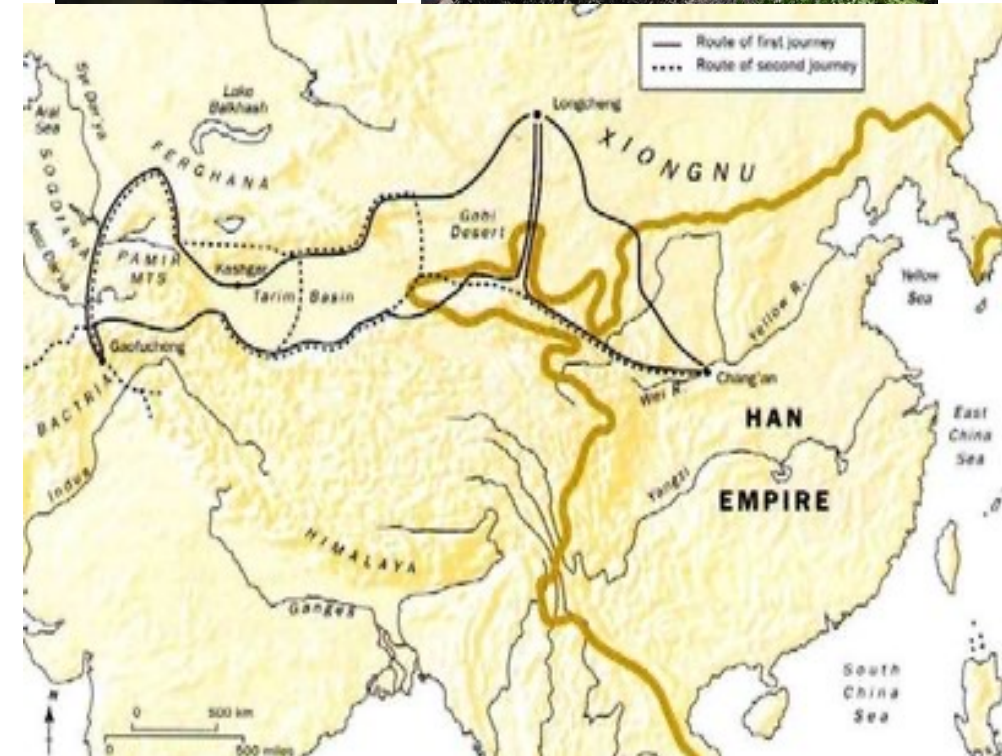
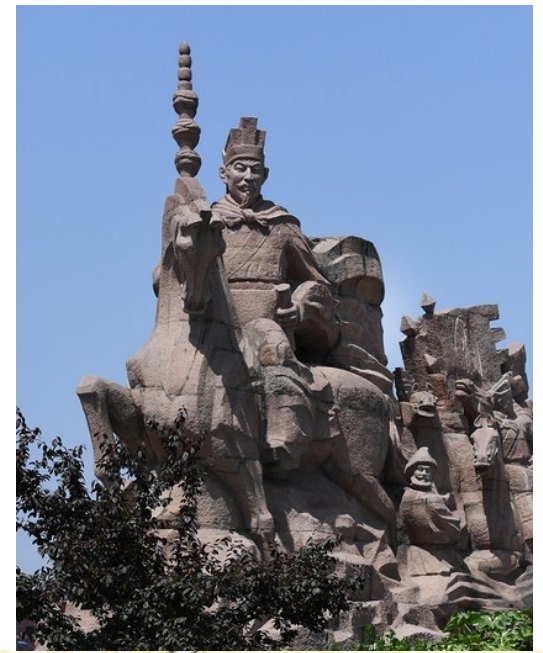
- Central Siberia discovered 1993
- Dated to 5000 BCE based on study of log coffin and contents of horses' stomachs
- Frozen in block of ice for 2400 yrs after grave robbery allowed water to seep in
- Wearing yellow Chinese silk shirt, red wool skirt





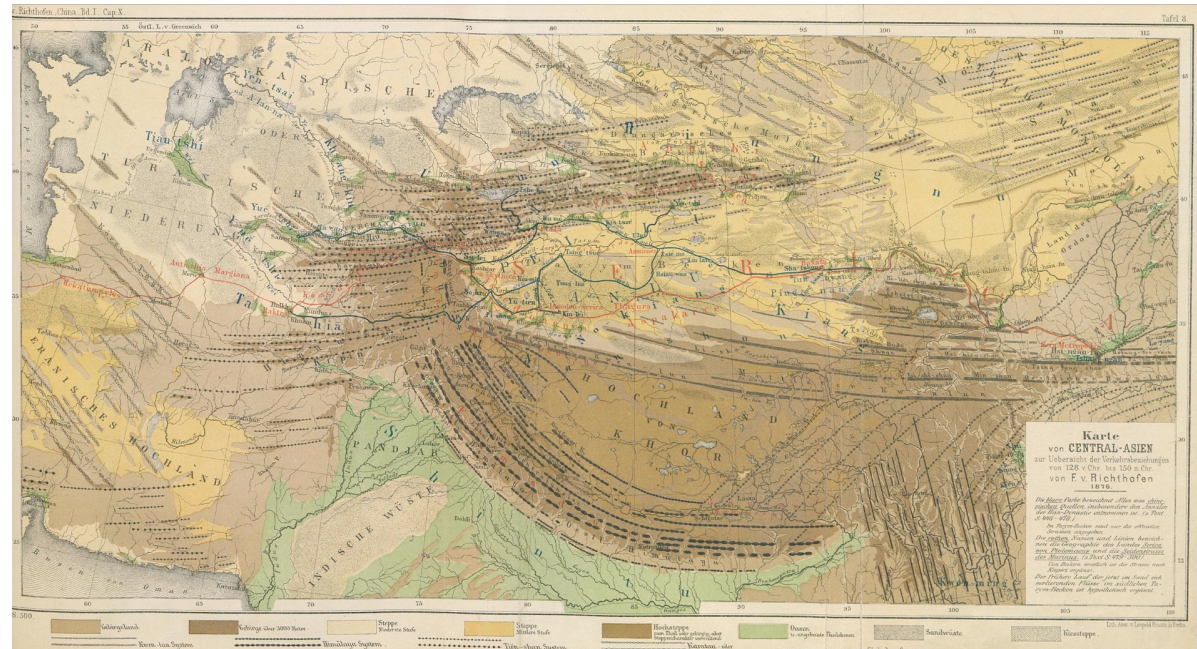
# Han Dynasty

- Emperor Wu sent emissary **Zhang Qian 138 BCE** north and west to seek alliance with Yuezhi peoples to fight Xiongnu tribes and to secure horses for battle (and maybe to spy??)
- Captured and enslaved by Xiongnu for 11 years, then went west, then was recaptured and finally returned to Xian 13 years after setting out
- Reported to Emperor Wu his surprise at finding Chinese goods in the west
- Set up trade of silk for Fergana horses
- Once freed, he continued to travel established political connections and trade routes
- China set up embassies all along trade routes



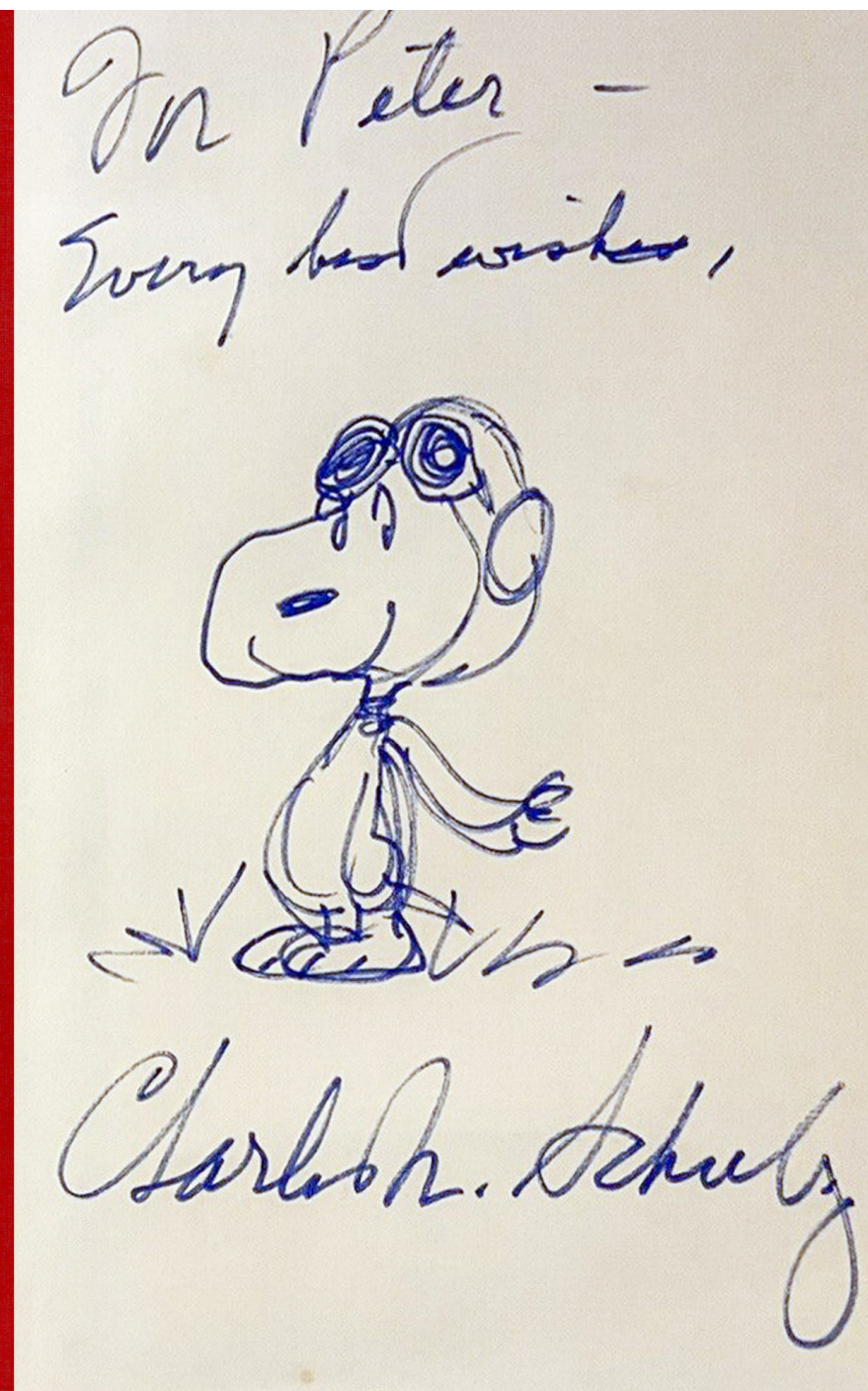
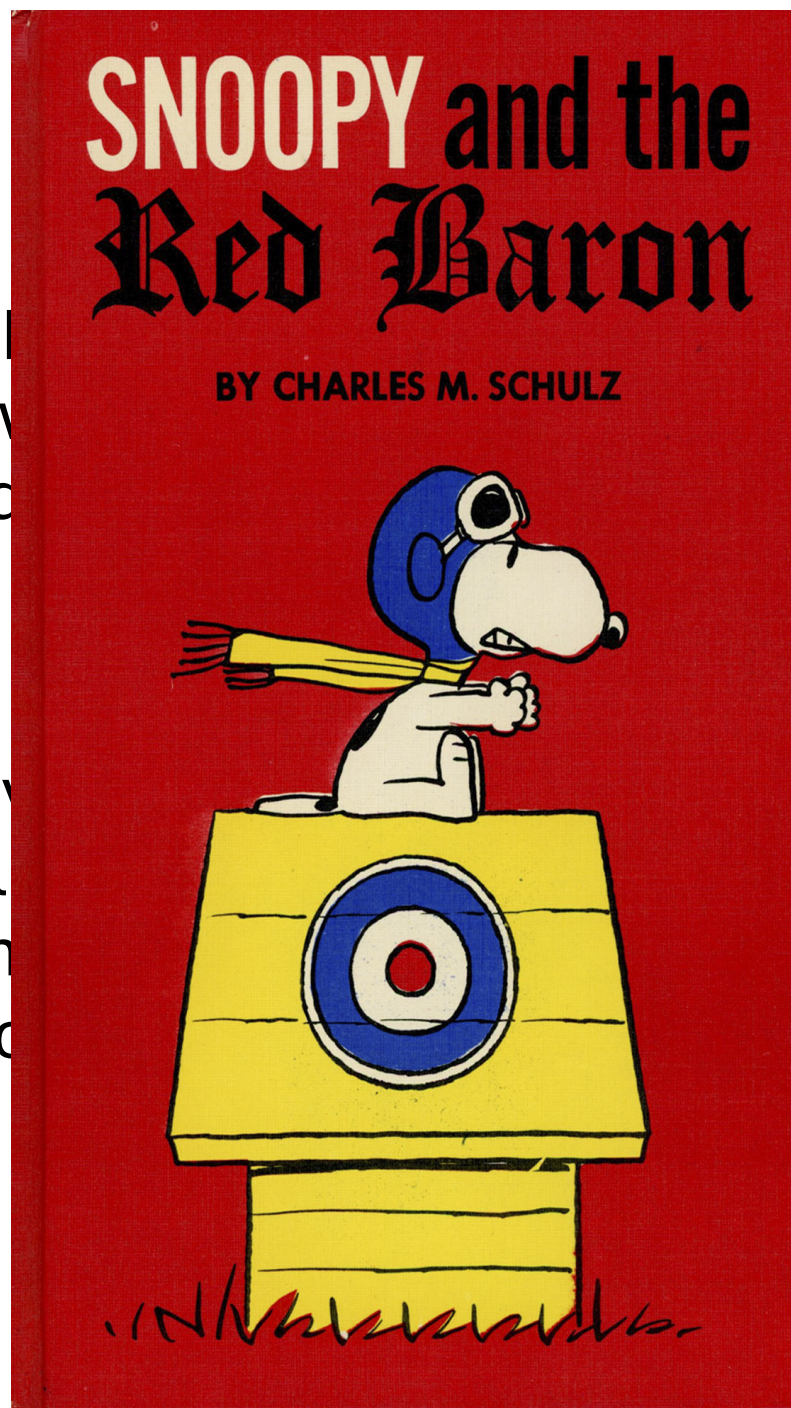
# Silk roads

- Name given to network of routes 4000 miles between eastern China and Middle East
- Named by Ferdinand von Richthofen 1877- geologist, hired to develop commercial railroad routes to import coal from China

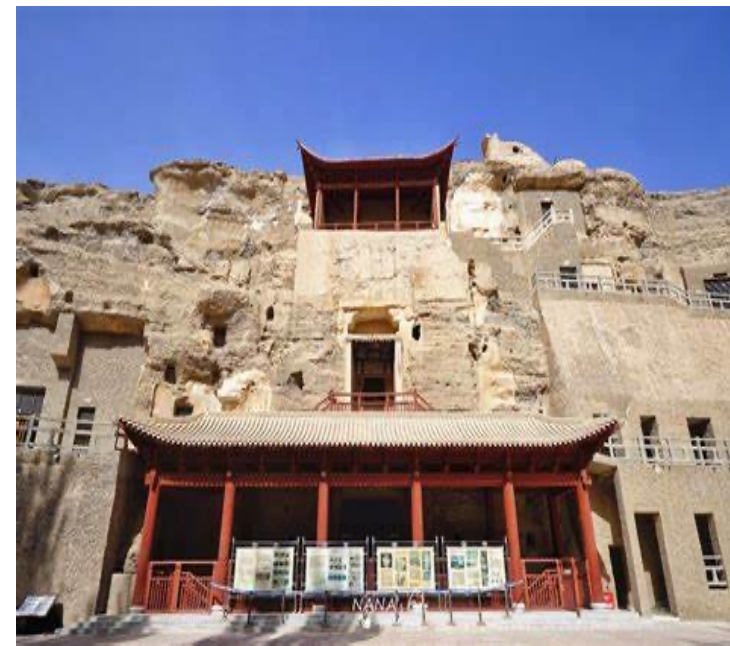


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# Silk Roads – Taklamakan Desert

- Trade pathways between oases (kingdoms)skirting the Taklamakan Desert
- Caravans traveled portions, not the whole distance – traders were locally specialized
- Varying level of control by local agents
  - Bills of passage
  - Taxes and tariffs
  - Guides
  - Extensive trading at each stop
- Currency was silk – also grain, coins from west



# Silk Roads

- Primary export of China remained silk fabric, thread, later paper
- Sericulture techniques kept secret - export of silkworms punishable by death
- Sea routes as well as land routes
- Remained most important trade routes between east and west until Ottoman Empire closed it off in 1453

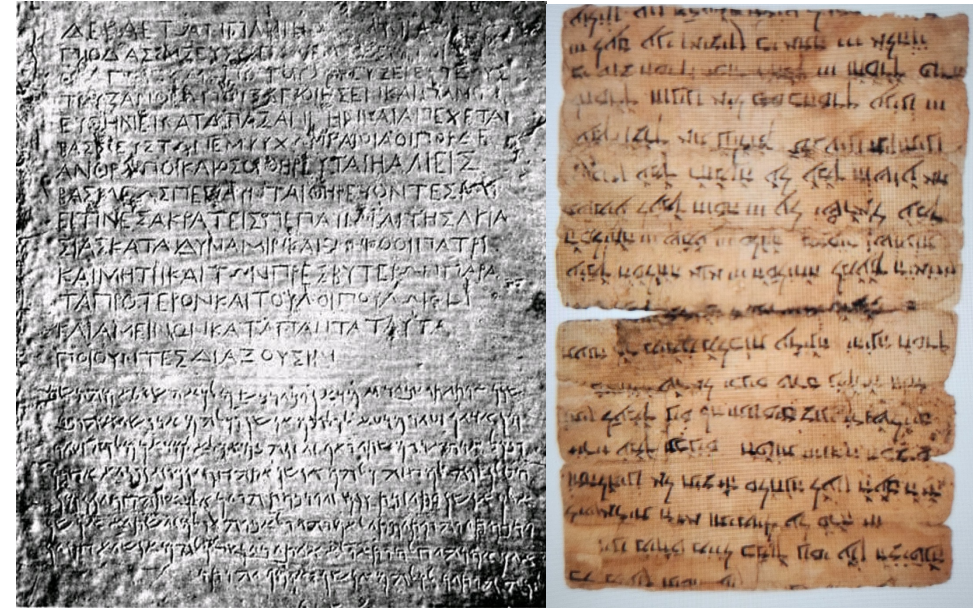


# Silk Roads

**Primary importance was not trade of goods, rather it was the exchange of cultures, languages, literature, ideas, sciences and technologies, and religions**

- Buddhism
- Zoroastrianism
- Christianity
- Islam

Also allowed epidemic Black Plague  
to China 6<sup>th</sup> c, from China 14<sup>th</sup> c





# Silk as Commodity

- Highly sought by the royalty and the wealthy in ancient Mediterranean cultures
- “glass togas” associated with prostitution and debauchery in Rome in 300’s BCE, banned by Tiberius
- Multiple attempts to grow silkworms in Mediterranean cultures were unsuccessful, mostly due to need for constant attention and feeding of worms



“The adulteress may be visible through her thin garment, meaning her husband has no more acquaintance with his wife’s body than any outsider or foreigner.”  
- Seneca

# Silk as Commodity

## Spread by both trade and conquest

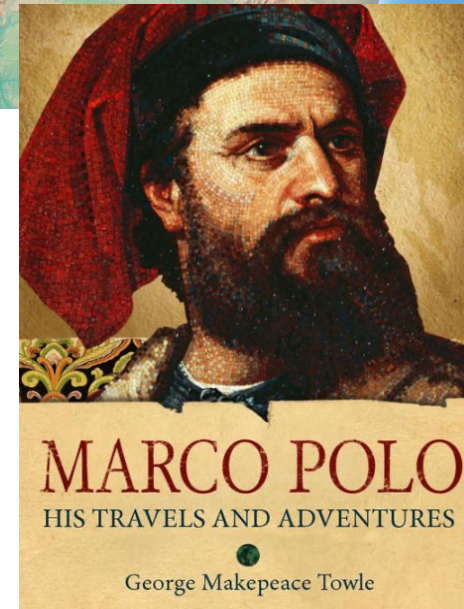
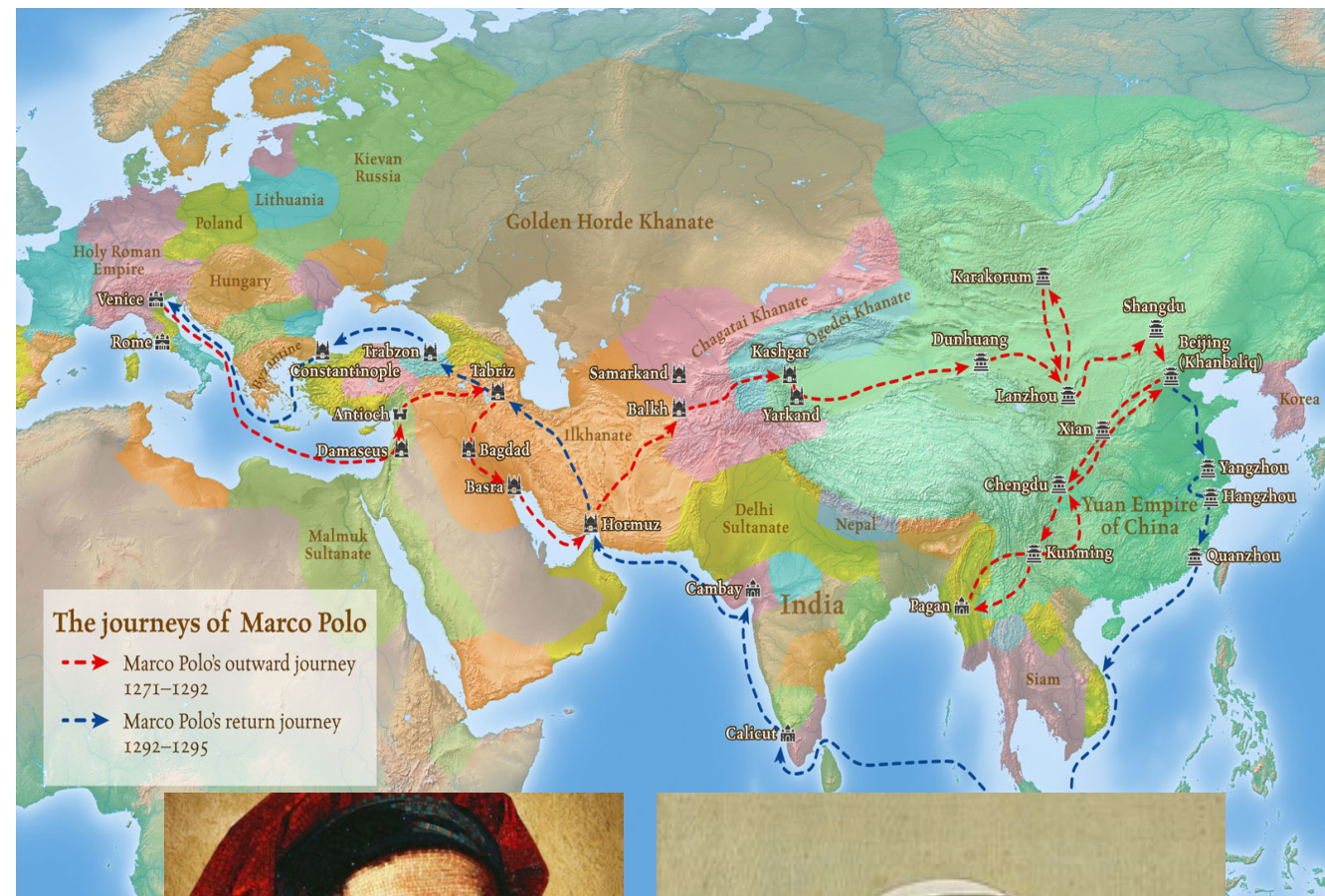
- Roman Empire 27 BCE – 476 CE
- Conquests of Alexander the Great 329
- Byzantine Empire 330 - 1453
- Huns 430-450 defeated Tang Dynasty and Roman Empire
- Arabic califates – 700's – Feranga valley through Asia – spread Islam
- Crusades 1095 - 1294
- Mongol empire – Genghis Khan 1204 – became the Yuen empire in China

Silk fabric found as far as Viking lands 800's, Indonesia 500's, west coast of Africa 1000

Brought to South America 1400's by Spanish conquistadors

# Marco Polo

- Venetian son of wealthy traveling merchant – silk and spices
- Traveled 1271 – 1295 with his father and uncle along Silk Road, with letter to Kublai Khan from the Pope
- Stayed with Kublai Khan at Shandou (Xanadu) and his winter home
- Became emissary of Khan to other nations
- Returned to Italy by sea, was imprisoned in Genoa (was at war with Venice) and dictated his travelogue



# Marco Polo

- “Now, on his birthday, the Great Kaan dresses in the best of his robes, all wrought with beaten gold; and full 12,000 Barons and Knights on that day come forth dressed in robes of the same colour, and precisely like those of the Great Kaan, except that they are not so costly; but still they are all of the same colour as his, and are also of silk and gold.”
- Of Peking: “no day in the year passes that there do not enter the city 1000 cart-loads of silk alone, from which are made quantities of cloth of silk and gold, and of other goods. And this is not to be wondered at; for in all the countries round about there is no flax, so that everything has to be made of silk. It is true, indeed, that in some parts of the country there is cotton and hemp, but not sufficient for their wants. This, however, is not of much consequence, because silk is so abundant and cheap, and is a more valuable substance than either flax or cotton.”



# Silk Technology Escapes China

50 BCE Han princess betrothed to Khotan Jade prince

He convinced her to smuggle silkworms to Khotan

She hid silkworms in her coiffure and mulberry seeds in her luggage

Today there is a thriving silk industry in Khotan



# Silk Technology Escapes China

In 552 CE, Emperor Justinian, sent spies to learn how silk was produced. He planted mulberry orchards, then sent 2 monks to smuggle silkworms back to Byzantium. They hid eggs in hollow bamboo rods, the worms hatched but did not cocoon.

Byzantium quickly became primary source of silk fabric in the Mediterranean region, although not as fine as Chinese silk



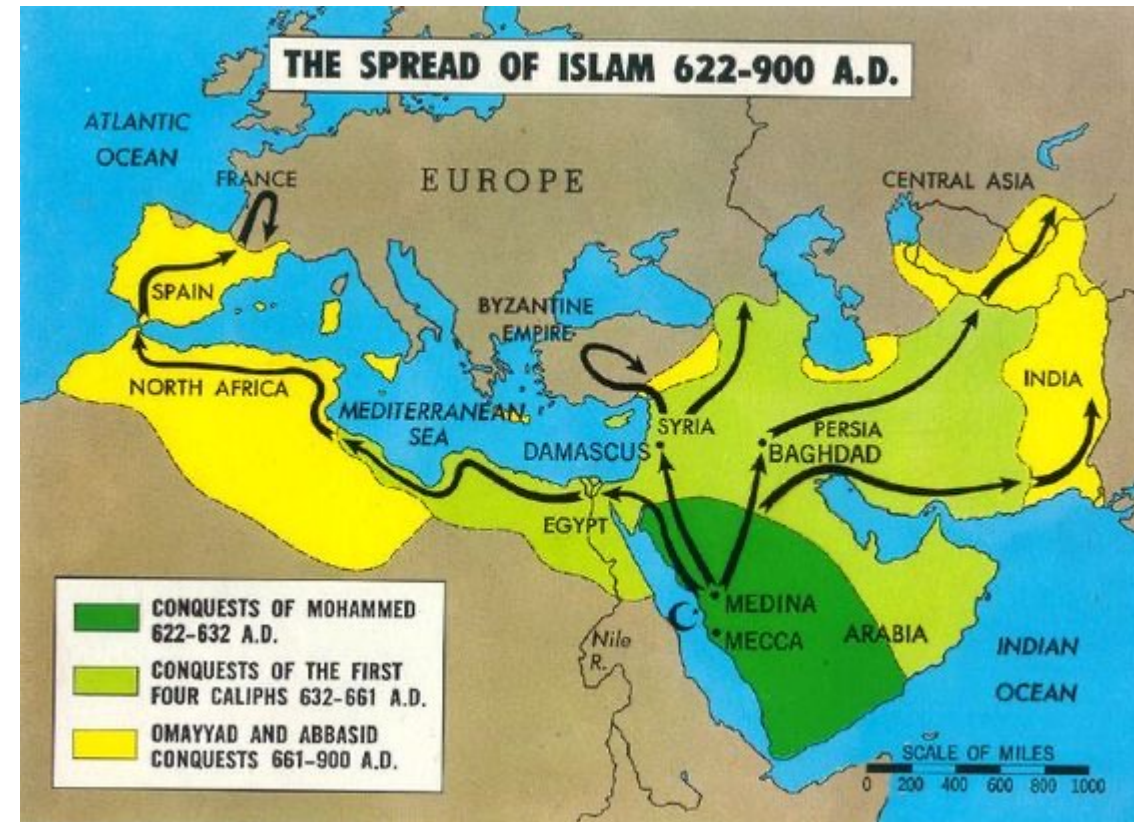
# Silk in Medieval Europe

- Sourced from Byzantium then Italy
- Expensive – used by royalty, the very wealthy, and the Church as clothing and decoration
- Church and royalty deeply intertwined – Pope Leo III crowned Charlemagne as Roman Emperor in 800
- In feudal Europe, became associated with the excesses and patronage of the Holy Roman Empire
- Popular in Britain and France after being brought back from Crusades



# Silk Production Spreads to Mediterranean

- 9<sup>th</sup> – 11<sup>th</sup> c Arab and Jewish immigrants brought sericulture and planted mulberry orchards along Islamic Mediterranean - North Africa, Sicily, and Spain
- Not as fine as Chinese silks
- 11<sup>th</sup> – 12<sup>th</sup> c sericulture in Northern Italy → Venice 1350 – 1700's
  - Silk fabric export source of great wealth in Venice
  - Contributed to already dominant maritime industry
  - Growth and empowerment of guilds





# Silk Production Spreads to France

- 1536 Francois I – invited 2 Italian merchants to Lyon to set up silk weaving, training poor girls at looms
- Louis XI bolstered national silk industry in Lyons
  - Required all imported silk thread to pass through Lyon
  - Brought Italian weavers to teach local guilds
- *Le Grande Fabrique* paired weavers and merchants
- By end of 16<sup>th</sup> c Lyon center of all European silk textile production
- By end of 17<sup>th</sup> c 14,000 looms operating, one third of population engaged in silk industry

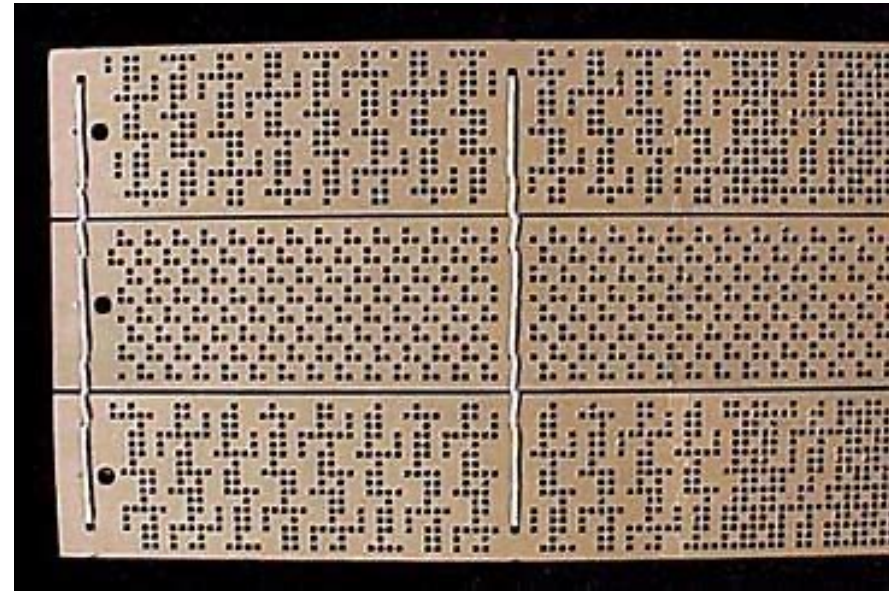
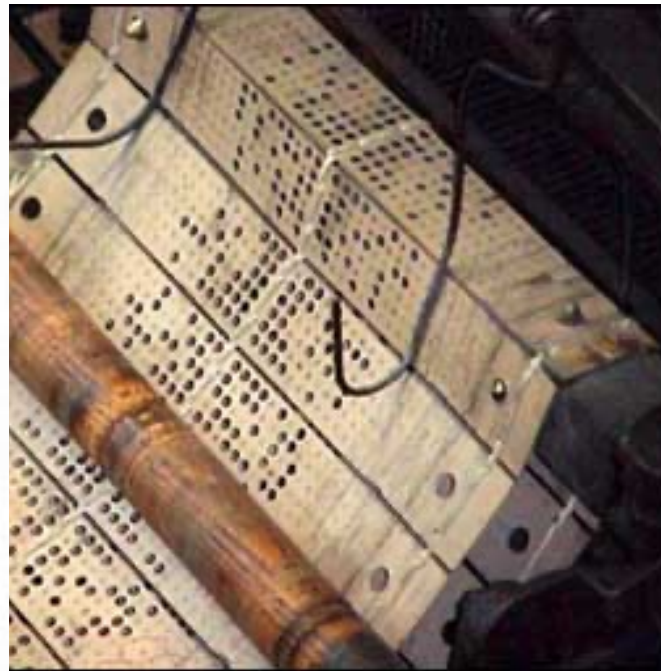
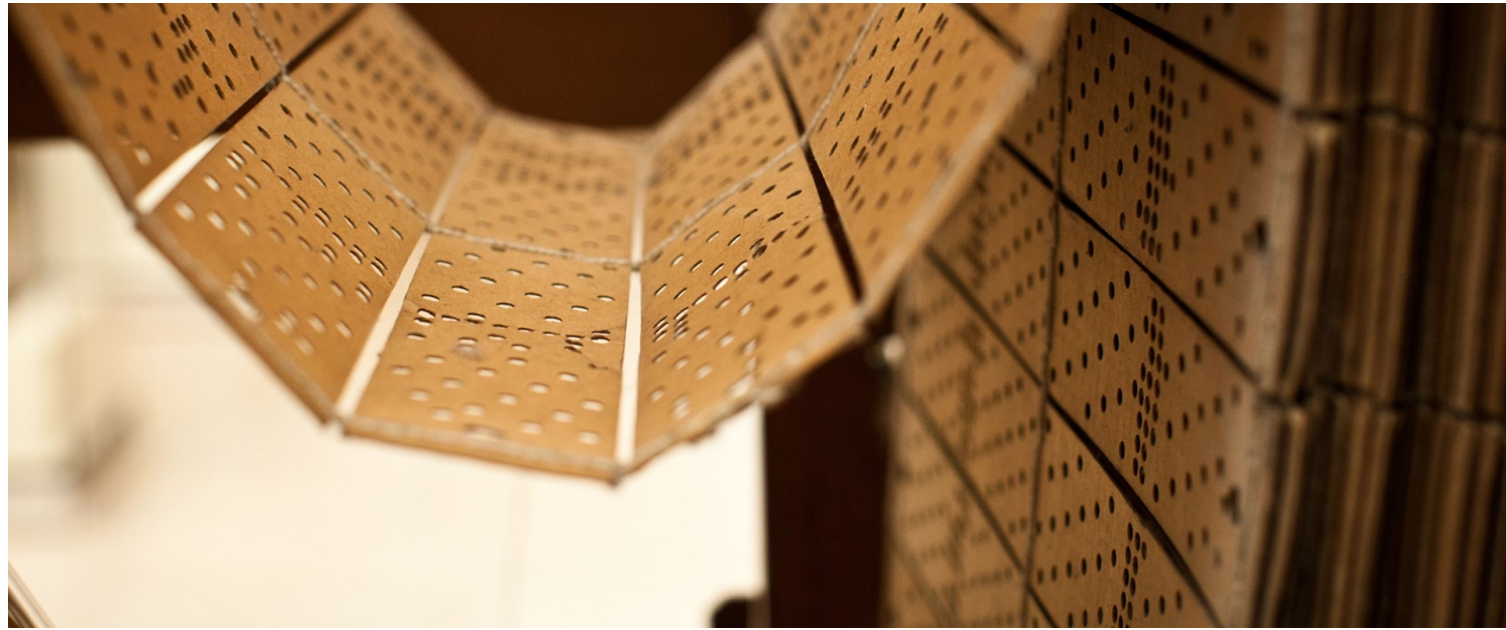
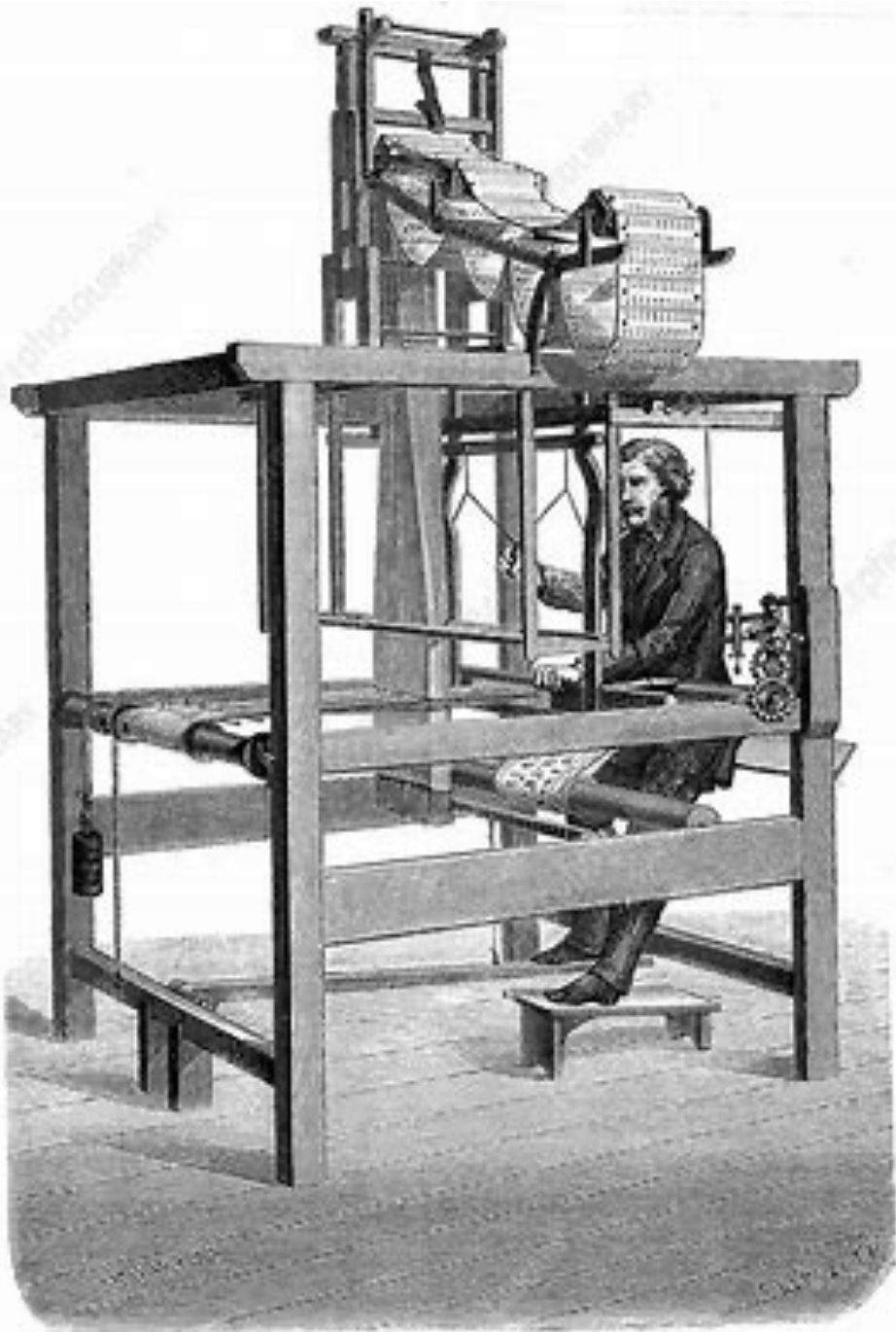






Jaquard Loom 1804 – modification of draw loom - lifting of warp threads controlled by punch cards

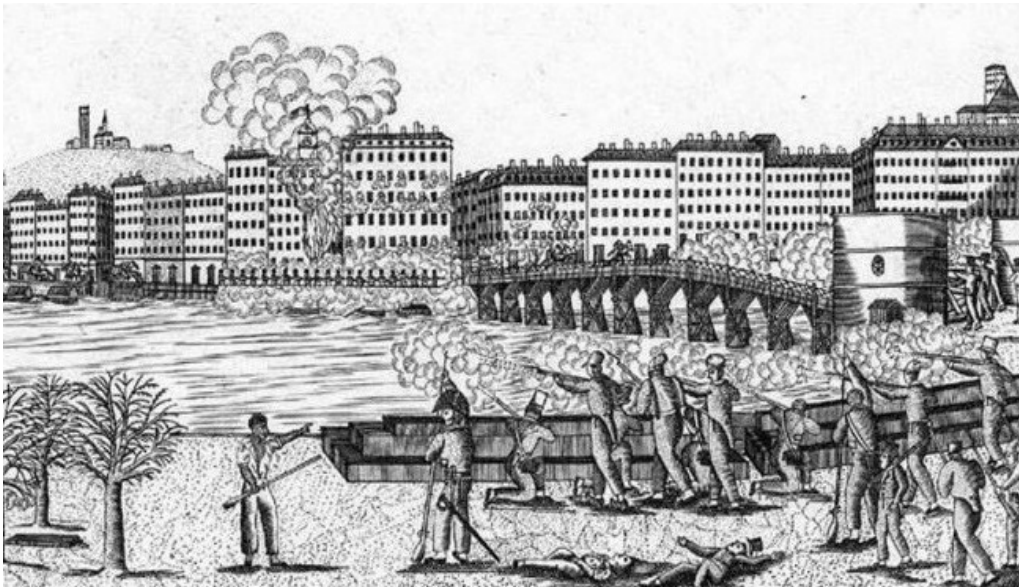




# Révolte des Canuts

## Weavers revolts 1831 & 1834 (1848)

- Drop in silk prices → weavers struck for fixed wages
- French king sent the army, hundreds killed
- One of the earliest large organized labor actions
- Influenced further labor actions throughout Europe



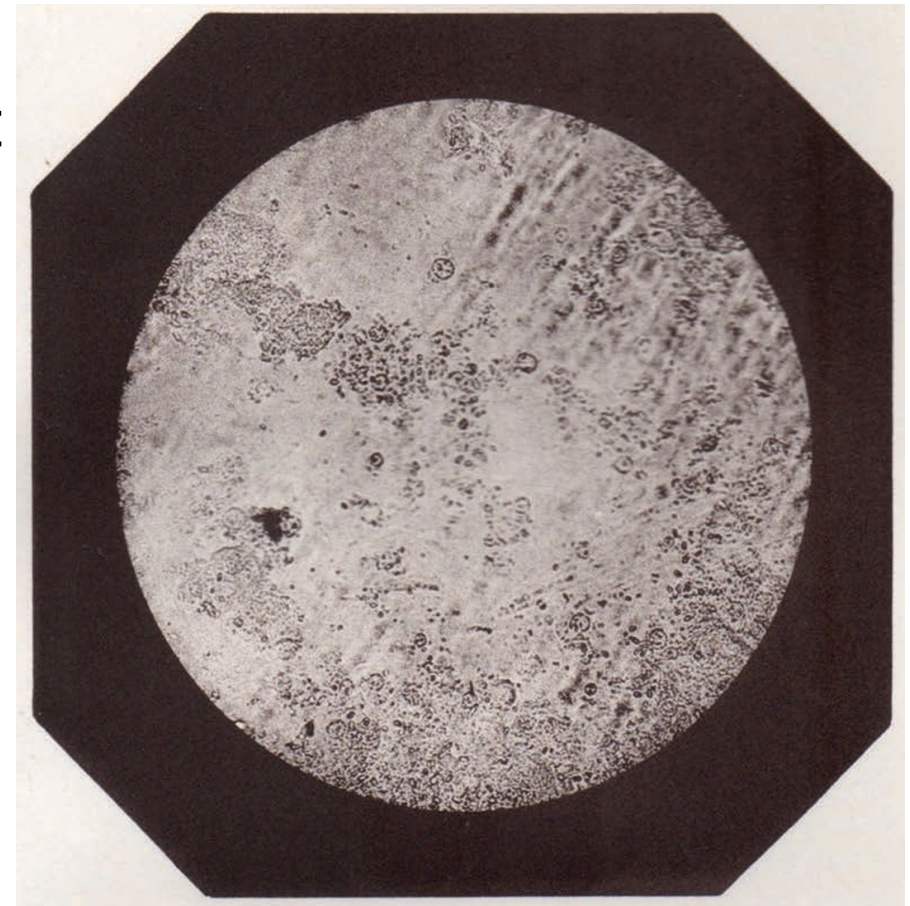
# Silkworm diseases - muscardine, pébrine, flacherie

Italy –early 1800's

- Bassi studied muscardine for 25 years
- proved it was a fungal disease and that hygiene measures could prevent spread

France – 1865 – sericulture was most important agriculture in France

- 2 remaining silkworm diseases devastated the industry, cocoon production ↓ from 26 million kg to 4 million kg in 8 years
- French Minister of Agriculture offered 500,000 francs for “infallible remedy”
- Pasteur proved that pébrine “corpuscles” were transmitted from sick to healthy worms, and that eggs from infected moths would produce sick worms
- Hygiene measures controlled the disease



# Silk Industry

- Remained important in France until early 1900's when Asian imports became less expensive
- 1900 – 1940 – Japan most important exporter of silk to Western countries – controlled 60% silk industry
- WWII – Japanese silk cut off
- Mao Zedong, Peoples Republic of China, Great Leap Forward decimated Chinese silk production
- India became major exporter of silk textiles

# Silk in India

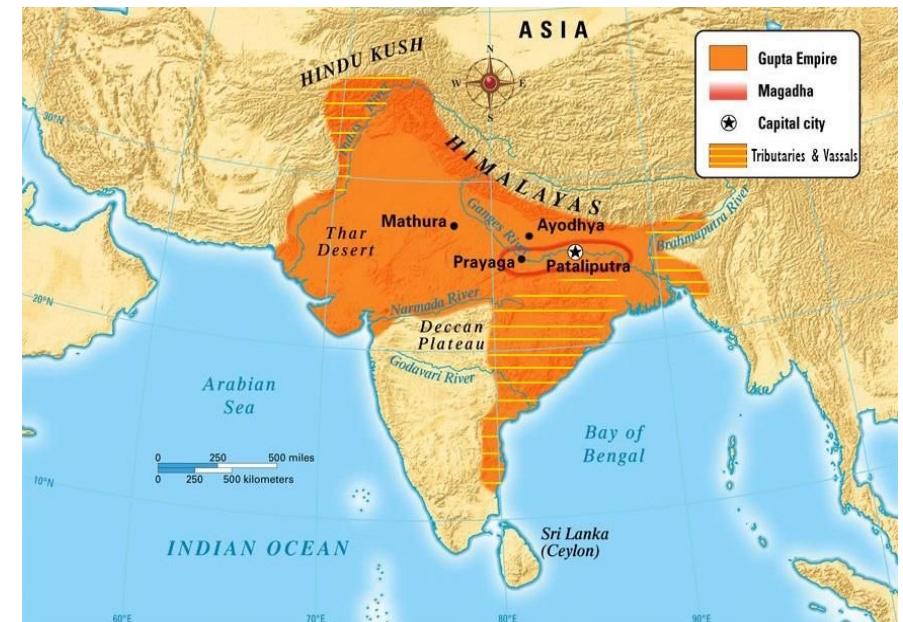
## Indus valley 2450 – 2000 BCE

- Gathered wild silk cocoons after moths hatched
- Degummed same as Chinese
- Exported silk fabric to Egypt, Persia



## Gupta period 400 – 600 CE

- Sericulture came to northern India from China via Buddhist monks
- India moved from wild silks to *Bombyx*
- India exported silk to Persia via Silk Roads

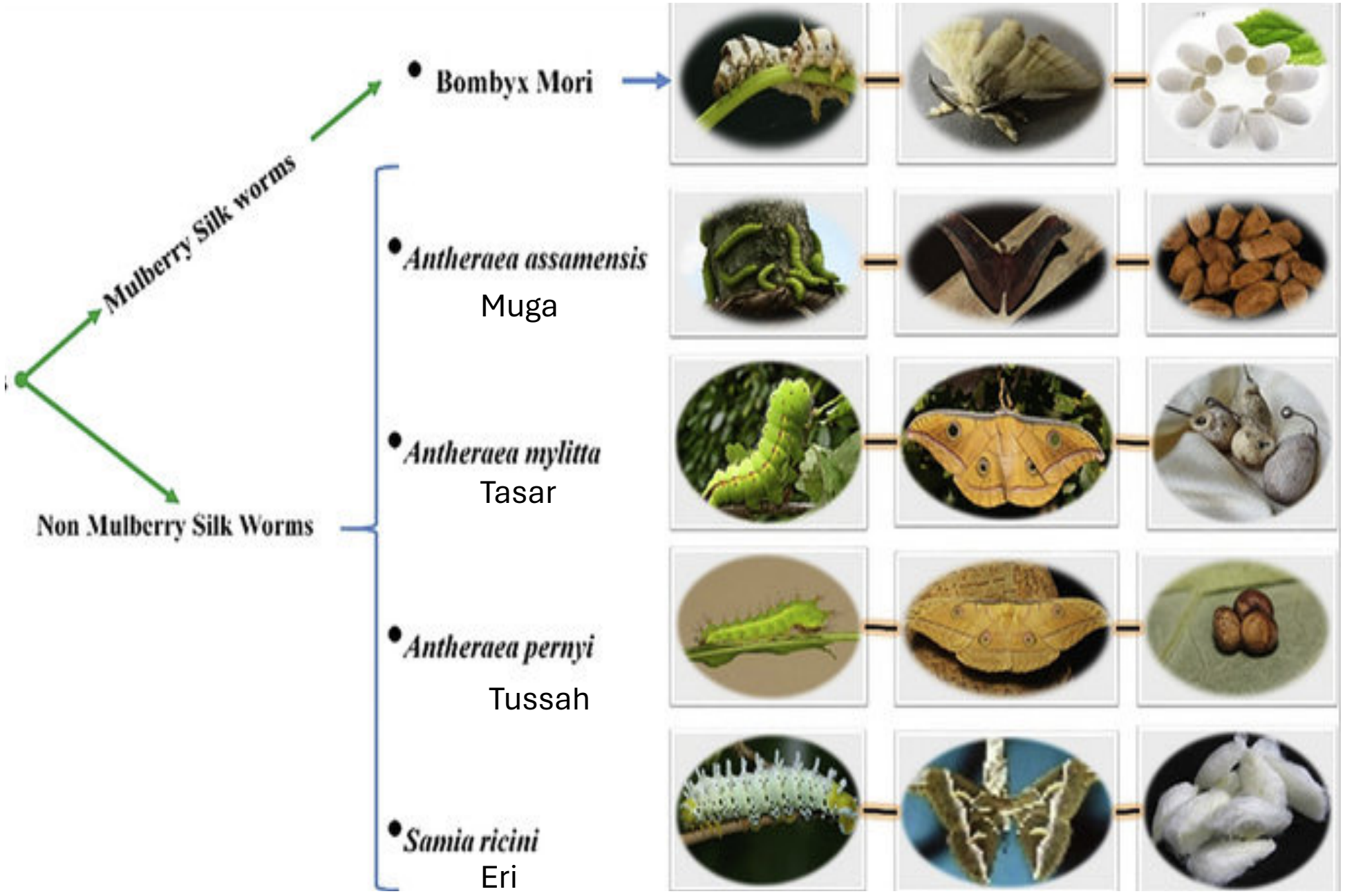




# Silk in India – Wild Silks

- Cultivated partly or not at all – not dependent on humans
- Moths allowed to hatch → short fiber lengths
- Must be spun, not reeled
- Preferred by Orthodox Hindi, Jain, some animal rights persons





# Silk in India Now – world's second largest exporter



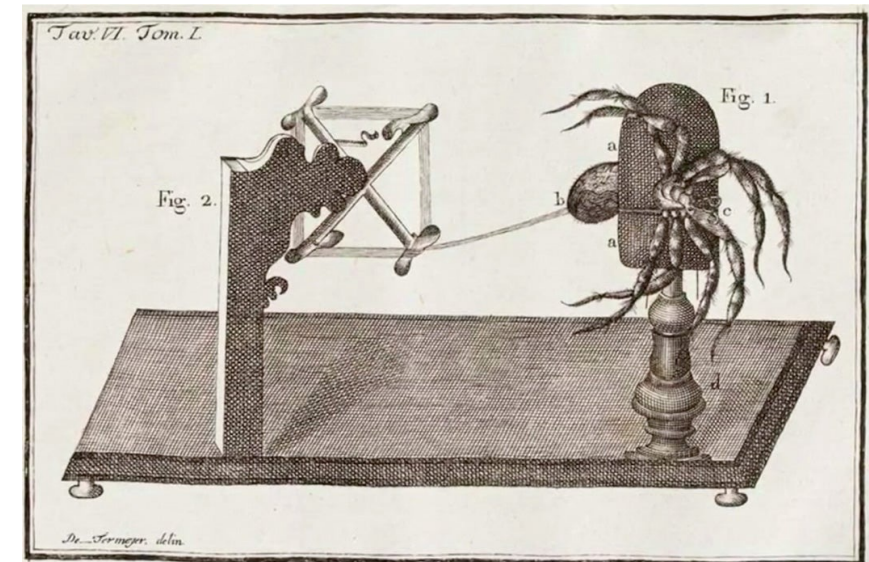
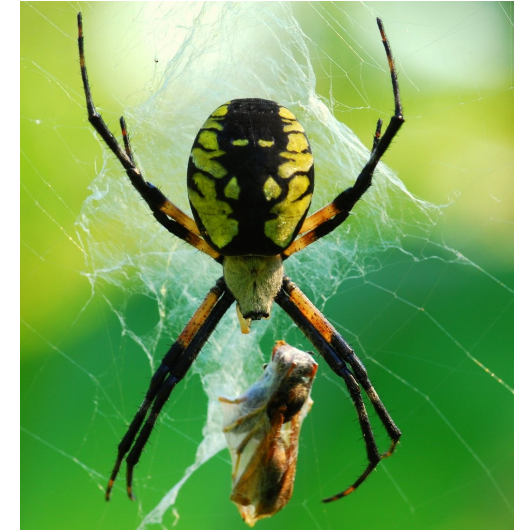
# Non apparel uses of silk

- Armor
  - Chinese, Japanese, Mongols
  - Bullet-proof vests 1890
  - Stronger and lighter than Kevlar
- Military balloons and parachutes
  - WWII shortage of silk spurred invention of nylon
- Cosmetics
  - Fibroin holds water, hydrates and moisturizes
- Medical
  - Suture from antiquity onward
  - Bioengineering nerve sheaths, cartilage, artificial vocal cords
  - Stabilization of vaccines, medications
  - Potential drug delivery vehicles



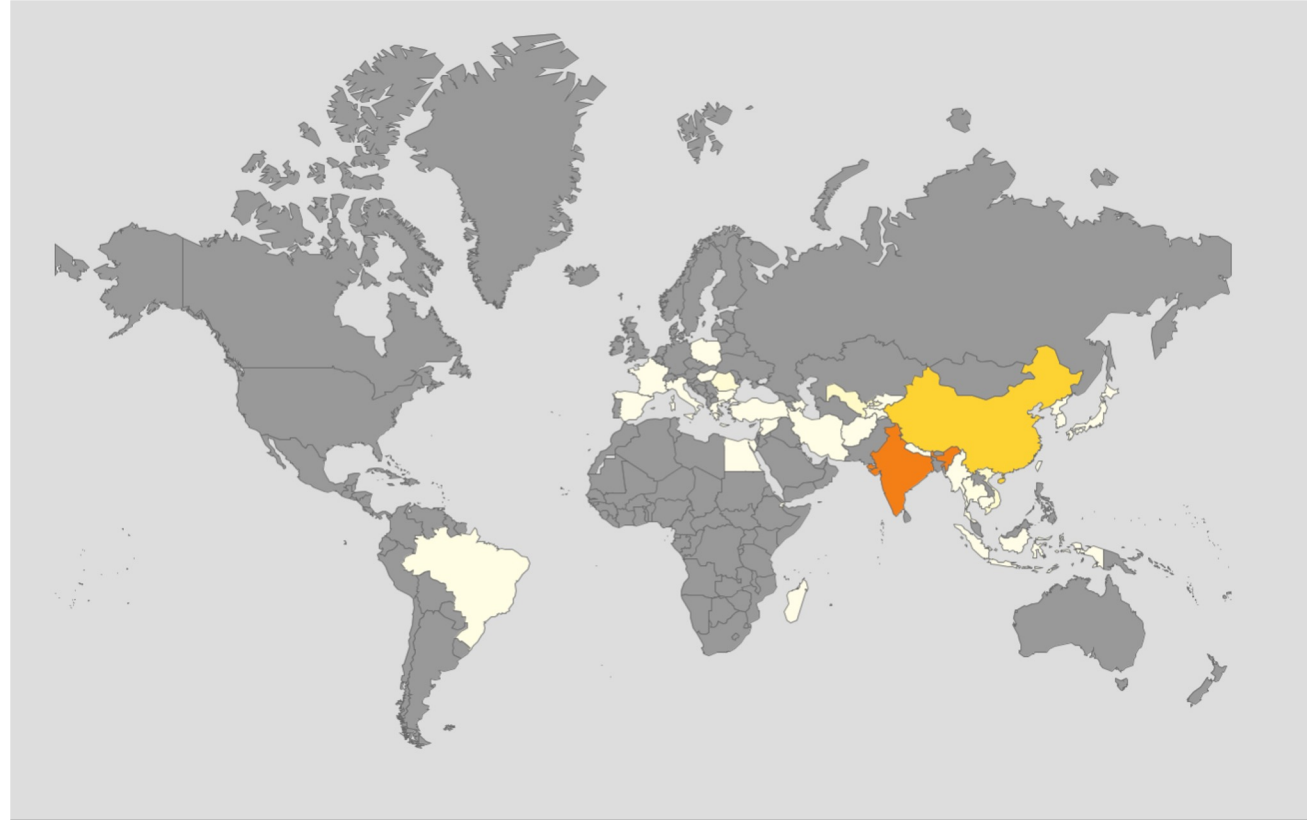
# Spider Silk –stronger than silkworm silk

In 2012, the Victoria & Albert Museum exhibited [the largest pieces of spider silk fabric](#) ever made: a shawl and a cape produced with the silk of 1.2 million golden silk orb-weaver spiders.



# Silk Today

- 0.2% of global fiber market
- \$17 BILLION market value (2021)
- China produces 146,000 tons, ~ 1 million silk workers, – 66% world production
- India – 35,000 tons - almost 8 million silk workers – linked to child labor – govt support of rural sericulture and weaving
- Uzbekistan, Viet Nam



# Silk Today

## Environmental Impact

- Silkworm farms use energy to keep worms warm
- Mulberry trees irrigation intensive
- Toxic dyes (not just silk)
- Peace silk – worms allowed to hatch
  - short fibers and varied thickness
  - less consistent
  - less sheen



# Questions and Comments





*Thanks for your attention!*

Extra slides

# Qing Dynasty

- “Starting in the mid-eighteenth century and continuing, with increased frequency, into the early decades of the nineteenth century, Europeans (especially the French), baffled by the low cost and high quality of Chinese silk products, began sending experts – industrial spies – to China to study and possibly acquire the technical “secrets” of Chinese silk production. They came back almost emptyhanded, apart from marginal details and processes which brought no radical change to the way sericulture and silk industry were practiced in the West.” -- Claudio Zanier, *The Silk Cycle in China and its Migration*

# There were strict clothing regulations in the Hàn Dynasty

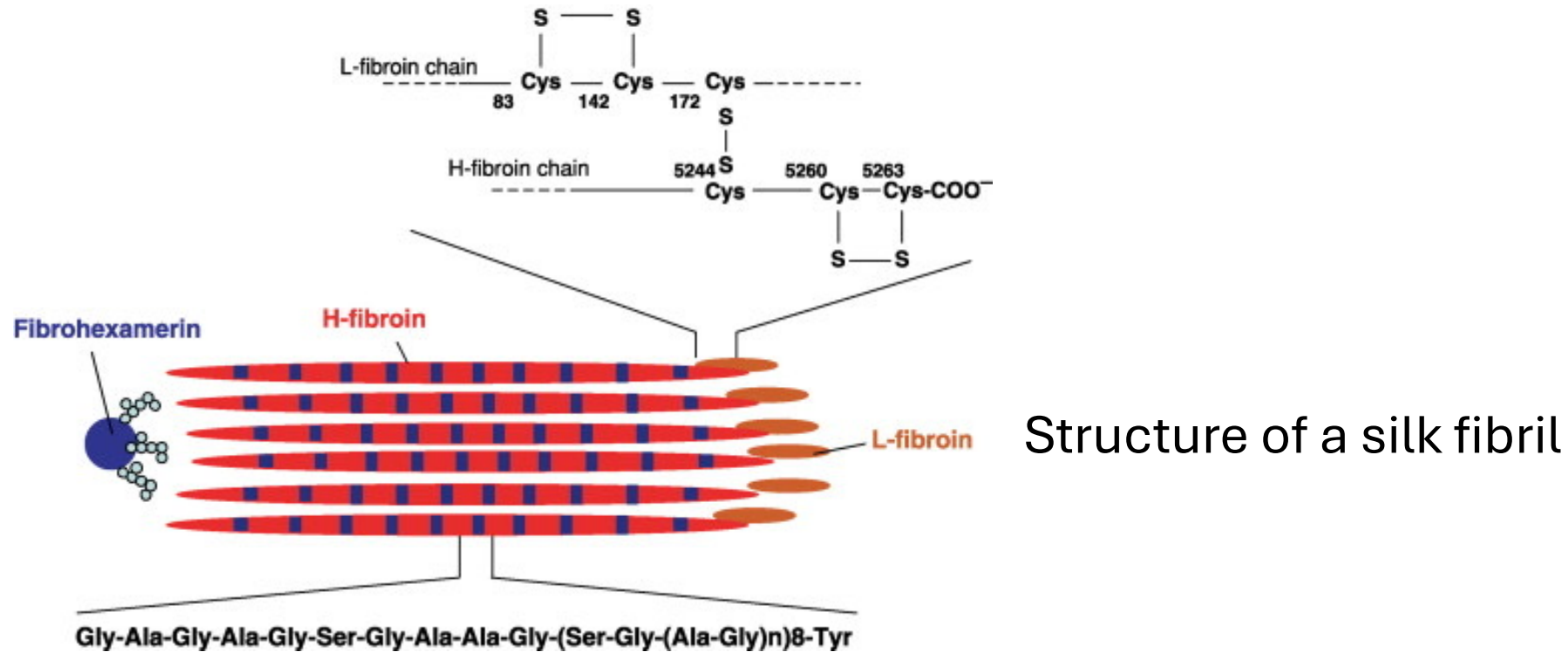
- Emperor Míng in 59 CE required black top and ocher-yellow bottom for the emperor and 12 ornamental symbols to distinguish social rank among others
- Women wore a 4-piece belted silk skirt



Jade silkworm carving

# Silk is made of fibroin and sericin proteins

- Fibroin is the main protein



- Fibrohexamerin helps hold the fibroin molecules together
- Sericin is a water soluble, gluelike protein with 32% serine that coats the fibers
- Fibroin/sericin are secreted by anterior/middle silk glands