Extreme refractive index wing scale beads cause the bright colors in pierid butterflies

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Abstract
Despite the limitation to a restricted range of organic materials, evolution has optimized the color response of many organisms to an amazing extent that often appears to surpass the physical limits of the employed organic materials. One such example are the common pierid butterflies which show bright colors ranging from white to red caused by various pterin pigments concentrated in scattering spheroidal beads in the wing scales (Fig. 1, refs. [1-3]). The final coloration arises from the interplay of absorption and scattering of light by these pigment-loaded granules. Given the sparsity of the beads in the wing scales, the high color brightness suggests a scattering strength of the beads that significantly surpasses that of chitin, from which the beads are composed of. To elucidate this apparent contradiction, we have analyzed the optical signature of the pierids' highly saturated pigmentary colors by using Jamin-Lebedeff interference microscopy combined with Kramers-Kronig theory and light scattering modeling [4,5]. Our study shows that both the shape of the beads and the unusually high complex refractive index of these pigmented granules are optimized to give rise to one of the brightest biological materials. Our results present yet another trick of evolution for optimized light scattering that might be useful for bio-inspired applications.

References

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Figures

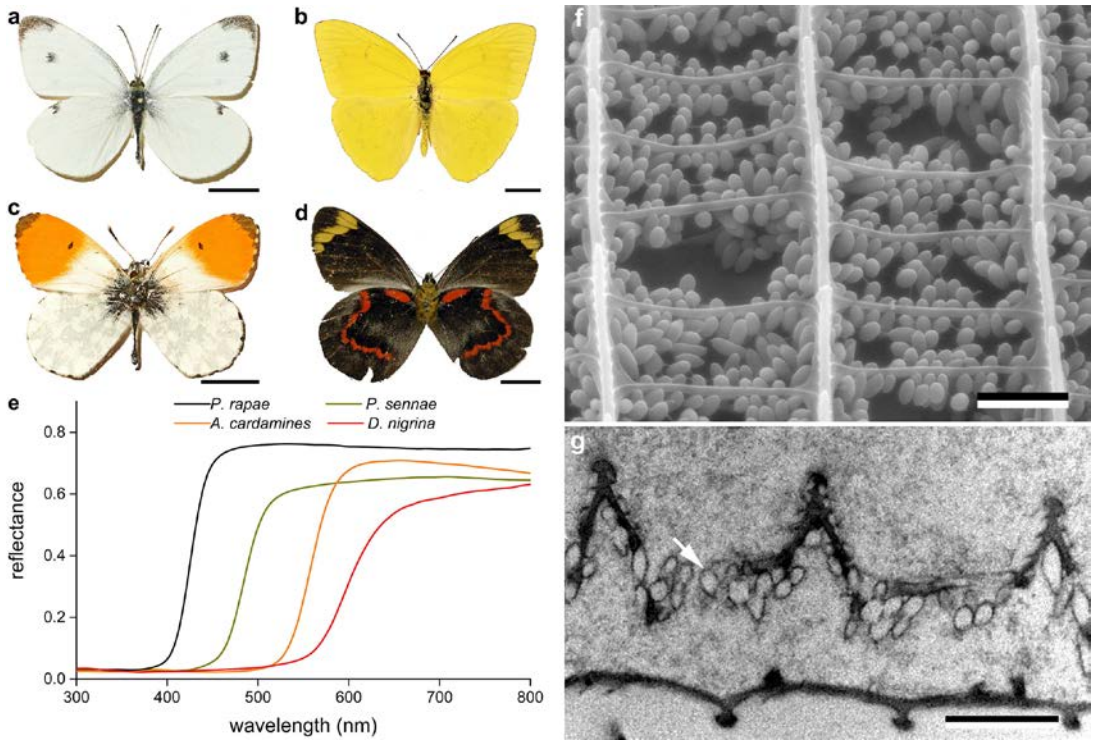

Figure 1: Pierid butterfly photonics. (a-d) Investigated Pierid butterflies with various body colors (bars: 1cm). (e) Reflectance spectra. (f,g) Scanning and transmission electron microscopy of a single wing scale showing the arrangement of spheroidal particles attached to the wing scale (bars: 2 µm).