Butterfly nanostructures gives a glimpse of intracellular membrane development (?)

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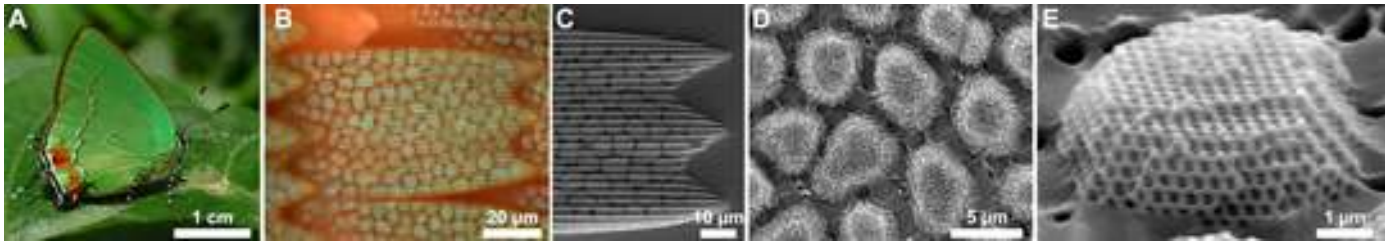
describing joint work with Bodo Wilts (Fribourg), Erdmann Spieker (Erlangen), Benjamin Winter (Erlangen), Benjamin Butz (Erlangen), Ullrich Steiner (Fribourg) and Stephen Hyde (ANU), and older results in collaboration with Maryanne Large (Sydney), Leon Poladian (Sydney), Shelley Wickham (Sydney) and Matthias Saba (Imperial College, London).



Insects have developed amazing functional nanostructures, such as the chiral 'gyroid' nanostructure in the wing scales of several green butterfly species [1,2]. This structure is a network-like highly symmetric nanoporous solid material, that is related to a famous three-dimensional surface first described by NASA-mathematician/physicist Allan Schoen and that is now known as the *Gyroid* [3].

In the specific case of the Green Hairstreak butterfly, this ordered porous chitin structure acts as a biophotonic crystal that emulates the reflection spectra of common leafs to allow near-perfect camouflage and has demonstrated chiro-optical properties [4-7]. The optical properties will not be the main focus of this talk.

Rather, this talk will focus on what we can learn about the in-vivo formation of this nanostructured material by analysis of the shape of the nanostructure, i.e., what does the nanostructure reveal about its own formation?

The formation of single gyroid photonic crystals embedded in highly-anisotropic case of solidified chitin in the wing scales of certain butterfly species is an exceptional feat of biological nanoengineering and evolutionary control of nanoscale organization. Previous developmental models hypothesize that the formation pathway involves nascent chitin deposition into the aqueous extracellular subdomain of a pre-shaped convoluted membrane of the smooth endoplasmic reticulum. Difficulties of *in vivo* imaging of the developing tissue have hindered the elucidation of the dynamic properties of this process in detail. Here we report the ultrastructure of the gyroid photonic crystals in the butterfly *Thecla opisena* whose unusual hierarchical ultrastructure allows novel insight into the formation mechanism. Rather than adopting the conventional form of a polycrystalline material that occupies most of the space available in the chitinous wing scale, the gyroid crystals here are organized in the form of isolated crystallites with a pronounced facetted shape. Their exclusive occurrence at the ribbed wing scale top surface, a chemical composition difference to the surrounding chitin case and a size-gradient along the scale asserts a time-dependent, two-stage formation process. The formation of this hierarchical structure arrangement is interpreted as a sequence of time-frozen snapshots of the morphogenesis, enabling not only a deeper understanding of the formation mechanisms of the nanoporous gyroid material, but also of the inner-cellular organelle membrane from which it is templated.

References

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