SERICULTURE TECHNOLOGY (22ZOONME21)

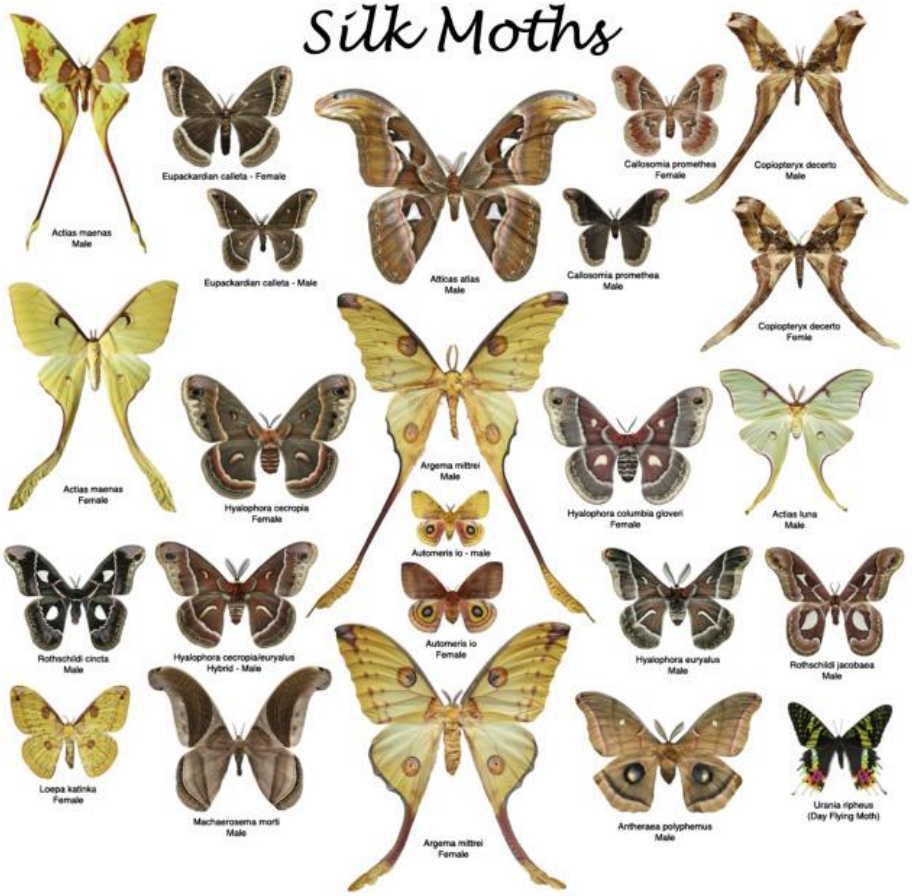
Qualitative properties of Silk

SYSTEMATIC CLASSIFICATION OF SILKWORM

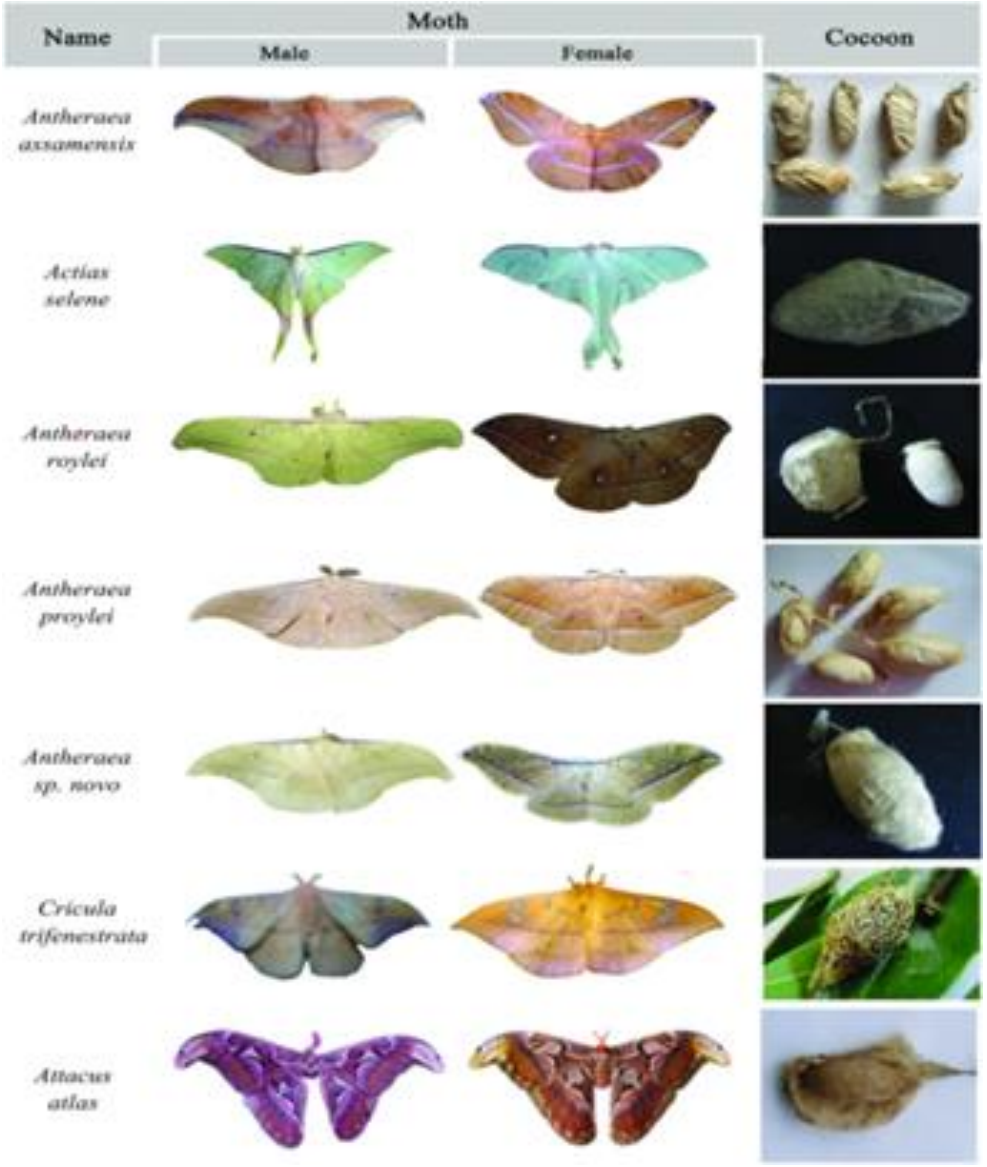
Phylum	Artropoda
Class	Insecta/Hexapoda
Ordo	Lepidoptera
Subordo	Macro Lepidoptera-Heterocera
Super Family	Bomycoiden
Family	Bomycidae
Genus	Bombyx
Species	B. mori

Introduction

- Mulberry silkworm – B.Mori – domesticated worm – reared throughout the world
- Wild ancestor – B.mandarina occurs wild in nature but only in a few isolated regions in the foothills of the Himalayas
- The native tribal people collect the cocoons of this worm
- Silk reeled from them is of a superior quality and is sold as wild silk and fetches a higher premium price because it is very rare



Some other Indigeneous silkworms...



Temperate Breeds	Tropical Breeds
1. Temperate breeds are all either Uni/ Bivoltines. They lay both hibernating and non hibernating eggs.	1. Tropical breeds are all Multivoltines. They lay only non hibernating aggs.
2. Temperate silkworm breeds are Susceptible to Fluctuating environmental conditions as well as poor quality leaves..,	2. Tropical silkworm breeds are resistant to fluctuating/varied environmental conditions and poor quality leaves
3. Temperate breeds are Good Yielders in general i.e., more cocoon weight, shell weight, filament length, denier etc., Eg. E16, Daizo etc	3. Tropical breeds are Poor Yielders in general i.e., more cocoon weight, shell weight, filament length, denier etc., when compared to temperate breeds Eg., Pure Mysore, Nistari, etc.,

EXTERNAL MORPHOLOGY

- Holometabolous insect
- Passes though four morphologically different stages in the life cycle
- Egg
- Larva
- Pupa
- Adult

Sex differences in the Adult

- The male and female moths can be identified from the size of the abdomen, the size of the antennae and the external genitalia

Character	Female	Male
Colour	Paler	Darker
Activity	Less active	More active
Antennae	Small	Large
Body size	Large	Small
Abdomen	Large and flat with seven segments	Long, narrow, eight visible segments
External Genitalia	The caudal end has a median knob-like projection with sensory hairs. This knob is protruded and retracted to expel the pheromone	The caudal end has a pair of hooks known as harpens helping in copulation

Fecundity

- The number of eggs laid by a female moth after mating

Hatching percentage

- the number of larvae hatched from disease free layings.
- The hatching percentage was calculated after deducting the number of unfertilized, unhatched and dead eggs from the total number of eggs laid.
- The formula for calculation is

- $$\text{Hatching percentage} = \frac{\text{No. of eggs hatched in a laying}}{\text{Total no. of eggs per laying}} \times 100$$

- **Weight of ten larvae of fifth instar:** It represents the weight of 10 randomly selected healthy and robust larvae weighed one day earlier to spinning.
- **Larval Duration:** Represents the total duration in hours of rearing period of silkworm from the time of hatching to that of spinning.

Yield of cocoons by number:

- This character represents the survival rate of larvae that spin cocoons.
- The 10,000 larvae brushed is taken as a standard unit.
- The formula for calculation is

- $$\text{Yield of cocoons by number} = \frac{\text{Total no. of cocoons harvested}}{\text{Total no. of larvae brushed}} \times 10{,}000$$

Yield of cocoons by weight:

- It is the total quantity of good cocoons in kilograms obtained for a standard unit of 10,000 larvae brushed. The formula for calculation is

- $$\text{Yield of cocoons} = \frac{\text{Total wt. of cocoons}}{\text{Yield of cocoons by number by weight}} \times \text{Total no. of cocoons harvested}$$

- **Single cocoon weight:** This represents the average weight of randomly selected twenty five cocoons in grams.
- **Single shell weight:** This indicates the total quantity of silk in grams from twenty five cocoons selected randomly.

Shell ratio:

- It is the ratio between shell weight and cocoon weight. It is may be expressed in percentage using the following formula
- Shell percentage = $\frac{\text{Total weight of shell}}{\text{Total weight of cocoon}} \times 100$

Leaf Cocoon ratio

- During each instar, mulberry leaves were weighed every day in the beginning of feeding, and then placed in a plastic sack covered with wetted piece of cotton in front of each replicate.
- The weighed leaves were offered to silkworm larvae 4 times daily, (i.e. at 9 a.m., 1, 4 and 9 p.m).
- At the end of each instar, the remaining food was weighed, young larvae (1st-3 rd instars) were fed on weighed chipped leaves, whereas the grown ones (4th and 5th instars) were fed on weighed whole leaves.
- The mature larvae were transferred to a mounting fork.
- The cocoons were harvested 7 days later, then the cocoon crop was weighed and food consumed per 1000 larvae and fresh cocoon yield per 1000 larvae were weighed to estimate leaf / cocoon ratio as the quantity of mulberry leaves consumed by the larvae to produce one kilogram of fresh cocoons

Cocoon shell ratio %

- Cocoon shell ratio was calculated for both sexes in each treatment according to Tanaka (1964) as follows:

- $$\text{Cocoon shell ratio (\%)} = \frac{\text{Cocoon shell weight}}{\text{Fresh cocoon weight}} \times 100$$

Filament length:

- Total length of filament of single cocoon reeled using epprouvette (a reeling device for monococoon reeling). Mean values of such twenty five observations.

Denier:

- Denier is the thickness of the filament and can be calculated using the following formula.

- $$\text{Denier} = \frac{\text{Weight of the reeled silk}}{\text{Length of the reeled silk}} \times 9000$$

Effective rate of rearing:

- This character represents the ratio of the number of larvae brushed and the number of cocoons harvested from them which is expressed in percentage, the ERR may be was calculated using the following formula.

- $$ERR = \frac{\text{No. of cocoons harvested}}{\text{No. of larvae kept after 3rd moult}} \times 100$$

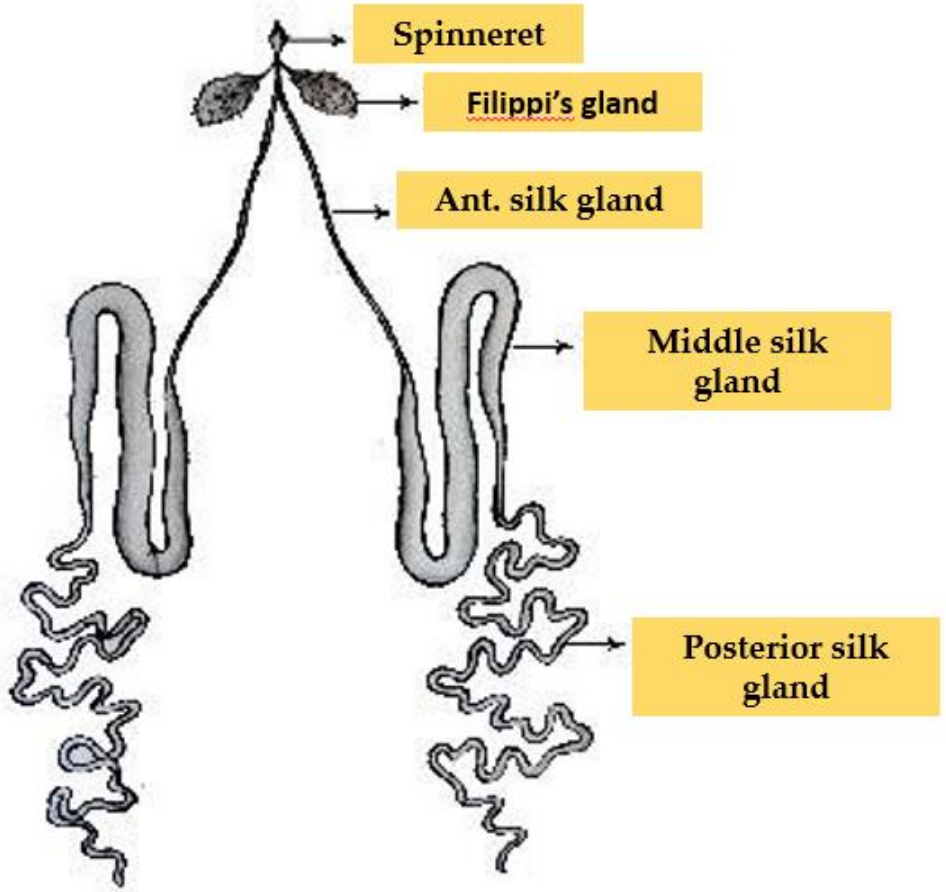


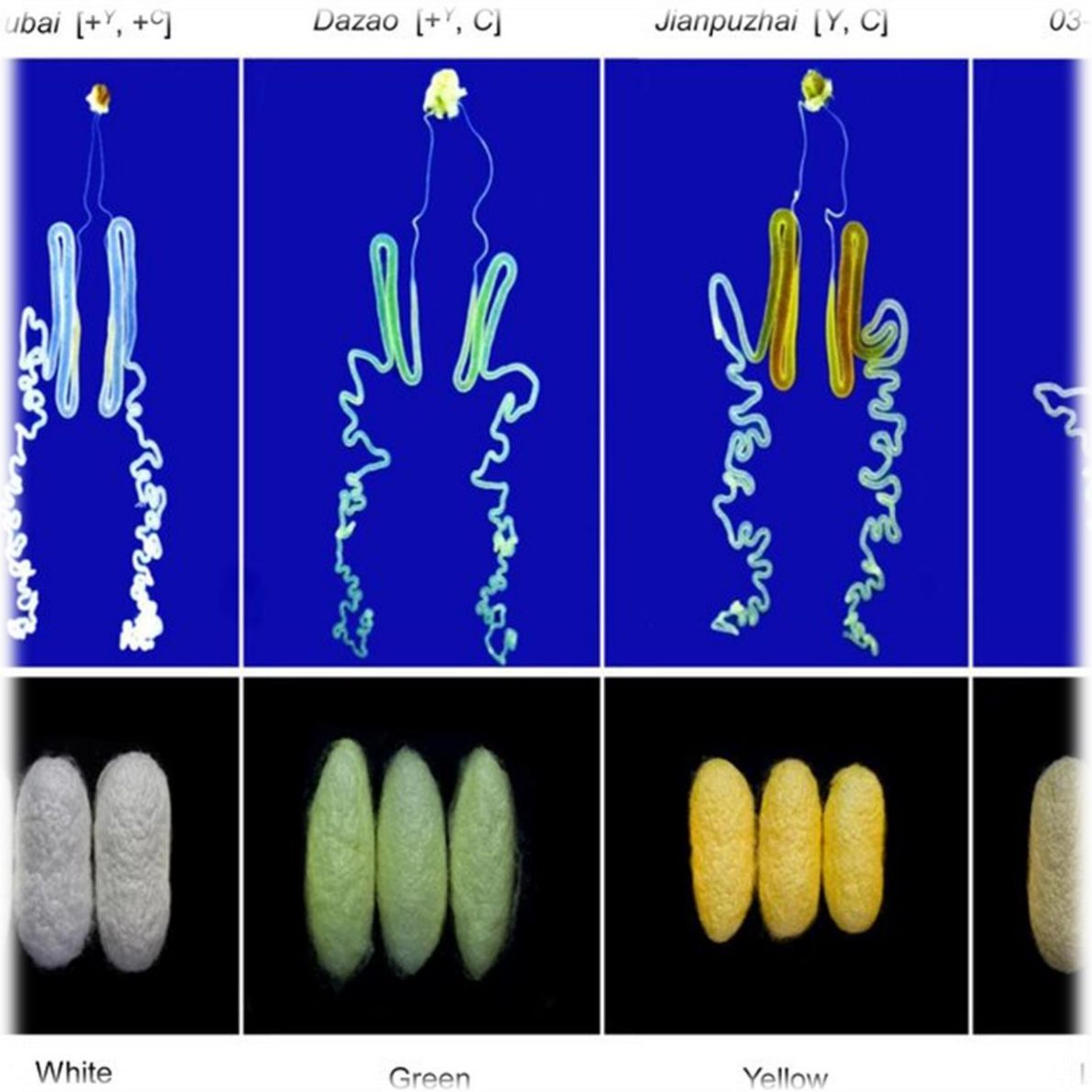

SERICULTURE TECHNOLOGY

(22ZOONME21)

REELING METHODS OF SILK FIBRE

Schematic representation of the silk glands in *Bombyx mori*





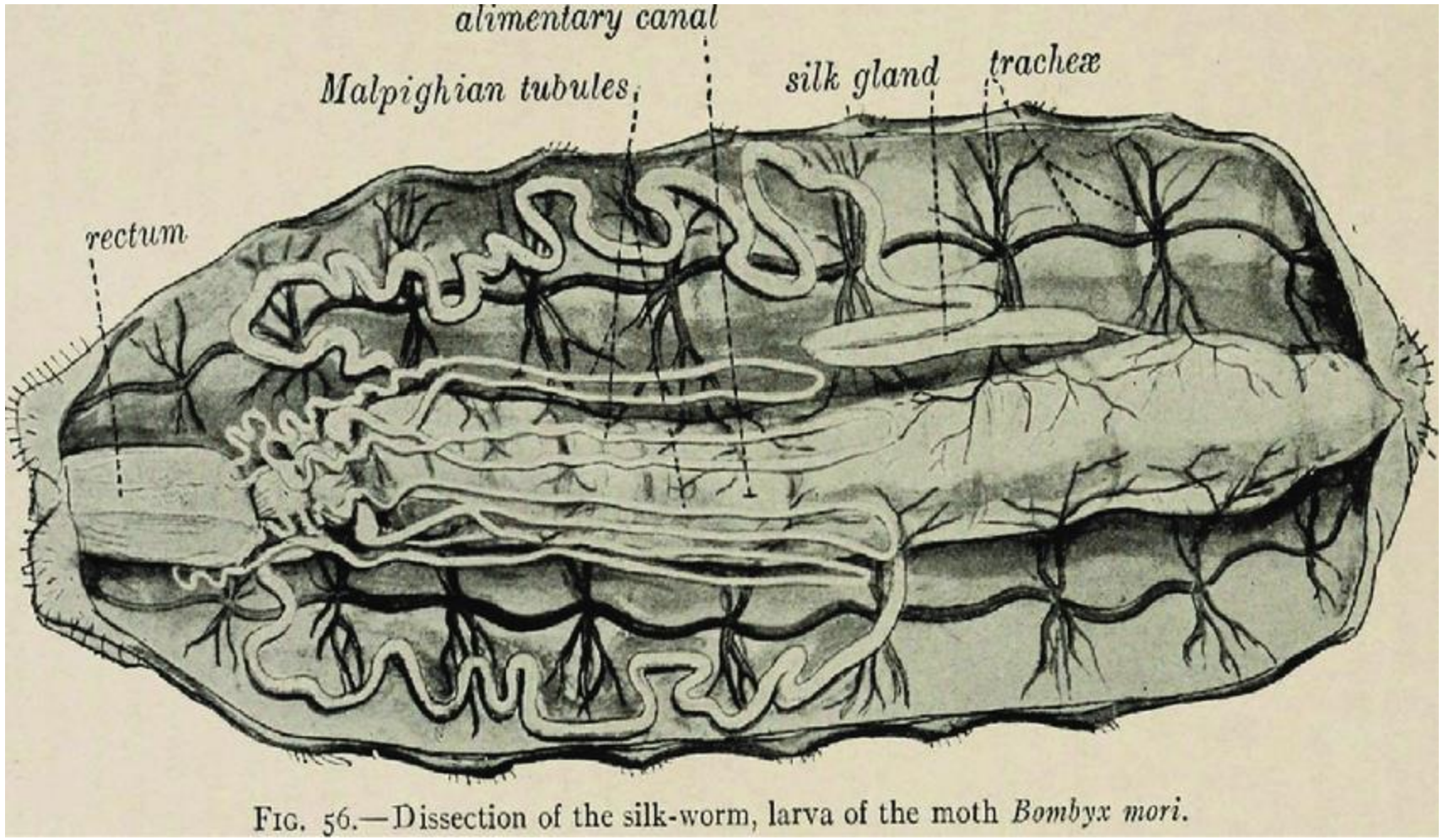
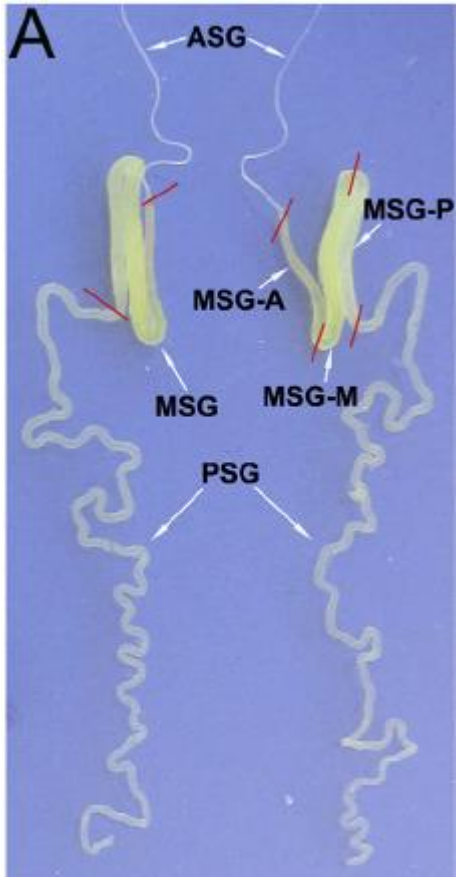
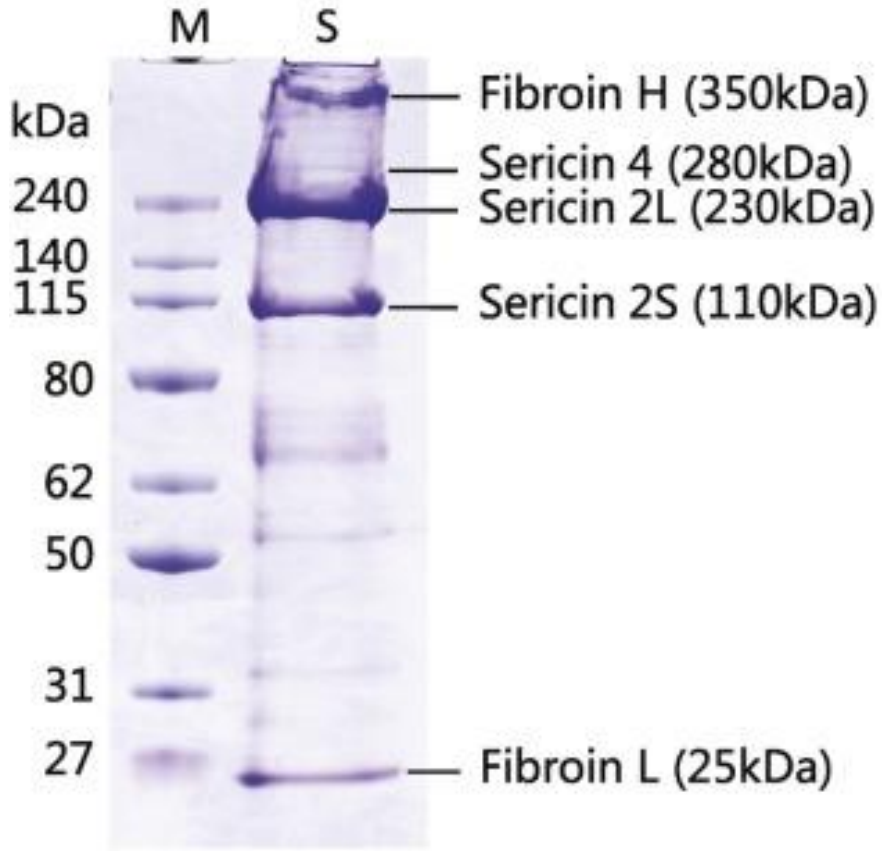


FIG. 56.—Dissection of the silk-worm, larva of the moth *Bombyx mori*.

Ref: https://www.researchgate.net/figure/Dissection-of-a-silkworm-larva-*Bombyx-mori*-showing-the-different-tissues-and-glands_fig2_350168307

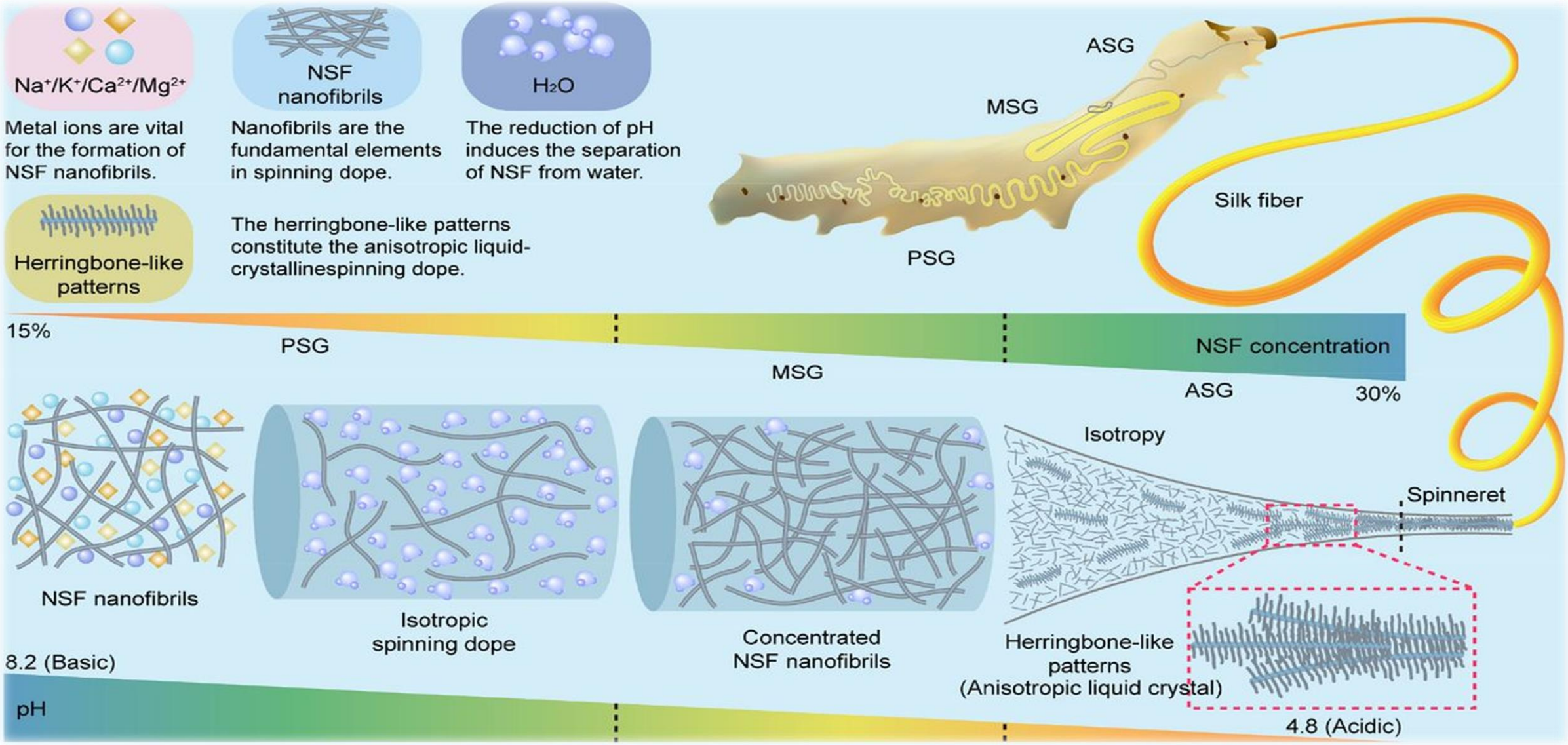
Total protein profile of *Bombyx mori* silk gland





Protein bands with molecular mass of 325/ 350 and 25 kDa representing fibroin heavy (H) and low (L) chains from middle region

Schematic illustration of the programmed self-assembly of natural silk fibroin (NSF) driven by pH gradient and metal ions in the silk gland of the silkworm



https://www.biorxiv.org/content/10.1101/2021.03.08.434386v1.full

Gradual increase in NSF hydrophobicity

Expressional pattern representation of Sericins in the silk gland and silk

Silk spinning stage (silk spinning type)	Middle silk gland (MSG) Sericin layer						References
	Anterior region (A-MSG) Outer sericin layer		Middle region (M-MSG) Middle sericin layer		Posterior region (P-MSG) Inner sericin layer		
1st instar (silky pad)	Sericin 2		Sericin 4	Sericin 1	Sericin 4	Sericin 1	Dong et al., 2013*
2nd instar (silky pad)	Sericin 2		Sericin 4	Sericin 1	Sericin 4	Sericin 1	
3th instar (silky pad)	Sericin 2		Sericin 4	Sericin 1	Sericin 4	Sericin 1	Takasu et al., 2010; Dong et al., 2013*
4th instar (silky pad)	Sericin 2		Sericin 4	Sericin 1	Sericin 4	Sericin 1	
5th instar (scaffold silk)	Sericin 2	Sericin 3		Sericin 1		Sericin 1	
5th instar (cocoon)		Sericin 3		Sericin 1		Sericin 1	

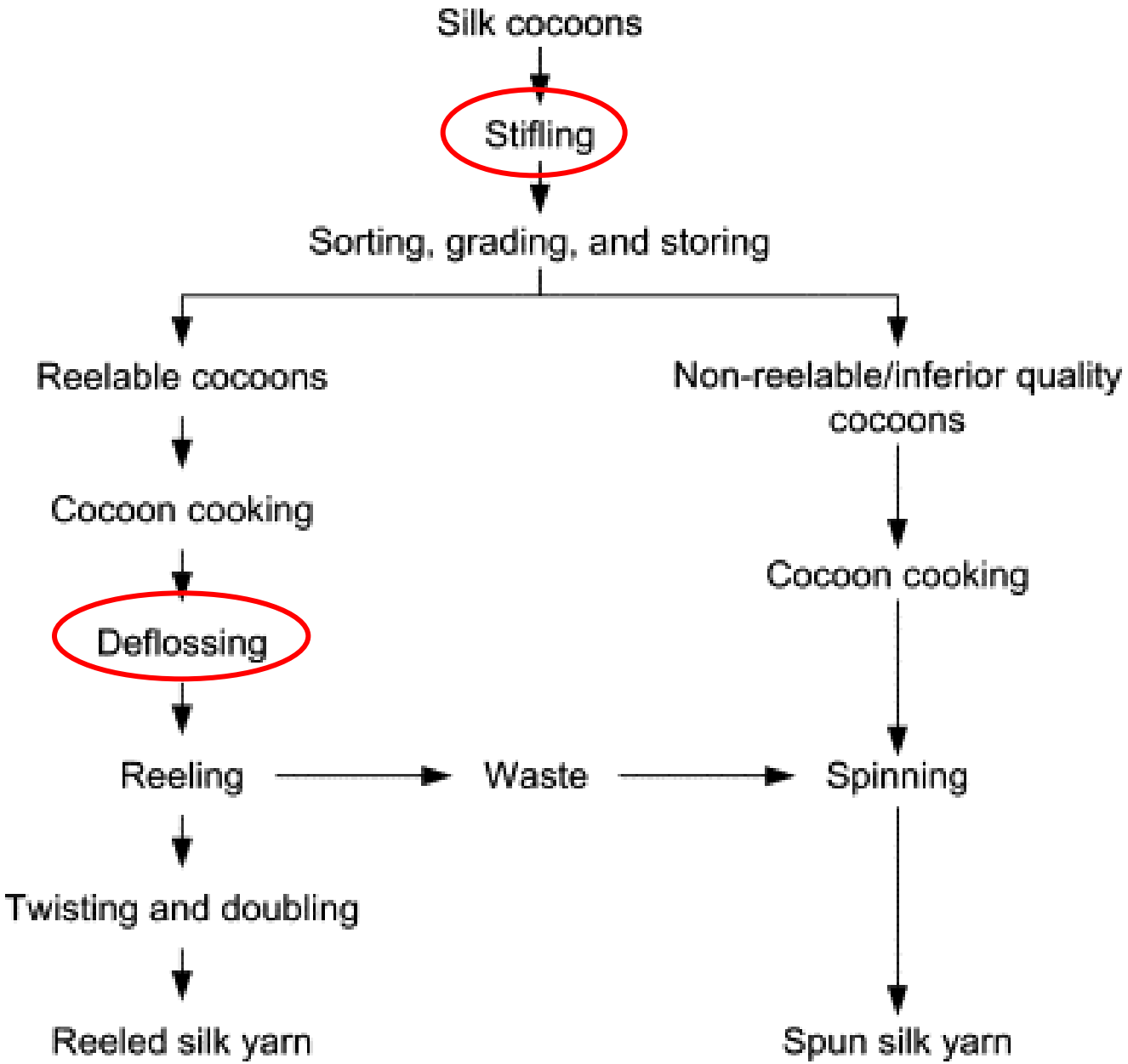
Ref: https://www.sciencedirect.com/science/article/pii/S0141813018359518

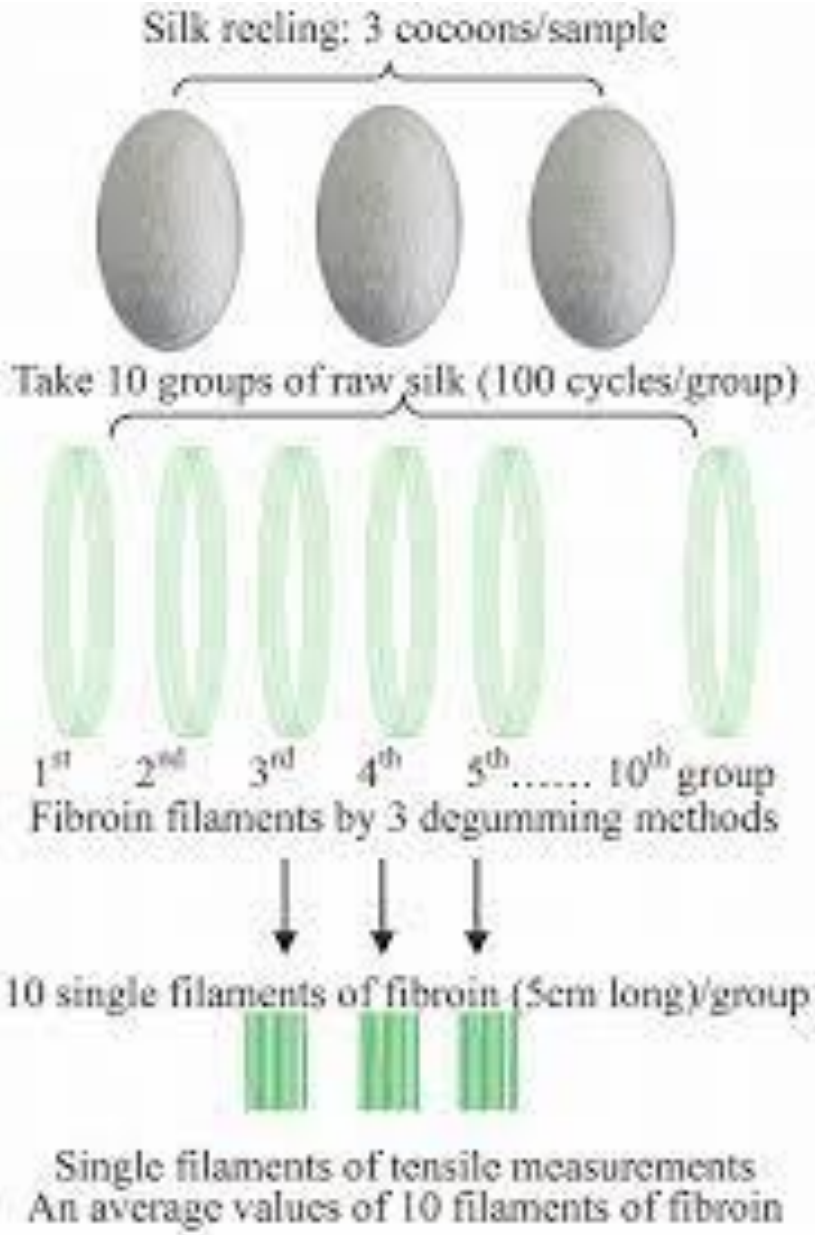
Cocoon Sorting is a process of separating defective cocoons from good cocoons.

The process also includes segregating cocoons according to their size (**riddling machines**).

Defective cocoons may be classified as:

- Double cocoons,
- Pierced cocoons,
- Urinated cocoons,
- Flimsy cocoons,
- Double cocoons,
- Pointed or constricted cocoons;
- Mould attacked cocoons and
- Immature cocoons.





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Deflossing:

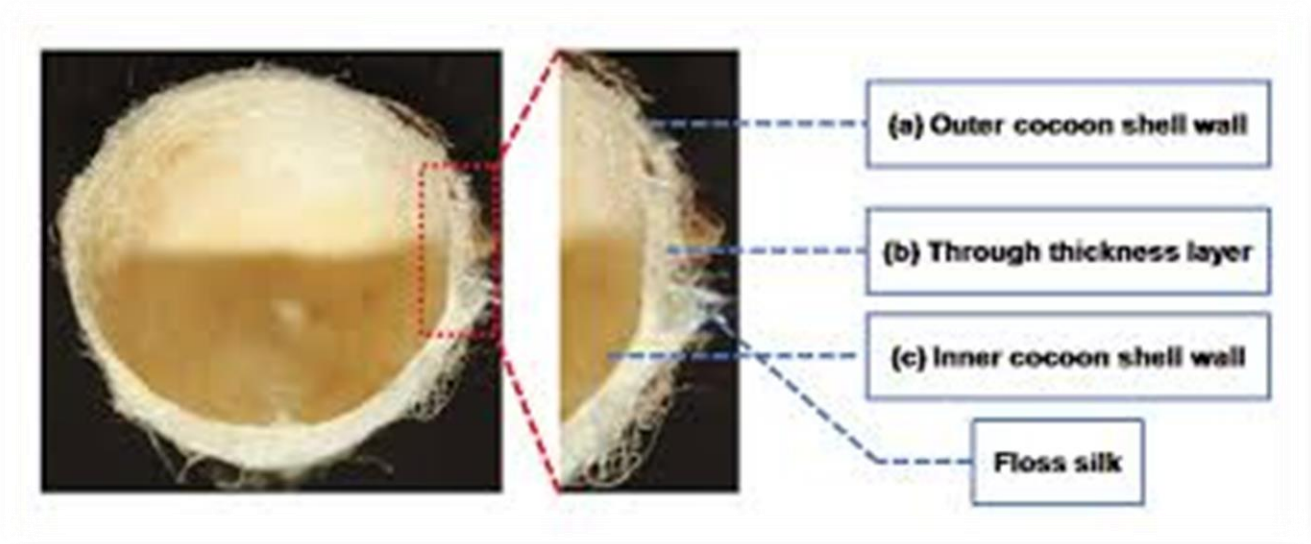
An unreelable layer of silk is called **floss. Process of removing floss is deflossing.**

It is a pre-requisite for extraction of silk (Reeling).

During the process of reeling, floss is removed by **brushing.**

In this process, some portion of reelable silk also goes as waste.

Deflossed cocoons minimize the loss during reeling.



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AGRICULTURE

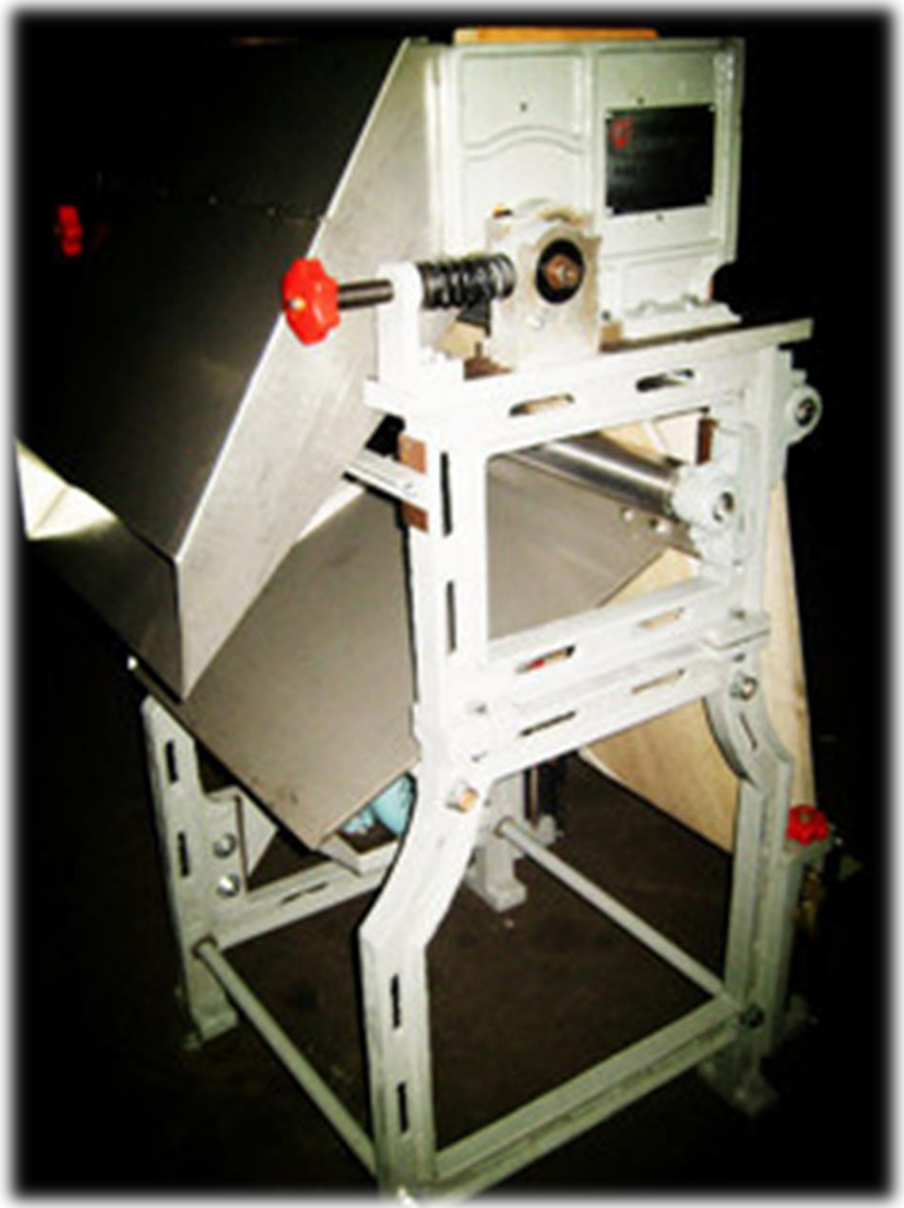
A smooth, efficient, low cost silk cocoon deflosser

M. J. Prabu

DECEMBER 12, 2013 02:58 IST
UPDATED: DECEMBER 12, 2013 02:58 IST

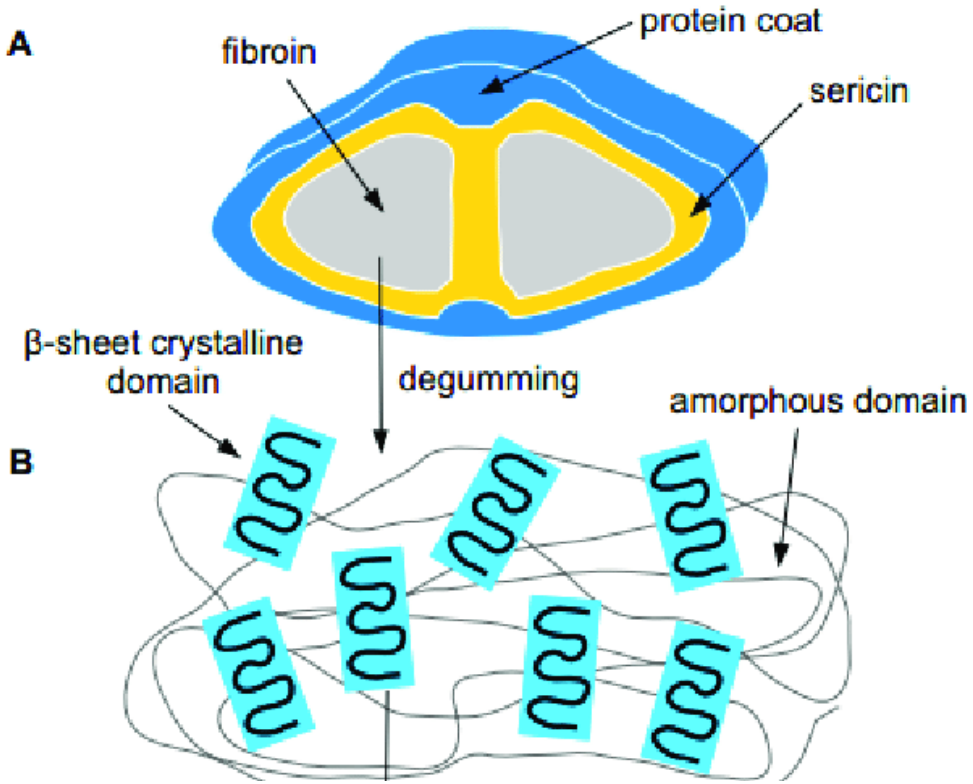
SHARE ARTICLE PRINT A | A | A

DOUBLE CAPACITY: The machine is simple to operate, portable and can remove about 80 kg of floss a day. Photo: Special Arrangement



Automated deflosser used in China

Schematic illustration of silk fibers produced by silkworms



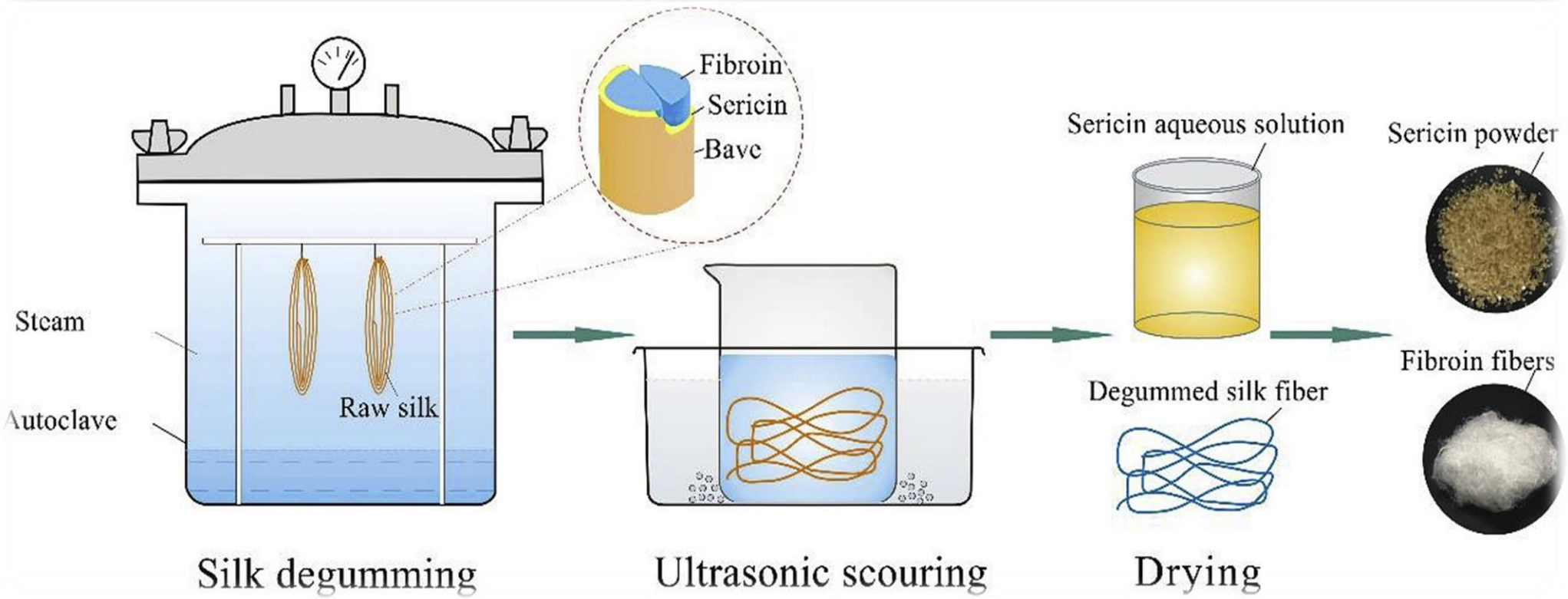
(A) The raw silk fiber is composed of two fibroin fibers held together with sericin covered with a protein coat.

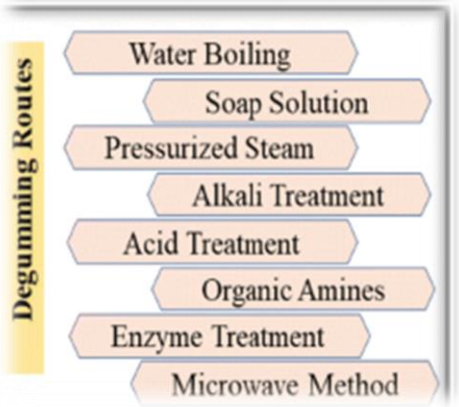
After **degumming**, the removal of sericin, the fibroin fibers are dissolved in solution.

(B) The illustration of β-sheet crystallite embedded in the amorphous matrix of silk fibroin fibers

Ref: https://www.researchgate.net/figure/A-schematic-illustration-of-silk-fibers-produced-by-silkworms-A-The-raw-silk-fiber-is_fig3_305924523

Degumming of silk fiber

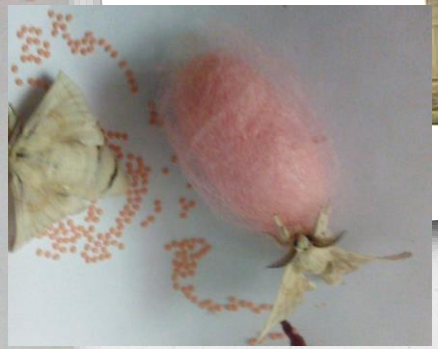


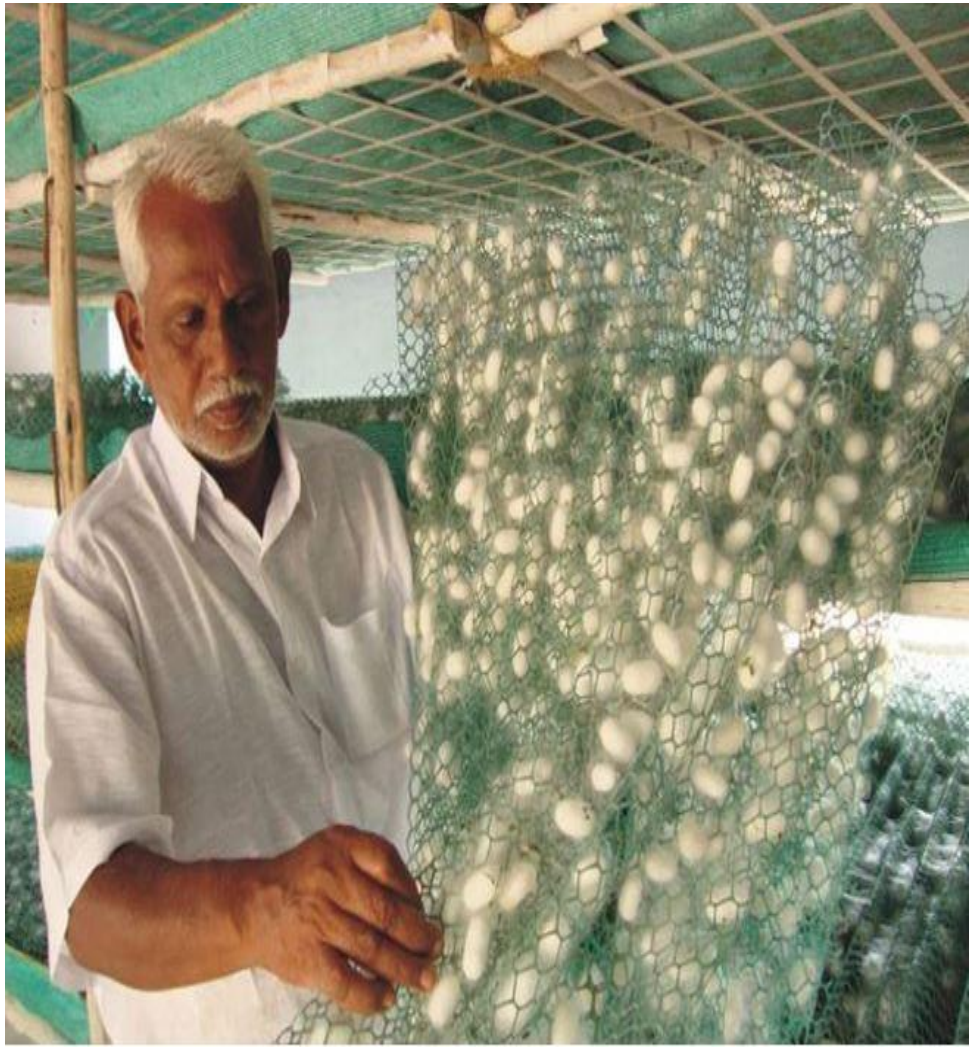


Ref: https://www.sciencedirect.com/science/article/abs/pii/S0959652618326477

Sericulture Technology
(22ZOONME21)

Silkworm Rearing Technology



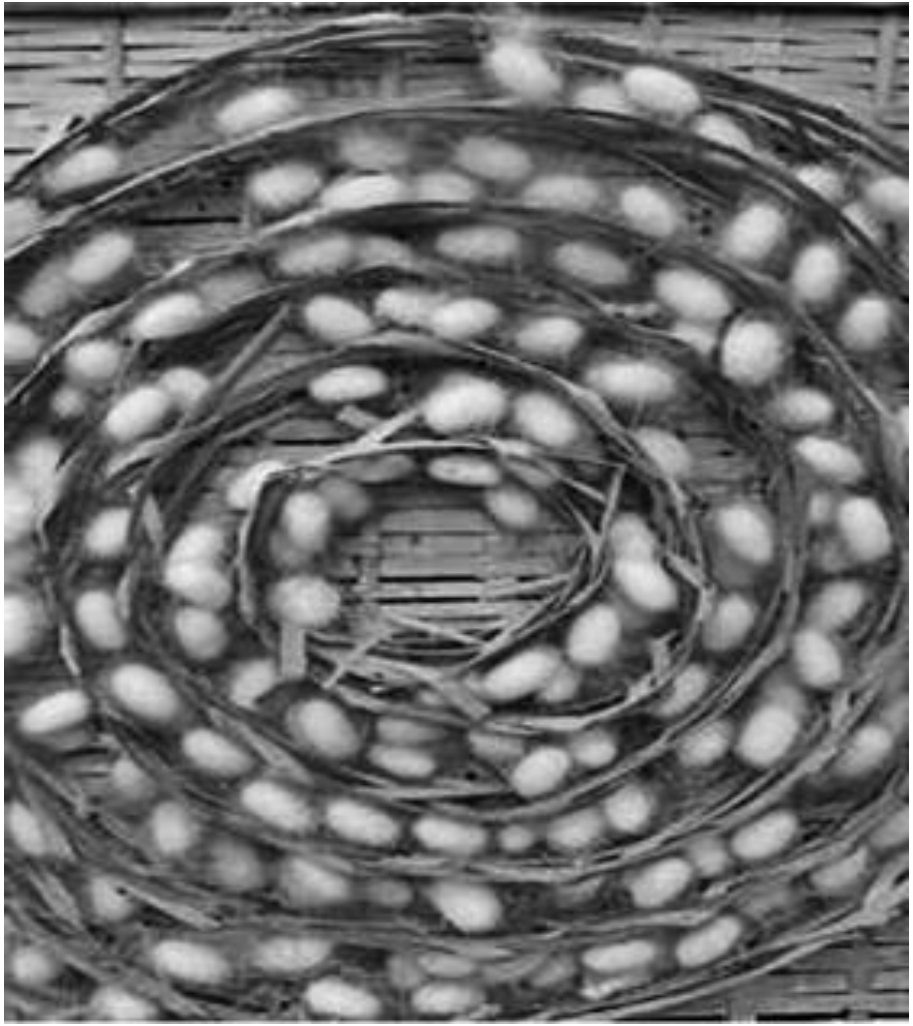


CONTENT

- ★ Hatching and Brushing
- ★ Chawki Rearing
- ★ Late age Rearing
- ★ ERR (Effective Rate of Rearing)
- ★ Spinning and Mounting
- ★ Silkworm Diseases and Pests
- ★ Economics

- ★ Favorable climatic condition for moriculture - Karnataka, Andhra Pradesh, Tamil Nadu, West Bengal and Jammu Kashmir.
- ★ Occupy 97% of total mulberry cultivation and contribute 95% of raw silk production in India.

- ★ Tamil Nadu stands first in cocoon productivity with an average of 69.69 Kg per 100 dfls, whereas the National average is 58.20 Kg.
- ★ Further, Tamil Nadu stands first in the production of chawki worms with 27 % of layings are distributed as chawki worms to the farmers, which is the highest at National level.

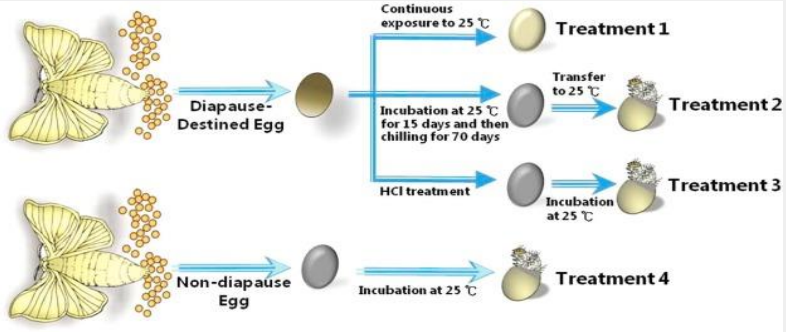


★ Silkworm eggs - Hibernating/Diapausing → Univoltine & Bivoltine races

(Stored and uniform hatching after a year too by artificial hatching).

- Non-hibernating/Non-diapausing → Multivoltine races.

★ Silkworm rearing - Care and Skill; reflecting cocoon quality + quantity



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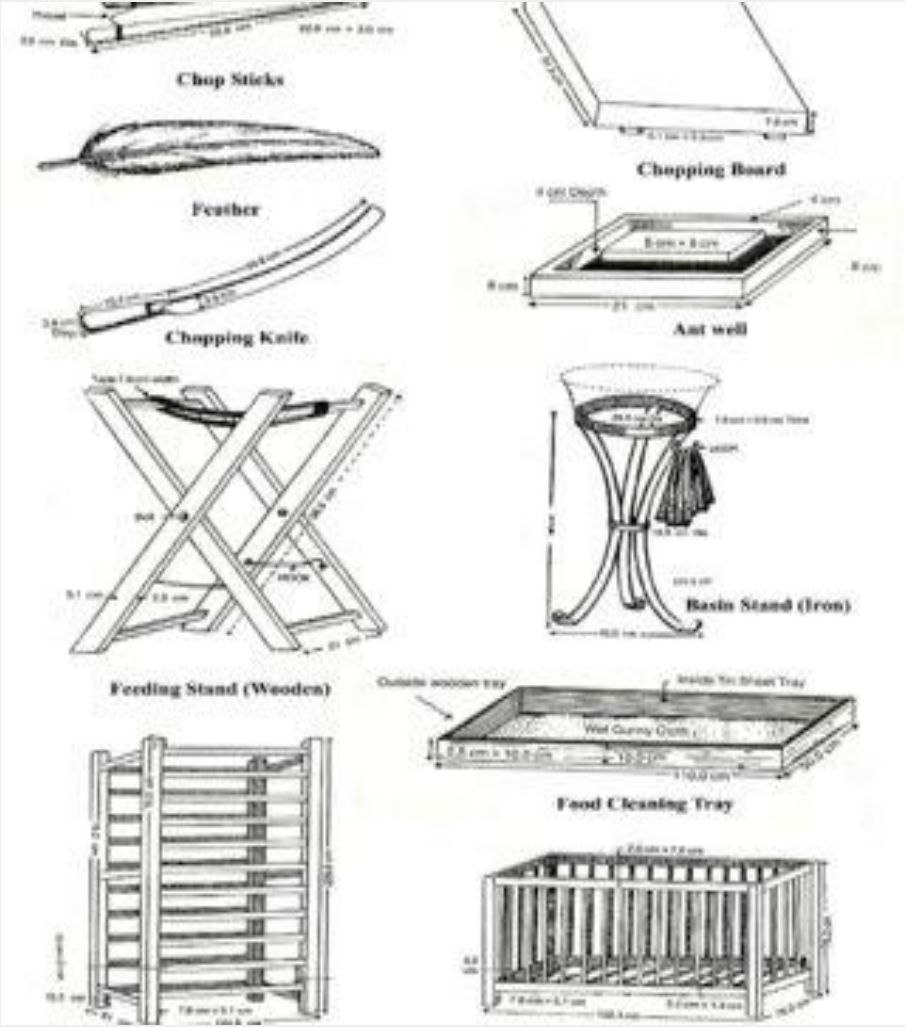


★ **Rearing equipments** – Chopsticks, foam rubber strips, chawky rearing trays, feather (white), paraffin paper, chopping board and knife, mats are kept ready for rearing.

★ Desire race of silkworm DFLs are procured from grainage.

★ The eggs are protected from ants, rats. They are incubated well and later kept in black box.

Hatching - eggs reach to blue egg stage (@50° C; 2-3 days)
- Phototrophic stimulus (90 % hatching).

★ If on I day 50 - 60 % hatches, hatched larvae can be refrigerated (10° C) and brushed.

Figure 2. Silkworm Eggs and Hatching

White eggs are empty shells from which larvae have already hatched. Hollowed eggs that are dark inside contain larvae about to hatch. Larvae bite open the eggshells from within to come out. The openings in white empty shells have been bitten open by larvae.

The ratio between hatched eggs and total eggs in a laying is called "hatching percentage". The hatched eggs, unfertilized or dead egg number is counted individually for calculating the percentage. This can be done using a colour ink pen and later it is calculated using the following formulae and method.

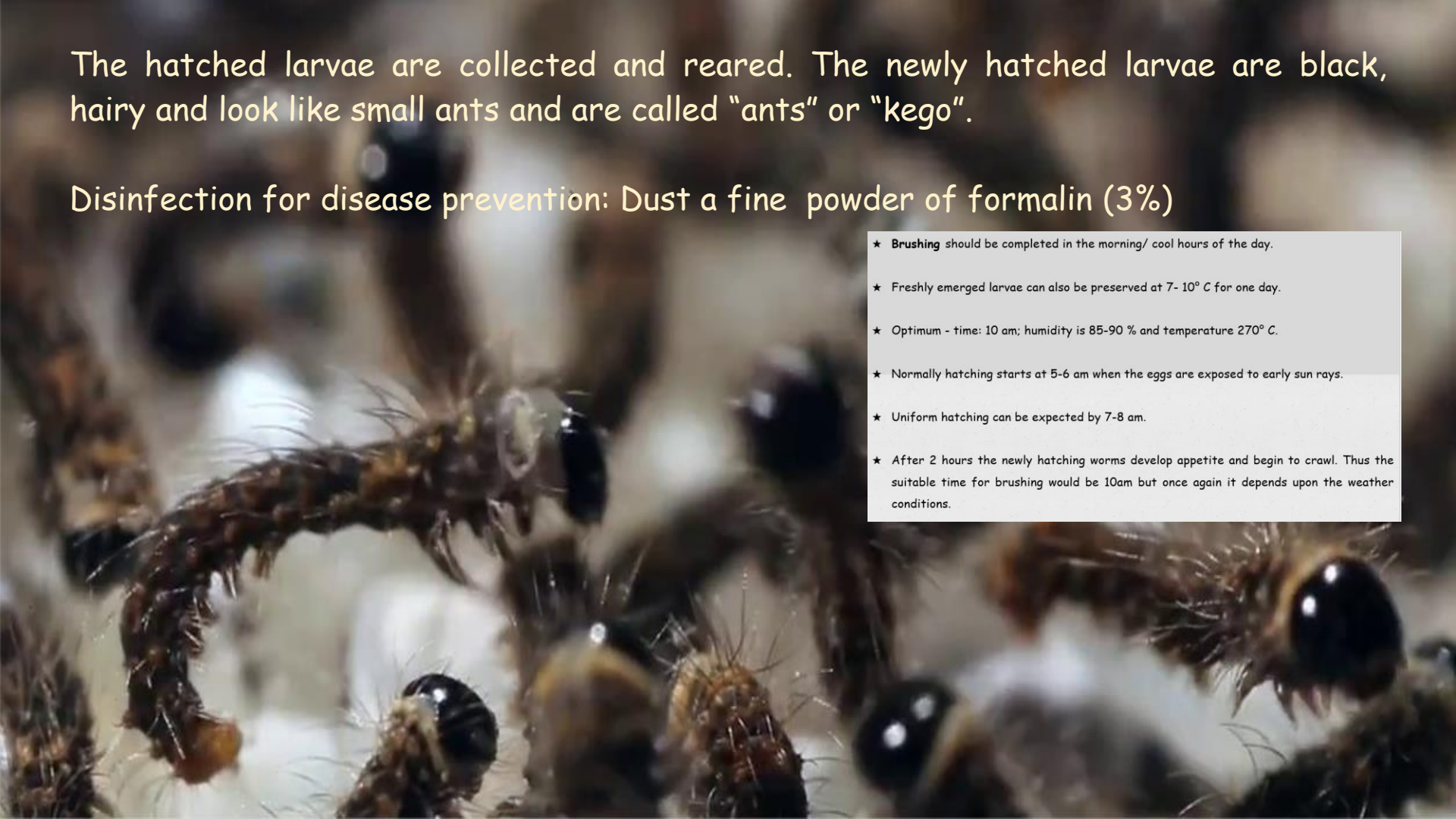
$$\text{Hatching percentage} = \frac{\text{Total No. of eggs hatched}}{\text{Total No. of eggs}} \times 100$$

$$\text{Unfertilised egg percentage} = \frac{\text{Total No. of dead / unfertilised eggs}}{\text{Total No. of eggs}} \times 100$$

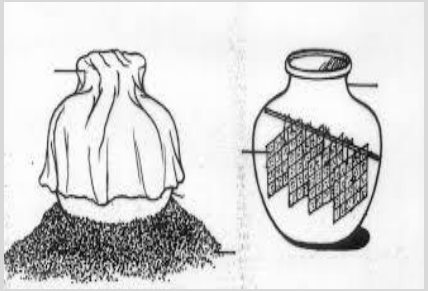
Total no. of eggs = Good eggs + dead eggs.

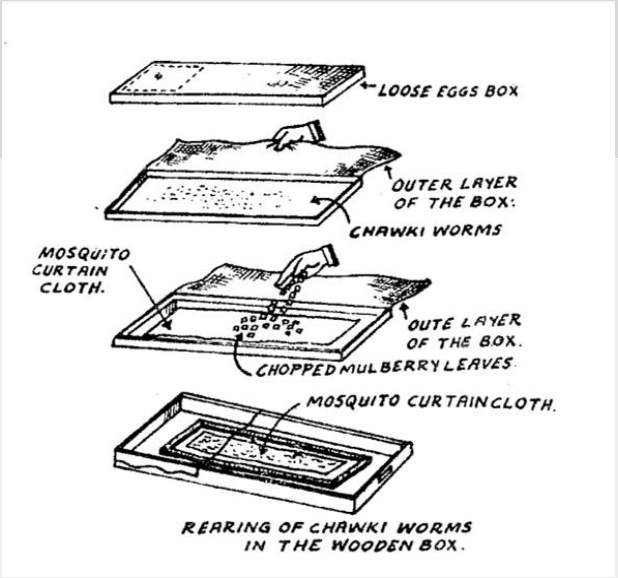
The hatched larvae are collected and reared. The newly hatched larvae are black, hairy and look like small ants and are called "ants" or "kego".

Disinfection for disease prevention: Dust a fine powder of formalin (3%)



- **Brushing** should be completed in the morning/ cool hours of the day.
- Freshly emerged larvae can also be preserved at 7- 10° C for one day.
- Optimum - time: 10 am; humidity is 85-90 % and temperature 270° C.
- Normally hatching starts at 5-6 am when the eggs are exposed to early sun rays.
- Uniform hatching can be expected by 7-8 am.
- After 2 hours the newly hatching worms develop appetite and begin to crawl. Thus the suitable time for brushing would be 10am but once again it depends upon the weather conditions.





REARING OF CHAWKI WORMS IN THE WOODEN BOX.

Brushing of loose eggs and feeding

- ★ Tapping method
- ★ Feather method
- ★ With mulberry leaves (0.5Sq. cm size)

- ★ Husk-feeding method

CHAWKI REARING

★ Total leaf requirement of silkworm larva in only 6.33 % during chawki rearing upto III moult.

★ But body weight increases by 400 times, while 300 times increase in body size and 500 times increases in silk gland weight are achieved during young stage provided the conditions and methods of rearing are ideal.

Stage of Worms	Optimum Temperature	Relative Humidity %
I	26°C - 28°C	85
I	26°C - 28°C	85
III	24°C - 26°C	80

★ Further the rate of increase in body weight of larva/ given time is more in the first instar and it decreases with the age

QUALITY OF MULBERRY LEAF -

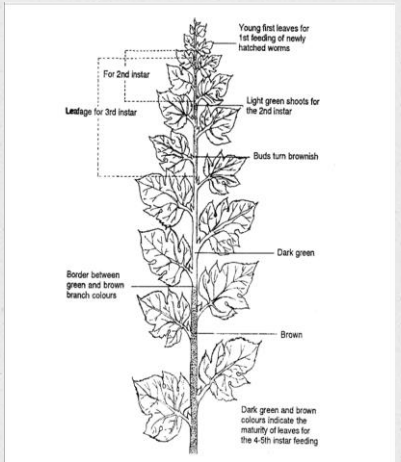
- ★ Mulberry raised under ideal agronomic conditions are better for rearing silkworms.
  - 1. Good soil, neither two clayey nor too sandy, but not acidic.
  - 2. Application of optimum and balanced fertilizers
  - 3. Suitable cultural operations
  - 4. Assured irrigations or rainfall

Leaf selection:

1. **Glossy leaf method** (leaf stands upright)
2. **Lenticel and Bud (LB) method**

Glossy Leaf Selection method

Lenticel and Bud (LB) method



★ Early age silkworms eat leaves the surface, late age worms form the edges.

The feeding activity of each instar of silkworm can be conveniently into **seven stages**.

1. First feeding stage
2. Sparse eating stage

3. Moderate eating stage
4. Actively eating stage
5. Premoulating stage
6. Last feeding stage
7. Moulting stage

Bed Cleaning:

Removal of old (unused) mulberry leaves, faecal matter of silkworms, exuviae, dead or unhealthy worms etc., from the rearing bed is called bed cleaning.

★ Out of the total weight of leaf taken as food, three fifth is excreted and only two-fifth is being assimilated by the silkworm.

★ Pilling of litter makes the beds moist - releases the fermentation process - releases injurious gases and favours pathogen multiplication.

I instar	–	Once
II instar	–	Twice i.e. once just after the I moult and again before setting for II Moult
III instar	–	Thrice i.e. once after moult, once in the middle of III age and once Just before setting for IV moult.

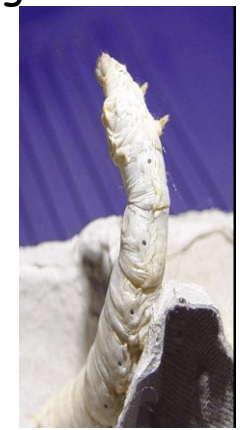
Moulting: The silkworm larval life has **five instars** and **four moults.** The larvae casts off its skin to accommodate the body growth. This is called moulting.

Body becomes stout, and shiny and amber coloured at the time of moulting (20 hrs for first stage; third age takes 1 day).

In relation to the size of the body,the head of the worm appears small and dark.
This is the time for bed cleaning and wide spacing.

Before Moulting

After Moulting



V Instar - Ready for mounting

Initial cocooning

Box rearing

REARING METHODS:

There are three methods of rearing

1. Shelf rearing

2. Floor rearing

3. Shoot rearing

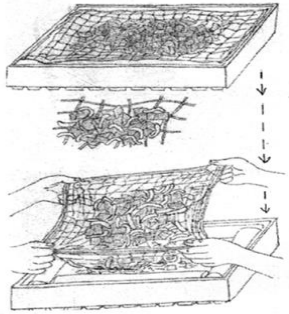
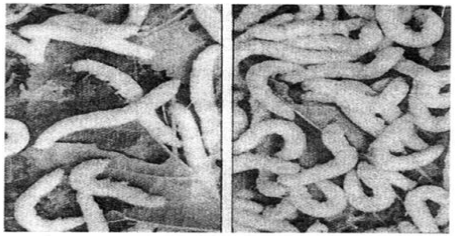


Fig. 3.5. Bed Cleaning



Normal Crowded

Co-operative rearing:

It have been organized to p**rovide technical assistance, idea conditions** etc. the rearing is conducted upto **second or third moult**.

- ★ These are also called as **chawki rearing centres**.
- ★ These centres are provided with ideal rearing houses with all the necessary equipment.
- ★ The total rearing are supervised by technical experts.
- ★ Mulberry leaf for rearing is provided form a single garden which ensures uniform quality of leaf.

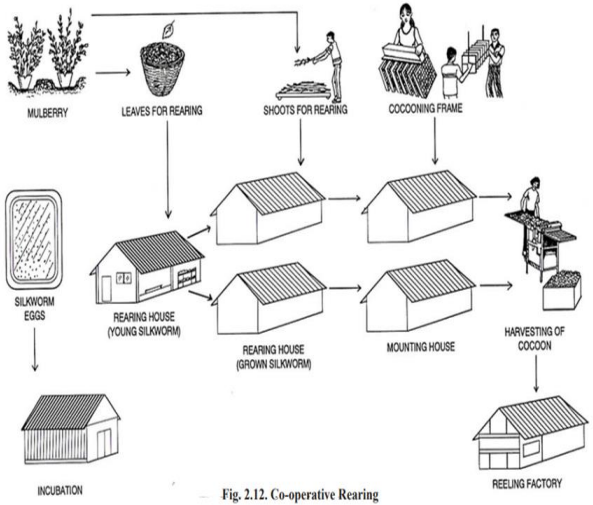


Fig. 2.12. Co-operative Rearing

Sericulture Technology
(22ZOONME21)

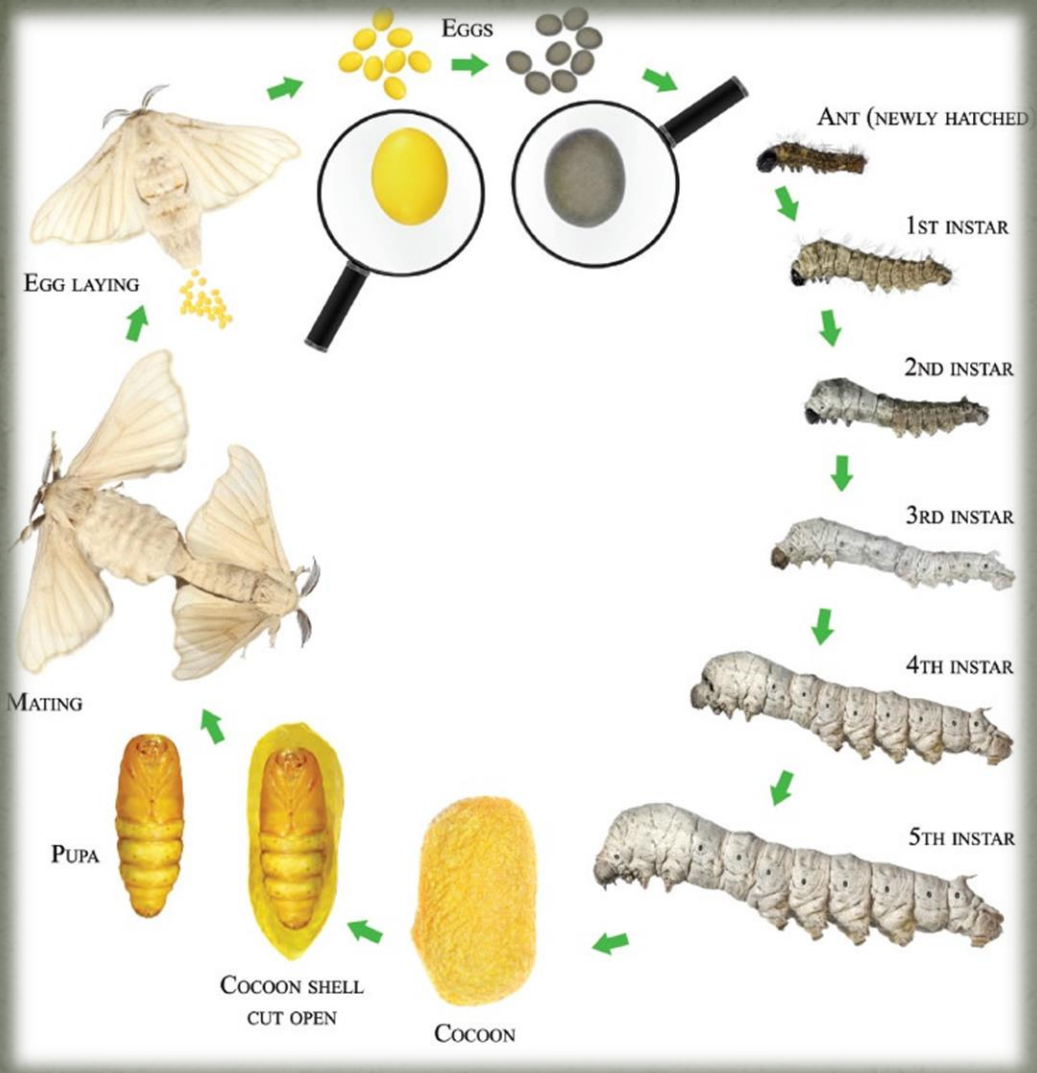
Sericulture and Moriculture – Artificial Diet as an Integrated Approach

Sericulture

- Sericulture is an art of rearing silkworm for the production of cocoons which is the raw material for the production of silk.

Con...

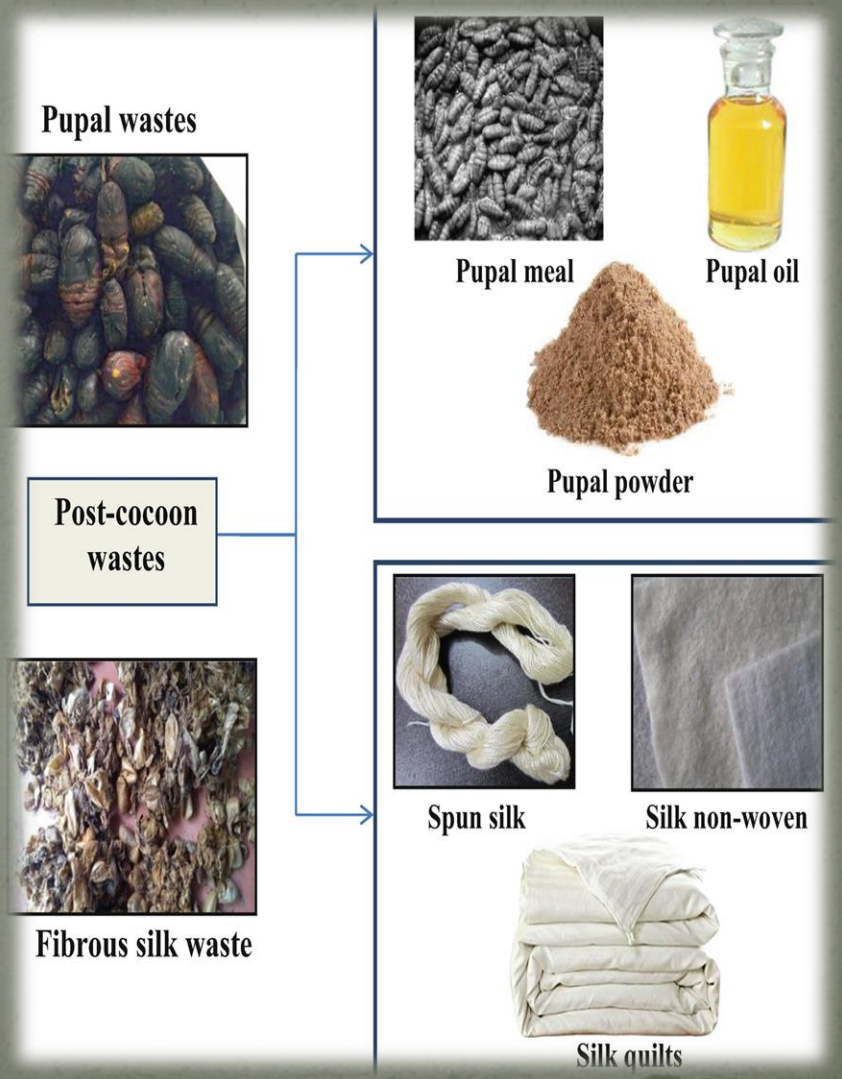
- High employment potential.
- Provides vibrancy to village economics.
- Low gestation and high return.
- Women friendly occupation.
- Ideal programme for weaker sections of the society.
- Eco-friendly activity.
- Satisfies equity concerns.



- **Tri moulters**
- **Tetra moulters**
- **Penta moulters**
- **Hexa moulters -**

Sericulture Activities

- Moriculture
- Silkworm Seed Production
- Silkworm Rearing
- Marketing of cocoons
- Silk Reeling
- Marketing of Raw silk
- Silk Weaving



- India occupies second position among the silk producing countries in the world besides being the largest silk consumer.
- Sericulture is a cottage industry, suitable for small farm and marginal holdings, which provides.

Sericulture in Tamil Nadu:

- Sericulture introduced in Tamil Nadu from the border area of Karnataka during early 1960.
- Now Tamil Nadu Stands number one in Bivoltine Silk production in India.

Race (Indigenous)	Type	Characters
Kashmir race (Kashmiri silk)	Univoltine	Extinct – white / yellow elongated-oval cocoons
Borapalu (WB)	Univoltine	Degenerated race – greenish –white / pure white; one end of cocoon is pointed
Nichi (Japanese) and introduced in Mysore	Bivoltine to multivoltine	(continuous rearing) – have short larval period than pure Mysore silk – white, peanut shaped cocoons
Chotopolu (WB) – No more available in nature	Multivoltine	White / yellow flossy cocoons
Bulupulu (WB)	Multivoltine	Yellow/greenish-white cocoons, small, flimsy and flossy
Nistari (Madrassi) – commercial indigenous race from China (1881) to WB		Cocoons – small, flossy and golden yellow – Characteristic of WB (tolerant to adverse conditions)
Pure Mysore from China (1895)	Multivoltine	Cocoon – yellow to greenish-yellow, soft, flossy. Only demerit – long larval period

Race (Indigenous)	Type	Characters
Nyapolu (native of K) – imported from China (1895)	Multivoltine	Resemble – Nitsari and Chotopul races. Cand flossy. Cocoons – white / light yellowOnly demerit – long larval period
Sarupat (Assam, NE India)	Multivoltine	Small, spindle-shaped, flossy, light creamy-white cocoons.
Moria (NE India)	Multivoltine	Small, spindle-shaped, flossy, light creamy-white cocoons.

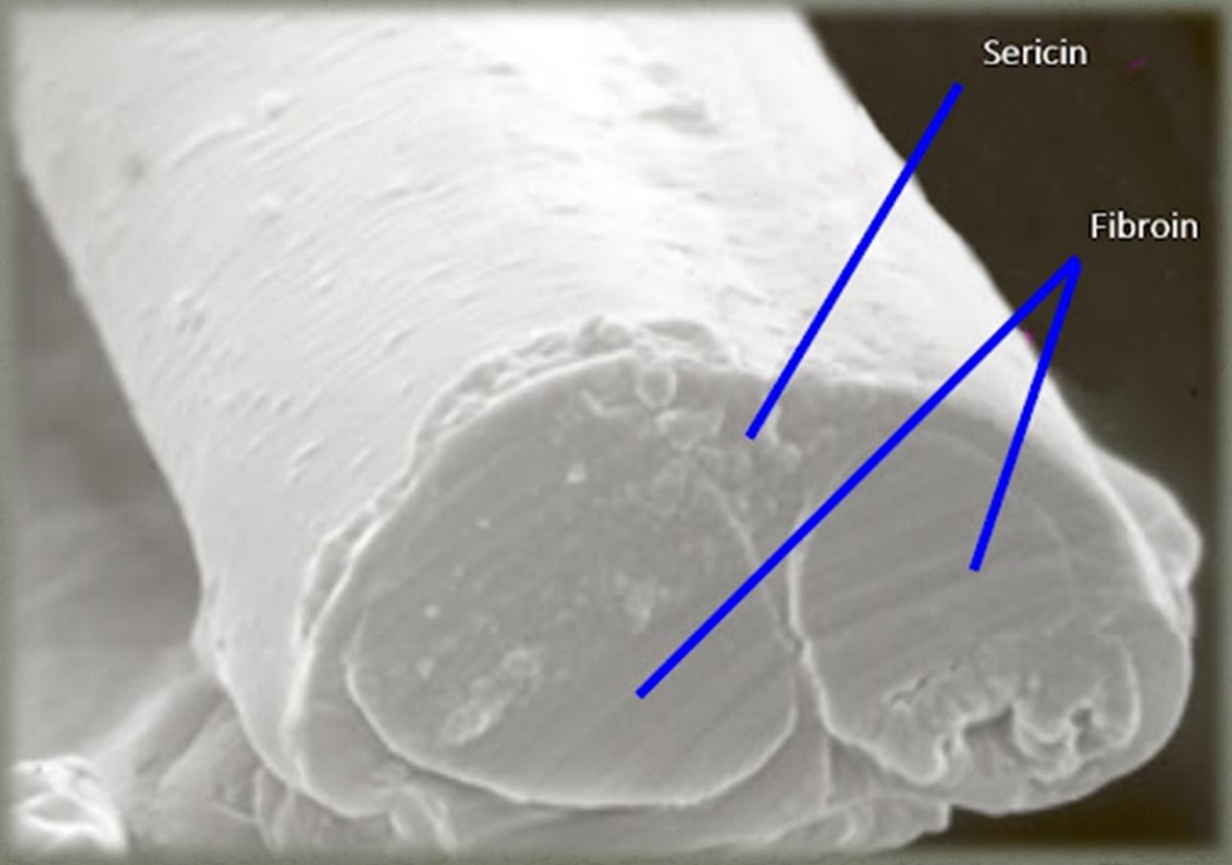
- Indigenous races are no longer used for commercial rearing because,

they are degenerate, low productivity, produce silk of inferior quality.

- Also pure - line selection method was a failure due to genetic variability.
- Importing new high-yielding races was a failure because of temperature inadaptability, poor quality of mulberry leaves and unpredictable rainfall conditions.

Silk Proteins

Silk emitted by the silkworm consists of two main proteins, sericin and fibroin, fibroin being the structural center of the silk, and serecin being the sticky material surrounding it.



MORICULTURE

- Mulberry silkworm - Monophagous insect.
- Mulberry – No. of sp. and varieties.
- Differ in suitability for silkworm rearing because of varying nutritious value and palatability for the worm.
  - Age & type of leaf cultivation,
  - Harvesting method adopted,
  - Duration of storage,
  - Season,
  - Fertilizer & irrigation schedules and
  - Affliction by pests and diseases.

- *Morus alba*
- *Morus indica*
- *Morus latifolia*
- *Morus nigra*

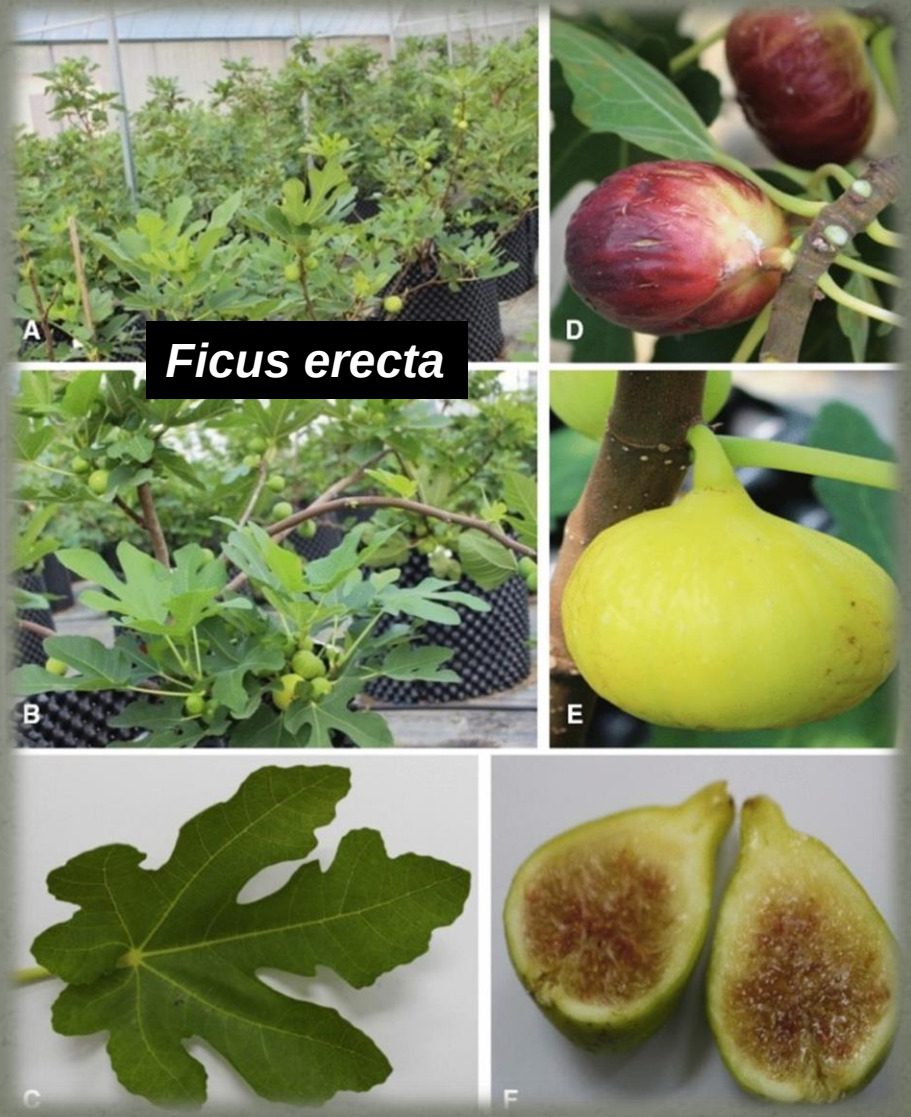
Grown through out India

- *Morus laevigata*
- *Morus serrata*

Grown in Himalayan region

- Most of the Indian varieties belong to ***Morus indica***

- So as an alternative for mulberry few alternative diet were used.



Artificial diet rearing system for the silkworm Bombyx mori (Lepidoptera: Bombycidae): Effect of vitamin C deprivation on larval growth and cocoon production

Ingredients	Quantities/100 g dry weight[a]
Dried mulberry leaf powder	25.0 g
Defatted soybean meal	36.0 g
Wheat meal	15.0 g
Corn starch	4.0 g
Soybean fiber	5.0 g
Citric acid	4.0 g
Ascorbic acid	2.0 g
Salt mixture	3.0 g
Agar	4.2 g
Vitamin mixture	399.0 mg
Sorbic acid	200.0 mg
Propionic acid	691.0 mg
Chloramphenicol	10.0 mg
β-sitosterol	500.0 mg

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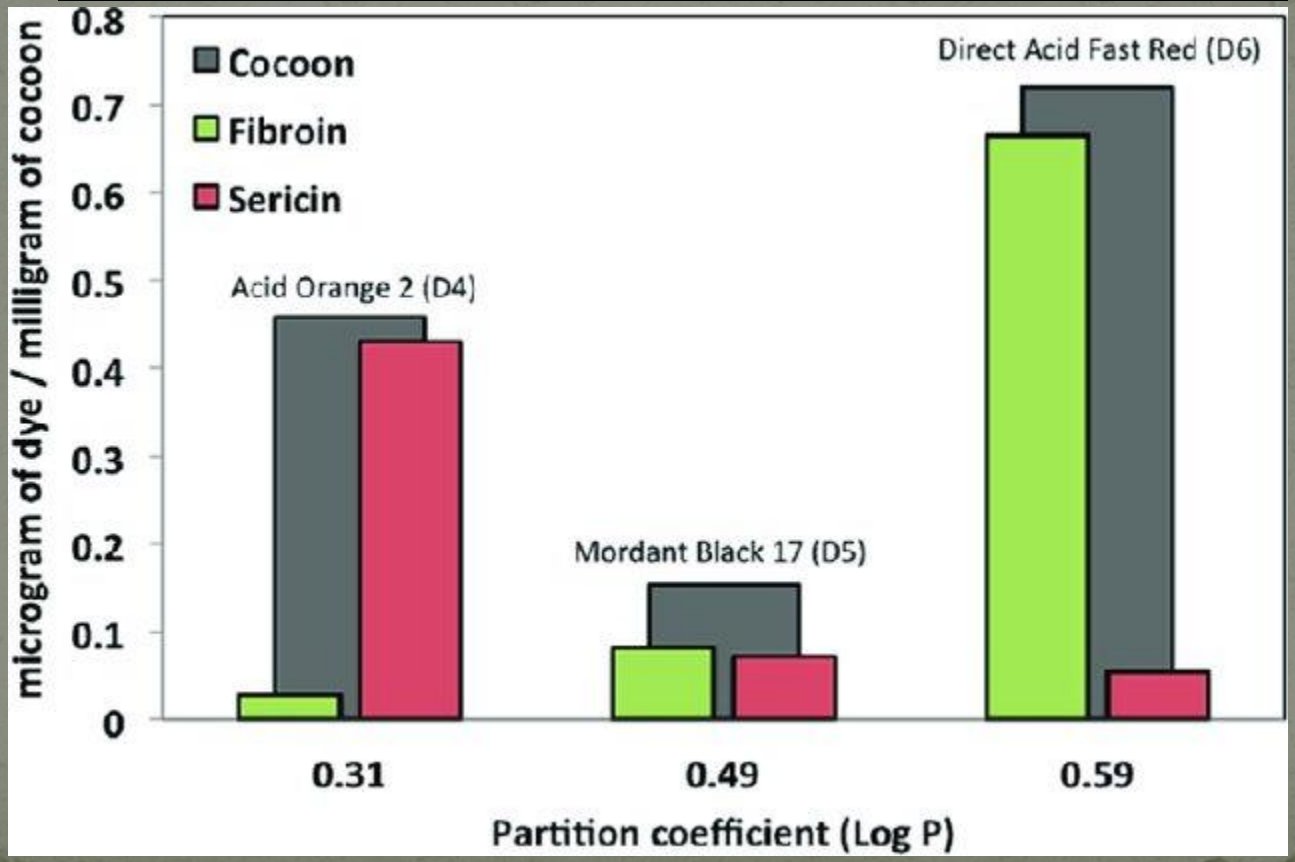
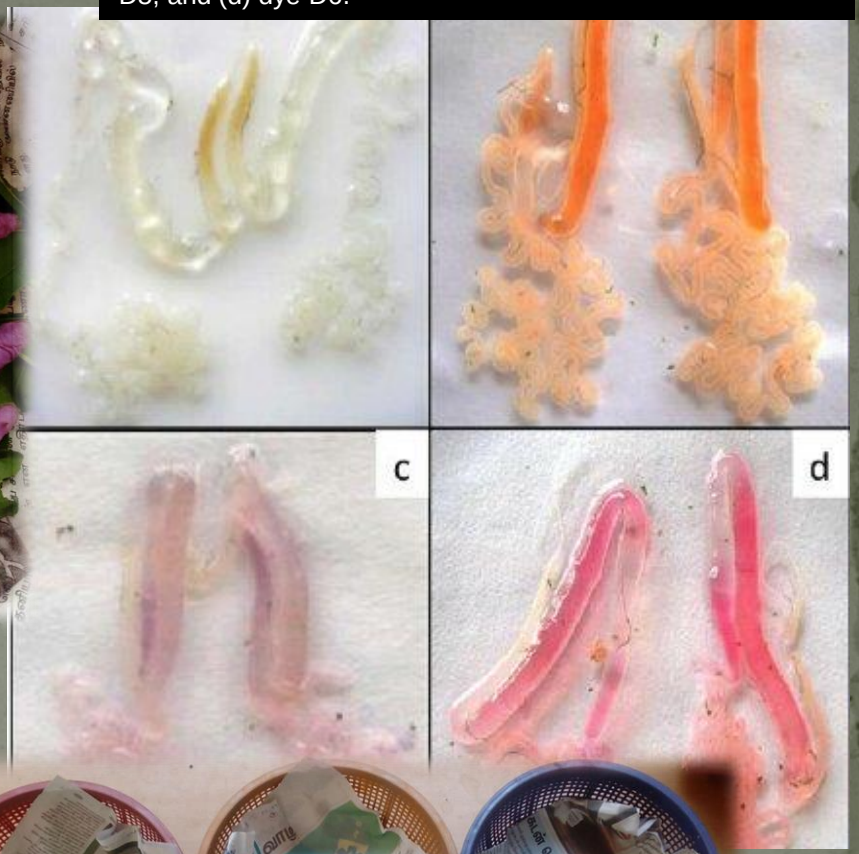
Quantification of dye in cocoon, sericin, and fibroin.



Harvesting of cocoons

Dissected silkworm glands for (a) control, (b) dye D4, (c) dye D5, and (d) dye D6.



Marketing of cocoons

- After getting the cocoon the farmers can sell the cocoon by them in the nearest Govt. Cocoon Markets

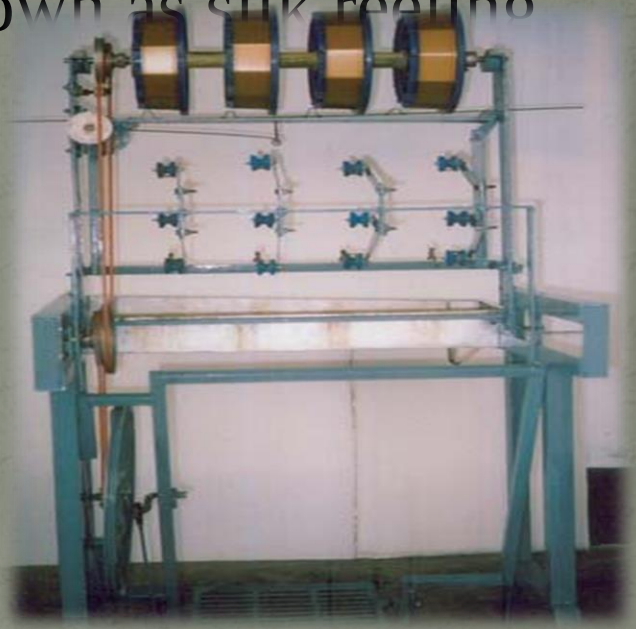
Silk Reeling

- Extraction of silk filament from cocoons by employing a set of processes is known as silk reeling
- Three types of reeling devices,

i. Charka, (50% silk produced)

ii. Cottage basins,(35-40%)

iii. Multi-end basins.(5-10%)



Looming

- The raw silk cannot be directly used for weaving.
- The raw silk is to be twisted before they are fed into looms.
- The operation of conversion of raw silk into twisted silk, is termed as twisting.
- Two types of looming -

i. Handloom

ii. powerloom

Power looming

Hand looming

Silk Weaving

Marketing of Raw silk

- The raw silks produced by the silk reelers are marketed directly to the weavers or through Silk Exchanges.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Bombyx mori derived Scaffolds and their use in Cartilage Regeneration: A Systematic Review

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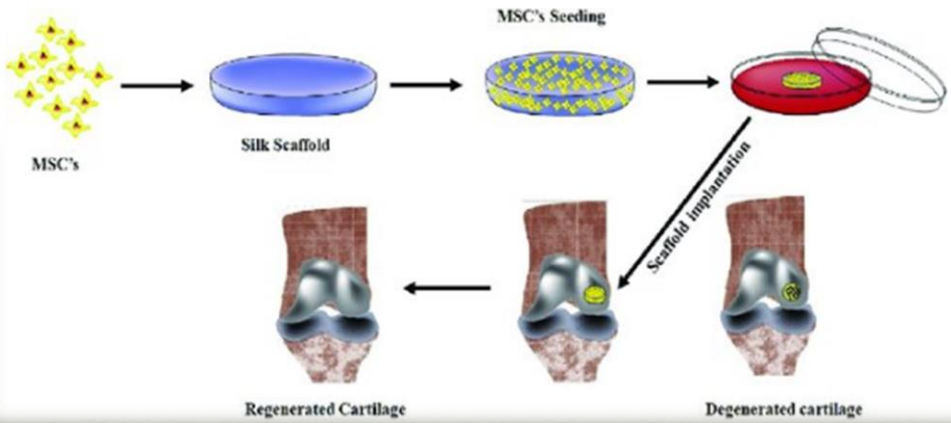

Figure

Caption

Fig. 4. Diagram showing the basic in vivo tissue engineering approach for cartilage regeneration using silk scaffold.

Ref: https://www.researchgate.net/publication/326677265_Bombyx_mori_derived_Scaffolds_and_their_use_in_Cartilage_Regeneration_A_Systematic_Review/figures?lo=1

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