CHAPTER

# 1 INTRODUCTION

Silk is the strongest of all natural fibres. It is comparable to steel or nylon in tensile strength, but considerably more elastic. It can be dyed, spun into thread or yarn and woven into fabrics that are warm in winter, cool in summer, resistant to wrinkling and exceptionally light in weight. Until the discovery of nylon in 1938, silk was the only fibre strong and light enough to be used in the manufacture of parachutes, surgical sutures and clothes.

## I SERICULTURE

The word 'Sericulture' is derived from the Greek word 'Sericos' meaning 'Silk' and the English word 'Culture' meaning 'Rearing'. Sericulture is the branch of economic entomology which deals with the cultivation of host plants and rearing of silkworms to produce raw silk. Sericulture is an agro-based and an eco-friendly industry. It plays a significant role in the rural economy, employment, poverty alleviation and earning foreign exchange. In India, mulberry sericulture is practised in various states, viz. Karnataka, Andhra Pradesh, Jammu & Kashmir, West Bengal, Madhya Pradesh and Maharashtra. The non-mulberry sericulture is also called **Vanya silk.** It is practised in Assam, Jharkhand, Odisha and Madhya Pradesh. More than 6 million people are involved in sericultural activities. It is necessary to upgrade the skills of the sericulturists to use the full potentialities of sericulture to produce qualitatively superior cocoons and to earn profitable income.

The major activities of sericulture comprise of food-plant cultivation to feed the silkworms which spin silk cocoons and reeling the cocoons for unwinding the silk filament for processing and weaving to produce valuable products. Silk is called the **"Queen of Textiles"** and is known for its qualities like luxury, elegance, class and comfort. It has overcome the challenges from other natural and artificial fibres and remained the undisputed "Queen of Textiles" for centuries. Silk has been intermingled with the life and culture of the Indians. Though India is producing all varieties of silk products such as dress materials, scarves/stoles, readymade garments, etc., the silk sarees produced in the country are truly unique. It is the traditional costume of the Indian woman since time immemorial. Saree stands as a living example of the excellent craftsmanship of the weavers of the country. Chemically speaking, silk is made of proteins. The silkworms feed on the selected food plants and spin cocoons as a 'protective shell' with silk fibre. Silkworm has four stages in its life cycle, viz. egg, caterpillar, pupa and moth. Man interferes in this life cycle at the cocoon stage to obtain the silk, used in weaving of the dream fabric. Today, India and China are the two main producers of silk with more than 60% of the world's annual production.

### 1. History

The Chinese sources say that Fo-xi, the first emperor of China was the first person to introduce mulberry cultivation and silkworm rearing. The reign of the emperor Hoang-ti dates back to 2677-2597 BC and it has been found that sericulture was already a long-established

Fig. 1. Silk moth on its Cocoon

profession. According to Chinese records, the discovery of silk production from *Bombyx mori* occurred in 2640 B.C. It is Si-ling-chi, the 14-year-old wife of China's third emperor Hoang-ti, who has been considered as the Lady of the Silkworms. One day, as she was making tea in the palace garden, Si-ling-chi accidently dropped a silkworm cocoon into a cup of hot water and discovered that the silk fibre could be loosened and unwound. She made a thread by twisting together fibres from several cocoons that was strong enough to be woven into cloth. The great prince, Hoang-ti, directed his wife, Si-ling-chi, to examine the silkworm and test the practicability of using the thread. Thereafter, Si-ling-chi discovered not only the means of raising silkworms, but also the manner of reeling the silk and of employing it to make garments. Si-ling-chi was later deified for her work and honoured with the name Seine-Than or "The Goddess of Silkworms". Sericulture during the following centuries spread through China and silk became a precious commodity highly sought by other countries.

There are many varieties of silks found around the world and are known by different names. In India, all the four types of major silkworms are reared. While the mulberry silkworms (*Bombyx mori*) are domestically raised, the others are wild varieties. The mulberry silkworm produces the thread or filament which is smoother, finer and more round shaped than any other type of silkworm. This round filament of mulberry silkworm can be reeled into a long and continuous thread which is relatively stronger. The silk producing mulberry silkworm transforms to a moth which cannot fly on its own, but produces eggs for the next generation of silkworms. Hence the cycle goes on perpetuating the whole process of silk production.

## 2. Silk Road/Silk Route

For centuries, it was the Chinese nobility which guarded the secret of silk production. Only members of the royal family were permitted to wear garments made of silk. But as the laws regulating sericulture were gradually relaxed, explorers and traders began to acquire enough samples of the fabric to create a demand for it in the West. For a while, Persia became China's trading partner, buying silk and reselling it to the Europeans at exorbitant prices. By the time the Han dynasty finally authorised direct trade with Europe (around 140 BC), the Chinese zealously had guarded the secret of production of silk for about 3000 years and traded silk besides spices and rare treasures along the world's longest trade route called **"Silk Road"**, which stretched from the Eastern China to the Mediterranean Sea [see map (Fig.2)]. There was an eager market for the fabric throughout most of the Roman Empire. Despite constant danger from thieves, the Silk Road, a perilous overland trade route through Asia Minor, came to be a major cultural link between the two continents.

The silk trade made China a wealthy and powerful country. But according to a legend, the Roman Emperor, Justinian balked at paying China's high prices for silk. Around 550 AD, he recruited two Persian monks and sent them to China as spies to learn the secrets of silk production. Two years later, the monks returned to Constantinople (now Istanbul, Turkey) with silkworm eggs and mulberry seeds concealed within their hollow bamboo canes. The Turks quickly established their own silk industry and broke China's monopoly.

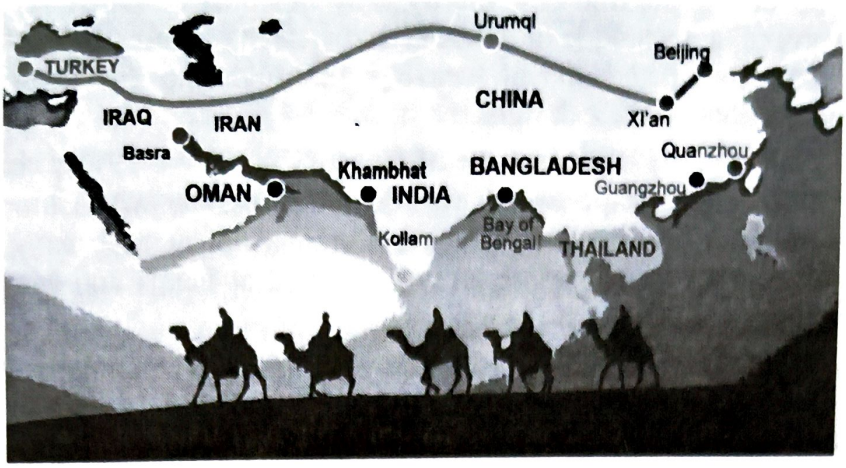



**Fig. 2. Silk route/road**

During the sixth century BC, Greek traders settled around the Black Sea and in Asia Minor and carried silk to the Mediterranean region. The silk probably could have been transported via Yarkand on the Silk Road to reach Greek traders at the mouth of the Indus, from where ships carried it from India to the markets of Mediterranean and the dyers of Phoenicia. The techniques of sericulture spread throughout the Mediterranean countries during the 7th century AD and then into Spain and Sicily following the Saracen invasion. The Chinese emigrants smuggled silk cultivation to Korea from where the silkworm was taken to Japan between 200 B.C. and 300 A.D. Japan eventually became the top producer of silk. By the 12th century, Italy had become the silk capital of the West and later, the French government spawned its own industry by subsidising farmers who planted mulberry orchards. For a short time, sericulture even spread to England and the American colonies. In 1810, a silk mill was built in Mansfield, Connecticut.

But during the twentieth century, the high cost of western labour, a shortage of mulberry leaves, world wars and two silkworm diseases (pebrine and flacherie) conspired to reduce the size and scope of western sericulture. Today, most commercial silk production is confined to China and Japan where it remains largely a cottage industry. In India, the main industry scientific investigation was started by scientist Leproy in 1905-06. India is still a major producer of "wild" (Tassar) silk.

Silk is a natural fibre and hence good for body. Its isothermal properties make it cool in summer and warm in winter. The cloth's absorbency helps in dyeing with any colour, thus obtaining infinite shades, designs and finishes. The applications of silk are many including the furnishings, costumes, embroideries etc., making it a desired material in fashion designing. Silk is also used as a ground material for painting and printing. In order to satisfy the demands of the fashion world, history tells us that there have had been many weavers, artists and technicians who have worked on silk.

(*i*) As per the historical events, though the silk travelled towards west, the Silk Road is generally referred to as having been 'opened' in the 2nd century BC during the time of Romans and the reign of the Han emperor Wu. Wu's ambassadors travelled as far west as Persia and Mesopotamia, bearing gifts including silk. Sericulture was established at an earlier period of 2nd century BC at Central Asia during the reign of **Han dynasty** (206 BC–AD 221). Rome was the country which had a huge demand for silk during this period and the supply was mainly shared by China and even India.

(*ii*) The Han dynasty was succeeded by the **Tang dynasty** (618–906 AD). The Tang had developed an impressive new weave silk satin and their embroideries depicting Buddhist images.

(*iii*) The weavers during the rule of **Ming dynasty** in China (1368–1644) started to weave figured velvets, a technique influenced by westerly sources. By the 6th century, Chinese workshops had skills of weaving, embroidering and painting textiles with European influence on their designs.

(*iv*) During the last dynasty of China, the **Manchu Qing** (1644–1911), chinoiserie became a famous fashion in Europe, which was decorated mainly with Chinese silks. Due to the battle of Talas during 751, China suffered a defeat and many skilled Chinese weavers were taken as war prisoners and resettled at Persia and Mesopotamia. Since then China started to keep off from the west.

(*v*) Later the **Yuan dynasty** (1260–1368) was established. The emperor **Justinian** gained the secrets of sericulture for the Roman Empire in 522 A.D., with the smuggling of the silkworm eggs from China by Persian monks. With China's monopoly on sericulture broken, silk importations from China became smaller and smaller.

(*vi*) In 877 A.D., the rebel chief **Biachu** captured Canfu, the centre of foreign silk trade, put to death all its inhabitants, destroyed all of the mulberry trees and silkworms of the region and levied heavy and cruel taxes on all foreign trade. These actions stopped foreign commerce in China for more than 60 years. However, by this time, silk production was so well established in western Asia and Eastern Europe that this wholesale destruction hardly affected the price of silk in the rest of the world. Persians and Arabs to certain extent spread the silk trade. Because of the predominance of Arabs, the Romans sought the alliance with Mongols for trade in the west which was called as the Pax Mongolica.

(*vii*) By 15th century, Italy emerged as the most important producer and trader of silk goods in Europe. There was a total devastation of sericulture due to the pebrine disease of silkworm in European countries, which otherwise concentrated later on silk processing and weaving.

(*viii*) During the 18th and 19th centuries, Europeans also produced several major advancements in silk production. England by the 18th century led Europe in silk manufacturing because of English innovations in the textile industry. These innovations included improved silk-weaving looms, power looms and roller printing.

(*ix*) In 1801, a Frenchman named **Joseph Jacquard** exhibited his new machine for figured silk weaving that gradually spread through the industry. The great French scientist, Louis Pasteur rescued the silk industry in 1870 by showing that the then epidemic Pebrine disease of silk-worms could be controlled by prevention through simple microscopic examination of adult moths. These advances set the trend for a more mechanized and scientific approach to silk production than existed previously.

(*x*) A Buddhist monk or missionary is credited with bringing the Chinese techniques of silk-reeling to India during the **Gupta period** (400–600 AD) and similarly the previous traveller might have brought the eggs of *Bombyx mori*. In Assam, the Bodo tribe, who originally migrated from the Central Asia are said to have brought the art of silk reeling with them.

(*xi*) **Sultan Tughluq** (1325–1350) had hundreds of manufacturers of golden tissues or silk, who use to weave fabrics for the court.

(*xii*) **Babur** who invaded India brought artists and craft workers along with him and allowed them with the skilled India artists.

(*xiii*) In 2014, UNESCO declared the 5000 km silk road of Chang'an–ianshan Corridor as **World Heritage Site**.

In India, the famous Vedic script 'Rig Veda' of India which was composed some three thousand years ago and the Sanskrit epic 'Ramayan' reveal the existence of silk, which was mainly referred to as golden threads. Currently, India is credited with the production of all the four commercially known varieties of silk in the world. While mulberry silk is domesticated and produced on a large scale in the rural areas, the non-domesticated wild silks, viz. tasar, eri and muga are produced in the wild and are named as **vanya silk** in India. In the earlier days the most sought after silk was tasar, which delivered beautiful lustrous silk. India is also the second largest producer of tasar silk, while the golden-yellow muga silk is predominantly produced in the state of Assam. India is a vast repository of ancient motifs, techniques and ideas and unique among silk-producing countries. Sericulture is home based in India, as is seen in China. Existence of low cost of labour and available natural resources has made these countries to adopt this enterprise on a large scale. A large proportion of population in India still is dependent on the non-domesticated vanya silk.

### 3. Some Facts about Silk and Its Trade

Some important facts about silk development in the ancient period are indicated below :

1. Silk trade started before the second century BC.
2. Later, ambassadors of the Chinese emperor, Han Wu Di travelled towards Persia and Mesopotamia with gifts including silks.
3. It reached Baghdad in 97 AD and important findings of silks have been made.
4. The Greeks and Romans began talking of Seres, the Kingdom of Silk during 400 BC.
5. The Roman Emperor Heliogabalus (218 – 222 AD) wore silk.
6. By 380 AD, Marcellinus Ammianus reported, "The use of silk which was once confined to the nobility has now spread to all classes without distinction, even to the lowest". The craving of silk continued to increase over the centuries.

## II. TYPES OF SILK

The four types of natural silk are produced in the world. Among them mulberry silk is the most important and contributes as much as 90% of the world production, therefore, the term "silk" in general refers to the silk of the mulberry silkworm. As mentioned earlier, three other commercially important types fall into the category of non-mulberry silks, viz. Eri silk, Tasar silk and Muga silk. India is the second largest producer of silk in the world. Among the four varieties of silk produced, in 2019-20, Mulberry accounts for 70.46% (25,239MT), Tasar 8.76% (3136MT), Eri 20.11% (7204MT) and Muga 0.7% (241MT) of the total raw silk production of 35,820MT, whereas it is 31 MT in Himachal Pradesh. There are also other types of non-mulberry silk, e.g., Anaphe silk, Fagara silk, Coan silk, Mussel silk and Spider silk, which are mostly wild and exploited in Africa and Asia.

### A. Mulberry silk

Most of the commercial silk produced in the world comes from mulberry silk. Mulberry silk comes from the silkworm (*Bombyx mori*) L. which solely feeds on the leaves of mulberry plant. These silkworms are completely domesticated and reared indoors. Mulberry silk contributes to around 90% of the world silk production.

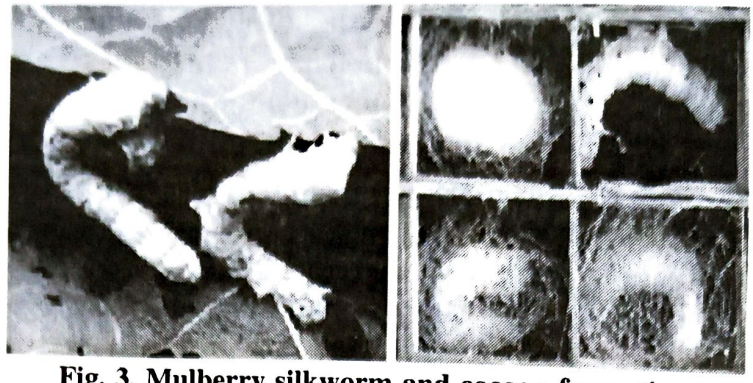


Fig. 3. Mulberry silkworm and cocoon formation

## B. Non-Mulberry Silk

### 1. Tasar/ Tussar/ Tusser/ Tushar/ Tussah silk

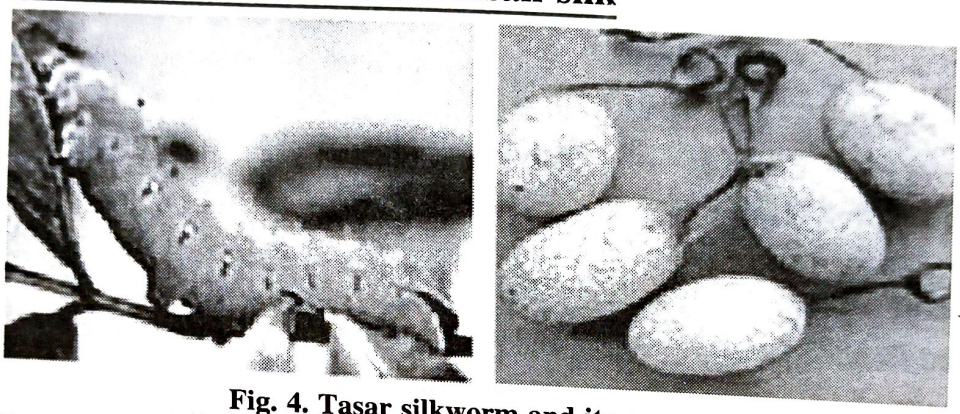


Fig. 4. Tasar silkworm and its cocoon

The tasar silkworms belong to the genus *Antheraea* and they are all wild silkworms. There are many varieties such as the Chinese tasar silkworm (*Antheraea pernyi*) Guerin, which produces the largest quantity of non-mulberry silk in the world. The Indian tasar silkworm, *Antheraea mylitta* Drury, is next in importance and then comes Japanese tasar silkworm, *Antheraea yamamai* Querin which is peculiar to Japan and produces green silk thread.

The Chinese and Japanese tasar worms feed on oak leaves and other allied species. The Indian tasar worms feed on leaves of *Terminalia* and several other minor host plants. The worms are either uni- or bivoltine and their cocoons like the mulberry silkworm cocoons can be reeled into raw silk.

### 2. Eri silk

These belong to either of two species namely *Samia ricini* and *Philosamia ricini*. *P.ricini* or castor silkworm is a domesticated one reared on castor oil plant leaves to produce a white or brick-red silk, popularly known as Eri silk.

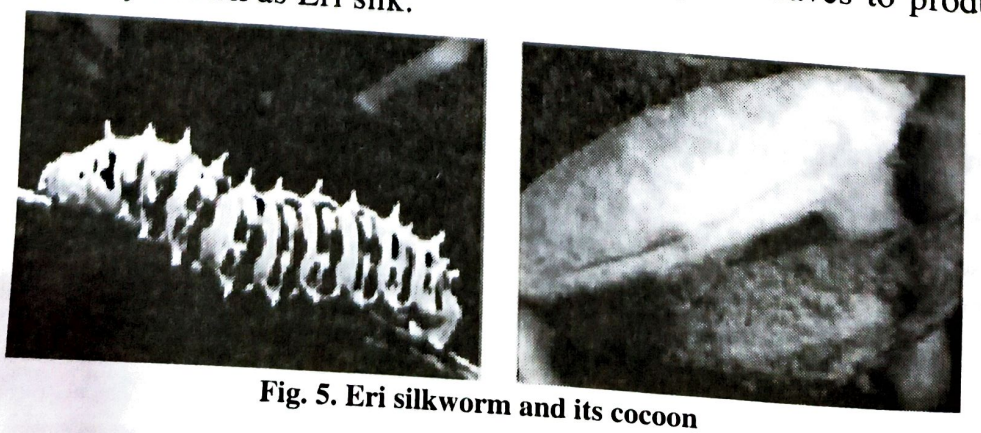


Fig. 5. Eri silkworm and its cocoon

Since the filament of the cocoons spun by these worms is neither continuous nor uniform in thickness, the cocoons cannot be reeled and, therefore, the moths are allowed to emerge and the pierced cocoons are used for spinning to produce the Eri silk yarn.

### 3. Muga silk

The muga silkworms (*Antheraea assamensis*) also belong to the same genus as tasar worms, but produce an unusual golden-yellow silk thread which is very attractive and strong. These are found only in the state of Assam (India) and feed on *Persea bombycina* and *Litsaea monopetala* leaves and those of other species.The quantity of muga silk produced is quite small and is mostly used for the making of traditional dresses in Assam itself.

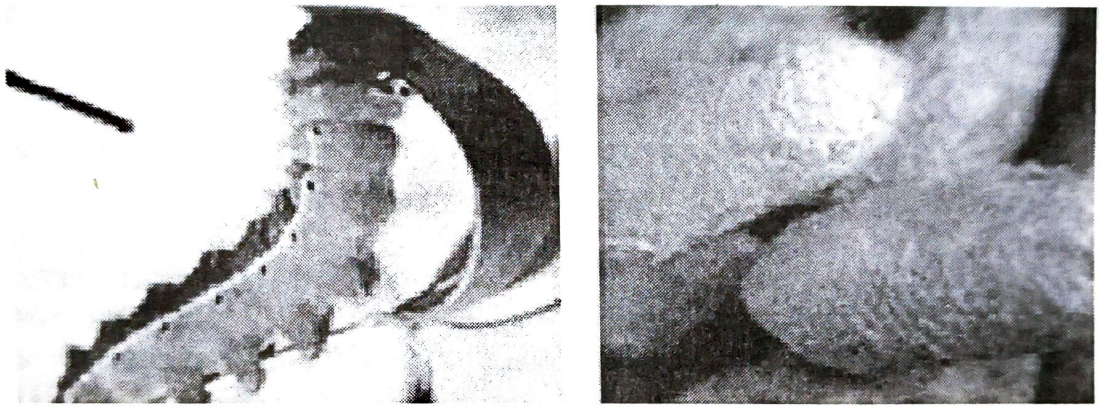


**Fig. 6. Muga silkworm and its cocoon**

### 4. Anaphe silk

This silk of southern and central Africa is produced by silkworms of the genus *Anaphe* having species as *A. moloneyi* Druce, *A. panda* Boisduval, *A. reticulate* Walker, *A. ambrizia* Butler, *A. carteri* Walsingham, *A. venata* Butler and *A. infracta* Walsingham. They spin cocoons in communes, all enclosed by a thin layer of silk.

The tribal people collect them from the forest and spin the fluff into a raw silk that is soft and fairly lustrous. The silk obtained from *A infracta* is known locally as "book" and those from *A. moleneyi* as "Trisnian-tsamia" and "koko" (Tt). The fabric is elastic and stronger than that of mulberry silk. Anaphe silk is used, for example, in velvet and plush.

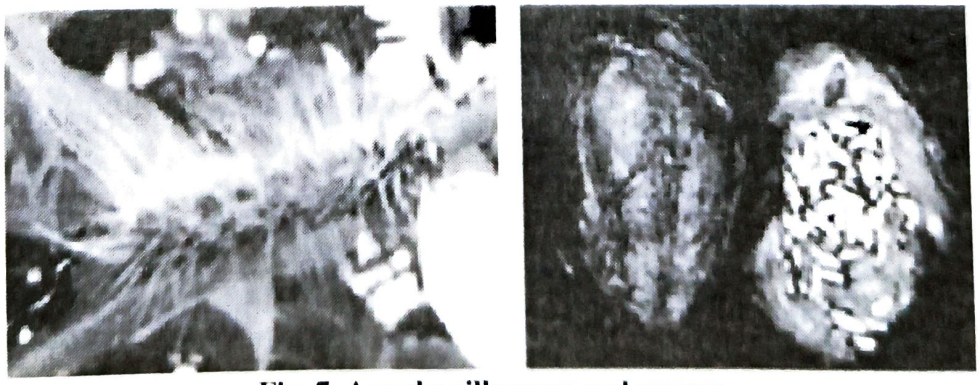


**Fig. 7. Anaphe silkworm and cocoon**

### 5. Fagara silk

Fagara silk is obtained from the giant silk moth, *Attacus atlas* L. and a few other related species or races inhabiting the Indo-Australian bio-geographic region, China and Sudan. They spin light-brown cocoons nearly 6 cm long with peduncles of varying lengths (2-10 cm).

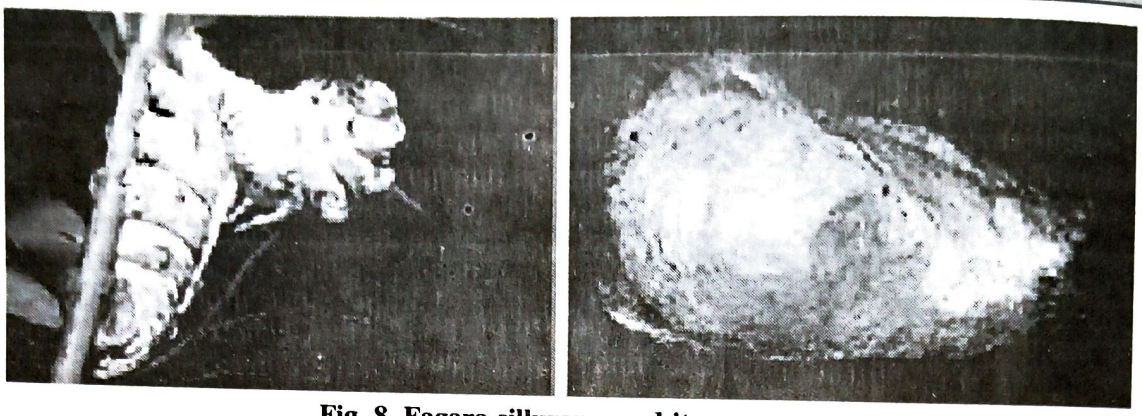
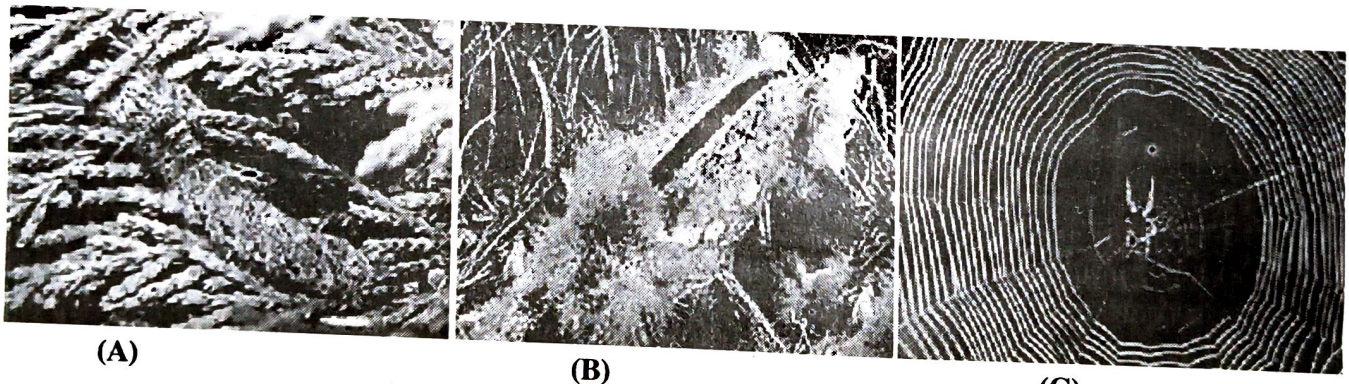


Fig. 8. Fagara silkworm and its cocoon

## 6. Coan silk

The larvae of *Pachypasa atus* D., from the Mediterranean bio-geographic region (southern Italy, Greece, Romania, Turkey, etc.), feed primarily on trees such as pine, ash cypress, juniper and oak.

They spin white cocoons measuring about 8·9 cm × 7·6 cm. In ancient times, this silk was used to make the crimson-dyed apparel worn by the dignitaries of Rome. However, commercial production came to an end long ago because of the limited output and the emergence of superior varieties of silk.



(A) (B) (C)

Fig. 9. (A) Coan silk (B) Mussel silk (C) Spider silk

## 7. Mussel silk

While the non-mulberry silks previously described are of insect origin, the mussel silk is obtained from a bivalve, *Pinna squamosa*, found in the shallow waters along the Italina and Dalmatian shores of the Adriatic.

The strong brown filament or byssus is secreted by the mussel to anchor it to a rock or other surface. The byssus is combed and then spun into a silk popularly known as "fish wool". Its production is largely confined to Taranto, Italy.

## 8. Spider silk

Spider silk is another non-insect variety. It is not only soft and fine, but also strong and elastic. The commercial production of this silk comes from certain Madagascan species, including *Nephila madagascarensis, Miranda aurentia* and *Epeira*. As the spinning tubes (spinne-rules) are in the fourth and fifth abdominal segments, about a dozen individuals are confined by their abdominal part to a frame from which the accumulated fibre is reeled out four or five times a month. Because of the high cost of production, spider silk is not used in the textile industry. However, durability and resistance to extreme temperature and humidity make it indispensable for cross hairs in optical instruments.

## III. CLASSIFICATION OF SILKWORM RACES

### 1. Races on the Basis of Origin

(*i*) **Indigenous species** – Silkworms originating in and have characteristic of a particular region or country also called native species e.g. Pure Mysore, Nistari.

(*ii*) **Exotic species** – Introduced into an area, where they do not occur naturally; also called non-native species e.g. E16, Daizo etc.

(*iii*) **Breed** – A stock of silkworms within a species having a distinctive appearance and typically having been developed by deliberate human selection.

(*iv*) **Races** – A population of silkworms within a species that is distinct in some way, also known as subspecies.

### 2. Races on the Basis of Voltinism

Voltinism is a term used in biology to indicate the number of broods or generations of an organism in a year under natural environmental conditions. Based on voltinism, *Bombyx mori* is divided in to 3 types :

(*i*) **Uni-voltine Races.** They produce one generation per year. The larval weight is comparatively higher and cocoons are heavy. Denier (unit of fibre thickness) of the silk filament is above 2·3. They are not suitable for summer and winter rearings since the larvae are weak against unfavourable conditions, especially to higher temperature. They lay only diapausing eggs. All European races are uni-voltines, e.g. E16

(*ii*) **Bi-voltine Races.** They produce two generations per year. The length of the larval stage is short. The leaf consumption to cocoon production (cocoon ratio) is less and the quality of the cocoons is inferior to that of uni-voltine races. Further, cocoon weight, shell weight, silk perentage filament length are lesser than uni/mono-voltines. Most of the temperate races are bi-voltines and lay both hibernating and non-hibernating eggs, e.g., NB4D2, NB18, KA, NB7 etc.

(iii) **Multi-voltine Races.** They produce more than 5-6 generations per year. The length of the larval duration is short. In most of the poly-voltine races the leaf cocoon ratio is high, cocoons are compact grained and cocoon layer is soft. The length of the filament is short (approximately 400 mts). However, the cocoon filament is fine and clean with little lousiness, but with more lustre. The larvae are robust and can tolerate fluctuating environmental conditions and hence, best suited for tropical climates. They lay only non-diapausing eggs e.g., Pure Mysore, C Nichi, Hosa Mysore.

### 3. Races on the Basis of Geographic Distribution

(*i*) **Japanese Race (Aboriginal in Japan).** Fecundity is higher, ranging from 600-700. The larvae are very active and leaf to cocoon ratio is less. Larval body size is small for long larval duration of around 26 days and the larvae are marked. The shape of the cocoon is strangulated, giving the appearance of peanut shape. Almost all races produce white cocoons. Further, percentage of double cocoons is more and quality of silk is better. Larvae are susceptible to grasserie and flacherie. There are uni and bi-voltine races in this group.

(*ii*) **Chinese Race (Aboriginal in China).** In Chinese races the fecundity rate is higher, ranging from 600-650 eggs. The progress of the larval growth is quick, as a result of which the leaf to cocoon ratio is less. Most of the Chinese races are plain without any markings. The shape of the cocoon is round/elliptical, and few of them are spindle shaped. The cocoon colour is white, golden yellow, flesh coloured or red. The silk

filament is fine and reelability is good. The Chinese races are resistant to high temperature and humidity. Uni, bi, multi-voltine races fall under this group and ever tri-moulters are noticed.

(*iii*) **European Races (Aboriginal in Europe and Central Asia).** The fecundity rate is medium, ranging from 550-600 and size of the eggs is large. The larval stage is long, the moulting period reduced by 1-2 hrs. The larvae are plain without any markings. The cocoons are big, long and elliptical. Cocoons are either white/flesh coloured. The percentage of double cocoons is less. The filament length is long with good reelability. European races are weak against high temperature and humidity. All are uni-voltines.

(*iv*) **South East Asian Races (Tropical).** The fecundity rate is lower, ranging from 400-500. Eggs are small. The larval length is short with a few exceptions, where the tropical races of India exhibit longer larval duration. The larval markings are not common in these races. Leaf to cocoon ratio is high. The size of the larvae is small. The shape of the cocoon is spindle, flossy with less filament length. The common cocoon colour is green/pink/yellow/white. Denier of the silk filament is fine. These races are resistant to varied environmental conditions, especially high temperature and humidity. Multi-voltines/poly-voltine races are very common.

**4. Races on the Basis of Moultinism**

Moulting or molting, also known as shedding or ecdysis is the manner in which an animal routinely casts off an outer layer or covering at specific points in its life cycle. Silkworms can be classified into tri-moulters, tetra-moulters, penta-moulters and hexa-moulters (very rare).

(*i*) **Tri-moulters.** These silkworms moult three times during larval period. The larval growth is limited and the larval duration is short ranging, from 15-18 days. Pupae and moths are small, cocoon weight is less, cocoon filament is fine and denier of the silk filament ranges from 1·6 to 1·7.

(*ii*) **Tetra-moulters.** These silkworms moult four times during their larval stages. The length of the larval stage is medium, ranging from 23-28 days. The larval growth and cocoon weight is medium. Denier is 2- 2·5. Tetra-moulters are cosmopolitan in their distribution.

(*iii*) **Penta-moulters.**These silkworms moult five times during their larval stages. The length of the larval stage is long, larval weight is high and the cocoons are heavy. filament length is more. Denier of the silk filament is very high.

**5. Races on the Basis of Geographical Zones**

(*i*) **Temperate Breeds**

(*a*) Temperate breeds are all either uni or bi-voltines. They lay both hibernating and non-hibernating eggs.

(*b*) Temperate silkworm breeds are susceptible to fluctuating environmental conditions as well as poor quality leaves.

(*c*) Temperate breeds are good yielders in general, i.e. more cocoon weight, shell weight, filament length, denier etc, e.g. E16, Daizo etc.

(*ii*) **Tropical Breeds**

(*a*) Tropical breeds are all multi-voltines. They lay only non-hibernating eggs.

(*b*) Tropical silkworm breeds are resistant to fluctuating/varied environmental conditions and poor quality leaves.

(*c*) Tropical breeds are poor yielders in general, i.e. more cocoon weight, shell weight, filament length, denier etc., when compared to temperate breeds, e.g. Pure Mysore, Nistari etc.

## IV. TYPES OF SILKWORMS ON THE BASIS OF HOST TREE

### A. MULBERRY SILK WORM (*Bombyx mori*)

*Bombyx mori* is extensively reared in India, China and Europe. Host plants are mulberry i.e.*Morus alba, M. laevigata, M. indica* and *M. serrata. Morus* spp. is avenue trees (multipurpose tree). Although it is a native of China, but introduced in all parts of the world. In India, major states of silk production are Karnataka, Andhra Pradesh, West Bengal, Tamilnadu and Jammu-Kashmir while Panjab, Maharashtra and Bihar are minor prodacess It has all, i.e. uni-voltine, bi-voltine and multi-voltine strains.

(*i*) **Uni-voltine** – one brooded race as it remains in the egg for 9-10 months, mostly found in Italy, France, Japan and China. In India, it is found in West Bengal, Punjab and Jammu & Kashmir.

(*ii*) **Multi-voltine** – many brooded race, i.e. hatches many times in a year. Silk is inferior to uni-volutine. It is reared in Karnataka, West Bengal and Assam.There are two races of multi-voltine in India : (*a*) Mysore of Karnataka (*b*) Nistri of West Bengal.

### B. NON-MULBERRY SILK WORMS

Silk worms other than mulberry silk worms are called non-mulberry silk worms. As they are reared outdoors in wild, they are also known as wild silk insects or *Vanya* silkworms. The only exception is the domesticated Eri silk moth (*Samia ricini*). All the commercially exploited wild silk moths of India belong to the family Saturniidae. They are capable of flight and follow the same pattern of life cycle.

#### 1. Muga Silkworm

Muga silkworm (*Antheraea assamensis*) produces silk of golden yellow lustre. The popular name 'Muga" is an Assamese word meaning brown colour. Muga silk is grown exclusively in the North-Eastern region of India, particularly in Assam. It is a multi-voltine insect with 5-6 generations a year. The **Ahom** kings patronised muga silk industry in Assam. Som (*Perseas bombycina*) and Soalu (*Litsea polyantha*) are the important food plants of the muga silkworm. A fully grown tree of 12 to 20 years can support the rearing of 5 to 10 layings and yield 500 cocoons in one season and one tree can be utilised for two rearings in a year. The silkworms are reared outdoors and as such are exposed to vagaries of nature. There are six crops in muga culture depending on the seasons. They are *Jarua* (winter), *Chotua* (late winter), *Jethua* (spring), *Aherua* (summer), *Bhodia* (late summer) and *Kotia* (autumn). Rearing performance is high in Kotia crop followed by *Jethua* due to favourable conditions.

**Life cycle of Muga Silkworm**

Its life cycle is similar to that of mulberry silk insect and completes in about 50 days in summer and 120 days in winter. Like the mulberry silk insect, the muga silk insect also has four stages in the life cycle – egg, larva, pupa and adult.

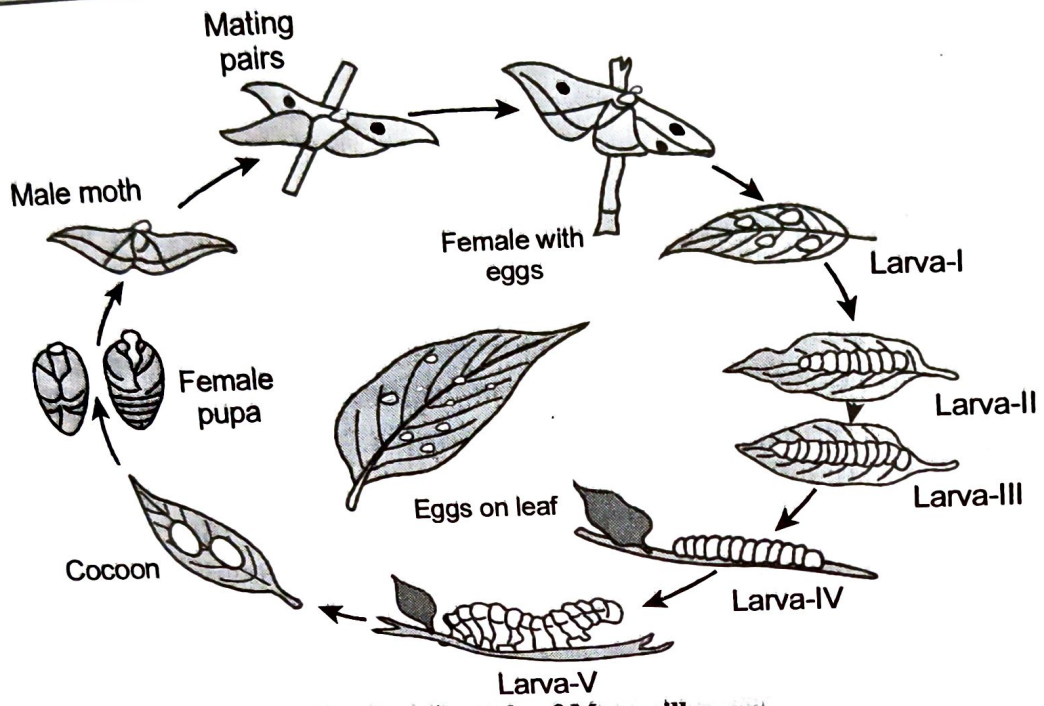



**Fig. 10. Life cycle of Muga silkworm**

(*i*) **Egg.** A female moth lays around 150 eggs. The egg is oval in shape, dorsoventrally flattened, bilaterally symmetrical and creamy to brownish grey in colour and measures 2·3-2·8 mm × 2·4 mm. They hatch in about 7 days in summer and 16 days in winter.

(*ii*) **Larva.** The newly hatched larva is black in colour with distinct yellow lines at the inter-segmental region. The body tubercles are yellow and are provided with setae. The head is small but distinct and black in colour. They measure 0·6-1·3 cm in length. They actively feed on the leaves of their food plants and pass through four moults like the mulberry silkworm and reach a size of 4·0-5·5 cm in length and weigh approximately 4·10-5·15 gm. The dorsal surface of the body is light green while the ventral surface is deeper in colour.

(*iii*) **Pupa.** The fully grown larva spins a cocoon around it and then transforms into a pupa. Spinning of cocoon takes 3 to 7 days in different seasons. The pupal stage lasts for 14 days in summer and 40 days in winter. The population in the hills undergoes diapause at the pupal stage to overcome the winter.

(*iv*) **Adult.** Moths emerge from the cocoon, mate and lay eggs and continue their generation. Like the mulberry silk moths, they do not have mouth parts and die in about a week.

## 2. Eri Silkworm

Eri silkworm, *Samia ricini* is the only fully domesticated silkworm feeding on Castor (*Ricinus communis*) and Kesseru (*Heteropanax fragrans*) plants. They are also reared on Tapioca (*Manihot utilissima*) and Payam (*Evodia flaxinifolia*). This silkworm derives its name 'Eri' from 'Eranda' in Sanskrit or 'Endi' in Assamese languages which means castor as its main food plant. It is multi-voltine in nature. Eri silkworms can be reared throughout the year in 5-6 crops when the climatic conditions are favourable and food plants are available. The methodology of Eri silkworm rearing is relatively simple. They are hardy and less susceptible to diseases. The colour of Eri silk is creamy white like mulberry silk and is less shining than the latter.

### *Life Cycle of Eri Silkworm*

*The life cycle of Eri silkworm has four stages – egg, larva, pupa (cocoon) and adult (moth). A complete life cycle lasts about 44 days in summer and 85 days in winter.*

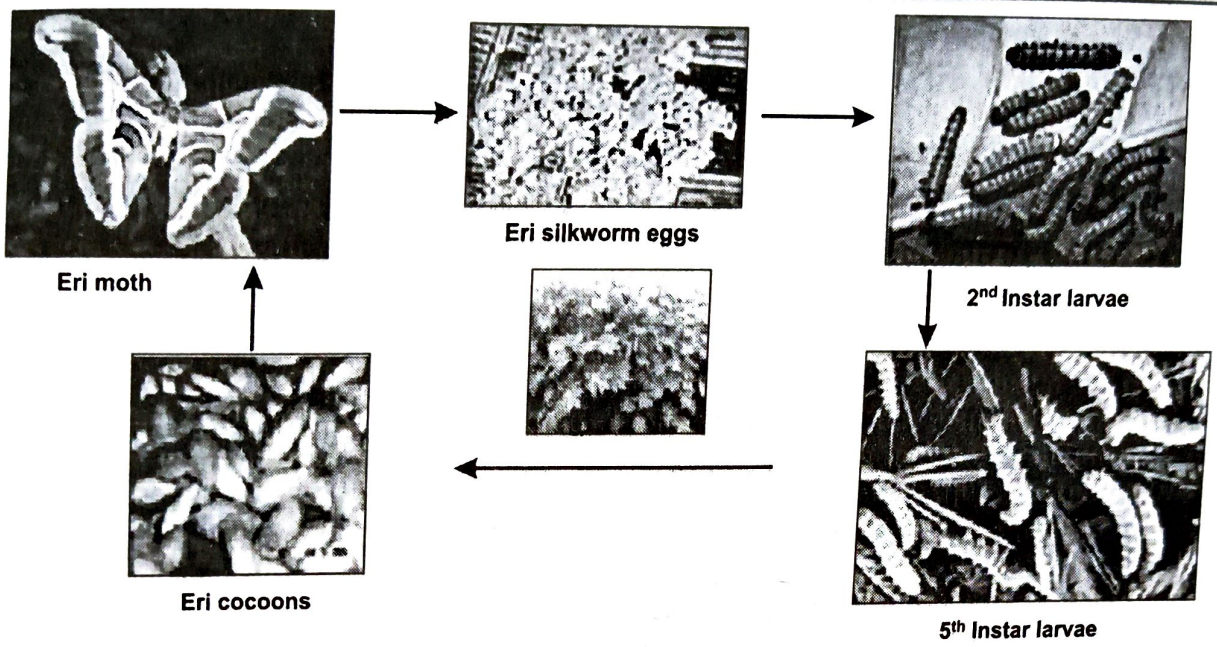



**Fig. 11. Life cycle of Eri silkworm**

(*i*) **Egg.** Eggs are ovoid in shape, candid white in colour, measure 1·5 × 1·0 mm and weigh 6 mg. By the time they hatch, they become ash to blackish colour. They hatch in 9-10 days in summer and 14-15 days in winter.

(*ii*) **Larva.** The new born larva is greenish yellow in colour, measuring about 5 × 1 mm. The fully grown larva measures about 7·0 × 1·5 cm and weighs 8 g, is translucent and covered with a white powdery substance. Different strains have different colours and body marking pattern. The larval span varies from 20 days in summer to 50 days in winter.

(*iii*) **Pupa.** A fully mature larva spins a cocoon around it and then transforms into a pupa. Spinning takes around two days and pupation takes another two days. The cocoons are long, soft and without a peduncle. One end is narrow and open. Pupation usually takes around 10-20 days depending on the temperature.

(*iv*) **Adult.** The adult moth emerges from the cocoon in about 10 days from the day of spinning. After mating, each moth lays around 400 eggs which depend on the feed and the season. The total life cycle lasts about 45 days in summer and 90 days in winter.

## 3. Tasar Silkworm

Tasar silk worm (*Anthraea mylitta*) is the tropical tasar silk worm reared largely in central India. *A. proylei* and *A. roylei* are temperate tasar silk insects reared in the Himalayan belt. They belong to the family Saturniidae of the order Lepidoptera.Tasar silkworms are primarily feed on Sal (*Shorea robusta*) plants in the forest. Asan (*Terminalia tomentosa*) or Arjun (*Terminalia arjuna*) plants are also the primary food plants in the systematic or natural plantations. They also feed upon *Shorea robusta*, *Zyziphus* and *Quercus* species. The Tasar silkworm is normally Trivoltine or bivoltine, which mean that it completes three or two life cycles in one year. The tasar silkworm shows wide variations in its appearance and biological traits due to its spread over vast areas in the states of Jharkhand, Bihar, Chhattisgarh, Madhya Pradesh and Orissa. Accordingly, two eco-races, i.e. Daba and Sukinda are widely used for commercial cocoon production.

It is considered the most abundant among the non-mulberry worms. It produces coarse

quality of silk in summer whereas November season has superior quality. In India, Mirzapur, Bihar is very important in cocoons produced in November-December. It is also found in China and Sri Lanka. Tasar silk is coarse and in little quality but costly.

**Races of Tasar silk worm**

(*i*) *Antheraea proylei* – Oak Tasar of India.

(*ii*) *Antheraea pernyi* – Oak Tasar of China.

(*iii*) *Antheraea yamami* – Tasar silkworm of Japan.

(*iv*) *Antheraea polypnemis* - Tasar silkworm of United States.

(*v*) *Antheraea roylei* - Oak Tasar of Himalayas.

The Indian Oak Tasar Silkworm *Antheraea proylei* is a hybrid of *A. pernyi* (Chinese) and *A. roylei* (wild). The silkworm is polyphagus and feeds on a variety of Oak flora that flourish in the sub-Himalayan belt extending from Jammu and Kashmir, Himachal Pradesh and Uttaranchal in the north to Assam, Meghalaya, Mizoram, Manipur, Nagaland and Arunachal Pradesh in the north-east. Oak tasar silkworm is completely domesticated in North-west and semi-domesticated in North-east region and hence the rearing differs. Thus, Oak tasar is reared indoors in North-west and outdoors in North-east. Because of variations in topography, climatic conditions, distribution of food plants and seasons of these two regions, different methods are adopted for rearing of Oak Tasar silkworm. *Antheraea proylei, Antheraea pernyi, Antheraea roylei* are found in Himachal Pradesh.

**Life Cycle of Tasar silkworm** (*Antheraea mylitta*)

(*i*) **Egg.** Egg is oval in shape, dorso-ventrally flattened and bilaterally symmetrical along the anterio-posterior axis. Eggs of tropical tasar measure about 3 mm in length and 2·5 mm in diameter and weigh approximately 10 mg; while oak tasar eggs measure about 2·5 × 2 mm and weigh about 7 mg. Freshly laid eggs are dark brown in colour. After washing, it becomes white, light yellow or creamy.The eggs hatch in around 12 days from the day of hatching.

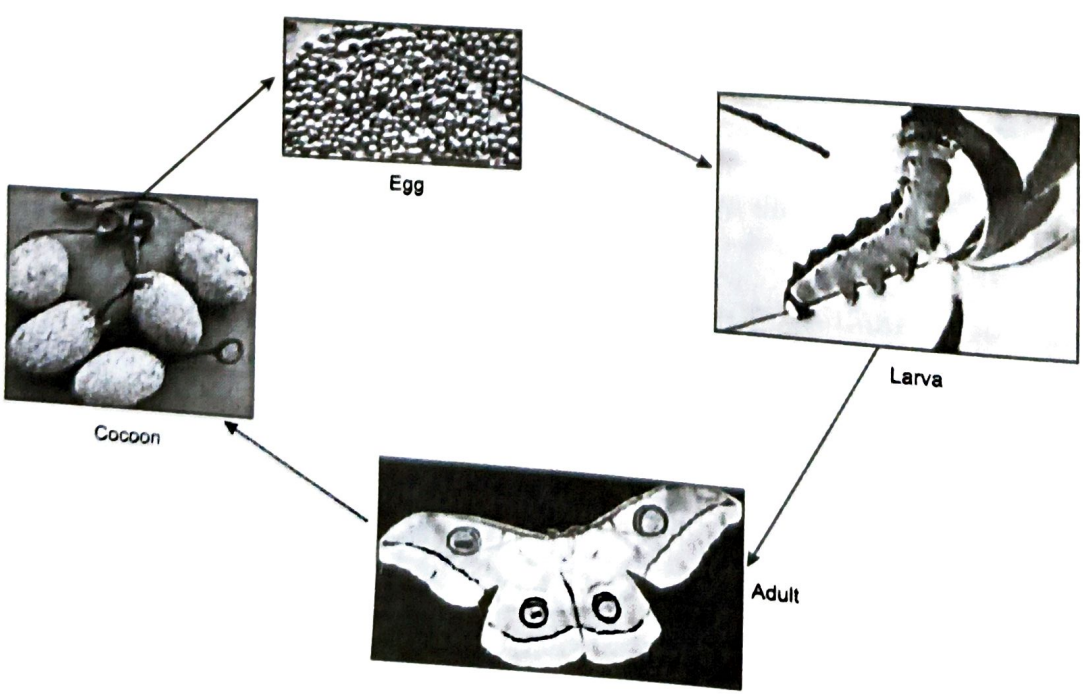



***Fig. 12. Life cycle of Tasar silkworm***

(*ii*) **Larva.** The newly hatched larva is dull brownish yellow with black head, measuring about 7mm long and 1 mm diameter and weighing about 8 mg. The larva at maturity measures about 13 cm long and 2·1 cm diameter and weighs about 50 gm. Various types of tubercles are present on the body. There are several hairs and setae, which are white, minute and irregularly distributed over the body. Shining spots are also present at the base of dorsal tubercles. The tasar silkworms moult four times and pass through five instars. The larval period varies between 30 and 70 days during different seasons in different races. The fully grown larva spins a cocoon taking support of one or two leaves and forming a hammock and a peduncle to firmly cling to the plant. The process takes place in 4-6 days and the shell is very hard.

(*v*) **Pupa.** The pupa is the resting stage in the tasar insects. Pupal period varies greatly, lasting from days to months depending upon the voltinism.

(*vi*) **Moth.** Females are bigger (4·5 cm) with a broad abdomen and narrow bipectinate antennae which are about 1·5 cm long. Males are smaller (4·0 cm) with a narrow abdomen and broad antennae. The females are grey or yellow, whereas males are brown or yellow or grey. Mouth parts are reduced, as moths do not feed. In male, the wingspan is about 16 cm, while in female, it is about 18 cm. Post-median line (PM) is red with a white line on the border. Ante-median line (AM) is usually black or dark brown in colour. The ocellus (OC: 70 mm) with a transparent area is prominently positioned at the centre of the wing. Each female moth lays around 200 eggs which continue their generation.

## V. SERICULTURE IS AN ECO-FRIENDLY INDUSTRY

1. It does not compete with other hill systems.
2. It increases the economy without damaging the environment.
3. It helps in the conservation of forest agricultural ecosystem.
4. It does not need any specific land. So there is little pressure on the land.
5. It is useful for communities in economical marginal category.
6. It does not require high input technology like chemicals and machines.

# QUESTION BANK

## I. FILL IN THE BLANKS

1. The non-mulberry sericulture is also called ..... .
2. Silk is called the ..... of textiles.
3. Chemically, silk is made of ..... .
4. Si-ling-chi was deified for her work and honoured as ..... of ilkworms.
5. Mulberry silk contributes to around .....of the world silk product ).
6. The tasar silkworms belong to the genus .....
7. Uni-voltine races produce ..... generation(s) per year.