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Colour Pattern of Butterflies (Insecta: Lepidoptera): A Review

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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Review Article

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ABSTRACT

Colour plays an important role in nature. Lepidoptera, with an estimated 160,000 recognized species, is one of the two or three most significant orders of insects. These insects are known for their tremendous range of color patterns, which are caused by the flattened and modified hairs called scales that cover the body and wings in a shingle-like arrangement. A unique color pigment and a distinct shape are present in every scale, which is a modified sensory bristle. Within a clearly defined network of wing veins, scales are arranged in rows. When groups of scales are designed to create specific color pigments, pattern growth starts, in the most basic manner.

Keywords: Color-pattern; Lepidoptera; nanostructure; Nymphalidae, Nymphalinae; Papilionoidea.

1. INTRODUCTION

Lepidoptera includes well-known insects such as moths and butterflies. A group of over 20 derived features, the most notable of which are the scales and proboscis, define the Lepidoptera as a monophyletic lineage. These insects are known for their tremendous range of color patterns, which are caused by the flattened and modified hairs called scales that cover the body and

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wingsin a shingle-like arrangement. Natural and sexual selection have driven the production of such systems that possess a diversity of physico-chemical properties [1]. Thin mosaics made by overlaying thousands of colored scales are the patterns seen on butterfly wings. A unique color pigment and a distinct shape are present in every scale, which is a modified sensory bristle. Within a clearly defined network of wing veins, scales are arranged in rows. When groups of scales are designed to create specific color pigments, pattern growth starts, in the most basic manner [2]. Both Butterfly and moth wings feature vibrant color patterns that aid in species recognition, mate selection, camouflage, warning signals, and predator defense [3].

2. BUTTERFLIES WING COLOUR PATTERNS

Butterfly wing patterns serve multiple functions, including predator avoidance and mate selection [4], making them an ideal case to test the signal partitioning hypothesis. Because most butterflies can fold their wings together, hiding the dorsal surface, a dorsal-ventral partitioning of visual signals may present one solution to accommodating potentially antagonistic selective pressures. Darwin and Wallace hypothesized that dorsal wing patterns play a significant role in mate signaling, while the ventral surface may be more vulnerable to selection by natural enemies [5]. However, no study has directly investigated this theory within a comparative framework. Butterfly signals can be distinguished between forewing and hindwing in addition to dorsal/ventral partition because of the butterfly's ability to conceal the forewing behind the hindwing when at rest. Butterflies have two surface axes, dorsal-ventral and forewing/hindwing, that can be used for different signal functions, which may be antagonistic [6].

Butterfly wing patterns in the visible or ultraviolet have been linked to thermoregulation [7,8], aposematism and mimicry rings [9,10,11], sexual selection [12,13] and crypsis [14,15]. Pigments, including melanins (black, brown), ommatins (red, brown), and pteridines (white, yellow, red), are responsible for the majority of scale colors [16,17,18]. A large number of butterflies are basking with their wings spread and their vertical body axis parallel to the incident radiation. The butterfly receives the most radiation when its wings are completely open and the least when closed [19,20,21,22,23]. Kevan and Shorthouse analyzed the significance of butterfly wings in thermoregulation and studied the phenomenon of thermoregulation in *Argynnispaphia* that maintained a body temperature of 34 +/-1.5 degrees Celsius by controlling the amount of incident radiation through wing position angles. [24,25].

2.1 Butterfly Wing Scales

Butterfly wing scales are similar to flattened sacs, measuring about 200 and 75 µm in length and width, respectively, and only a few micrometers thick. The lower lamina of a butterfly wing scale is almost always smooth, whereas the upper lamina is often highly structured. The structure is made up of parallel longitudinal ridges spaced 1 to 2 µm apart and cross ribs separated by 0.5 to 1 µm. The space between upper and lower lamina can be nearly empty or highly structured, depending on the butterfly species and scale type [26].The scale material comes in two varieties: it can be nearly transparent or have pigment that absorbs strongly. Stavenga et al., investigated Morpho scales by focusing monochromatic laser beams into a single, isolated scale. They used a detector to scan the entire scale in order to measure the scattering profile [27].

According to the Vukusic et al., the scale cover on butterfly wings is responsible for the super hydrohobic and self-cleaning properties [28]. Butterflies lack the ability to groom themselves by rubbing their large wingspan, which prevents them from reaching the entire surface with their legs. Because of this, they are entirely dependent on the wing surface's ability to clean itself. Moths and butterflies frequently have translucent or translucent wings [29] Glasswings exhibit low reflectance due to their hair-like scales [30] and saturniid moths [31].

Organic farms prohibit the use of agrochemicals, which have been shown to be sensitive to pesticides by various groups of organisms such as butterflies [32], weeds [33], carabids [34,35], and birds[36]. Therefore, the absence of agrochemicals on organic farms is crucial for species richness.

2.2 Butterflies and Organic Farming

Butterflies are likely to respond to organic farming [37,38], and their mobility makes them sensitive to landscape structure. Furthermore, butterflies are great for use as umbrella species or indicator species in environmental conservation due to their many features (New 1997). For example, their biology is very well known, and they are easy to recognize. Butterflies may be beneficial as markers of biodiversity, in the words of researcher [39]. Moreover, butterflies are interesting from the perspective of conservation because they play a significant role in pollinating wild plant species [40]. Comparing organic and conventional farms, there were no noticeable differences in the array of butterflies, variety of species, or quantity of observations. Whereas there was a positive correlation between butterfly abundance and large-scale heterogeneity, butterfly diversity and small-scale landscape heterogeneity were positively associated. For the species composition, both large- and small-scale heterogeneity were significant. The landscape organization appeared to be more relevant for butterfly diversity and species composition than the farming system in general [41].

(a)*Appias albino darada* - upper side &underside

(b)*Danaus chrysippus chrysippus* - upper side & underside

(c)*Cynthia cardui* -upper side& underside

Fig. 1. Colour pattern of different butterfly species

3. GLIMPSES FROM PAST

Weibullet al.[42], studied the *w*aterproof and translucent wings at the same time: problems and solutions in butterflies and this was the first examination to the effects of reduced scale cover on translucency, or hydrophobicity, and on the morphology linked to improved waterproofing in butterfly wings. The majority of butterfly wings are known as "super-hydrophobic" because their contact angle (CA) with a water drop is greater than 150°. Strongly overlapping scales generally cover butterfly wings; however, transparent or translucent wings have less scale cover, which may have an effect on the wings' hydrophobicity. They were talked about two species in his studies, *Paranticasita(Nymphalidae)* and *Parnassiusglacialis* (*Papilionidae) P. sita* lives for up to six months as an adult and migrates over great distances, whereas P. *glacialis* lives for less than a month and does not migrate. These two species have very different life histories. We used atomic force microscopy and scanning electron microscopy to analyze wing morphology and measure the water CA. The wing surfaces of *P. sita* are super-hydrophobic, with a CA > 160°, whereas those of the *P. glacialis* aren't (CA=100–135°) [42].

Otaki and Yamamoto, 2004, studied the species-specific color-pattern modifications of butterfly wings and analyzed the developmental mechanism of the wing-wide color pattern organization. They also examined the effect of tungstate on color-pattern determination in a variety of butterfly species and showed aspects of color pattern determination in various butterfly species that were both divergent and convergent. They used the following six Lepidopteran species: (i) *Vanessaindica* (Nymphalidae, Nymphalinae); (ii) *Lycaenaphlaeasdaimio* (Lycaenidae, Lycaeninae); (iii) *Ypthimaargus* (Nymphalidae, Satyrinae); (iv) *Coliaseratepoliographus* (Pieridae, Coliadinae); (v) *Papilioxuthus* (Papilionoidea, Papilioninae); and (vi) *Graphiumsarpedonnipponum* (Papilionidae, Papilioninae). In the case of *V. indica*, the modification degree (MD) was assigned from 0 (normal) to 5 (most aberrant) as real numbers when modification variations can be aligned in a linear series [43]. This was based on the examination of several color-pattern elements, particularly parafocal elements in the hindwings, according to researcher wing color pattern analysis [44,45].

Nishida et al*.,* 2023, studied butterfly wing color made of pigmented liquid. *Siproetastelenes* and *Philaethriadiatonica*, two butterfly species that are not closely related, were discussed in this paper. They emphasized the green color of Siproetastelenes (*Nymphalidae: Nymphalinae)* and *Philaethriadiatonica (Nymphalidae*: *Heliconiinae*).

4. CONCLUSION

The result of this study revealed that the wing scales of both the dorsal and ventral surfaces of pinned *S. stelenes* were detach, the green part of the wing remained unaffected. This indicates that the green coloration is not come from scales. In the green areas, they discovered that the costal area of the wing sometimes contained tiny, moving air bubbles and had no green color [46].

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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