

## The Secrets of the Blue Morpho Butterfly: Applying the National Museum of Natural History Resources to Create Novel Science Activities

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Science activities at the Smithsonian National Museum of Natural History (NMNH) are carefully designed interactions between regular visitors, museum staff and scientific instrumentation. An emphasis on incorporating the use of microscopes into these activities has led to the development of an activity that has proven effective in engaging many audiences to appreciate and understand the cycle of science inside the museum, its applications and impact on people's lives, and the role of different microscopes as fundamental scientific tools.

The activity was based on the marvelous Blue Morpho butterfly (*Morpho peleides*). This butterfly is an excellent example of a beautiful and apparently simple creature, which under careful inspection reveals scientific concepts such as structural coloration, evolution, nanotechnology, waterproofing, nanoscale, and biomimicry. Through original activity design, our education team has brought together all these apparently different concepts in a format that presents them as an example of the science cycle at the museum and its influence on society.

Butterfly samples were obtained from the NMNH's Live Butterfly Pavilion and coated by a sequence of carbon evaporation and AU/PD sputtering on a LEICA ACE600 high vacuum sputter coater. Cross-section samples were prepared by freezing wing sections in liquid N<sub>2</sub> and cleaving them. Scanning Electron Microscope (SEM) images were obtained using the FEI APREO SEM and the tabletop SEM Hitachi TM3030. The activity is guided by staff and takes place in Q?rius, The Coralyn W. Whitney Science Education Center. The activity employs one Olympus SZ67 stereo microscope connected to a monitor, a Hitachi TM3030 SEM, images from the APREO SEM and Blue Morphos.

The activity starts with the visitor taking the place of a researcher with a new specimen to study: the Blue Morpho butterfly (Fig 1). The visitor uses the stereo microscope to observe the wings at high magnification and discovers the first secret: the wing is covered by scales (Fig 2). Then, the visitor observes the same specimen under a tabletop SEM where 15000X magnification is reached (Fig 3). The resulting image clearly displays the ridges and layered structure on top of the butterfly's scale. An image of the cross section is also shown, giving a better idea of the actual shape of the ridges and layers (Fig 4). Now it is possible to discuss how this nanostructure fulfills very important roles for the butterfly.

This opens the door to the second secret: the Blue Morpho is not blue. The Morpho's blue color is the result of constructive and destructive interference between light wavelengths inside the layers of the nanostructure. This cancels out long wavelength colors and increases the output of short wavelength colors, especially blue [1]. A demonstration of this consists in getting the wing wet with a drop of alcohol, which covers the nanostructure and reveals the butterfly's pigment color, a less attractive dark green (Fig 5). The visitor observes this in real time under the light microscope, observing how the alcohol quickly evaporates leaving the structure, and thus the blue color returns. Then, it is possible to test the wings with another liquid: water. This butterfly lives in the rainforest, so it is important to understand how it interacts with water, especially after the wing's peculiar interaction with alcohol. The visitor adds a couple water droplets on the wings and discovers the third secret: the butterfly is waterproof. A model of the scales is used to explain how the difference between surface tensions allows the wing to get wet with alcohol but at the same time to be waterproof.

For the next secret we use two specimens of the same butterfly, one viewed from the dorsal (top) and other from the ventral (bottom). Visitors discover the last secret: the butterfly has two completely different sides, and they aid the butterfly in mating, defining territory and providing protection (Fig 6) [2]. Finally the technology and engineering applications are discussed. Visitors learn that this nanostructure is being applied in the development of new display technology, photovoltaics, selective gas/vapor sensors, and self-cleaning optical coatings, among others [3].

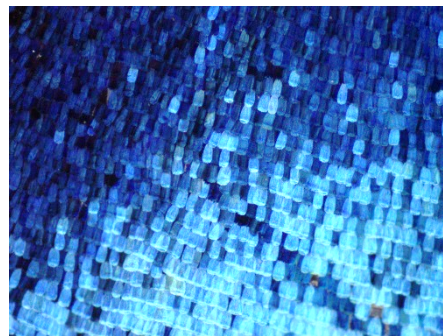
This activity has proven to be very popular with visitors; it creates meaningful interactions between them, the staff and advanced scientific instrumentation. It unifies the work of basic sciences with current developments in technology, demonstrates the research done in the museum, and provides a clear example of the incredible complexity of a seemingly simple species. Furthermore, the activity is also executed by bilingual staff, which increases the opportunities to engage with diverse audiences that may be underserved due to the lack of materials in their native language.

References:

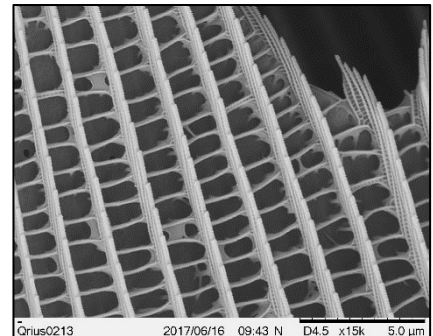
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- [2] P. Vukusic *et al*, Proc. R. Soc. Lond. B **266** (1999), p, 1403.
- [3] R. H. Siddique *et al*, Proc. SPIE **9187** (2014), p. 91870E



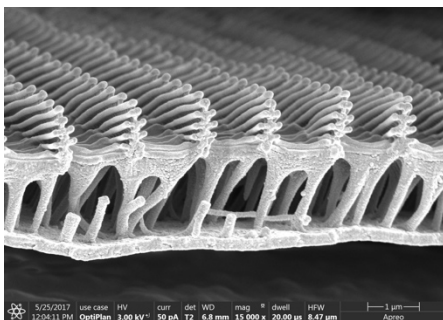
**Figure 1.** Activity Layout at the NMNH



**Figure 2.** Blue Morpho's scales at 35X Magnification



**Figure 3.** Blue Morpho's scales at 15,000X Magnification



**Figure 4.** Cross Section image of the Blue Morpho's scales at 15,000X Magnification



**Figure 5.** Blue Morpho's scales wet with alcohol at 5X magnification



**Figure 6.** Dorsal (top) and Ventral (down) views of the Blue Morpho