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NATURAL SCIENCE

Art and architecture

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Insects have inspired artists and poets and also provided architects with examples of materials and methods that can be used.

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THE GOLDEN EMPEROR moth, Leopa katinka, is a variety of wild silk moth found in north-eastern India.

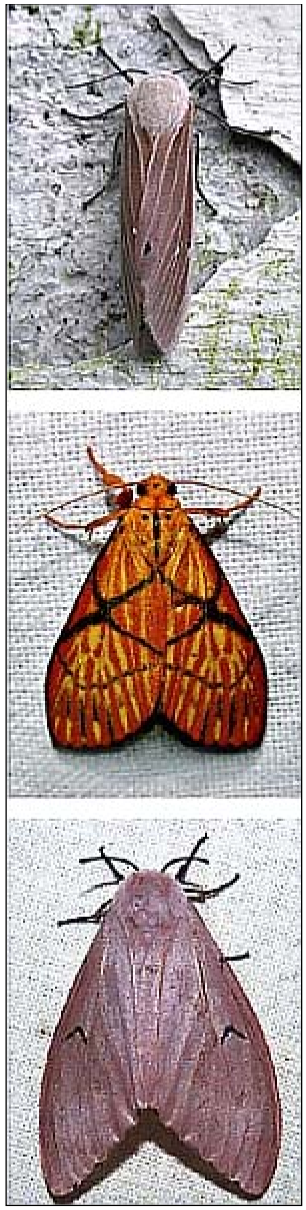
Series

This is the fourth part of an eight-part series on insects.

THE colours and forms of moths and butterflies have inspired artists and poets for centuries. One of the oldest industries to evolve from insects is sericulture, or silk production. According to Confucius' records, silk was discovered in the third millennium B.C. in China. The Chinese held a monopoly over silk to the extent that anyone attempting to export silk came under the death sentence by imperial decree. Both raw and woven silk played a major role as virtual currency and was a symbol of status and style in many cultures, for instance, among Persians, Byzantines, Turkish nomads and the Sogdian merchants of Central Asia[1].

Silk moth

A delightful legend records that one day a silkworm cocoon accidentally fell into the teacup of Empress Xi Ling, wife of the Yellow Emperor. She started unwinding the silk threads in order to rescue the cocoon from her cup and in the process discovered silk. On the emperor's advice, she began to observe the life of the silk moth and soon learned to grow it and extract silk. She then trained her entourage to raise silk moths and thus began the industry that remained a closely guarded secret for several centuries. Although this story is attributed to several princesses, records point to the empress as the first sericulturist.



Creatonotos transiens; the arctiid moth; and Lymantria lepcha.

Moths are usually seen more as being destructive in nature rather than as the insects that have dictated the economy of countries for centuries (and still do). The moth is the butterfly's closest relative, yet there is a persistent notion that moths are not as colourful as butterflies. Moths far outnumber butterflies in species diversity and exhibit colours and forms that are quite fascinating. The selection of moth images on these pages bears testimony to this fact.

The Saturniidae family, to which silk moths belong, includes some of the most spectacular species of the order Lepidoptera. The moths of this family all produce lustrous silk. They are wild species and differ from the ones that feed and grow on mulberry trees. The Indian subcontinent is believed to have about 50 species of silk moths that may be of economic importance. Of these, at least 24 species have been recorded in north-eastern India, which is an ideal habitat for these species and is, consequently, a centre for wild silk culture[2]. Hence, sericulture could be further developed as a livelihood option for people living in remote areas. Muga, Eri and oak tassar are examples of silk cultured from wild species of moths. There are probably many species of silk moths still undiscovered in regions such as Nagaland.

MOTHS CAN BE as colourful as butterflies. Cyana sp.

The domesticated silk moth, Bombyx mori, is quite different from the silk-producing wild species described above. The caterpillars of these moths feed on the leaves of the mulberry tree and moult several times before spinning themselves into silky cocoons. Rearing the caterpillars, removing the silk, and so on, require knowledge and skill.

There are many legends about how the Chinese monopoly over silk was broken. One has its source in the records of the seventh century monk Xuanzang. Around the first century A.D., a Chinese princess was given in marriage to one of the princes of Khotan. Before her journey to that country, she discovered that Khotan had neither mulberries nor silkworms. She could not imagine a life without silk. So she hid a few mulberry seeds and silk moth cocoons in her headdress and smuggled them out of China, much to the delight of the King of Khotan, who had long wanted to make silk in his country.

WEAVER ANTS, OECOPHYLLA smaragdina, make their nest by sticking leaves together using the silk produced by their larvae.

Yet another legend, based on a story by Procopius, a Byzantine scholar from Palestine, describes how two monks smuggled silkworm eggs in bamboo rods hidden in their clothes. They were sent by the Byzantine Emperor Justinian so that he could start a silk industry in his empire.

In the moth's world, silk is not merely a material to form cocoons for the pupa to metamorphose in. Several caterpillars hang on to silken thread to move out of their homes or to move in search of food. Others use thread to form pads on which they can moult.

Silk in the insect world

"as a representative

of the insect world

i have often wondered

on what man bases his claims

to superiority

everything he knows he has had

to learn whereas we insects are

born

knowing everything we need to

know"

(ABOVE AND BELOW) The white colour in these pierids is largely the result of the effect of the scattering of light.

– From Don Marquis' book the lives and times of archy and mehitabel

Silk may have been discovered accidentally by humans, but in the insect world, silk is a material that is instinctively secreted by several different types of insects, not just moths.

The weaver ant, Oecophylla smaragdina, constructs its nest using the silk produced by its larvae. Larvae that are ready for metamorphosis are held by the worker ants, and their silk is woven to bind leaves together to form a nest.

Caddisflies (order Trichoptera) produce protective cases in which their larvae develop. They obtain materials from their immediate environment and stick them together using silk to form the cases. When the larvae are ready to pupate, the cases are closed with pads of silk similar to those produced by moths. The labial glands, generally used to produce saliva, take on the function of silk production in Lepidoptera and Trichoptera. This spinning habit appears to have evolved around 250 million years ago.

The bagworm moth, as its name indicates, builds narrow cylindrical or conical bag-like structures on leaves or branches within which its young develop. The larvae pop their heads and a part of their bodies out of the bags to feed on leaves. At the slightest disturbance, they retreat into their bags. Silk covers the mouth of this bag when the larvae get ready to transform into adults. The insects of the order Embioptera are commonly known as web-spinners and produce silk from structures on their legs. Very small in size (1.5-2 millimetres), they construct silken tunnels or chambers to live in.

THE COLOURS OF this butterfly, Euthalia nais, commonly called baronet, are the result of pigments produced by biochemical reactions.

There are many more examples of silk production among insects such as midges, glow worms, fleas, wasps, sawflies and bees. Silk is also used by insects for mechanical reinforcement, thermal regulation and altering humidity conditions.

From silk to art

The ancient Chinese used silk fibres not only to weave cloth but also to make canvases for paintings. In the second century B.C., silk was used to make paper. Insects have been a favourite subject with oriental painters. The earliest of such pieces were made by Huang Ch'uan in A.D. 950. To serve as a painting model for his son, Huang painted a dozen insects in a work titled “Beautiful Birds Sketched from Life”.

Butterflies

Along with figure and landscape painting, “Bird-flower-insect” painting has long been a major branch of Chinese art. Over the centuries, several artists devoted themselves to insect-painting, an impressive example being the four-metre-long scroll by Chu Ju-lin, alive with dozens of butterflies and bugs. Chinese insect paintings are supposed to have feng shui aesthetics. In this system, the butterfly is a symbol of eternity, and a butterfly over flowers represents sweet love and perfect marriage. Butterfly art was most popular in medieval Japan, where it featured prominently on family crests known as ka-mon.

THE LARVA OF a bagworm moth popping its head out of its nest to feed.

Butterflies have fascinated human beings of all cultures, their colour being a prominent reason for their popularity. The German poet, thinker and scientist J.W. von Goethe said: "... all nature manifests itself by means of colours to the sense of sight".

Insects have two main mechanisms[3] by which they produce colour which inspires artists. Physical or structural colours are produced by the scattering, interference or diffraction of white light by the surface of any material. Pigmentary colours are produced by the absorption of visible light by a variety of chemicals. Both these processes, either individually or together, are responsible for the colours of insects.

Butterflies and moths belong to the order Lepidoptera, which means "wings with scales". Scales are modified hairs covering the bodies and wings of these insects. They are arranged in several rows and constructed in patterns based on a genetic blueprint. The orientation and stacking patterns of scales influence the production and perception of structural colour. The construction of scales is flexible, allowing for variability in shape and the emergence of new shades of colour. In short, butterfly wing colours are the result of the structure and optical properties of its scales.

The pigments responsible for colour are obtained from food synthesised by, or in rare cases obtained from, microbes resident in their bodies.

The butterflies of the Pieridae family are generally referred to as whites and yellows. The white colour of the cabbage white butterfly is largely the result of scattering of light. When all light is reflected off the body of the insect (because of the pattern and arrangement of its scales), it appears white. In some pierids, the colour is the combined effect of scattering and a class of pigments called pterins. Pterins, along with melanins, produce black colour.

THE INDIAN PURPLE emperor butterfly, Apatura ambica. Looking at it from two angles shows one how the colours produced by interference change with a change in the position of the viewer.

Interference colours, common in butterflies, result from the reflection of light from surfaces that are created by scales arranged in complex ways. In other words, the wavelength (colour) of reflected light depends on the spacing and angle of the scales on the wing. These reflecting surfaces produce the shades of blue, green, silver, gold and brass yellow seen in butterflies. Additionally, when there is a change in the position from which one sees an insect, the colour seen may also change, as moving is equivalent to changing the distances (and angles) between scales. This results in iridescence.

This phenomenon, more common among beetles than butterflies, can also be the result of diffraction. When light strikes the cuticle (hard body covering) of the beetle, it is bent to varying degrees and splits into its spectral colours. One of the perceivable effects of this is iridescence, which is lost if the light is dim. Since diffraction colours are not produced in dim light, beetles and butterflies that iridise in bright light look black or brown in low light.

Among the most attractive butterflies in the world are the swallowtails. Exquisite, colourful and dainty, Kaiser-i-hind, Bhutan glory, peacock and dragontail butterflies are a treat for a lepidopterist. With a wingspan of 190 mm, the southern birdwing is the largest butterfly in India. Equally attractive and pleasing to the eye are the colourations of nymphalid and lycaenid butterflies. Their colours, especially yellow, are due to pigments called flavoids, which are obtained from food. While black is predominant in several swallowtails, black and brown are seen in nymphalids. Melanin is the pigment responsible for most of the dark patterning on the body and wings. Melanins, found in the cuticle of insects, are black, brown, tan or reddish brown pigments and are produced by complex biochemical reactions.

THE NEST OF the tree ant, Crematogaster. Rufous woodpeckers use this ant's nest to raise their brood.

Ommochromes are red, yellow or brown pigments that are produced by the cells that form scales. In many butterflies and moths, the appearance of the red or brown colour during pupation is due to the synthesis of these pigments. Ommochromes help insects remove certain molecules that may be toxic if allowed to accumulate. Like tigers and elephants, butterflies, moths and a number of other insects figure prominently in illegal trade. While a lot of attention is given to controlling trade in tiger parts and elephant tusks, little has been done to curb the surprisingly huge global trade in insects.

The trade in butterflies alone is around $200 million though butterfly collection is banned by the Wildlife Protection Act of 1972. Insect poaching is as rampant as tiger poaching. The atlas moth and several wild silk moths fetch high prices in the international market. Swallowtails and colourful nymphalids are collectors' items besides being in demand as souvenirs, for jewellery, and so on. Habitat destruction combined with active collection by poachers is likely to spell doom for many of these exquisite insects unless the public is educated on the issue and stringent laws are enacted to combat this silent aggression against insects.

Insect architecture

Insects have not only inspired artists but also provided architects with examples of materials and methods that can be used. Insect nest-building is done predominantly for the purpose of rearing young. Apart from web-spinners, insects construct homes to raise their brood in safety. The activities of termites in building mud houses are legendary. Their naturally air-conditioned structure is built to house their queen and her constantly increasing colony of soldiers and workers. The buildings of honey bees and potter wasps are also well known. However, there are other spectacular insect architects.

Paper wasps & hornets

These social insects also raise large colonies whose members are differentiated on the basis of caste. Here again, the queen lays eggs to produce workers who build large nests to house the ever-increasing number of colony members.

SANJAY SONDHI

HABITAT DESTRUCTION IS a threat that may spell doom for pretty butterflies such as this five bar swordtail, Graphium antiphates.

Three different materials are used in the building of these nests. The nest (usually spherical though it can also be tubular or conical) is usually suspended from a support by means of a short stalk. So the first material is a special secretion produced by the queen that sticks the stalk firmly to the support. The strong adhesive property of this material has evoked much interest in the scientific community.

The second raw material for nest-building is cellulose from plants. The cellulose is mixed with salivary secretions and made into a papery material that is then used to construct individual cells. One egg is laid inside each cell.

The third material is silk. While the colony is started by the queen, the work is soon taken over by worker wasps. The silk is spun by larvae when they are ready to metamorphose, to plug the opening of their cells.

At Rishi Valley School, in Andhra Pradesh, the students once let a paper wasp queen build her nest under a table in their classroom. They noticed that rather than going to plants, the wasp that started the nest would chew off bits and pieces from the files kept on the table to use as building material. Since she took a particular liking to pink files, her nest was white and pink in colour. As the nest grew in size, the wasps and the students began to get jittery in each other's presence. However, despite our best efforts, the nest could not be detached from the surface of the table as the stalk of the nest was stuck firmly. We could well understand why this glue produced by the wasp would provoke so much interest among scientists.

A WORKER HORNET busy putting the finishing touches to a new funnel-like entrance to the nest.

The principle of nest construction and the raw materials used are similar for hornets and paper wasps. However, the design and the finished product are quite different. Hornet nests, built both on trees and below the ground, have hexagonal cells laid out in a circular/spiral manner along a central pillar. These cells are covered completely from the outside, with specific openings that serve as entrance and exit. Hornets often change the exits and entrances, closing old ones and opening new ones.

Tree ants of the Crematogaster species build nests on trees quite unlike those of the weaver ant Oecophylla.

Tree ants

These nests are almost the size of a football. The ants share these dwellings with the rufous woodpecker, which uses it to lay eggs and raise her chicks. The relationship between the two is a source of curiosity. The ant is the woodpecker's food and the eggs of the bird are food for the ant. Yet, they both give up this feeding habit when the woodpecker builds her nest. She bores a hole into the side of the ant's nest and creates a chamber to lay the eggs, and the ants do not seem to mind. The woodpecker returns the favour by protecting the ants from other woodpeckers that might feed on them.

Carpenter bee

Masons, weavers, diggers and paper-makers are not the only architects among insects. There are carpenters too. The carpenter bee, or Xylocopa, is large, shiny blue and is often mistaken for a bumble bee. It looks intimidating but rarely stings; indeed, only the female possesses a sting.

The carpenter bee tunnels into wood with the help of its strong mandibles (the "upper jaw", so to speak). However, it does not eat the wood. Instead, it spits it out to create chambers inside the wooden tunnel. A single large hole is the entrance to the residence. Although Xylocopa is a solitary bee, it makes its nest close to others of its kind, and they all share responsibilities such as guarding the nest while others are away foraging. Sometimes, mothers, sisters and children cohabit the same tunnel but in cells that are separated by pieces of wood.

THE CARPENTER BEE, Xylocopa. For all its intimidating look, it is one that does not sting often. The male does not even possess a sting.

The architectural abilities of insects are worthy of wonder. The geometric accuracy of the hexagonal cells of hornets, bees and wasps; the tenacity of their silk fibres; their knowledge of cellulosic paper: these raise a whole lot of questions about the origin and evolution of life on earth and about instinct versus learning.

Present-day Japan is witnessing a renewed enthusiasm for insects. Even in Tokyo, where living space is a constraint, people of all ages are finding room for some wilderness. Insects are sold live in vending machines and department stores. They are the subject of the popular videogame Mushiking, which features battles between different species of beetles.

The film Beetle Queen Conquers Tokyo premiered on May 17 on Independent Lens on PBS (Public Broadcasting Service). It explores modern-day Japan's new-found social relationship with insects and the country's fascination for nature's "most efficient creature in space, design, and function – insects". The film raises a pertinent question: Is our "instinctive" repulsion to bugs merely a trick of conditioning? The film-makers believe that "insects, like haiku or a Zen garden, can represent the world at large writ small".

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