Dear visitors,

For three months in the 2020 early summer, we held the curator course at the Nature and Science Museum in Tokyo University of Agriculture and Technology (TUAT). The students made the exhibition panels that links the permanent exhibition with respective student's expertise and interests.

The students focused on exhibits related to sericulture and textiles, which was the beginning of TUAT and respective panel was deeply surveyed from the student's perspective.

The students made various efforts, such as assigning themes that were not always close to contents that they studied or challenging to interpret unfamiliar ancient writing. While there were many limitations in COVID-19 pandemic, they practiced “we were able to communicate through this virtual student exhibition.” Please enjoy it!

Nature and Science Museum 東京農工大学 科学博物館

Silkworm Studies

at the Tokyo University of Agriculture and Technology

The history of the Nature and Science Museum, Tokyo University of Agriculture and Technology (TUAT), dates back to 1886, when the Reference Exhibition Room was established at the research laboratory of silkworm diseases at the Ministry of Agriculture and Commerce. Since then, the museum has collected and displayed organized collections of cocoon and silk yarn specimens. In this exhibition room, there are approximately 100 specimens of cocoons that have been collated from across the world since the 1900s. Specimens are exhibited in boxes with detailed information describing the name of the specimen, place of origin, and year of collection. There are cocoons and silk yarns for the eight domestic species and seven foreign species, and these are displayed in the raw-silk specimen cases. Furthermore, there are displays of materials used for education and practical training from earlier times, such as cocoon-making models and sick silkworm models.

In TUAT, research on silk fibers became the basis of current engineering research, whereas biological research on silkworms continued in the area of agricultural science. *Sangaku*, silkworm studies, one of the various sectors of agricultural science, studies the biology of silkworms and has contributed to the improvement of production technology in the silk yarn industry through research in silkworm breeding and growing. Silkworm studies have also played an important role in basic biology including genetics, embryology, and physiology. In fact, silkworm research has contributed to proof for the law of Mendelian inheritance, isolation, and identification of sex pheromones and other hormones, and isolation of mRNA from eukaryotes. Recently, the creation of genetically modified silkworms and decoding of the silkworm genome have been explored.

Currently, silkworm research is applied to and focused in biotechnology. This has included: developing new materials, such as silk-based medical materials and cosmetic materials; developing pharmaceuticals, such as using genetically modified silkworms vaccines against intractable diseases; and producing fluorescent-colored raw silk. Advanced research using silkworms is also conducted in TUAT. For example, the genetic analysis of silkworm early pupation under stress clarified that the expression of superoxide dismutase (SOD), which decomposes superoxide radicals, must be decreased and superoxide radicals in the body must be increased. This kind of research is useful in understanding the evolution and success of insects due to their high environmental adaptability.

Photos by Laboratory of sericultural science, Tokyo University of Agriculture and Technology

東京農工大学 科学博物館
Nature and Science Museum
Curator course 2020

Knowledge of silkworm and cocoon materials

1 Introduction

The history of the National University Corporation Tokyo University of Agriculture and Technology Science Museum dates back to the “reference goods display area” established at the Silkworm Disease Testing Center of the Ministry of Agriculture and Commerce in 1886. Since then, the University of Agriculture and Technology has focused on the collection and exhibition of prefectural silk materials, and now the exhibition room of the museum displays samples of cocoons and raw silk, cocoon-making samples, and collections related to the sericulture of the Imperial Family.

2 What are domestic silkworms and wild silkworms?

Approximately 600 kinds of silkworm are now known in Japan. These can be classified into domestic silkworms and wild silkworms.

It takes a long time to raise silkworms and create good varieties.

Since the breeding environment is different between domestic silkworms and wild silkworms, the nature of the silk produced also differs. The chart below shows a comparison between domestic and wild silkworms.

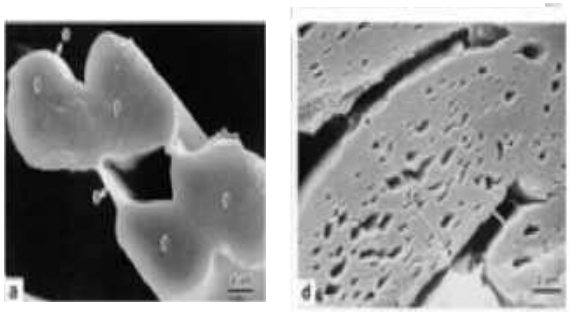
	domestic silkworms	wild silkworms
Ease of breeding	○	△
Raw silk productivity	○	△
Habitat in the wild	×	○
Indoor breeding/ Breed improvement	◎	○
Silk luster	○	△

3 Characteristics of wild silkworm yarn

There are five species of wild silkworm on the market: Japanese oak silkmoth Chinese tasar moth, Eri silkmoth, Tasar silkmoth, and Muga silkmoth The silk of the Saturniidae family, a group of Japanese oak silkmoth, is porous, with many vesicles in the cross section. This structure makes a stronger luster than the silk of the domestic silkworm. In particular, the silk of Japanese oak silkmoth is called “diamond of fiber” because of its beautiful luster. The wild silkworm's yarns are difficult to dye and mass-produce, unlike the yarn of domestic silkworms, which have been reared and bred for thousands of years. Although it is difficult to produce the individuality of the yarn from each species of wild silkworm is very attractive.

Fig.1. The cocoon collection Ⅰ in the Nature and Science Museum, Tokyo University of Agriculture and Technology.

Fig.2. SEM image of a cross-section of dense cocoon thread and porous cocoon thread (Akai, 2007).



Bombycidae family (left) and Saturniidae family (right). The thread of Saturniidae has many small holes in the fiber cross-section, whereas Bombycidae does not.

4 Important characteristics of silkworms for breeding

①Sturdy
：Whether the larvae and pupae are robust.
②Fertile
：Normal eggs and those with high hatch rates and high collection efficiency should be selected.
③Cocoon yield
：The heavier and more robust the cocoons are, the higher the yield. However, the heavier the cocoon, the less robust it tends to be, and a balance needs to be considered.
④Efficiency of silk production
：Silkworms that produce a large amount of cocoon yarn should be selected.
⑤The quality of silkworm
：high release rate and long cocoon thread.

Fig.3. The cocoon collection Ⅱ in the Nature and Science Museum, Tokyo University of Agriculture and Technology.

Fig.4. Geographic races (Kogensya HP)

[Japanese race].
Developmental course of the larvae ：long.
Cylindrical cocoons with thick fibers.

[Chinese race]
Developmental course of the larvae ：relatively short.
Oval cocoons with long, thin cocoon threads.

[European race]
Developmental course of the larvae ：long.
The cocoons are bale-shaped or oval and have thick cilia.

[Tropical race]
Developmental course of the larvae ：short.
Cocoon is spindle-shaped and silkworms produce high numbers of cocoons →cocoons. -breeding of these varieties produces a breed more suitable for sericulture.

5 Column: Do you know that sericulture is still practiced in the center of Tokyo?

The location is “1-1 Chiyoda, Chiyoda-ku, Tokyo,” that is, the Imperial Palace. The history of sericulture in the palace dates back to the Nihon Shoki. In the fourth year of the Meiji Era, the Majesties of the then Empress (later Empress Shoken) started sericulture in the palace in order to encourage sericulture in Japan, and “sericulture” has been inherited by the current Michiko Empress. The Japanese breeding silkworm “Koishimaru” is difficult to breed and the thread production is small, so we faced a crisis in which this strain was interrupted. However, successive Majesties have consistently bred this breed.

Kaiko Yashinai no Zenzu

Complete Illustration of Silkworm Cultivation (No. 1~7, 9~10)
1883, Utagawa Yoshifuji (1828~1887)

Ukiyo-e, a popular printmaking style developed in the Edo period, is one of the most famous and traditional achievements of Japanese culture. Many *Ukiyo-e* were created on the themes of sericulture, spinning, and weaving, collectively called sericultural *nishiki-e* (*sanshoku-nishiki-e*). Many sericultural *nishiki-e* were printed during the late Edo and Meiji periods, with their content varying slightly from period to period. In some works of the Meiji period, the Emperor is portrayed observing operators at work, demonstrating the connection between the imperial family and the sericulture industry.

The "Complete Illustration of Silkworm Cultivation" (*Kaiko Yashinai no Zenzu*) depicts the sericultural process of boiling cocoons, taking up thread, grooming, reeling in, making silk, producing silk wool, and weaving. The people in these prints are female, and their clothing is glossy (contrasting the reality of their work), meaning that these prints are more akin to depictions of beautiful women and genre prints of manners and customs than actual sericulture operations.

1. Hatching

Silkworm eggs laid on paper hatch in *kokuu*, the 6th solar term, equivalent to April 20 in the Gregorian calendar. This is called *kaeru*, hatching.

2. Picking Mulberry Leaves

After their birth, silkworms are given mulberry leaves picked in the mountains, and grow gradually until they make cocoons.

3. Feeding Young Silkworms on Mulberry Leaves

Those responsible for feeding silkworms do not mix the newly-born with those hatched on previous days, but place them separately in *oshiki**, feeding them finely chopped mulberry leaves.

**oshiki*: square trays made from Japanese cypress

4. Grown Silkworms

Silkworms grow larger as they are fed mulberry leaves, and are eventually transferred to *sanpaku*, bamboo blinds, where they continue to feed on mulberry.

5. After *Oonemuri*, the Great Slumber

The fourth dormancy is called *oonemuri*, the great slumber. After molting, the supply of mulberry leaves must be increased, and rapeseed stamen may also be provided.

6. Cocoon Making

Leaves and twigs of Japanese chinquapin are laid out, and the silkworm larvae (ripe silkworm) placed on them to make cocoons. Four or five days later, the complete cocoons are removed from the scaffold. This operation is called *shuuken*.

7. Preservation of Cocoons and Disposal of Chrysalides

The cocoons are dried, then soaked in salt*. Bamboo blinds are put on the bottom of a large jar, followed by paulownia leaves, upon which the cocoons are placed and then sprinkled with salt.

*salt: Chrysalides are killed by exposure to salt. Otherwise, the cocoons would be damaged by the emergence of the adult, or by molds inside.

9. Creation of Silk Floss

Cocoons which do not become threads are made into silk floss. The cocoons are sorted into upper, middle, and lower ranks*, and after shaping, multiple slices are tied up in bundles of silk floss.

*upper, middle, and lower: These are cocoon ranks. Upper cocoons are pure white, but stains are visible in middle and lower cocoons. (Source: Isehara Cultural Assets Site)

10. Filature

Pristine white cocoons are used for fine threads, while blackened ones are used for coarse threads.

Silkworms and Cats

Cats appear in the *Kaiko Yashinai no Zenzu*, because sericulture farmers kept them as a countermeasure against damage by mice, which can eat the larvae of silkworms. From the latter half of the Edo period in particular, keeping cats was actively encouraged.

Current Use of Silkworms

While Sericulture has declined in Japan, silkworm studies currently play important roles in genetics, embryology, and physiology, since silkworms are easy to handle as experimental animals. Silkworm research is applied to developing new materials, pharmaceuticals, and producing fluorescent-colored raw silk.

Shinban Yousan Hanei Sugoroku (1876)

◇About Sericulture Sugoroku

Sugoroku is a game of dice which depicts the silk production process, from the hatching of silkworms to the production of silk threads. Because of this, it is also called Sericulture Sugoroku.

It is said that the Sericulture Sugoroku originated from the "new edition Oshu-style Sericulture Hayami Shuroku Roku," which was distributed to late Edo-era farmers as a New Year's gift. It was also used to educate children in villages where sericulture was important, about the procedures involved in silk production. Therefore, it is considered to have a role as *nishiki-e* for foreigners. It should be noted that the order of sericulture procedures and their names may differ depending on the region.

① Sweeping off the baby silk worm
The silkworm that just hatched from the egg is swept into the rearing container using a hawk's feather.

The feather broom on display in our museum

⑧ Silk worms in 'Funa no ioki'
The silkworm molts four times, at which time they become inactive and do not eat much mulberry leaf. The sleeps are known as, in order, shishi no ioki, taka no ioki, funa no ioki, and niwa no ioki. However, they are depicted out of order here.

⑨ Feeding with chopped up mulberry leaves
The silkworms are fed with chopped mulberry leaves to ensure that each worm eats the same and grows homogenously.

⑩ Preparing the shed for silkworm
The method of raising silkworms by stacking the silkworm beds like shelves is called 'shelf- keeping'.

The shelf used to raise silkworms

⑫ Silk worms in 'Niwa no ioki'
This is when silkworm is in Niwa no ioki' sleep, the last one.
Silkworm farmers have long kept cats to protect their precious silkworms from rats. Long ago cats became the "cat gods" for silk farmers, and they came to cherish them.

⑬ The last sleep of the silkworms
The fourth rest is also called the Great Sleep. After waking up from a heavy sleep, the silkworm starts to eat more mulberry leaves than before. In this scene, we see that the silkworms are fed whole mulberry leaves because it is no longer possible for the silkworm to eat chopped leaves.

⑯ Collect the Twigs
It is believed that they are preparing the materials for making mabushi. The mabushi is a frame made of twigs or straws. It is made in such a way that the silkworm can easily cocoon on it as silkworms have a habit of cocooning where there is a section of twig or straw.

In this Sugoroku, eda-mabushi is picked up. In this museum, the wara-mabushi, the modified straw-mabushi and the Shimada-mabushi are on display.

straw-mabushi

⑰Remove cocoons from mabushi
The cocoons are removed from the mabushi.

⑱Grading cocoons
The cocoons removed from the mabushi are sorted according to their state and quality.

⑲The moth emerges from the cocoon
The silkworms that will spawn the next generation emerge from their cocoons as adult moths.

㉒ Saltwater soaking
One of the methods of killing the pupae inside the cocoons is the salting method, in which they are salted and sealed. The pupae are slaughtered to prevent them damaging the cocoons when they emerge, or else they die and decay inside the cocoon, causing mold inside.

㉓ Made into mats
Silkworm cocoons that are not used for silk are boiled with lye, rinsed with water, dried, and brushed into cotton.

㉔Hand Filature
This shows an instrument for reeling filament by hand, called a hand filature. It is a historical instrument that winds the thread onto a spool as the cocoons are stirred in a pan to separate the filaments.

Hand Filature displayed in the museum

㉕Silk Reeling Machine
In this illustration, workers use a machine to reel the silk off cocoons to make yarn. In this museum, the Minorikawa-type multi-thread reeling machine and Masuzawa-type multi-thread reeling machine are exhibited.

Minorikawa-type multi-thread reeling machine

◇How to Play SUGOROKU◇

The game begins at the 'START' at the bottom right of the board, and moves to the right. Roll the dice and move the number of blocks shown on the dice.
When you hit the square marked "Tomari(泊), you should skip one turn.
When you reach the square in the middle with the 'Silk reeling machine' on it, you will have won the game.
When you get surplus one, go back to Block 24, "Zaguri."
If you get surplus two, move back to Block 23,"Made into mats."
If you get surplus three, move back to Block 22, "Saltwater soaking."
If you get surplus four, move back to Block 21, "Gathering cocoons."
If you get surplus five, move back to Block 20, "Drying cocoons."

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ガラ紡績機械とは

撚子(よりこ：原料の綿)の入った筒から自動で糸を引き出し、紡ぐ機械です。日本で最初の紡績機械で、1873(明治6)年に臥雲辰致(がうんたっち)により発明されました。糸を紡ぐときにガラガラと音を立てることから名付けられ、通称ガラ紡とも呼ばれます。

それまでの手紡ぎから、同時に何本も紡ぐことが可能になり、大幅に生産性が向上しました。また、取り扱いが簡単であること、安価で小資本でも操業できることなどの利点から、ガラ紡績機は日本の産業革命の担い手となりました。1942年には最大402万錘が稼働し、経済発展を支えましたが、西洋紡績技術の導入により徐々に衰退していきました。しかし近年、ガラ紡糸の独特な風合いや、製造過程に発生する繊維くず(落ち綿)を再利用できる点が見直されています。さらに、ガラ紡技術はNGOによりネパールやタンザニアへ輸出され、国際貢献に寄与しています。

ガラ紡糸は西洋紡績糸と比べて撚りが甘く、でこぼこして切れやすいという特徴があります。一見短所のようですが、これらの性質が高い吸水性・保水性や柔らかさをもたらしています。ガラ紡糸は手紡ぎ糸に近いあたたかな風合いをもち、現在もタオルや衣料品に用いられています。

(左)ガラ紡績機械　(中央)ガラ紡糸　(右)ガラ紡糸を織って作った布

(Left)Gala Spinning Machine　(Center) Gala Spinning Thread　(Right) Cloth made of galabo yarn

What is Gala Spinning Machine?

Gala spinning machine automatically pulls out yarns from a tube containing raw materials like cotton pliers and spins them. The first spinning machine was invented by Tacchi Gaun in Japan in 1873 (Meiji 6). It was named after the rattling sound it made while spinning and was commonly called the Garabo.

The machine has greatly improved the productivity of spinning many yarns simultaneously instead of conventional hand spinning. In 1942, the machines were in operation at the maximum capacity of 4,020,000 weights, supporting the economic development of the native country until the introduction of western spinning technology, which gradually led to the decline of the spinning industry. In recent years, the unique texture of Galabo yarn and the ability to recycle fiber scraps (cotton waste) generated during a manufacturing process have been improved. Thus, the Garabo technology is now being exported by NGOs to Nepal and Tanzania, contributing to the international community.

Compared with western spun yarns, the Galabo yarn has a lower twist and is characterized by its bumpiness and tendency to break. At first glance, this may seem to be a disadvantage, but these characteristics give it high water absorption, water retention, and softness. A Garabo yarn has a warm texture similar to a hand-spun yarn, and it is still used for spinning towels and clothing.

以下のリンクからガラ紡績機械が稼働する様子を動画で見られます！

Click the link below to watch a video of the Gala Spinning Machine in action!

https://www.youtube.com/watch?v=HpIb8bvw4qg

Nissan Automatic Silk Reeling Machine , Type HR-2

is a machine for making silk from cocoons of silkworms.

It automatically takes out the yarns from multiple cocoons and turns them into a single raw thread.

That's the point!

The machine automatically replenishes an additional cocoon when it almost consumes the yarn from one cocoon.

The cocoon is made of a single yarn, which is thin inside.

When a machine senses that a yarn is getting thin, it replenishes additional cocoons to make raw silk to maintain a certain thickness.

This disk of the machine acts as a sensor to maintain the thickness of the yarn.

This machine has enabled the efficient mass production of silk, which is very uniform and impossible to be made manually, with only three people per set.

The machine is so advanced and creative that it has acquired many patents.

It has greatly contributed to technological innovation in the silk industry.

ジェット織機　Jet Loom

－ハイスピードで安全に織る織機－

ーLooms with high speed and safetyー

ウォータージェット織機（Water Jet Loom）

この織機は、1950年代にチェコスロバキアで生まれた“水を使ってよこ糸を運ぶ”というアイデアをヒントにプリンス自動車工業が独自開発した水の噴流でよこ糸を挿入して織る織機である。生産能力はシャトル織機の数倍有り、よこ入れは水鉄砲と同じ原理で水を噴射して行う。

長所：超高速で織ることができ、対人生産性に優れ、製織コストが安い。
短所：素材が疎水性長繊維合繊（ナイロン、ポリエステルの裏地等）に限られる。

この織機を使うと製織布は濡れてしまうため、水分の吸引を行う構造になっている。長時間放置するとカビが生える恐れがあり、場合によっては乾燥工程を通す必要もある。

A water jet loom, originally developed in the 1950s in Czechoslovakia and then later refined by Prince Motors, Ltd., uses a stream of water to insert weft threads during weaving . Water jet looms have a much greater production capacity than a shuttle loom. Due to the use of water, the produced textile is wet; to avoid the growth of mold or ruining of the textile, the loom is structured to suck water. In some cases, a drying process is necessary.
Advantages: ultrahigh weaving speed, extensive human productivity, and low weaving cost.
Disadvantages: a drying process is required before finished materials can be stored or transported, and only hydrophobic, long-fiber synthetic fibers (e.g., nylon or polyester lining) can be handled.

動画で見てみよう→
Scan QR code to watch videos!

エアジェット織機（Air Jet Loom）

20世紀に入り、人口の急増とともに織物需要が急増したことにより、従来のシャトル織機より速く織ることができるエアジェット織機が開発された。
圧縮した空気流で横糸を飛ばして織る織機であり、従来のシャトル織機の6倍の速さで織ることができる。

長所：各種素材の織物を超高速で織ることができる。対人生産性に優れる。
短所：圧縮空気を得るためのエネルギーコストが高い。

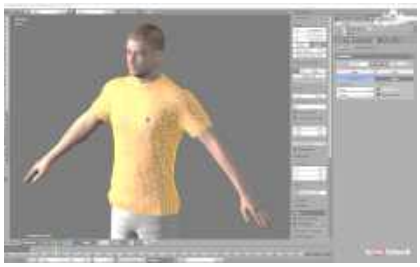
また、シャトルを叩いて飛ばす際に生じる衝撃音による騒音を解消したため、作業環境の改善にもつながった。
エアジェット織機の登場により、織物が安価に、豊富に提供されるようになった。

The air jet loom was developed at the beginning of the 20th century to address the heightened demand for textiles associated with the rapid population increase. Six times faster than the conventional shuttle loom, the air jet loom uses compressed air to weave textiles. Furthermore, air jet looms do not use a shuttle, which drastically reduces noise, thus improving the working environment. However, the required compressed air is costly. Still, the widespread use of the air jet loom has decreased the cost of textiles.

動画で見てみよう→
Scan QR code to watch videos!

未来の織機予想－20XX年の織機－　Looms in the future

◆織機から直接衣服をつくる！？
Make clothes directly from looms!?



送られたデータを読み込んで、織機から直接衣服を織ることができるようになったとしたら、3Dプリンターでは生み出せない質感の衣服を作ることができるかもしれません。
If it enables to make clothes directly from looms, it will possibly make better clothes than 3D printer in texture.

◆「透明マント」が現実に！？
Is it possible to make Invisibility cloak in real?

負の屈折率を持つ人工物質であるメタマテリアルを用いた素材を使って、SFやファンタジーでお馴染みの「透明マント」のようなアイテムも織機で作れる未来もあるでしょう。
Using metamaterials, which are man-made materials with negative refractive indexes, we may be able to make items such as the "invisibility cloak" familiar in science fiction and fantasy in the future using looms.

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The tradition and application of silk

Silk is luxury fiber is made from cocoons produced by silkworms.

How to produce raw silk

Cocoons of silkworms

Drying and storing cocoons

:kills pupas of silkworms and stops propagation of mold

Selection of good cocoons

:removes of dirty cocoons

Boiling cocoons and yarning fibers

:simplifies disentangling the fiber from cocoons and twists the fiber to form yarn

Stabilization

:makes the silk's strength, gloss, and texture uniform

Finish!

Following are the advantages of silk

- Exhibits a special gloss
- Can be dyed vividly
- Exhibits high strength
- Exhibits hygroscopicity and high permeability

Traditional usage of silk

Kimono

Strings of Koto

New future potential of silk

Silk has high biocompatibility, therefore, it is expected to be used in medical and cosmetic applications.

Silkworm cocoon

Nakazawa Laboratory, Tokyo University of Agriculture and Technology

Liquefaction

Cosmetics

Nakazawa Laboratory, Tokyo University of Agriculture and Technology

Spongy formation

Regeneration medical base material

Nakazawa Laboratory, Tokyo University of Agriculture and Technology

Membrane formation

Wound healing agent

Nakazawa Laboratory, Tokyo University of Agriculture and Technology

Powderization

Health food effective for lifestyle disease

Plastic resin

Nakazawa Laboratory, Tokyo University of Agriculture and Technology

The Ministry of Agriculture, Forestry and Fisheries of Japan aimed to create a new market and establish silk production systems in 2019.

Silk is now attracting renewed attention in both the textile and non-textile fields!

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2020年度 博物館実習