The development and evolution of butterfly wing patterns: finding the primitive pattern

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Synopsis: The color patterns of butterflies and moths constitute a highly evolved system of visual communication used in sexual signaling, camouflage, warning, territoriality and mimicry. These patterns are based on extensive modifications of a groundplan of three pairs of bands. The ancestors of this pattern can be found as far back as the dragonflies, which are among the first winged insects, and model simulations will illustrate how this could have happened.

Outline: The development and evolution of butterfly wing patterns have been extensively studied over the past 30 years. Much of our understanding of the structure of these color patterns derives from the classical work of Schwanwitch (1924) and Süffert (1927). These authors independently derived the diversity of color patterns in the butterfly Family Nymphalidae, from a common ”groundplan” composed of three parallel pairs of bands that run from the anterior to posterior margin of the wing. Each pair of bands has a characteristic pigmentation pattern and is called a symmetry system because the pigments of the bands mirror each other. Subsequent work by these authors and their associate showed that the “nymphalid groundplan” (Figure 1) applies widely to other Families of butterflies and to many moths as well.

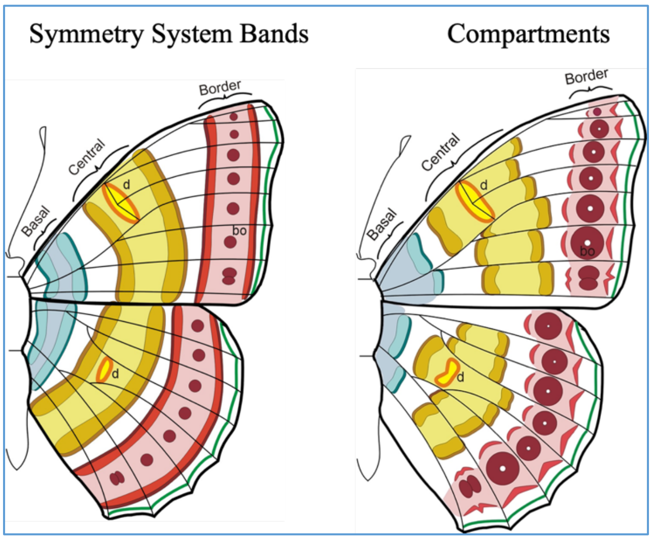

Figure 1. The **Nymphalid Groundplan** is composed of 3 sets of bands called the basal-, central- and border- symmetry systems. In some butterflies and moths the bands are un-interrupted, as in the left panel, but in most cases the bands are disrupted by the vein system (as in the right panel), which compartmentalizes the pattern into semi-independent developmental units (after Nijhout, 1991).

A long-standing question in this field is whether the Nymphalid Groundplan somehow represents the primitive butterfly wing pattern from which all others were derived. The butterflies are phylogenetically within the moths, so if there is a primitive pattern of Lepidoptera, it needs to be sought among the moths. Recently, Schachat and Brown (2016) studied the color patterns of the Micropterigidae, the most basal group of moths, and deduced that their color patterns were based on a system of 5-6 parallel bands. In many moths and butterflies the crossbands are interrupted by the wing veins and appear as a row of spots, and it is still an open question whether bands arose from rows of spots or whether rows of spots came from broken bands.

In my presentation I will show that the primitive color pattern from which the moth patterns evolved arose long before the evolution of the Lepidoptera. Color patterns of the caddis flies (Trichoptera) and scorpion flies (Mecoptera) all resemble those found in the basal moths. I will show that these patterns are all based on variations on a set of 6 parallel bands, and that this basic patterning system can be found in the earliest winged insects, represented today by the dragonflies (Odonata).

A simple reaction-diffusion system can readily generate three symmetry systems, that can be visualized as either 3 pairs of bands or 6 identical bands (e.g. the yellow stripes in Figure 2).

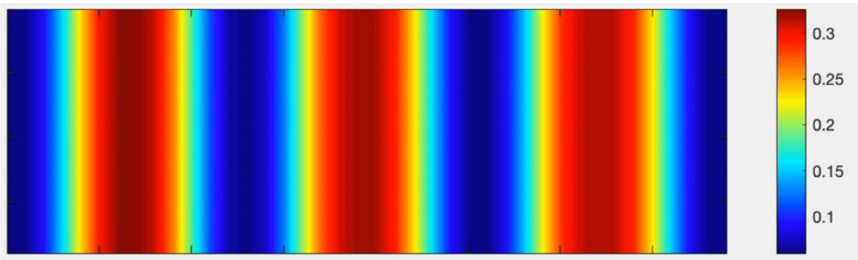

Figure 2. Pattern of three symmetry systems formed by a substrate-depletion model of reaction-diffusion.

I will show that from this banding system, a lateral inhibition mechanism can, in turn, generate much of the diversity of spotting and banding patterns that we see in the dragonflies and other patterned insect wings, including the Lepidoptera.

References:

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