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Butterfly Wing Colors Come From Space-Age Structures

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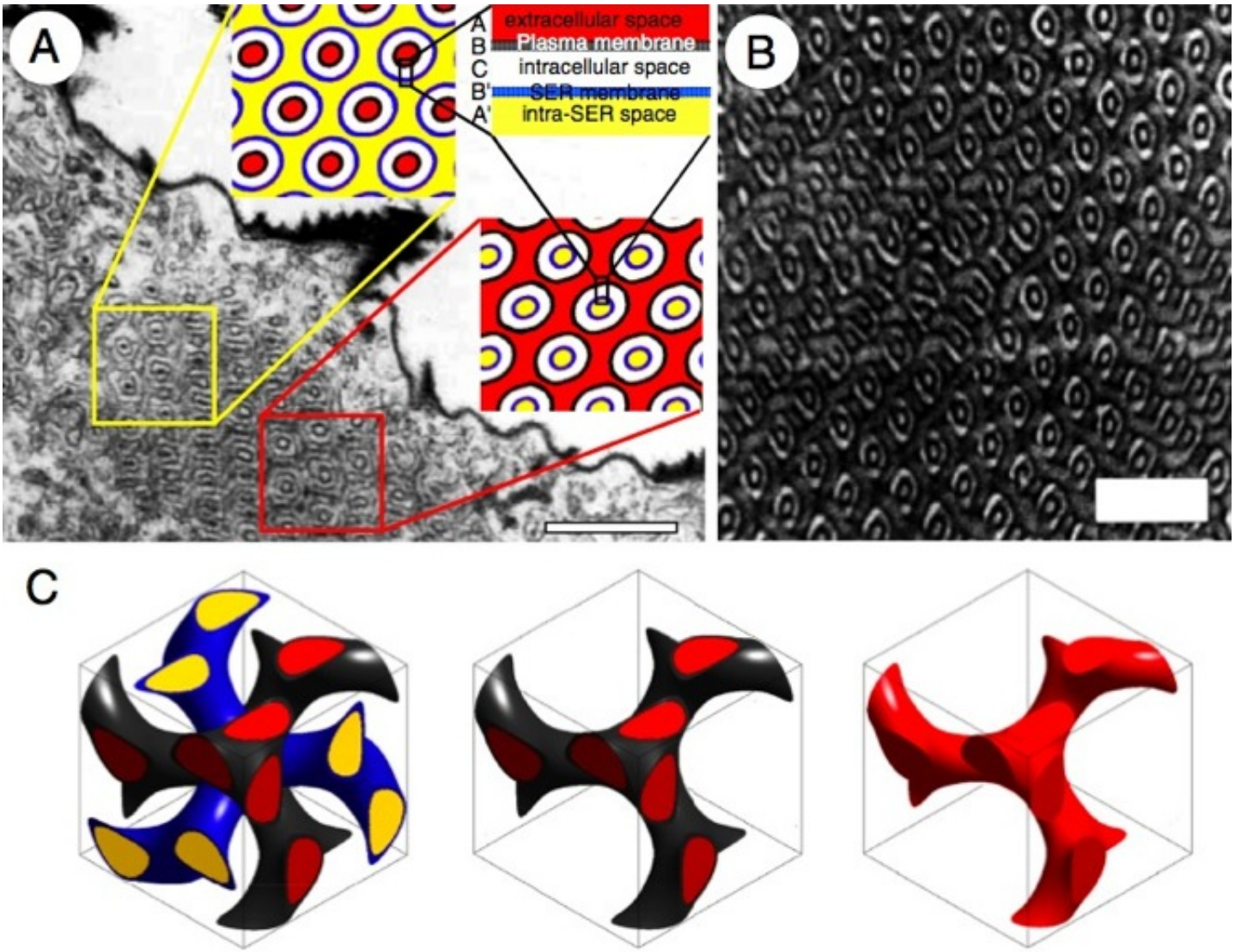


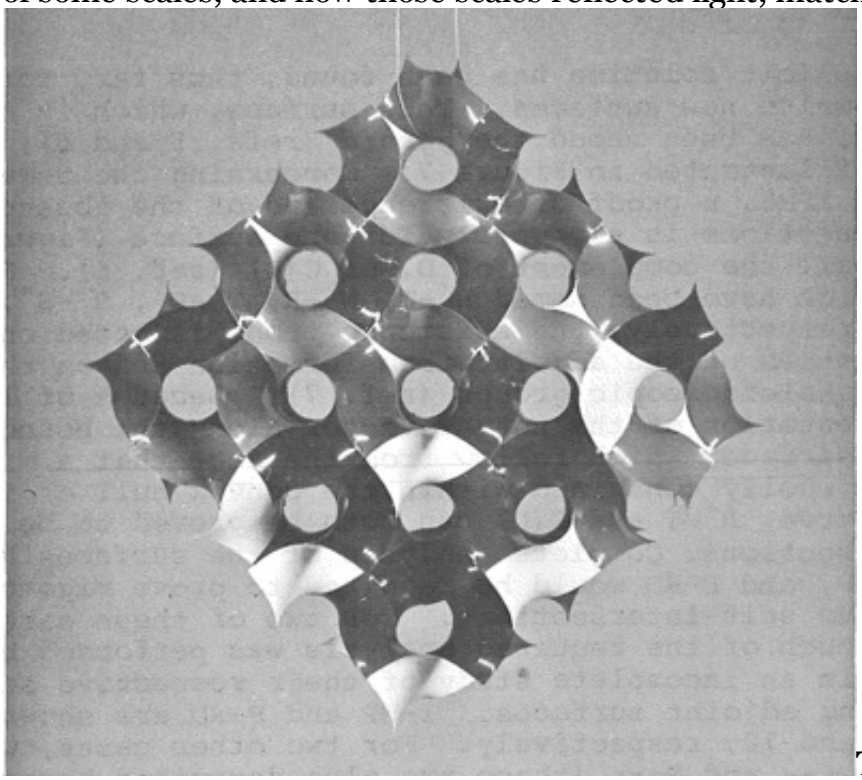
Some butterflies get their fabulous colors from light refracted through membrane shapes that were first discovered by mathematicians and applied in space-age material science.

Using microscopes with three-dimensional nanoscale resolution, Yale University researchers found that shades of green in the wings of five butterfly species are produced by crystalline structures called gyroids.

The gyroid shape was conceived in 1970 by NASA physicist Alan Schoen in his theoretical search for ultra-light, ultra-strong materials for use in space. The new study describing the shape in butterflies is in the June 15 *Proceedings of the National Academy of Sciences*.

Gyroids have what's known as an "infinitely connected triply periodic minimal surface": For a given set of boundaries, they have the smallest possible surface area. The principle can be illustrated in soap film on a wireframe (see image at right). Unlike soap film, however, the planes of a gyroid's surface never intersect. As mathematicians showed in the decades following Schoen's discovery, gyroids also contain no straight lines, and can never be divided into symmetrical parts.

Yet even as mathematicians speculated on the nature of gyroids, entomologists found them in nature, at least in two dimensions. Microscopic images of butterfly wings showed that the surface of some scales, and how those scales reflected light, matched the predictions of gyroid math.



Those analyses looked only at scale surfaces. In the new study, the researchers look at three dimensions using a microscopy technique called synchrotron small angle X-ray scattering. Something like a combination of an

electron microscope and X-ray machine, it revealed butterfly gyroids in structural high-definition.

The gyroids are made of chitin, a polymer used in insect exoskeletons, secreted by wing cells that fold naturally into gyroid shape. After cells die and decompose, the chitin shells remain. Light refracts through them, with subtle variations in gyroid shape and proportion producing different hues.

While the gyroids studied by the researchers were only responsible for green wavelengths, the basic principles — chitin shells in mathematically complex shapes — are likely used by butterflies to produce other colors, said study co-author Richard Prum, a Yale University biologist.

"By varying the kinds of proteins included in the membranes, butterflies may be able to develop strikingly different structures," he said.

Material scientists now use synthetic gyroids to make photonic devices, such as solar cells and communication systems, that manipulate the flow of light.

"Nature and the evolution of structures that create colors can be an excellent guide to how we might assemble and manufacture photonic materials," said Prum. "Organisms have already been there."

Images: 1. Wing scale photonic nanostructure, from electron micorscope to model./PNAS. 2. Soap film around a wire frame./Wikimedia Commons. 3. A gyroid model built by Alan Schoen./NASA. 4. Flickr/Claudio Gennari.

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Citation: "Structure, function, and self-assembly of single network gyroid (I4132) photonic crystals in butterfly wing scales," by Vinodkumar Saranathan, Chinedum Osuji, Simon Mochrie, Heeso Noh, Suresh Narayanan, Alec Sandy, Eric Dufresne, and Richard Prum. Proceedings of the National Academy of Sciences, Vol. 107 No. 24, June 15, 2010.
Brandon Keim's Twitter stream and reportorial outtakes; Wired Science on Twitter. Brandon is currently working on a book about ecological tipping points.


Brandon is a Wired Science reporter and freelance journalist. Based in Brooklyn, New York and sometimes Bangor, Maine, he's fascinated with science, culture, history and nature.
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Kajabla

What does the author mean by "For a given set of boundaries, they have the smallest

possible surface area"?
Doesn't a sphere have the smallest possible surface area in a given space?

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SeattleSlough

Correction: The butterfly was here first. The Creator designed the gyroid milennia ago. Science discovered and copied it recently.

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Marticus

That's pretty awesome.

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