The Study of Butterflies

2. Flight, Fuels and Senses

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Peter Smetacek works on the taxonomy and zoo geography of Indian Lepidoptera. He is also interested in exploring the potential of Lepidoptera as bio-indicators of ecological functions and groundwater.

In the second part of the series on butterflies, we look at some general aspects of their structure, flight, fuels and senses.

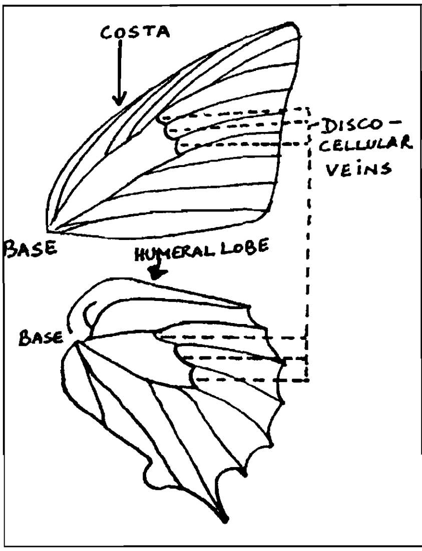
All butterflies share one common feature – they can fly. In no species of butterfly are the wings aborted, as in the case of some female moths. The wings are of prime importance since they are the means of flying, the primary mode of progression for all butterflies. The legs are mainly used for perching, and secondarily for moving about in the immediate vicinity.

Part 1. The Naming of Indian Butterflies, *Resonance*, Vol.5, No.6,p.8-14, 2000.

All butterflies have four wings. Each wing has a 'skeleton' or supporting frame of tough, hollow 'struts' called veins, and these are covered on both surfaces by a thin, transparent membrane stretched taut over the frame. Numerous very small, tile-like scales are attached to the wing membranes, and these come away like powder on one's hand if the wings are touched. These scales distinguish butterflies and moths from all other insects and give the order to which they belong its name (Lepidoptera means 'scale winged'). The colours and patterns on the wings of butterflies are entirely due to these scales, the pattern being formed by the process of pointillism (See *Box* 1).

Box 1. Pointillism

Some of the French Impressionist painters, notably Georges Seurat and Vincent van Gogh, popularised the art form known as pointillism. In this, no lines or brush strokes are used. Instead, objects are defined purely by points of different colours, which may vary from points smaller than the dot on the 'i' to dabs with rather larger brushes. In the patterns found on the wings of butterflies, all lines, spots, bands and other markings are formed by concentrations of scales of the same or different colours. As Euclid suggested in a rather different context, all lines are formed of a series of points which, however, unlike the geometric abstractions, do occupy some space on the butterfly's wing!



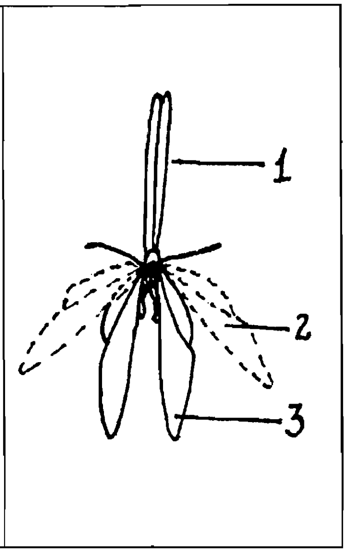


Figure 1 (left). The wings of a butterfly showing the neuration. Note the numerous veins at the costa of the forewing and the near lack of veins perpendicular to the costa.

Figure 2 (right). A butterfly's wing stroke. 1- the position where the stroke begins, with the wings held together. 2- mid-stroke. 3- completed stroke. Note how the wings travel through an arc of nearly 180° during each stroke.

Flight

The structure of the supporting frame of the wing, which is called its neuration or venation, is useful in distinguishing between the families of butterflies. In all butterflies, the leading edge or costa of the forewing is specially stiffened and strengthened by numerous veins (*Figure* 1). This part of the wing cleaves the air during flight. The remainder of the wing is more flexible, and this flexibility has to do with the method of flight.

Starting from the position where the wings are held together above the body, and perpendicular to it, a flight is initiated by a 'peeling apart' of the costae of the two forewings (*Figure* 2). As the wings open, this movement is transmitted down the wing, so that by the time the two costae are about 25° apart, the bottom of the forewings are still nearly together. As the forewings continue to separate, the hindwings, too, draw apart. At the completion of the wing stroke, at which point the wings are angled below the body of the butterfly, the costae of the forewings are separated by an angle of 20° or less below the butterfly. From this position, the wings are 'feathered' back above the body for another stroke, just as an oar is feathered forward in a rowing boat.

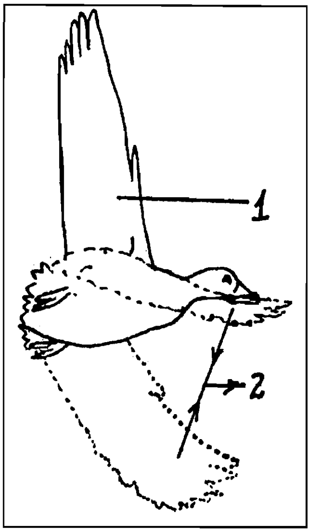


Figure 3. A duck's wing stroke: 1- the position where the stroke begins. 2- completed stroke. Note how the wings travel through an arc of only above 90° during each stroke.

In this method of flapping, which is more or less in a vertical plane in relation to the body, butterflies differ from birds and many insects, who do not carry the downward stroke as far as butterflies (*Figure* 3).

Besides flapping their wings to fly, butterflies can also glide. Some species can stay aloft for extended periods by this means. If they had rigid wings, they could be said to glide in the strict sense of the term. As matters stand, the gliding flight of butterflies has been compared to parachuting, rather than gliding proper, since the wings assume a concave shape similar to that of a parachute. This, combined with the large surface area perpendicular to the direction of descent yields a drag force opposing the force of gravity. This serves to slow the rate of descent.

The Wings

Compared with the wings of other flying insects, butterflies have relatively few veins. There are no muscles in the wing, most movement being controlled from the base of the wing. Except for the discocellular veins, there are no veins perpendicular to the costa. This is to enhance the wing's flexibility, but has the drawback of not enabling the circulation of haemolymph, or 'butterfly blood', through these veins. This would have been useful in controlling body temperature. However, there is another way of dealing with this.

Butterflies are poikilothermic or 'cold blooded', so they depend largely on external heat to carry on metabolic processes. The sun is the source of the heat they use, and only a few butterflies are capable of activity during the sun's absence, i.e. at dawn, dusk or on heavily overcast days. Many of us have noticed butterflies settled on the ground, on perches like bushes or trees or even on one's hand! Many sit with their wings closed, while others open them a little and others hold them flat.

At such times, the butterflies are warming themselves to enable them to achieve flight. For this, their internal temperature has to be over 30°C, generally between 35°C to 40°C. Since there is no circulatory system in the wings, they are hardly used as absorptive surfaces except in an area up to a few millimeters from the body. Instead, the wing surfaces are used as reflectors.

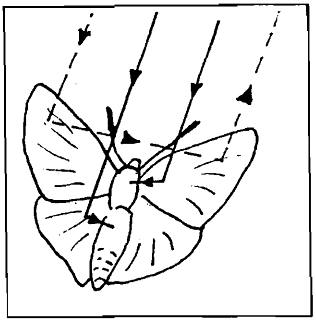
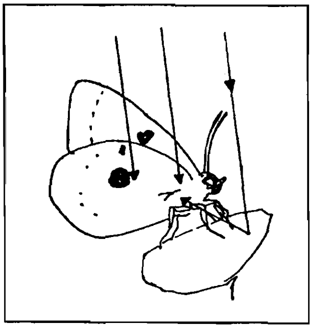


Figure 4. Reflectance basking: many butterflies open their wings in order to reflect sunlight on to their bodies. At an angle of about 45°, rays striking the outer half of the wings are reflected outwards, while those striking the inner half of the wings are reflected on to the body, where they are absorbed.

During flight, the air rushing over a butterfly's body causes a cooling effect that ameliorates not only the heat absorbed by basking, but even the heat generated by the muscular activity involved in flying. As a result, the butterfly has to sit and bask from time to time. When it perches after flight, it has its wings closed over its back. From this position, the wings are opened and the angle between the forewings adjusted to reflect the desired amount of the sun's rays on to the thorax and parts of the abdomen, where they are absorbed (*Figure* 4). The wider the angle between the wings, the less of the sun's rays are being reflected on to the body from the wings. When the wings are held horizontally or flat, few of the rays falling on them reach the body. When there is an angle of 45° between the wings, the inner half of the wings is reflecting on to the body while the rays falling on the outer half are reflected outwards. When the angle is narrowed to 20°, almost the entire rays falling on to the wings are being reflected on to the body.

Some butterflies do not open their wings to bask. These generally show the underside of their bodies to the sun and absorb direct rays as well as rays reflected off nearby objects. The base of their wings, i.e. where they join the body, is generally suffused with dark scales to aid in absorption (*Figure* 5).

Figure 5. Absorptive basking: some butterflies bask with their wings held closed over the back. The rays that strike the body and the base of the wings are absorbed.



The connection between forewings and hindwings serves to distinguish butterflies from moths. In butterflies, the lower edge of the forewing and upper edge of the hindwing overlap. The area of overlap is increased by an extension of the hindwings called the humeral lobe, which is specially strengthened. In moths, the wings overlap but the costa of the hindwing possesses a stout spine or spines near the base, called the frenulum, which fits into a cradle of hairy bristles called the retinaculum, situated at the base of the forewing on the underside.

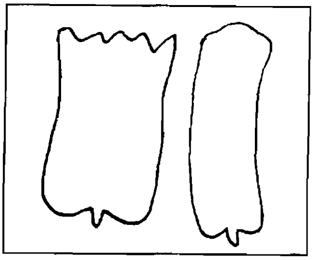


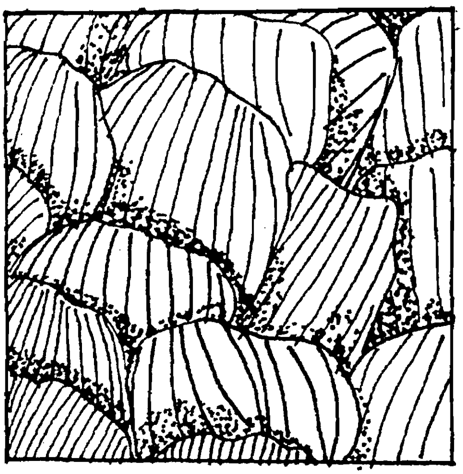
Figure 6. Types of pigmented scales.

The Scales

There are several types of scales that cover a butterfly's wing and these are responsible for the colour and pattern on both surfaces of the wing. Viewed under a powerful lens, they are of varying shapes and sizes, from hair-like, to racquet shaped, to broad, flat tile-like ones, (*Figure* 6). The majority have the function of building up a colourful pattern, and are of two types. The pigmented scales are variously coloured, each scale bearing only a single colour. The browns and blacks are caused by pigments called melanins, while the yellows, oranges and reds are coloured by pteridine pigments. These scales are responsible for most of the colours on butterfly wings (*Figure* 7). The second type of scales in this category are colourless, but possess ridges, or else are composed of several layers of transparent membrane separated by a material of a different refractive index. These scales break up incoming white light into the shining greens, blues and reds often seen on the wings of some butterflies.

Male butterflies also possess a different type of scale, which may be hair-like or racquet shaped. In some species these are scattered over the wing, while in others they are collected in certain areas. These scales are scent dispersing scales and are used in courtship. They are known as androconia and, when collected in sufficient numbers to be visible to the naked eye, are known as 'sex brands'. These are usually oily looking, darkish patches on the wings of males on which a female's antennae are rubbed during courtship (*Figure* 8).

Figure 7. A view of the scales arranged on a butterfly's wing.



Intake and Use of Fuels

Insects have no haemoglobin or myoglobin to transport oxygen within the body. Air is conveyed directly to the flight muscles from the spiracles on the sides of the body through a system of tracheae, so that each mitochondrion is individually supplied by a part of the network of air-tubes. Although this is the main supply of respiratory gases to all parts of the body, especially oxygen, some of the oxygen

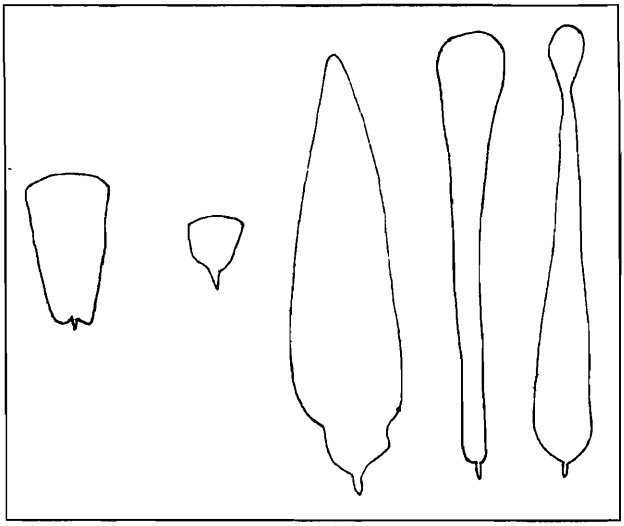


Figure 8. Types of androconial scales.

used is also obtained by the process of diffusion.

Flight is an energy intensive activity, involving rapid oxidation of respiratory fuels, mainly carbohydrates and fats. In some Lepidoptera, oxygen intake, which is 7-12 μL/min/g at rest, increases to values of 700-1660 μL/min/g during flight, a hundred fold increase. Such increases in respiration rates during flight are normal among flying insects, but unmatched elsewhere in the animal kingdom.

In the adult stage, butterflies depend largely on the oxidation of carbohydrates and fats for energy, especially during flight. The fats are obtained during the larval stage and stored in the body. Carbohydrates in the form of sugars are obtained from nectar, the sap of certain trees, over-ripe fruit and other natural sources. Some butterflies do not need to feed in order to carry out the main functions of the adult stage, which are the location of mates, copulation and the location of a suitable food plant for the progeny and the actual laying of eggs.

In some butterflies, especially the tigers and crows (Danainae), male butterflies freshly emerged for their pupae search first for a certain species of plant rather then females. They congregate in large numbers about such plants, notably *Crotalaria, Heliotropum and Aegeratum conyzoides*, where they obtain pyrrolizidine

In addition to nectar, butterflies are also found feeding on fruit, sap, flowers, carrion, bird or mammal faeces and wet mud. While the first three are mainly sources of sugar, the latter three are presumably mainly sources of amino acids and mineral salts.

alkaloids from the flowers or sap. These alkaloids are essential to prime the scents, to be dispersed through the organs of the wings of the males, that ensure successful courtship. Only after obtaining a sufficient supply, do the males go in search of females.

Besides such alkaloid containing plants, butterflies are also found feeding on fruit, sap, flowers, carrion, bird or mammal faeces and wet mud. While the first three are mainly sources of sugar, the latter three are presumably mainly sources of amino acids and mineral salts. Some butterflies, especially the blues, are attracted to perspiration, settling on damp clothes, hands or even one's face. It has found that such bold butterflies are actually in search of sodium salts. Sodium is required for the formation of the male's spermatophores, which are passed to the female during mating, as well as for the proper functioning of the nervous system.

The choice of feeding sources varies from group to group: some groups never visit flowers while others may visit flowers occasionally but are attracted in large numbers to rotting crabs or cowdung. Males of some whites (Pieridae) and swallowtails (Papilionidae) congregate in large numbers at particular patches of wet sand or mud.

The Mouth

All butterfly food is in liquid form, since the mouth consists of grotesquely elongated jaws (parts of maxillae) which are fused to form a hollow tube, the proboscis. The length of the proboscis varies with those groups fond of probing flowers, such as swallowtails, possessing relatively longer tubes than those that prefer over ripe fruit or sap, such as browns (Satyrinae). In every case, the tube is rather narrow and held neatly coiled up between the labial palps when not in use. Not every liquid can be sucked up. The feeding of a butterfly is very similar to a human using a drinking straw. The straw is represented by a proboscis while our mouth is represented by a cavity in the head called the cibarium, which can be expanded or contracted by muscles and thus create a suction pressure that draws liquid up the proboscis (*Figure* 9). Anyone who has used a straw will be familiar with the ease with which watery solution can be sucked up and the difficulty encountered when thicker solutions are to be sucked up, especially when using a thin straw. Butterflies face much the same problem and are, thus, restricted to diets of nectar and fruit juices in which sugar concentrations vary from 15% to 30%. By contrast, bees prefer nectar containing 30% to 50% sugars. In fact, plants can attract different insect species for pollination, by varying the consistency of their nectar. Bees rarely visit the plants attractive to butterflies since they find sugar concentrations below 30% too low to be economically exploited. By thus attracting particular insects, plants improve the probability of cross-pollination, since particular insect species will be on the look out to visit certain species of plants and altogether avoid other species in the course of their wandering.

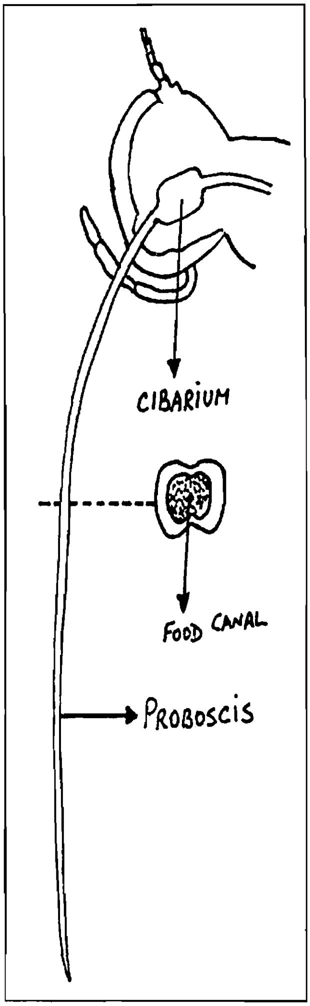


Figure 9. Cross-section of a butterfly's head, showing the proboscis and cibarium.

Location of Mates and Larval Food Plants

The colours and patterns on the wings of butterflies serve as important means of recognising members of the same species. However, they do not see the colours exactly as we see them, since the range of radiation to which their eyes respond is 2500Å to 6300 Å. Compared with our own visible spectrum, 4000 Å to 7800 Å, this is low, so they can perceive much more in the ultraviolet part of the spectrum but less than us in the red part of the spectrum.

Recent work with butterfly wings exposed to ultraviolet radiation has revealed unexpected patterns as well as great difference in patterns between some species that look confusingly similar to us. In other cases, there is no difference in the patterns.

Butterflies lack complex organs of hearing, but the sense of smell is well developed (see *Box* 2). This is used to help locate flowers, larval hostplants on which the female lays her eggs as well as sources of other needs such as amino acids and mineral acids.

Box 2. Hearing and Taste

Although adult butterflies do not have complex hearing organs, they do respond to sounds, sensed by sacs at the base of the wings in some groups, and by leg bristles and abdominal organs in other groups. Caterpillars react to sound vibrations in the range of 32 to 1024 cycles per second. Compared with this, humans register sounds in the range of 16 – 20,000 cycles per second.

The organs of taste in butterflies are very sensitive. They are located in the palps, at the tip of the proboscis and also at the tips of the forelegs in some groups. Often, such 'tasting toes' are reduced and not used to walk upon. Some tiger butterflies belonging to the Danainae respond to sugar solutions as dilute as 1/120,400 part per thousand, which is roughly 2,000 times more sensitive than the human tongue.

Males typically locate females visually and, having cornered one, the male folds his wings over her antennae so as to bring them into contact with the androconial scales on his wings where a scent, called a pheromone, is released. If this excites the female sufficiently, mating takes place. This process is often repeated several times before a female is sufficiently aroused and successful mating can take place. Once mating is complete, the male departs and the female, in due course, begins to search for a suitable plant to lay her eggs on. This is usually located by smell. The eggs are sometimes laid randomly but often, she takes great pains to conceal them in cracks in bark, on the underside of leaves and so on. From these will spring the next generation who, however, have to pass successfully through the caterpillar and pupal stage before they emerge as butterflies.

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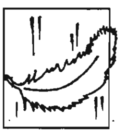
Suggested Reading

[1] **M J Scoble, *The Lepidoptera: Form, Function and Diversity*, Oxford University Press, 1992.**

[2] **P R Ackery and R I Vane-Wright, *Mileweed Butterflies: Their Cladistics and Biology*, British Museum (N.H.) London, 1984.**



Biology cannot fathom whether life may be a part of some cosmic design. But biology does show that the evolution of life on earth is governed by causes that can be understood by human reason.

T Dobzhansky