Biomimetics, Color and the Arts

by

Franziska Schenk

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What color is that dress?

It's about an overexposed photograph of a dress, whose colors were as chameleon-like as the perceptions of its viewers. Is it gold and white? Was it black and blue?

A passionate debate exploded around the world with tens of millions of social media posts, in part fueled by A-list celebrities.

http://www.norwalkreflector.com/article/6502576

What color is that butterfly?

"Any account of colour in art must begin with the belief, which dominated Western culture for centuries, … that colours are of two distinct types:

- those that are stable attributes of material substances,

- and those, that are 'accidental', such as the evanescent colours of the rainbow and the colours of some birds' feathers, which change according to the viewpoint of the spectator."

Gage: Colour in Art, 2006

What color is this painting?

Prelude:

The Coelacanth and two different types of color

The story of the coelacanth, collage, 1997

Latimeria, oil on canvas, 1999

The Future: All that Glitters is not Gold

STRUCTRUAL COLOURS

Colour from mainly transparent materials – physical structures – no chemical pigments.

Hue often changes with angle.

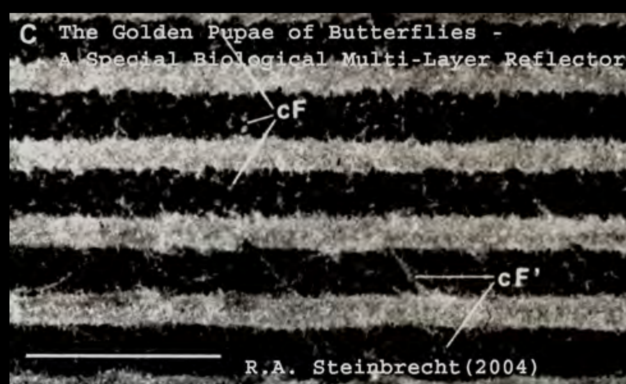
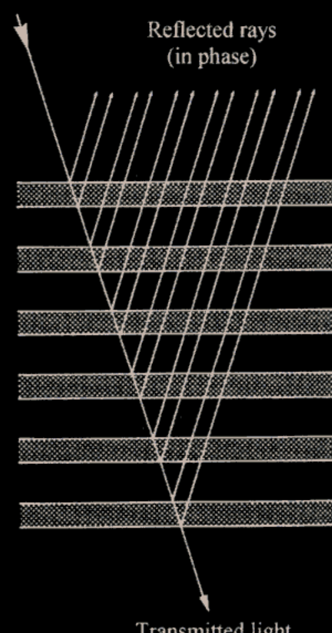


Figure 5 Transmission electron micrographs of thin sections through the cuticle of *E. core*. **A** Detail from METAL-cuticle with alternating C- and D-layers responsible for the interference effect.

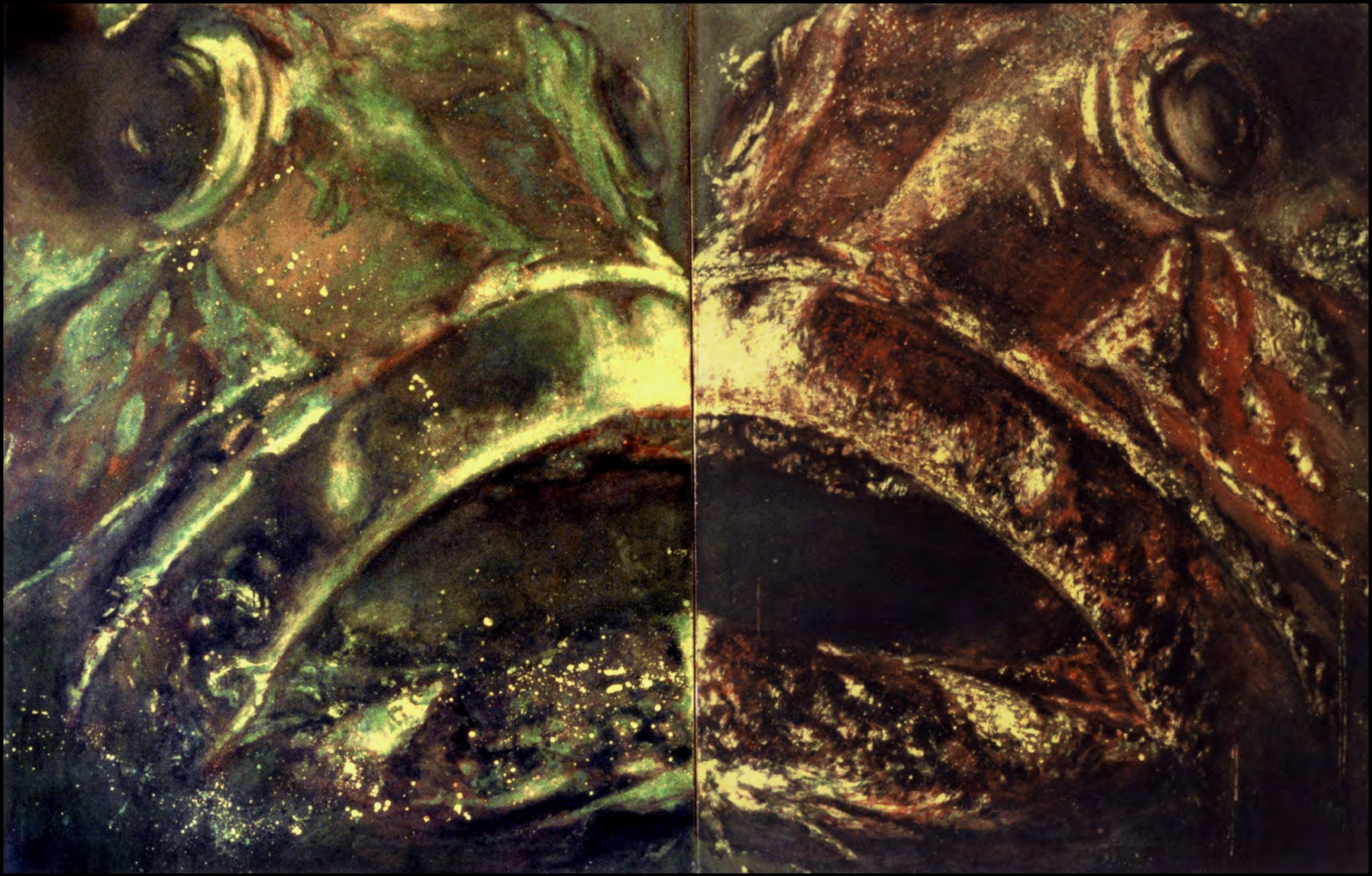


First iridescent flakes:

Titanium dioxide mica flakes

Gold: the Colour of Icons

Denizen I, oil on canvas, 5’ x 4’, 1999



Denizen II, diptych, oil on canvas, 5’ x 8’, 1999

Skulduggery, diptych, oil on canvas, 6’ x 14’, 1999

The Chameleon and the nano-particle



Silver - Varnishing Act

Franziska Schenk, Varnishing Act, diptych, mixed media, each panel 5’ x 4’, 2000

Bio-inspired “pigments” and their conversion to the painter’s palette

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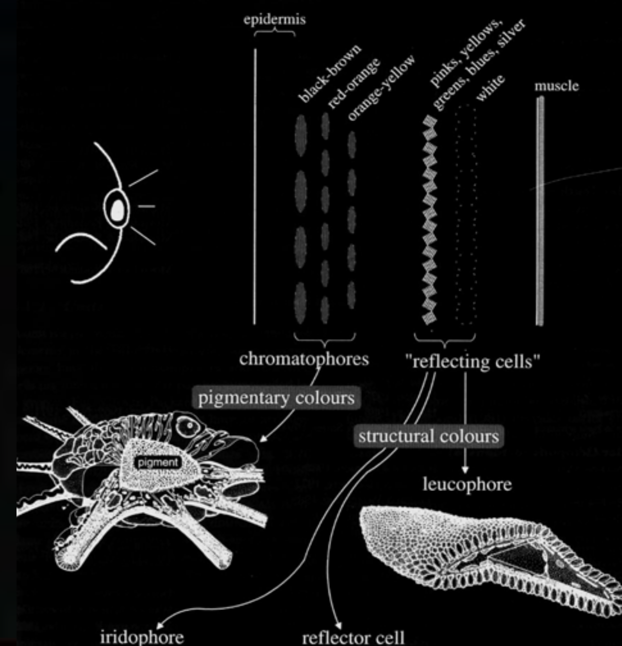
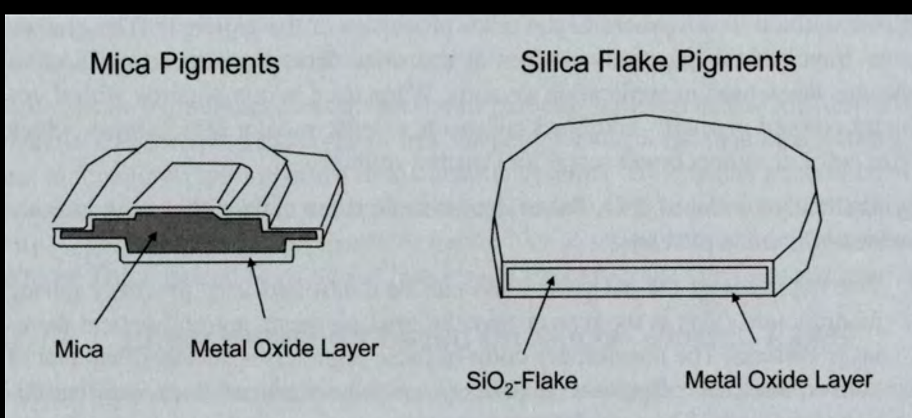
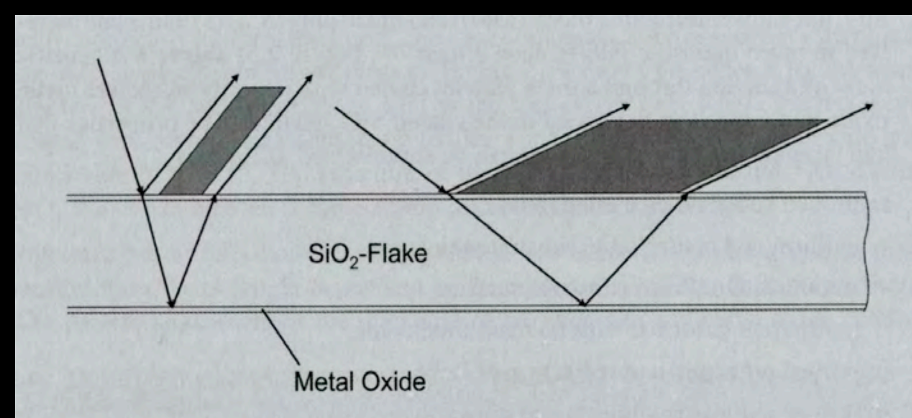
‘Chameleonesque’ colour







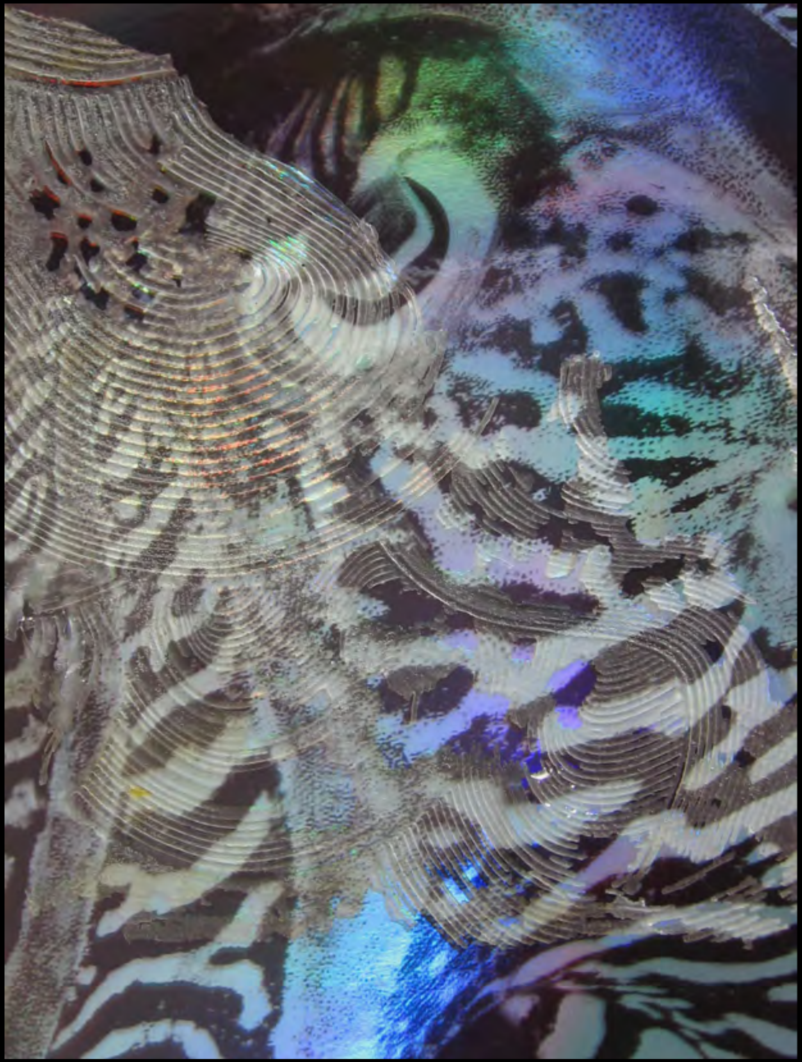
Two distinct types of colour

"Any account of colour in art must begin with the belief, which dominated Western culture for centuries, … that colours are of two distinct types:

- those that are stable attributes of material substances,

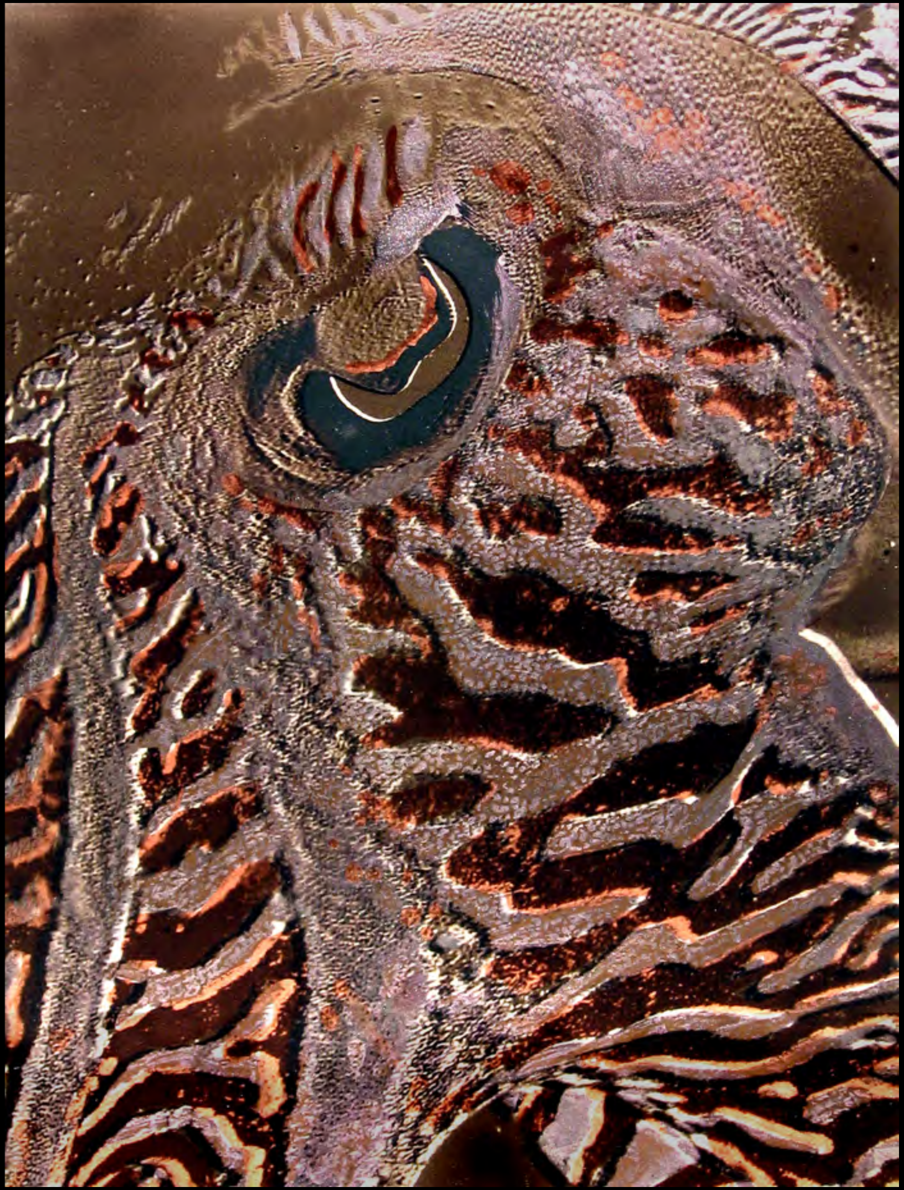
- and those, that are 'accidental', such as the evanescent colours of the rainbow and the colours of some birds' feathers, which change according to the viewpoint of the spectator."

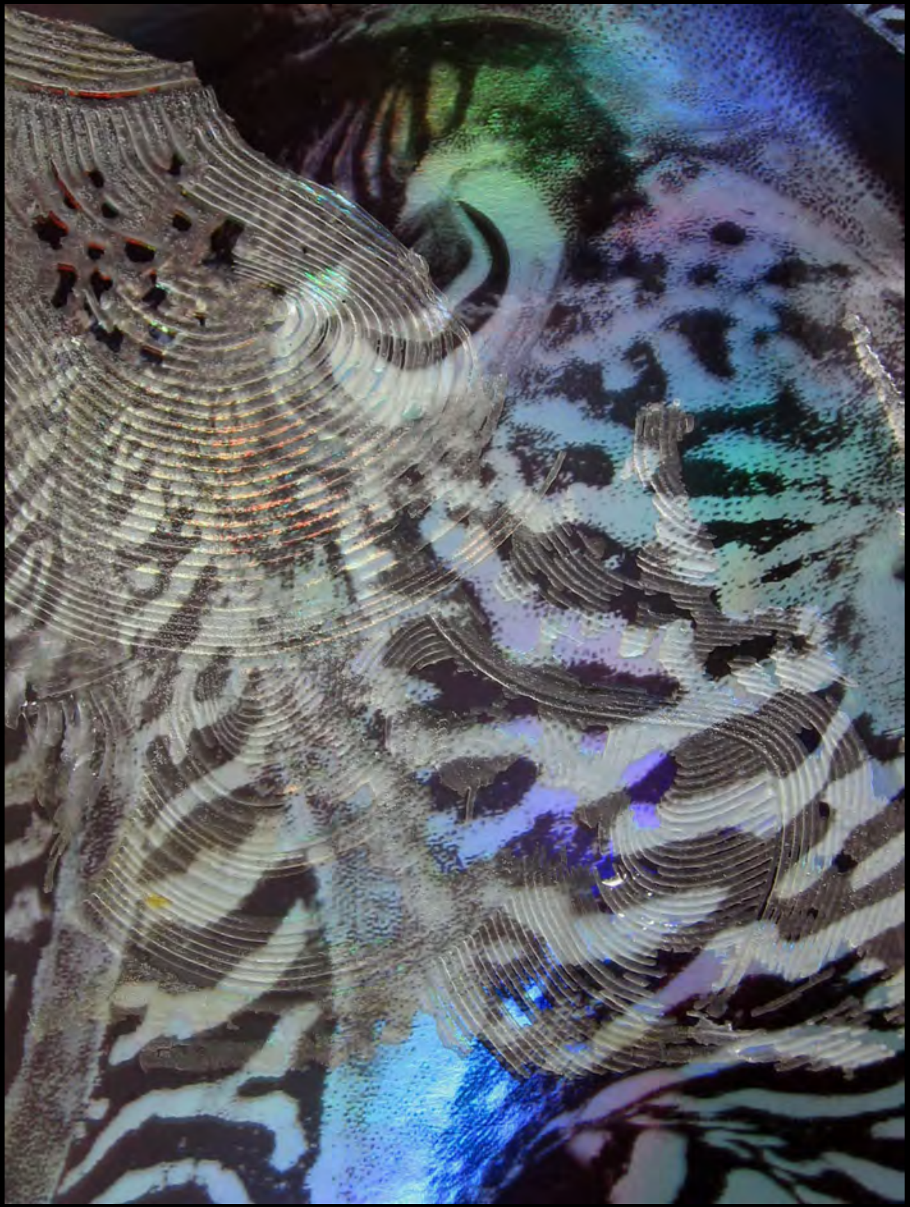
Gage: Colour in Art, 2006

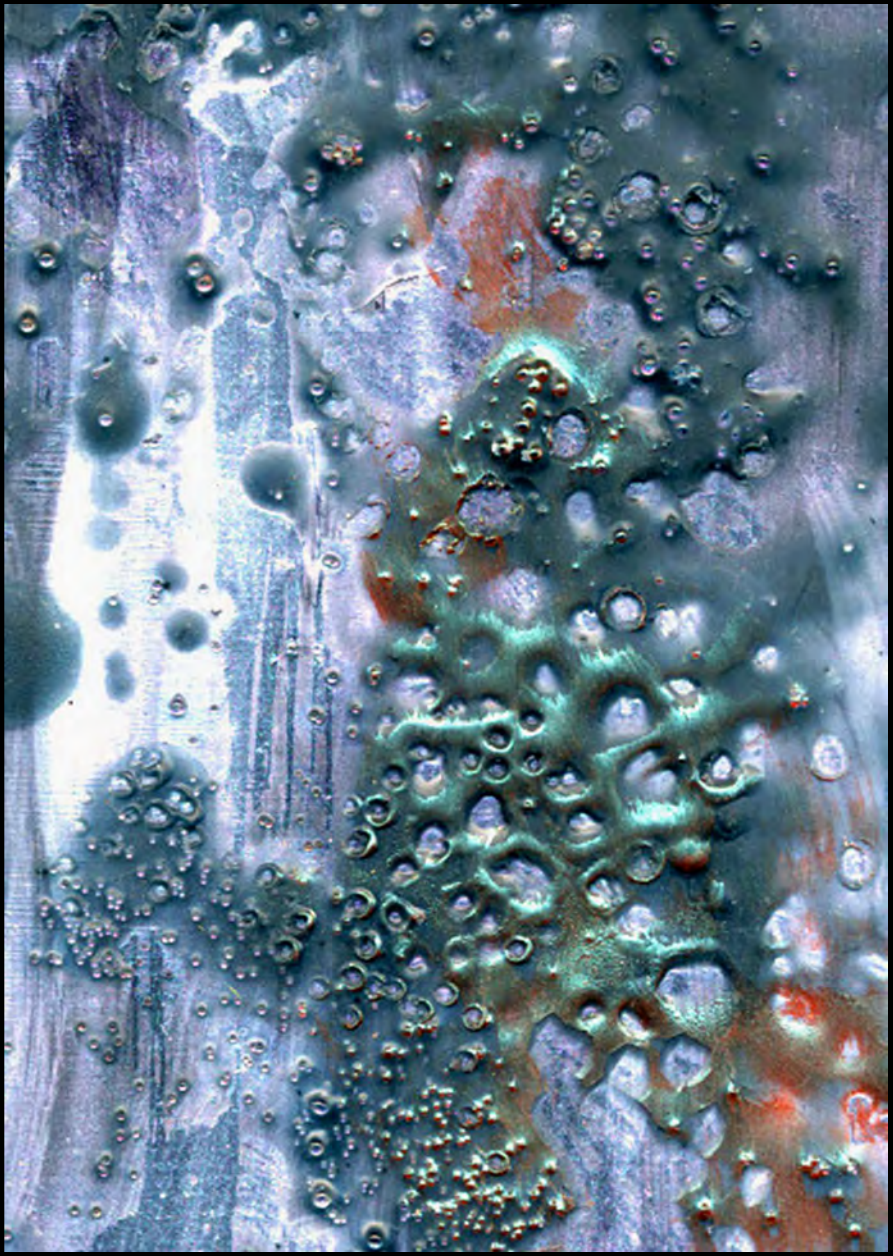
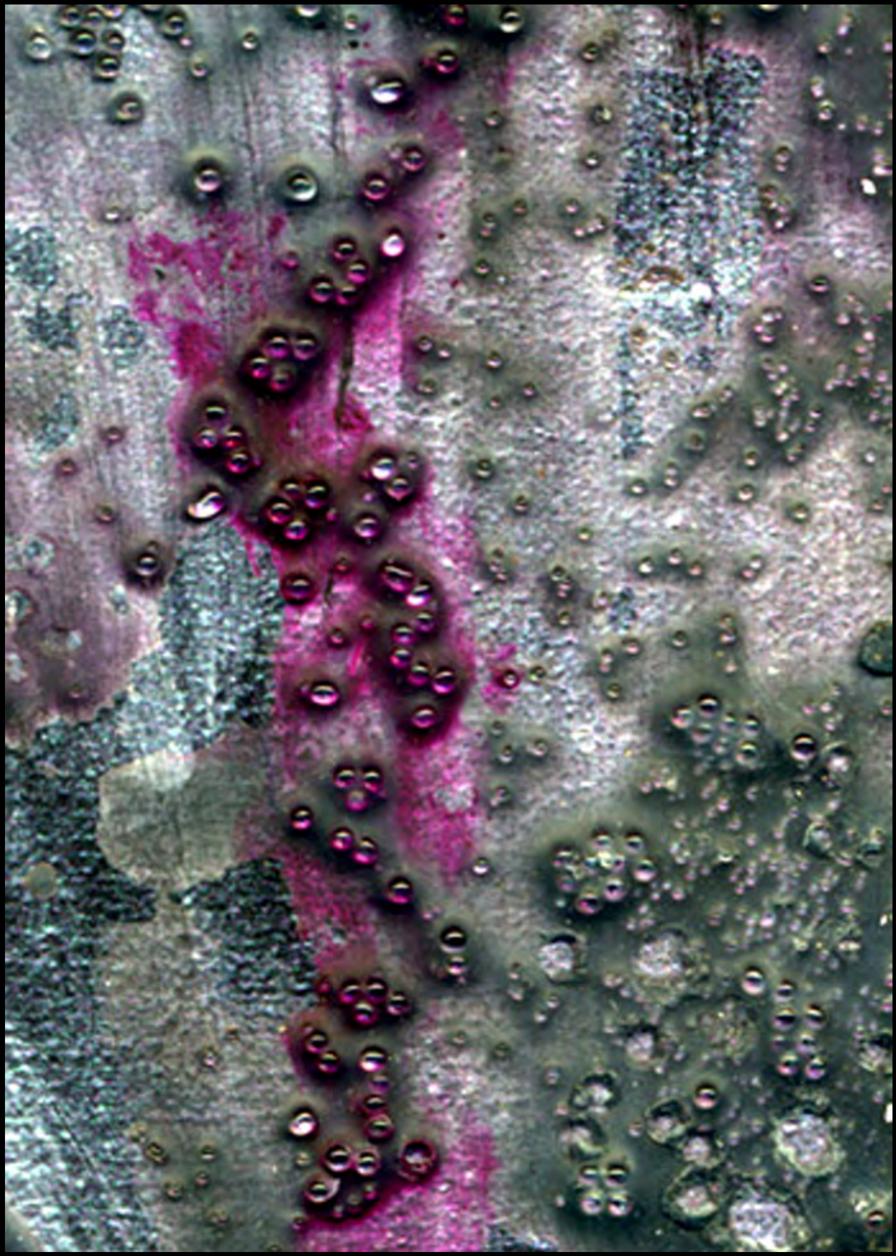


Mantle of Many Colours, triptych, iridescent paint on board, 4’ x 9’, 2004


The Voyage of H.M.S. "Challenger."
Cephalopoda Pl. I.
F Schenk

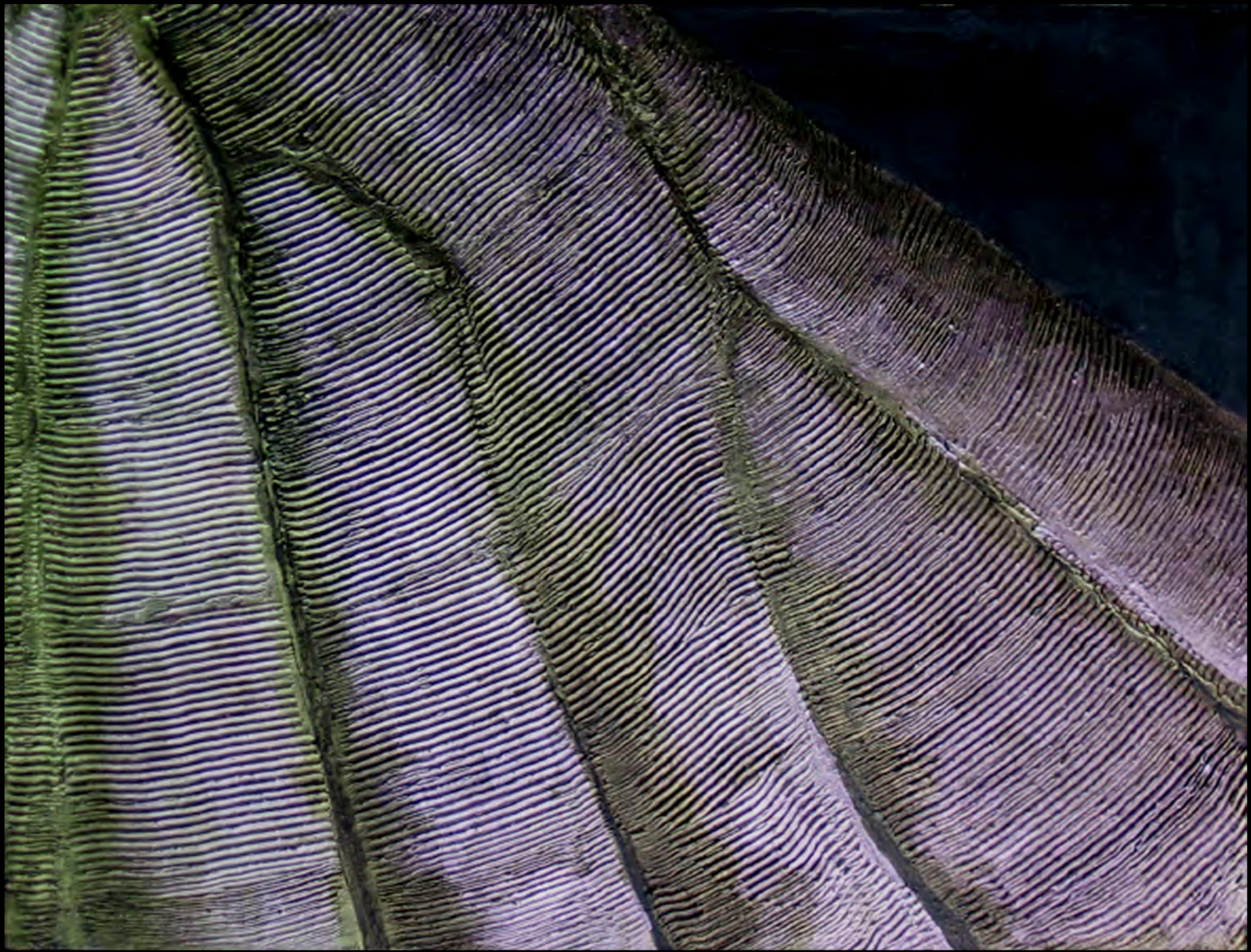



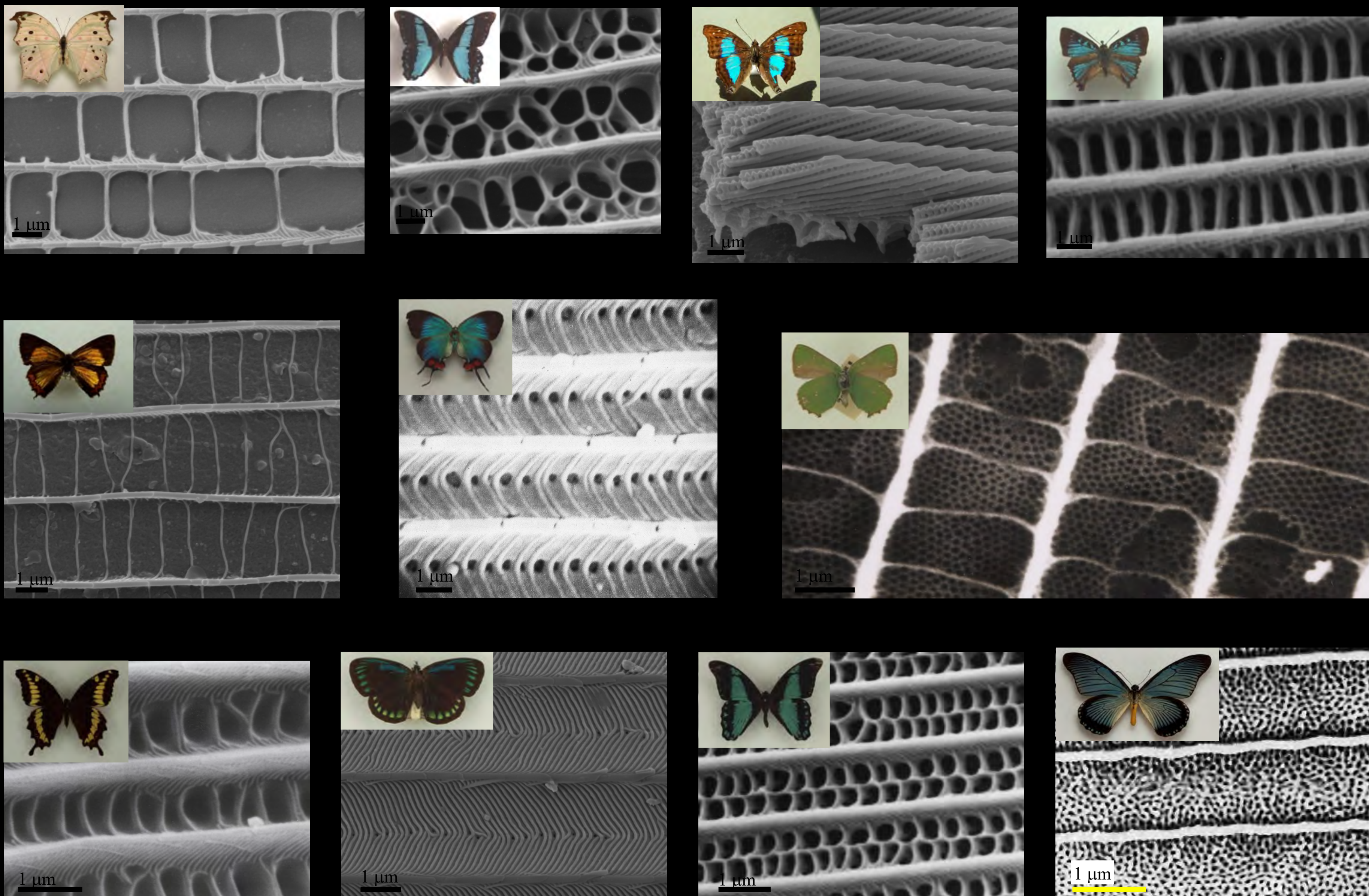
Sea Change, diptych, mixed media, 3’ x 4’, 2006

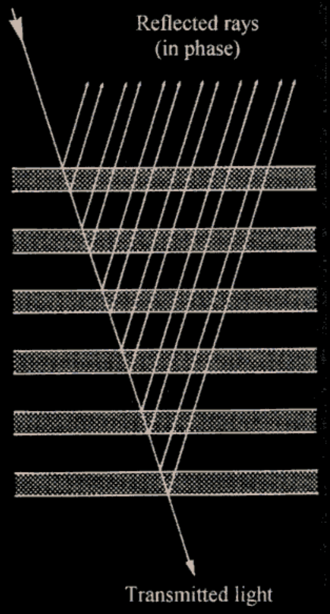
How to mimic butterfly color?



Salamis parhassus , iridescent paint on board, A 4, 2009

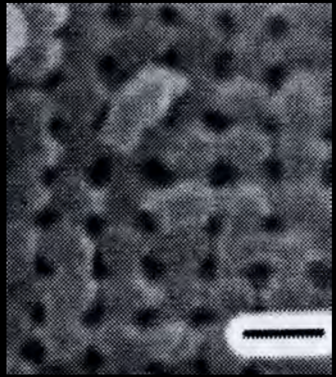
The diversity of butterfly scale architecture

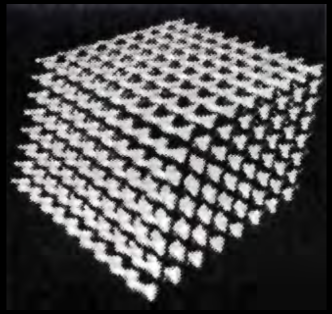




Multilayer reflectors

- alternating layers of materials each with a different refractive index
- ‘simple’ optics
- constructive interference
- each light wave is scattered only once within structure

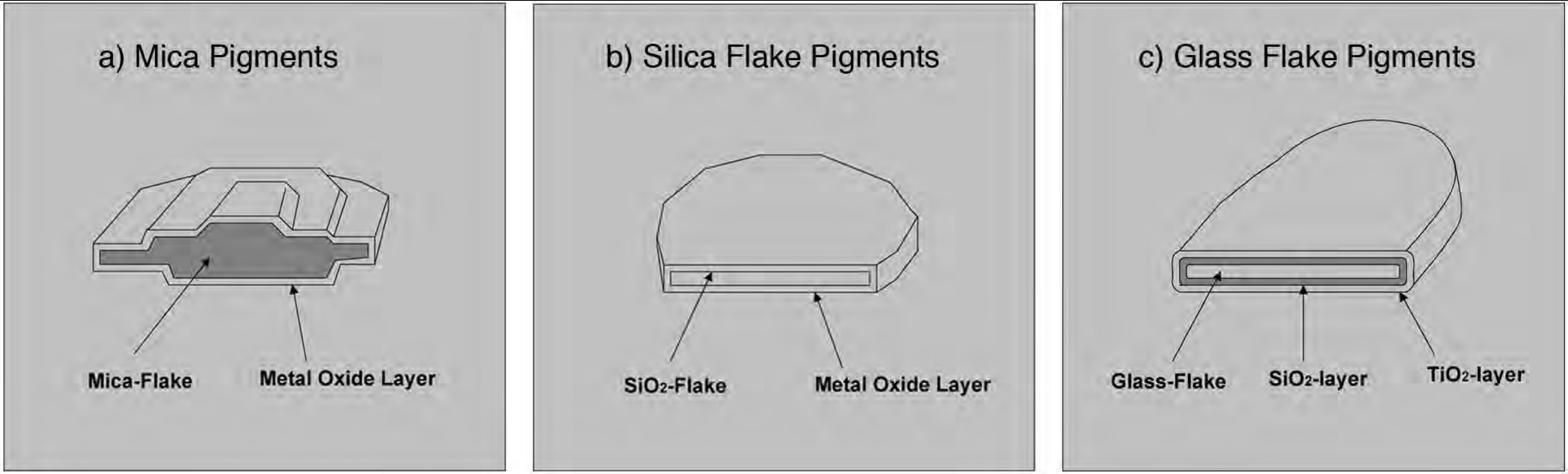




Photonic crystals

- ordered 2D and 3D lattices
-‘complex’ optics (quantum optics/photonics)
- each light wave is scattered more than once
- all the probabilities for wave paths need to be considered
- large computers are required for the calculations

Special Effect Pigments



The Blue Jewel

THE MORPHO

Klots: Living Insects of the World (1959):

"like jewels, the flashing blue of their wings is plainly visible from several hundred feet

… living color that changes with every tiny shift of the light or angle of view."

… almost three-dimensional colors "

Simon: The Splendor of Iridescence (1971):

"… the blue colour is, in the truest sense of the word, superficial, that is, a result of surface structure only.

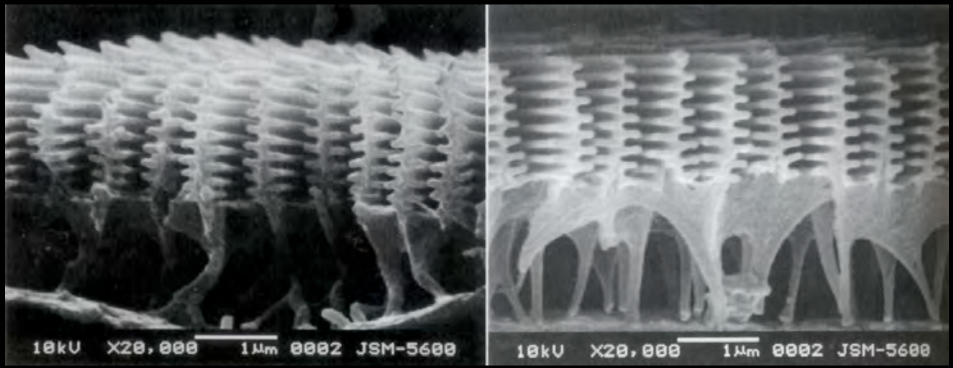
… the living colour resides in scales consisting of "dead" tissues that do not change."

Iridescent colour glows for millions of years

In Pursuit of *Morpho* blue

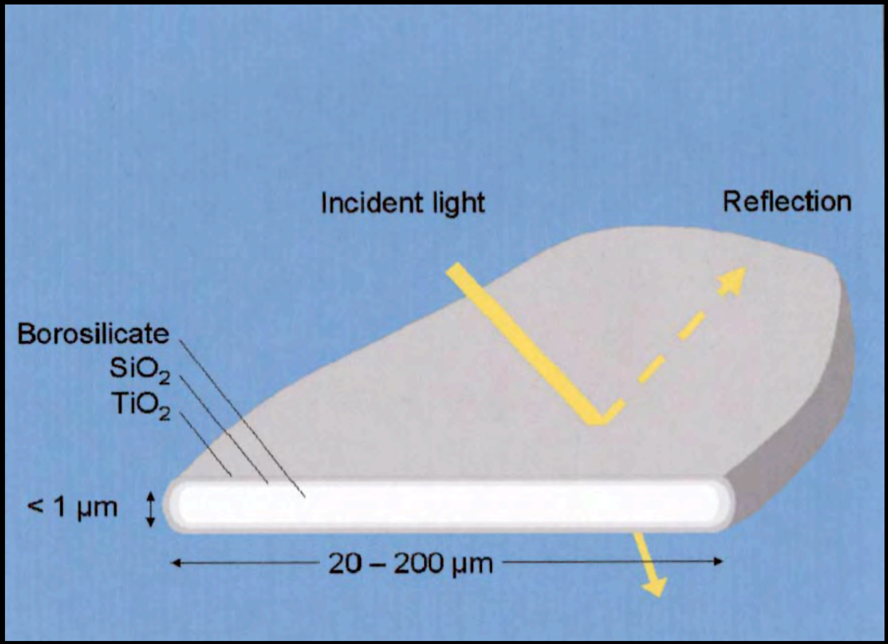
S. Kinoshita and S. Yoshioka:

M. didius M. sulkowskyi



Ground scales of M. didius and M. sulkowskyi

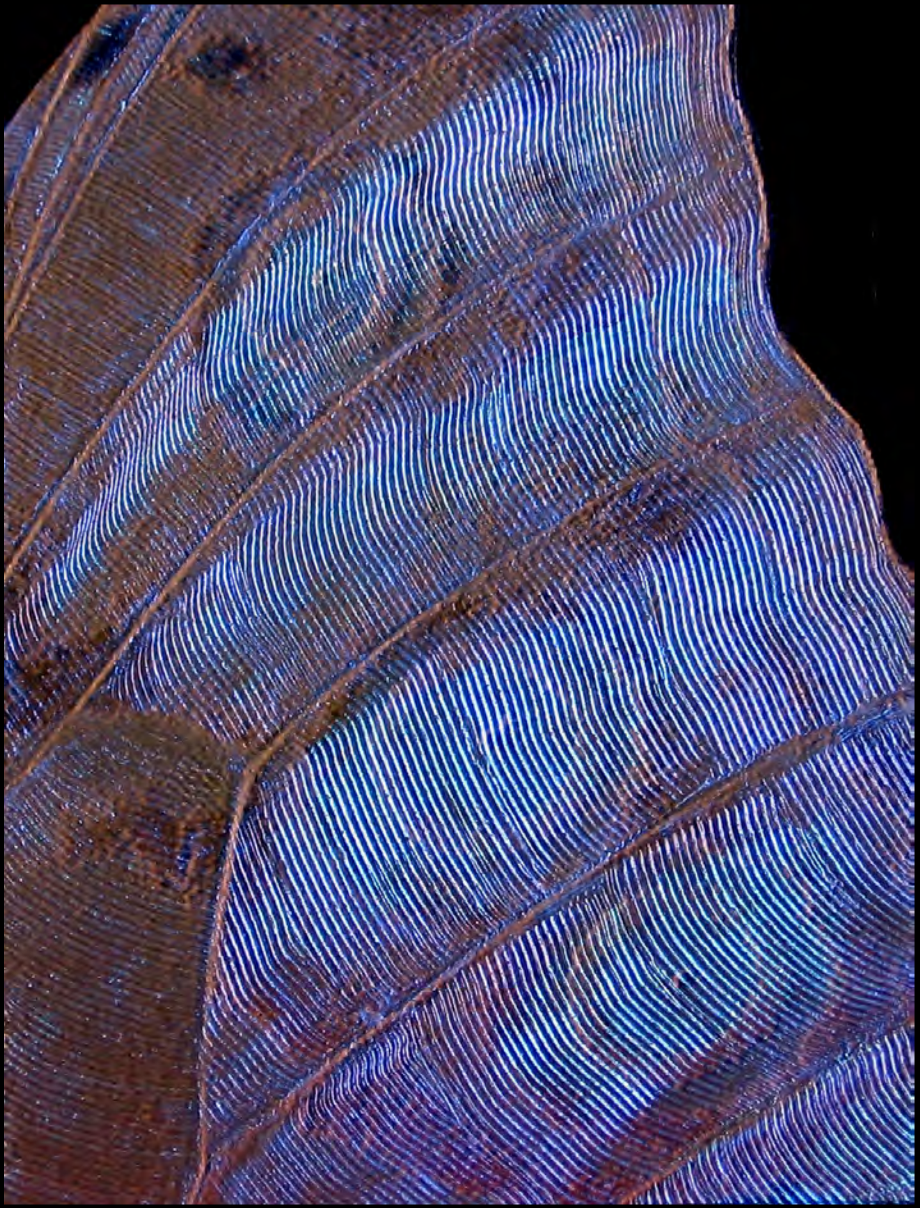
Glass Flake Pigment



- Launched in 2004
- High transparency and gloss
- Pure, intense interference colour
- Smooth surface and rounded edges

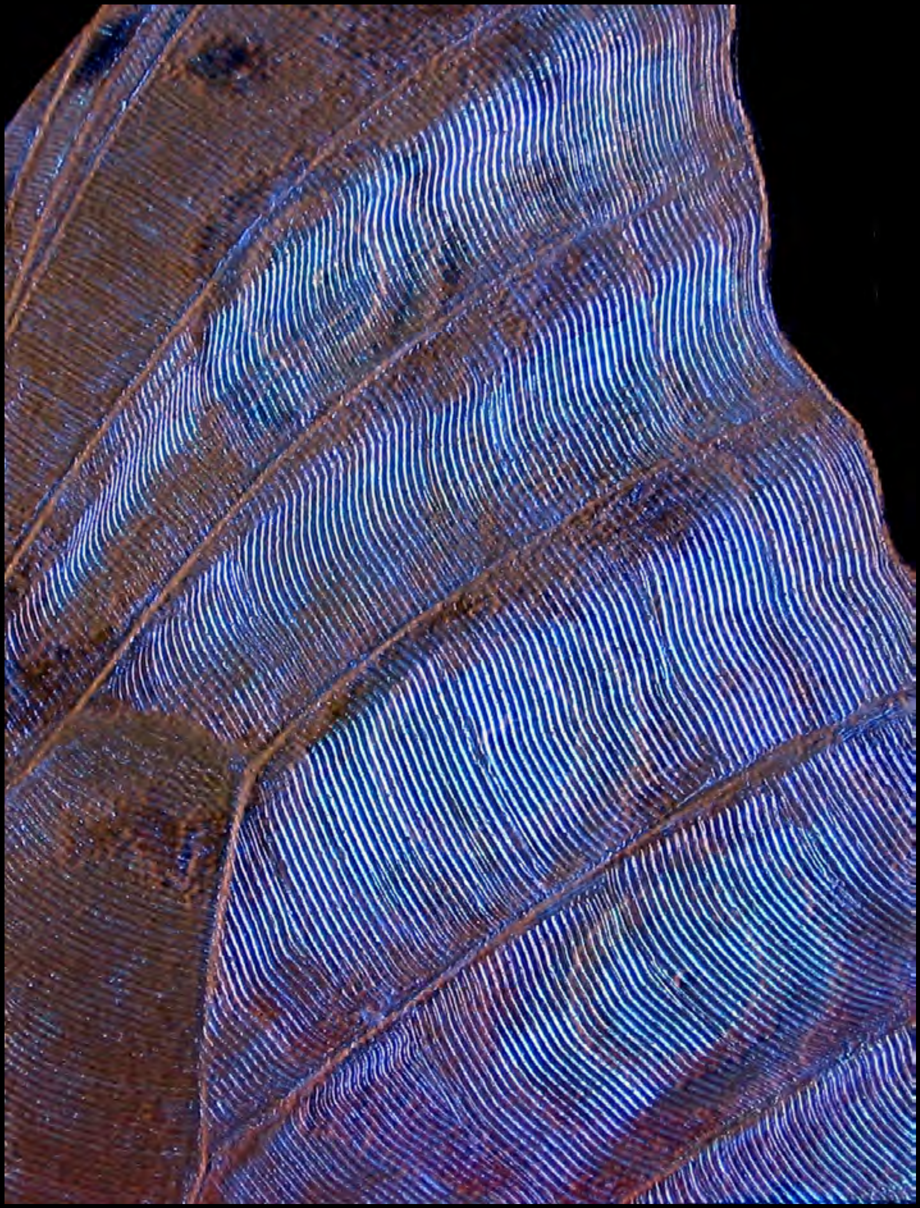
Photo of Morpho wing section

Morphp Painting I, iridescent paint on board, A4, 2007



Morpho Painting II, iridescent paint on board, A4, 2007

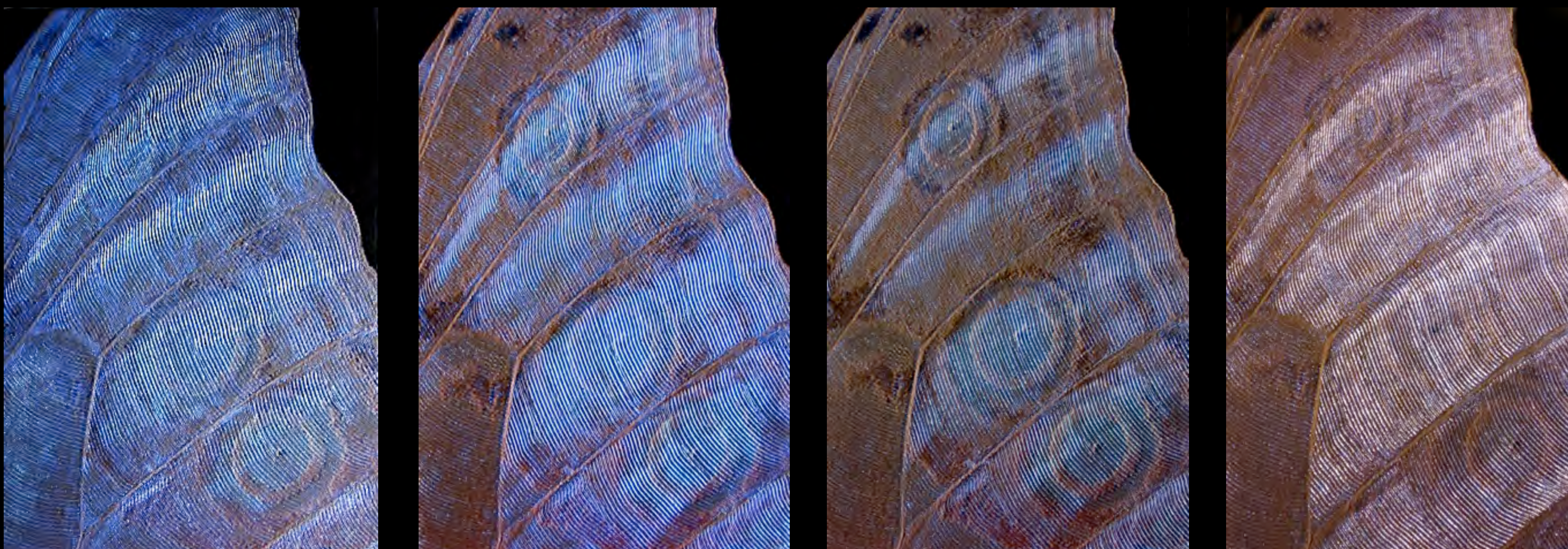
The same painting lit from a different angle

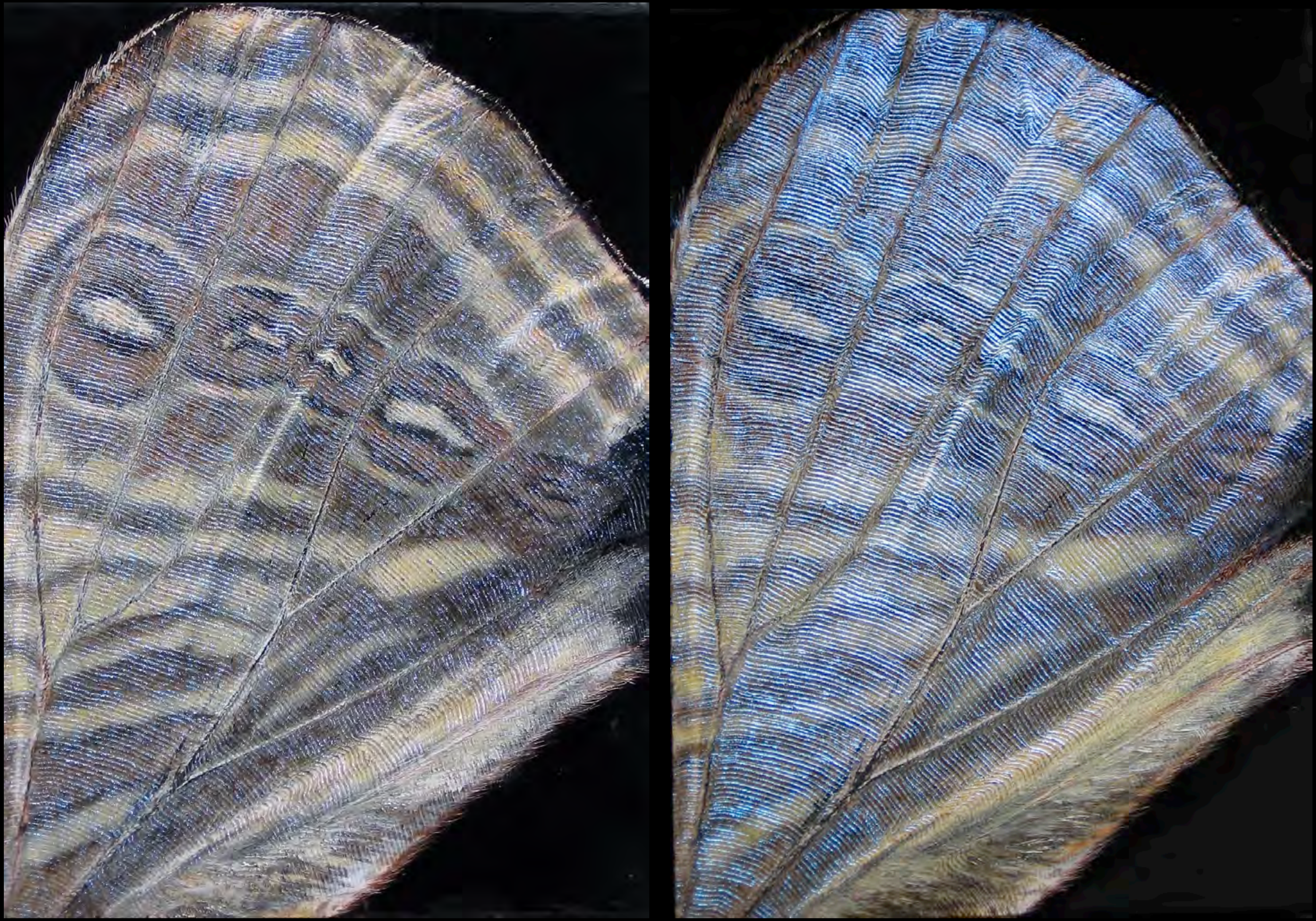


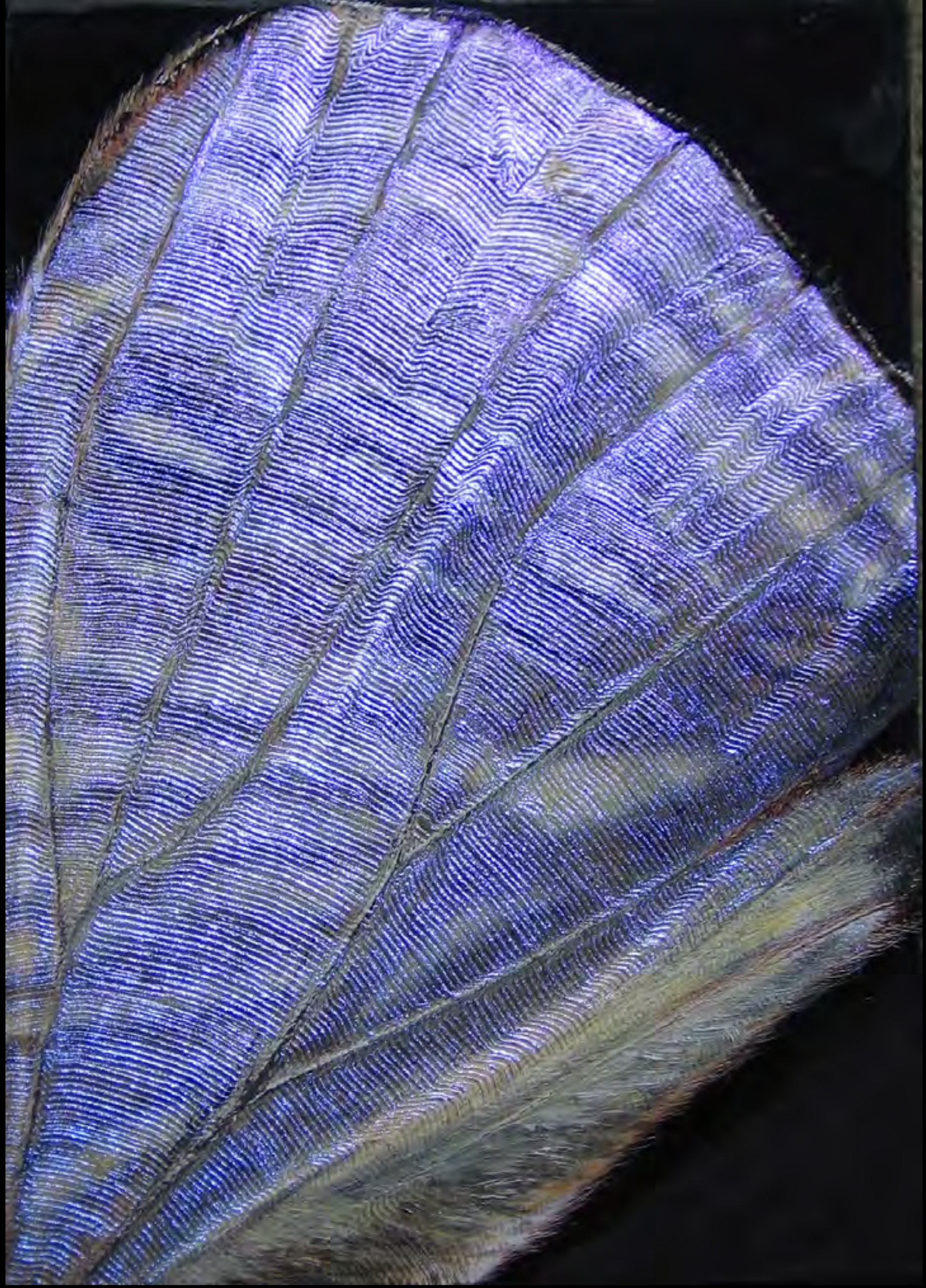
Morpho Painting II, iridescent paint on board, A4, 2007

The same painting lit from a different angle

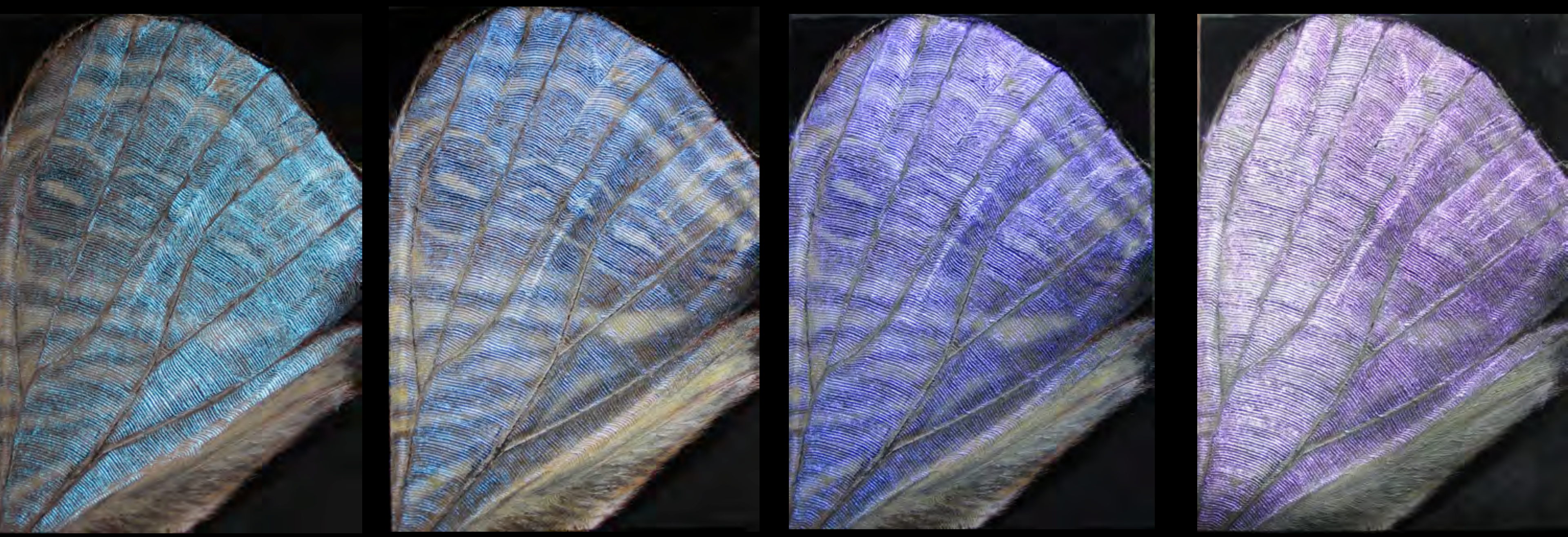
Morpho rhetenor

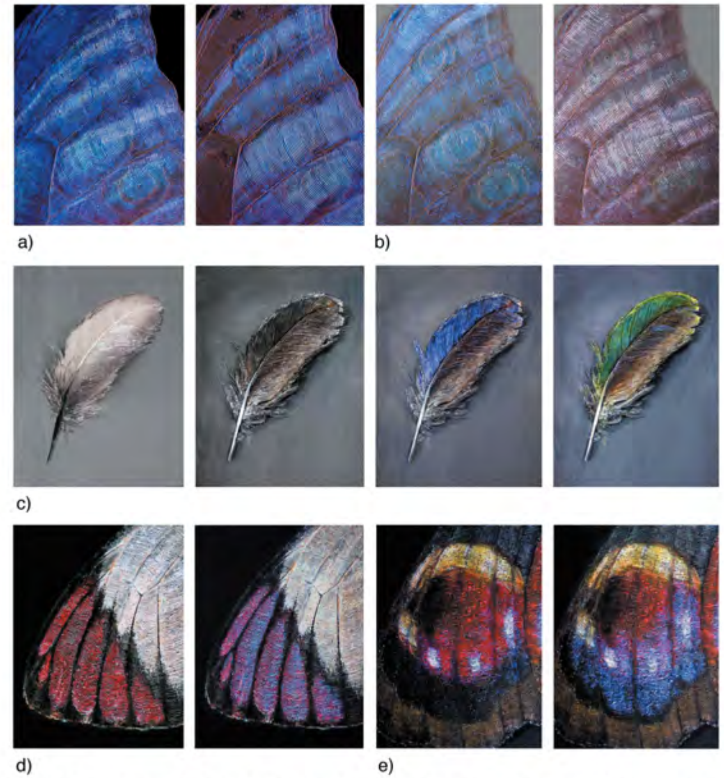







Morpho sulkowskyi



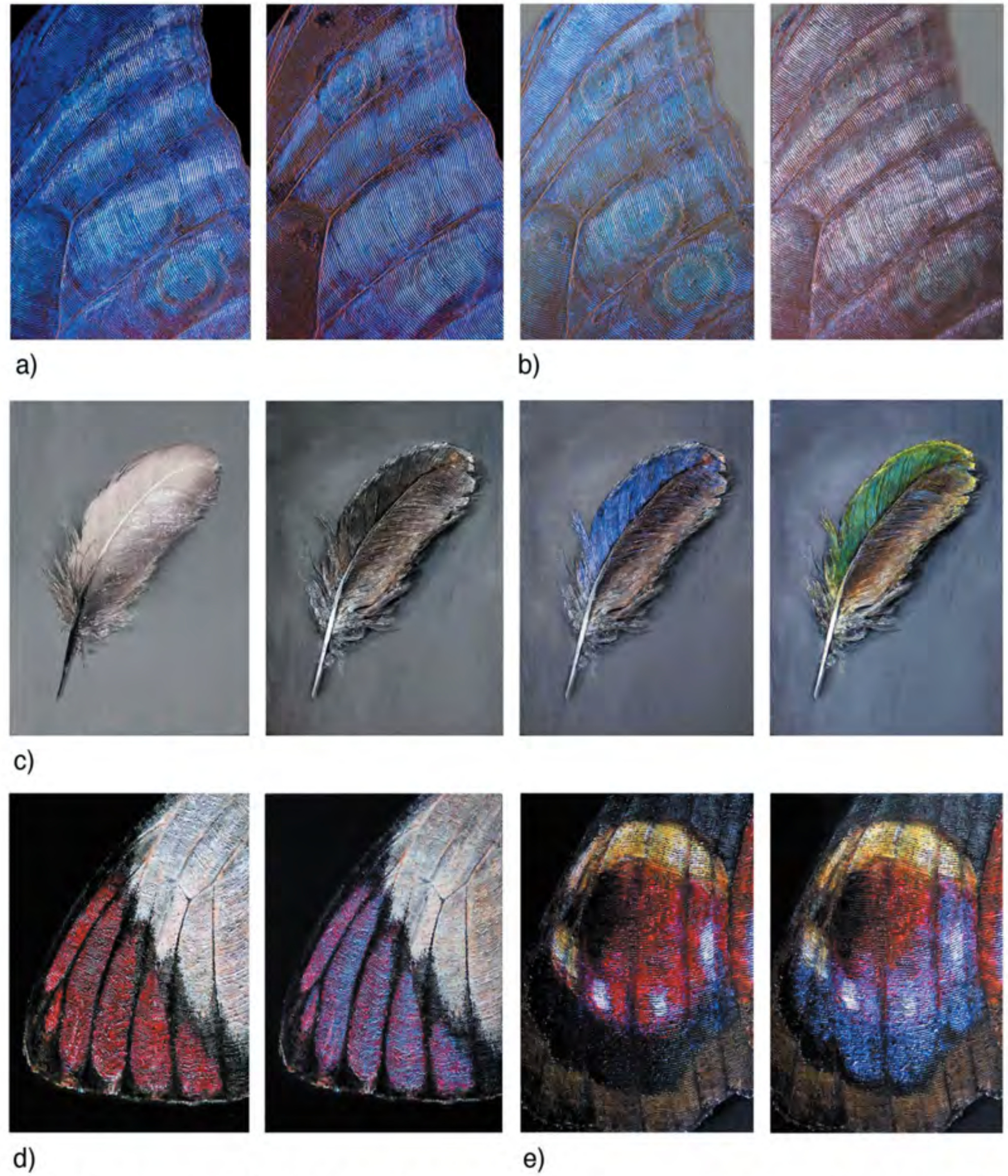


Franziska Schenk, paintings, A4 size, 2008–2009. Different stages of the painting process are represented. (a) Morpho didius: A dark ground is overlaid with interference blue, giving rise to metallic hues. (b) Morpho sulkowskyi: On a lighter ground the same blue generates two-color opalescence. (c) Poicephalus senegalus: A brown base is covered with interference blue which, in turn, is overlaid with a chemical yellow to arrive at green. (d) Colotis regina: Red pigment is overlaid with interference blue to generate purple. (e) Inachis io: Interference blue on red creates purple; on black a vivid blue results. (© F. Schenk)

Iridescent color: From nature to the painter’s palette, Leonardo, 2011

Interaction between chemical pigments and structural color

In collaboration with Andrew Parker, Natural History Museum, London



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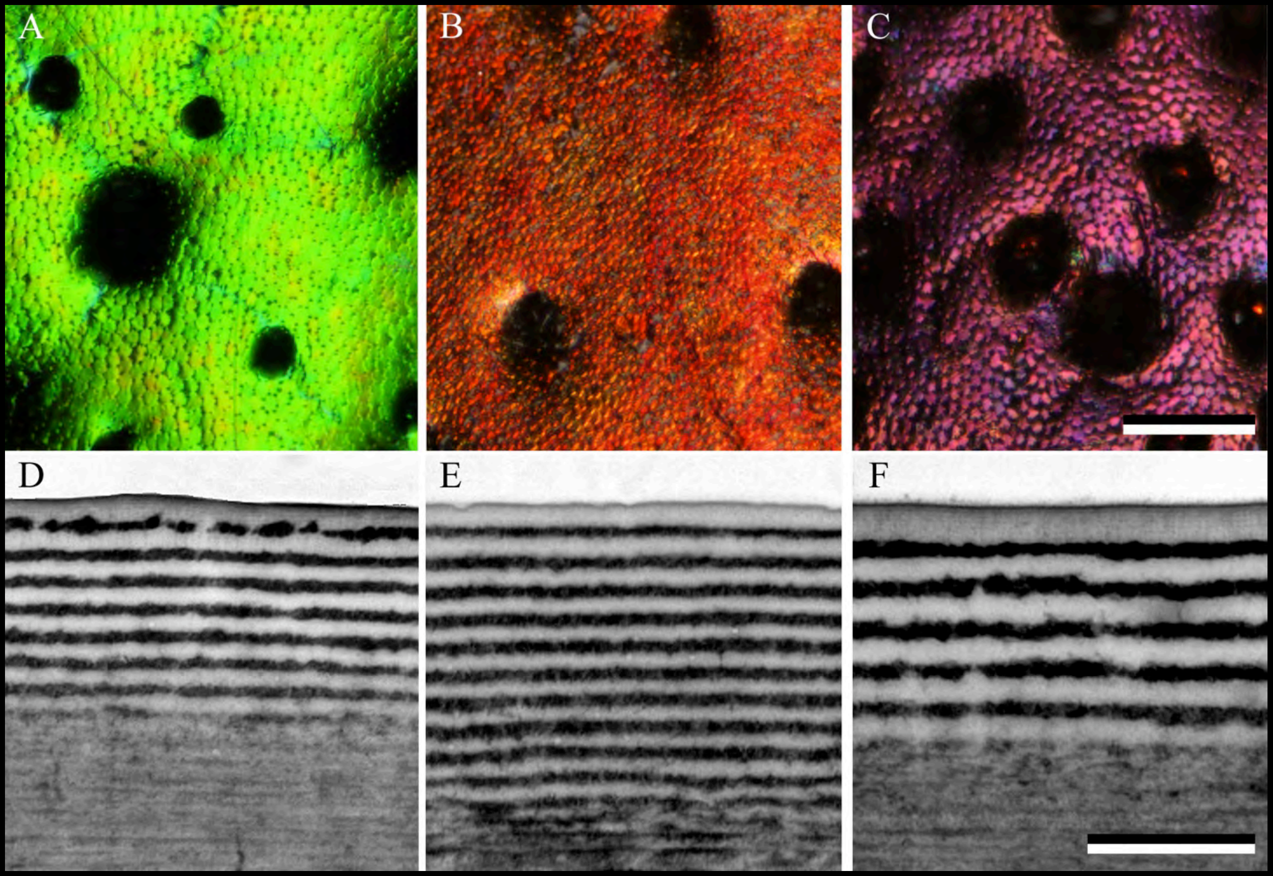
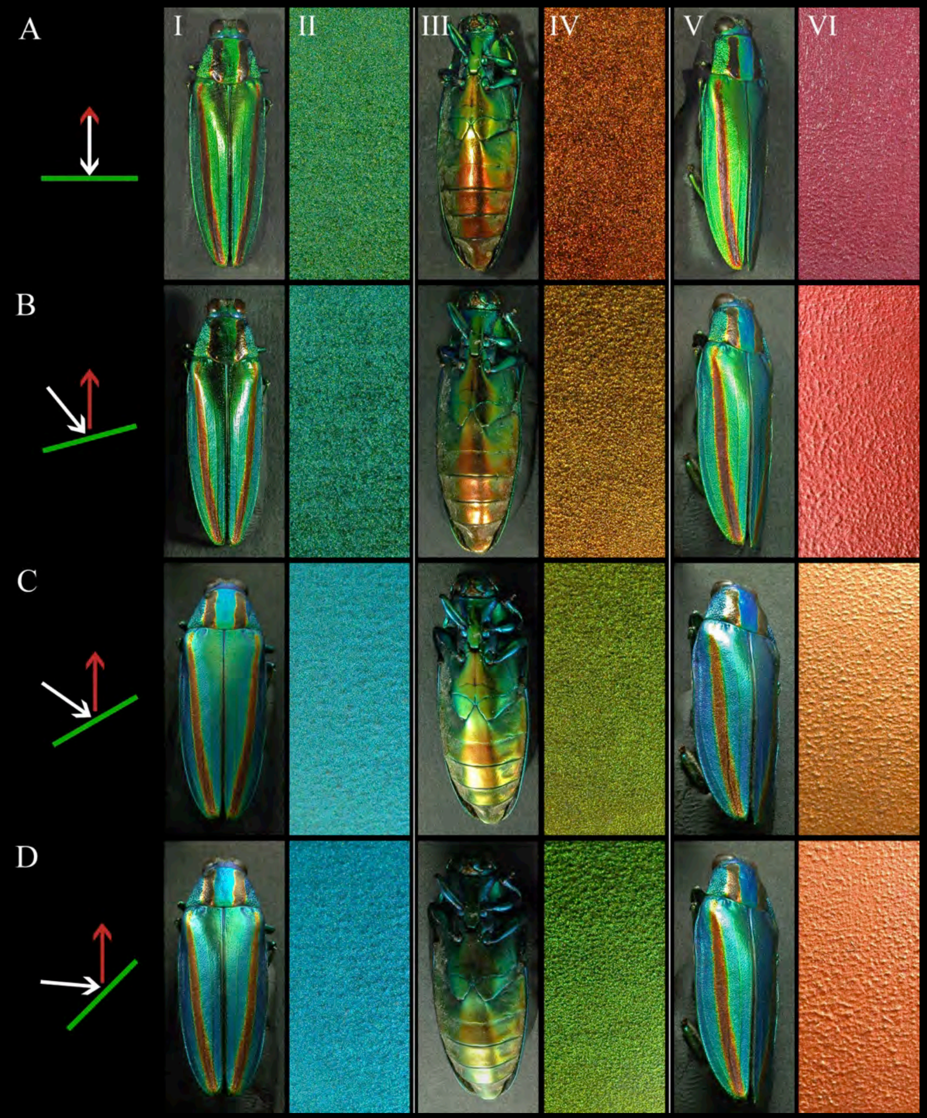
The Japanese jewel beetle: a painter's challenge

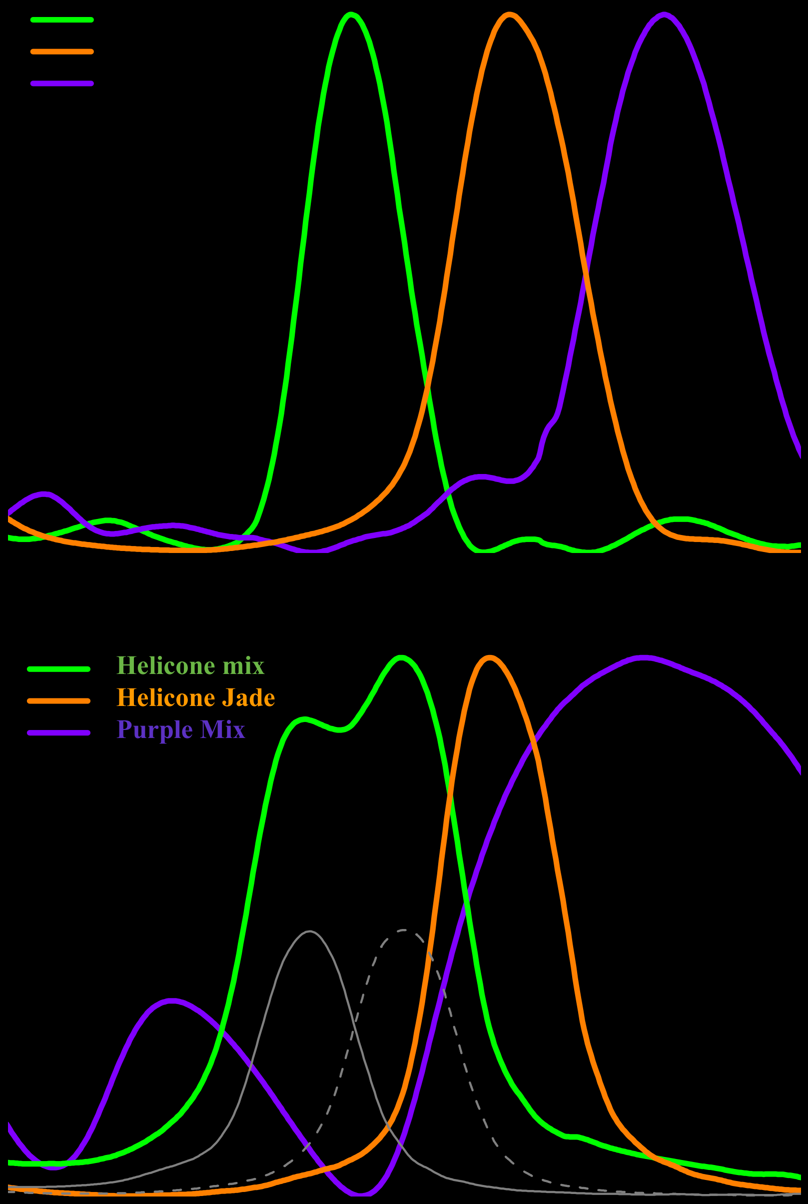
Published in: *Bioinspiration Biomimetics* and *Zetesis* (Nov 13)



Photographs and transmission electron microscopy (TEM) images of the cuticular surface of the Japanese Jewel Beetle, *Chrysochroa fulgidissima*. **A** Green part of the elytron. **B** Orange ventral area. **C** Purple stripe of the elytron; bar: 100 µm. **D-F** Transversal TEM sections of the cuticle of the three cases of **A-C**, showing the multi-layered structure; bar: 1 µm.



The three colour cases of the Jewel Beetle, the green part of the elytra (column I), the orange underside (column III) and the purple stripes of the elytra (column V), together with the mimicking effect paints (columns II, IV, VI) illuminated from various angles and observed from the mirror angle. From row **A** to row **D** the angle of light incidence increased in steps of about 10º. The animal and the colour samples were rotated around an axis perpendicular to the longitudinal (viewing) axis.



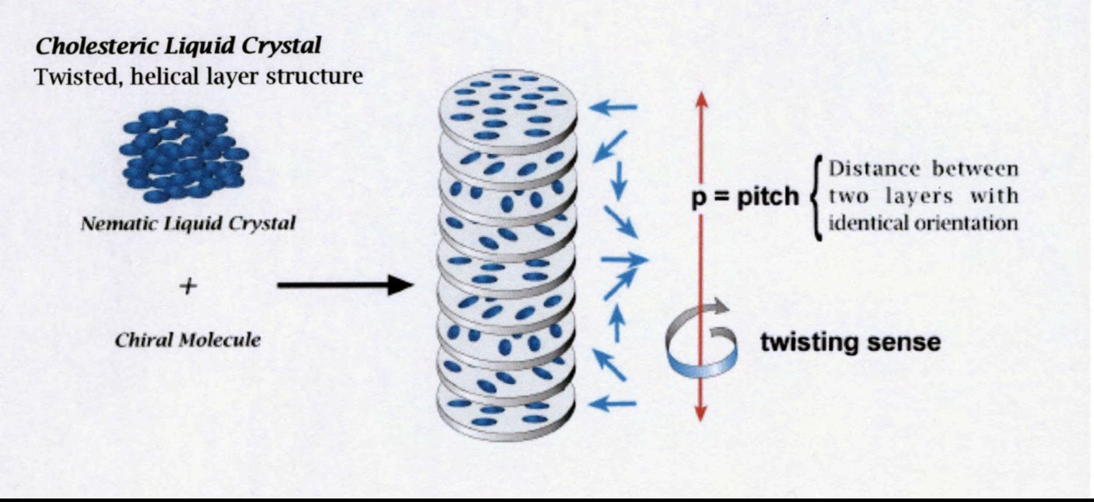
Normalized reflectance spectra with perpendicular illumination of the Japanese Jewel Beetle and effect paint. **A** The reflectance spectra of the green part of the elytra, the orange underside and the purple stripes of the elytra of the jewel beetle. **B** The spectra of the effect paints used in mimicking the beetle colours. The grey curves represent the reflectance spectra of the two components that together make up the green Helicone® mix spectrum.

Classic multilayer "pigments"

Table S1. Composition and architecture of investigated effect pigments for mimicking the purple stripe of the Jewel Beetle.

	product line	type	layer arrangement
a) Non-quarter wave multilayer pigments			
BASF	Variocrom™	Magic Purple	Fe_2O_3 / SiO_2 / Fe_2O_3 / SiO_2 / Fe_2O_3
Merck	Colorstream®	Royal Damask	TiO_2 / SiO_2 / TiO_2
BASF	Firemist®	Colormotion Ruby	TiO_2 / SiO_2 / TiO_2 / glass flake / TiO_2 / SiO_2 / TiO_2
b) Quarter-wave multilayer pigments			
Merck	Iriodin®	Lava Red	Fe_2O_3 / synthetic mica / Fe_2O_3
Merck	Miraval®	Lilac	TiO_2 / SiO_2 / glass flake / SiO_2 / TiO_2
BASF	Firemist®	Red	TiO_2 / glass flake / TiO_2

Special effect pigments with a twist: Colesteric "pigments"



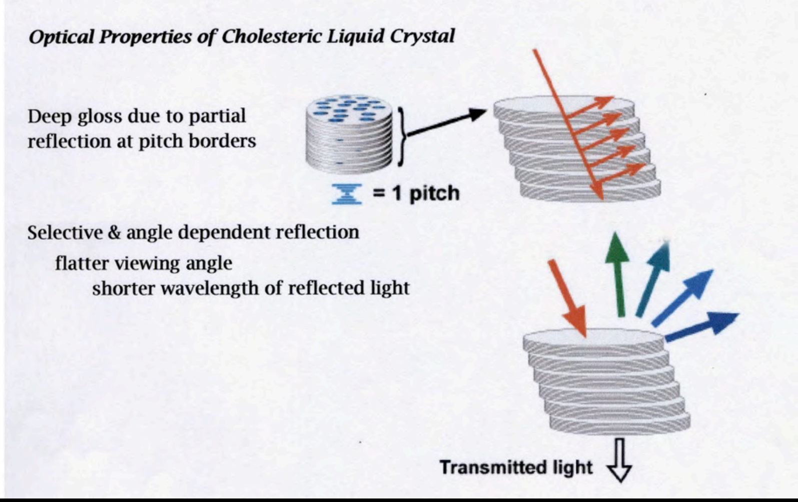


Figure 5. Optical principles of cholesteric liquid crystal pigments. Courtesy of Kobo Products, Inc. (2008)

To obtain maximum reflectivity, at least six helices or a **thickness of approx. 4 µm** is required (Makow 1985). However, as with other effect pigments, the overall particle diameter is also important. The larger the circumference, the brighter the effect; here pigments with particles having an average diameter of 35 microns have been used.

LCP-liquid crystal pigments

- Transparent, colourless layered platelet
- All layers are composed of the same material…
- … namely a highly cross-linked, liquid crystalline organic polymer with a helical superstructure
- Cigar-shaped liquid crystal molecules are fixed into layers of parallel rows
- Each layer has a slightly different molecular orientation. One turn of the helix represents a rotation of 360°
- The distance between two layers with the same molecular orientation defines the “pitch” - which determines the colour.

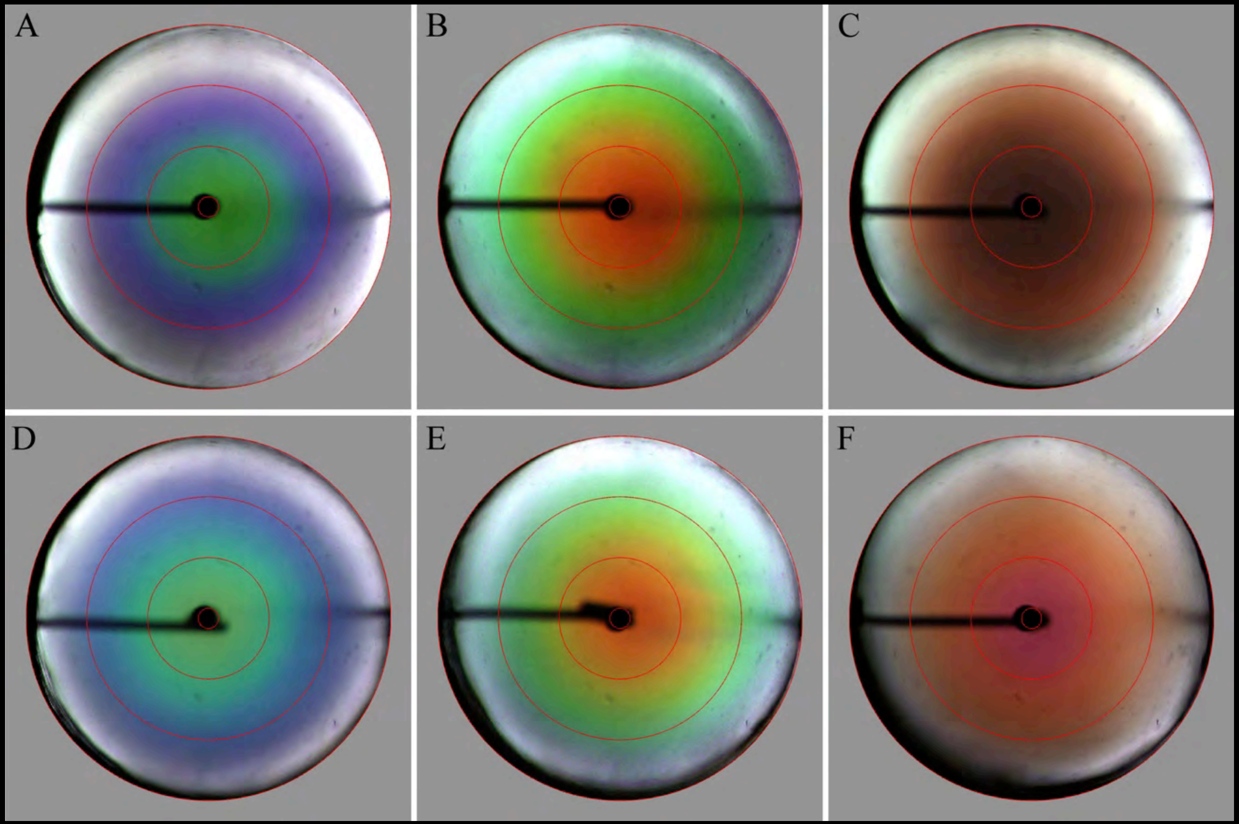
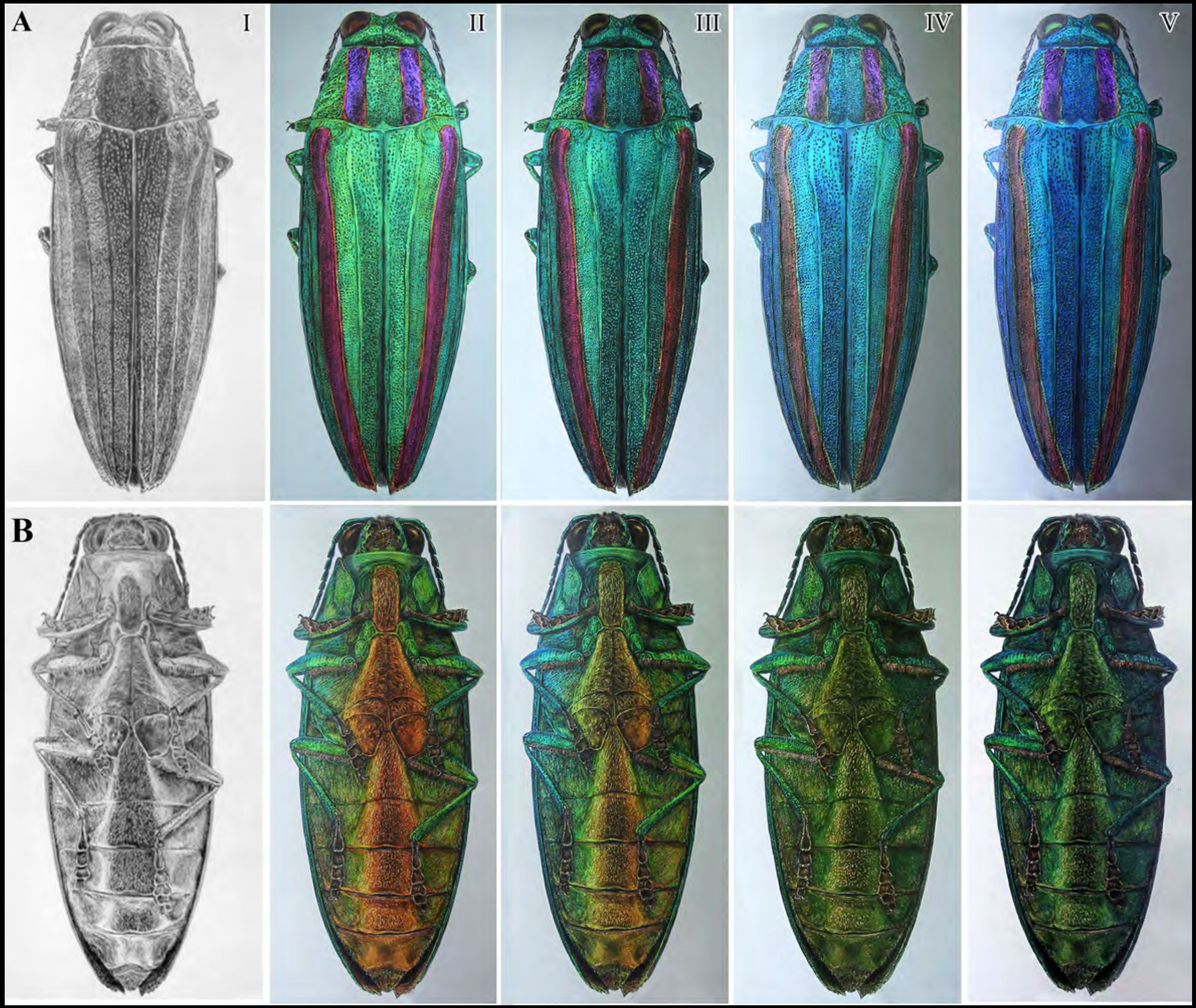


Figure 4. Scatterograms of the Japanese Jewel Beetle and effect paints. **A** Scatterograms of the green part of the elytra. **B** The orange underside. **C** The purple stripes of the elytra. **D-F** Scatterograms of the effect paints mimicking the three beetle cases. The red circles indicate angular reflection directions of 5º, 30º, 60º, and 90º. The black bars at 9 o'clock are due to a glass pipette holding a piece of cuticle (**A-C**) or a piece of effect paint (**D-F**). The central black circle is due to a small central hole in the scatterometer's ellipsoidal mirror (for details of the method of imaging scatterometry, see Stavenga *et al.* 2009, 2011).


A
I
II
III
IV
V
B

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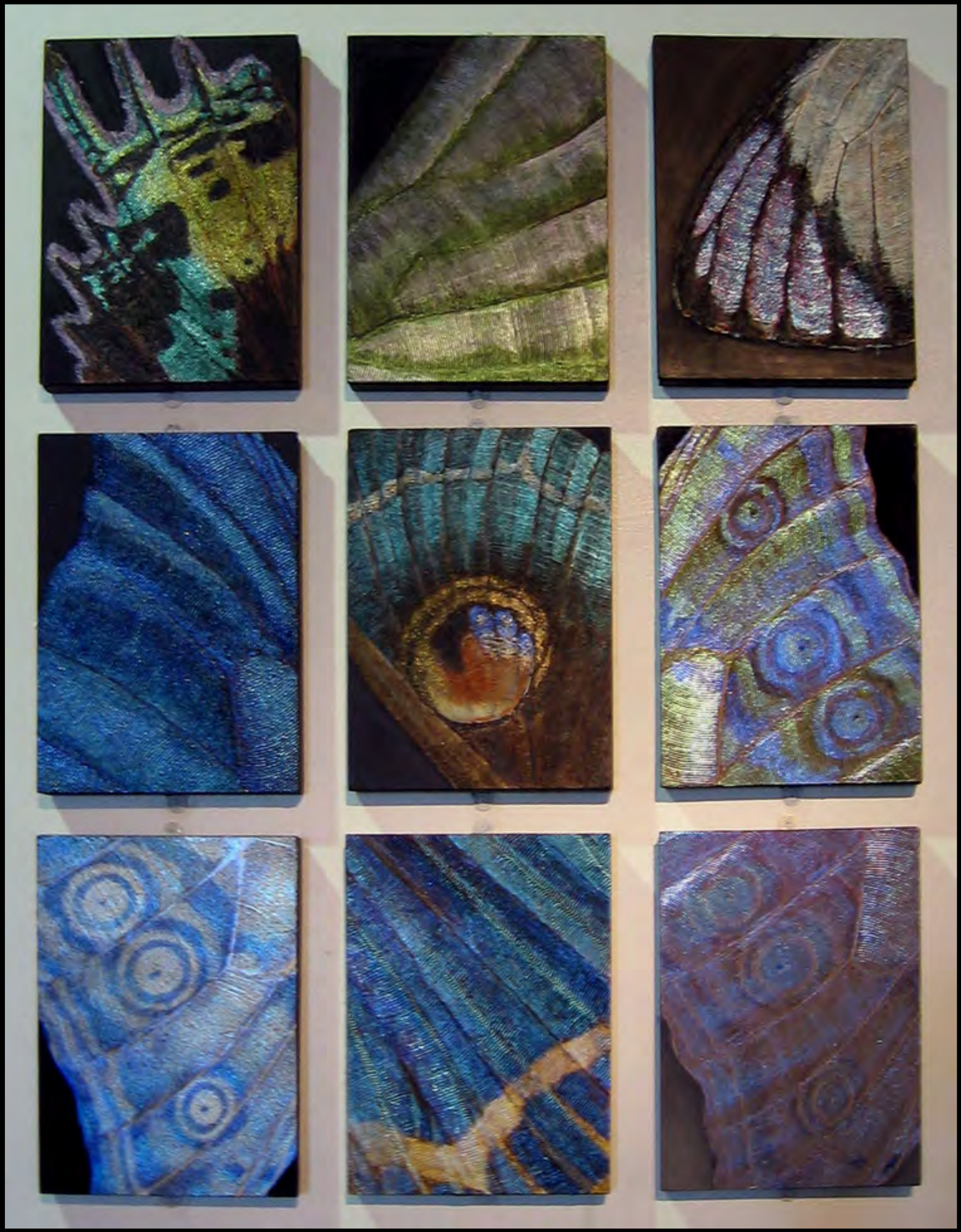
In the Eye of the Beholder: The Art of Evolution

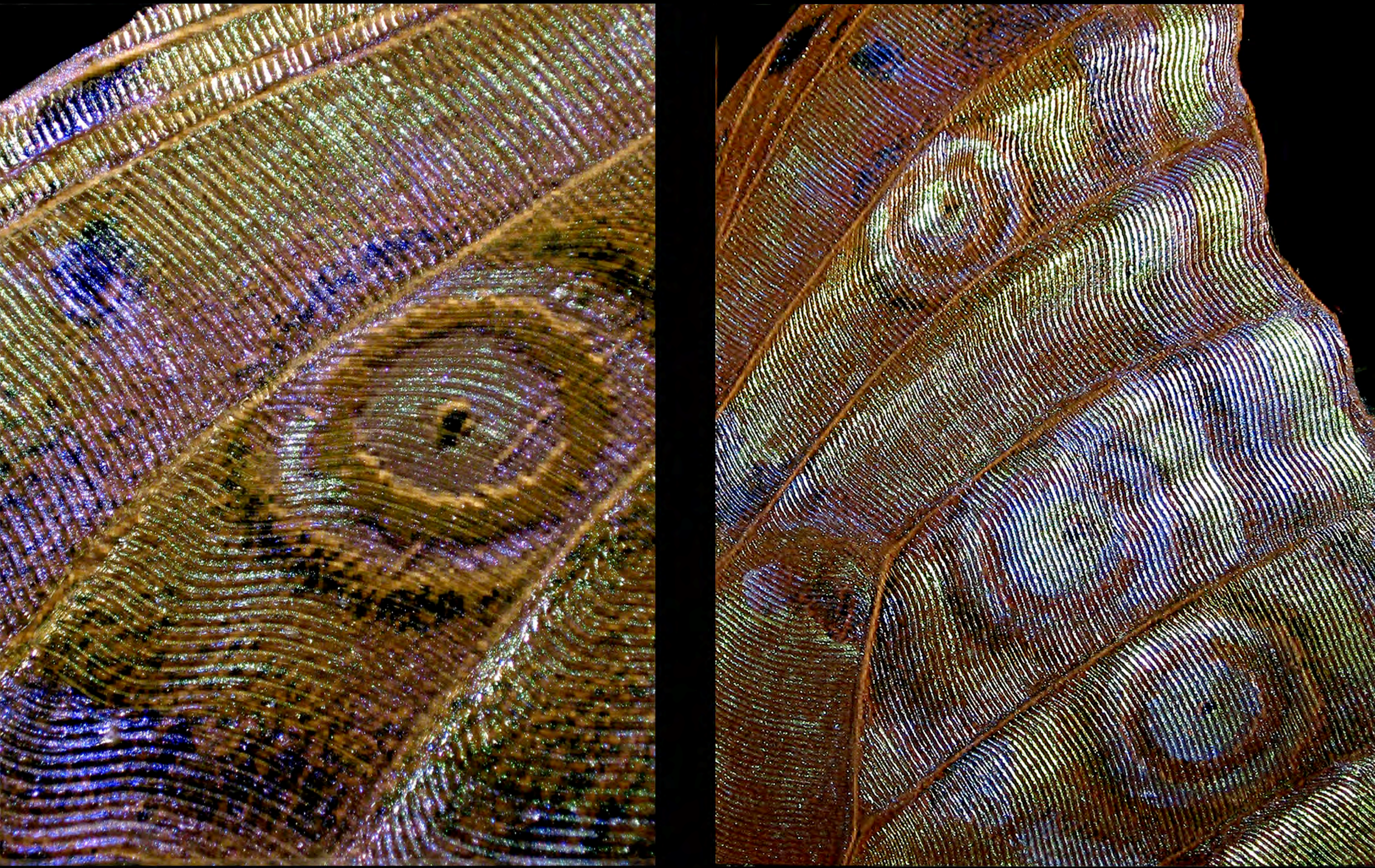
How to mimic processes underlying the evolution of color patterns?



F. Schenk, Butterfly segments, each A4, 2008/9

Eyespot Painting I, iridescent ‘paint’ on board, A4, 2008

The same painting lit from a different angle



Eyespot Painting II, iridescent ‘paint’ on board, A4, 2008, detail and full piece

Darwin, The Descent of Man, 2nd ed, 1896, pp 427

matter being drawn towards a central point from a surrounding zone, which latter is thus rendered lighter; and, on the other hand, that a white spot is often formed by the colour being driven away from a central point, so that it accumulates in a surrounding darker zone. In either case an ocellus is the result. The colouring matter seems to be a nearly constant quantity, but is redistributed, either centripetally or centrifugally. The feathers

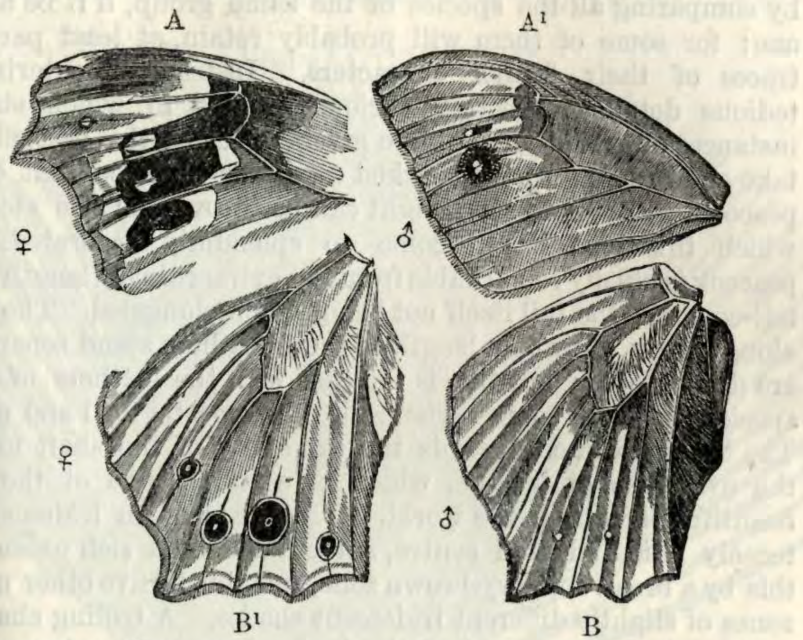


Fig. 53. Cyllo leda, Linn., from a drawing by Mr. Trimen, shewing the extreme range of variation in the ocelli.

A. Specimen, from Mauritius, upper surface of fore-wing
A¹. Specimen, from Natal, ditto.
B. Specimen, from Java, upper surface of hind-wing.
B¹. Specimen, from Mauritius, ditto.

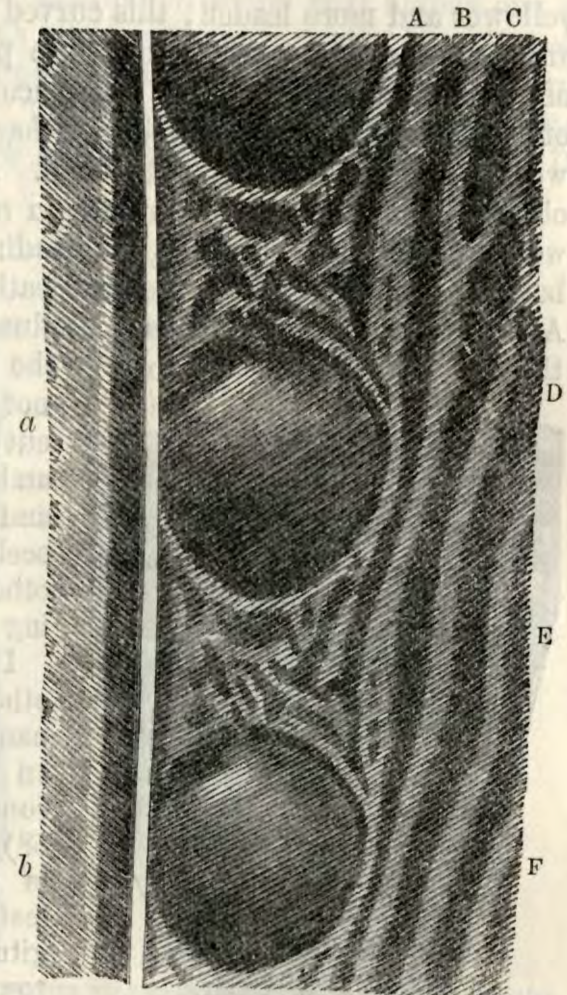
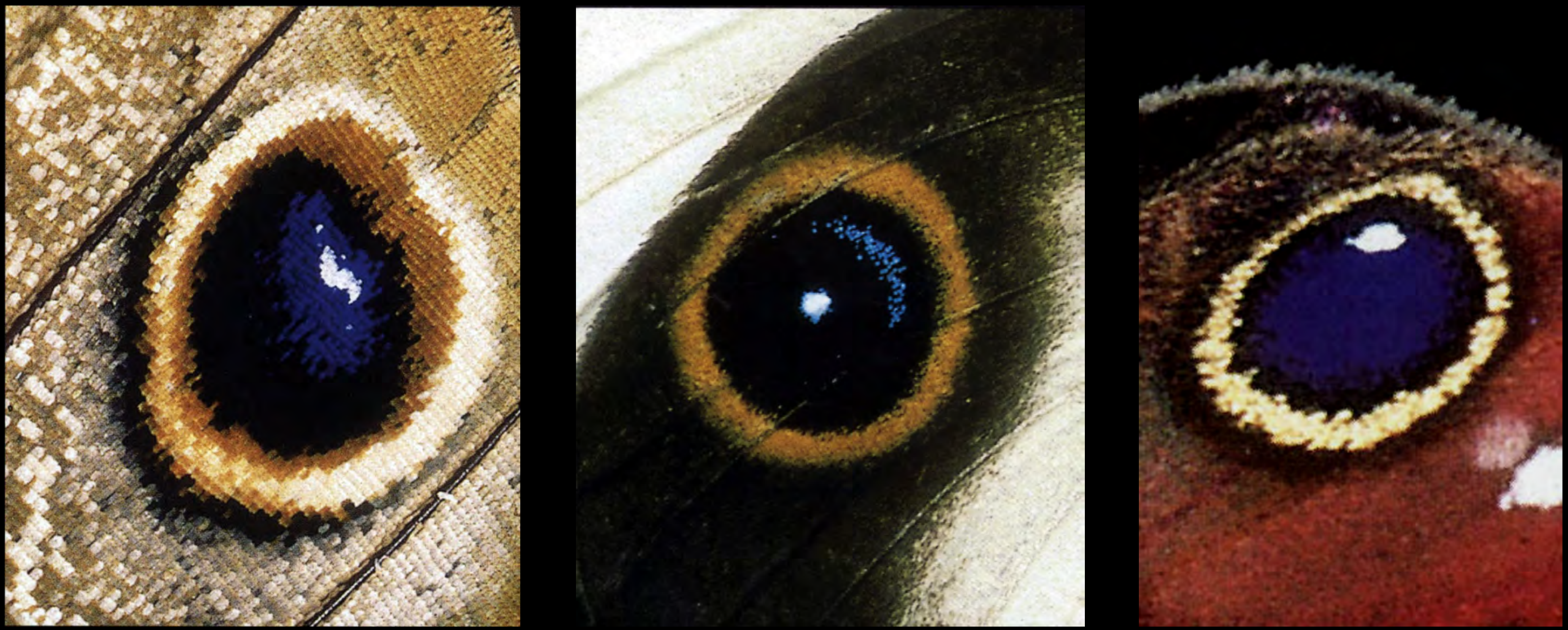


Fig. 57. Part of secondary wing-feather of Argus pheasant, shewing two perfect ocelli, *a* and *b*. A, B, C, D, &c., are dark stripes running obliquely down, each to an ocellus.

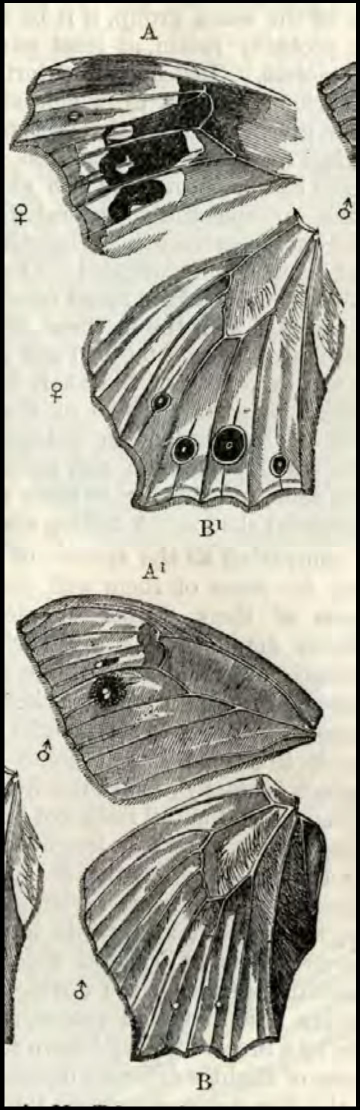
[Much of the web on both sides, especially to the left of the shaft, has been cut off.]

How did the butterfly acquire iridescent patches in its eyespots?

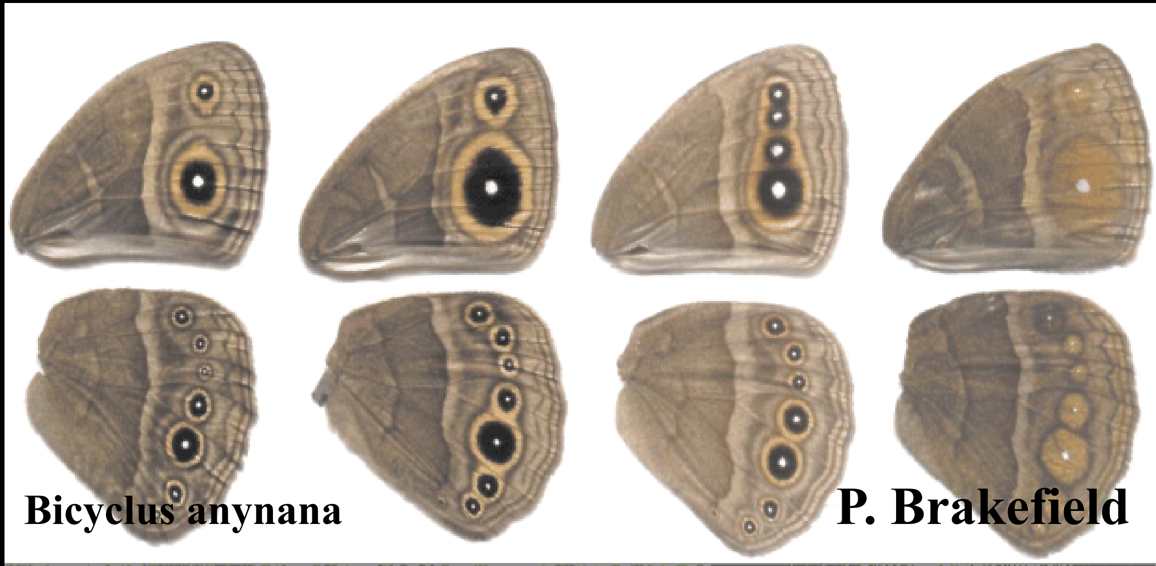


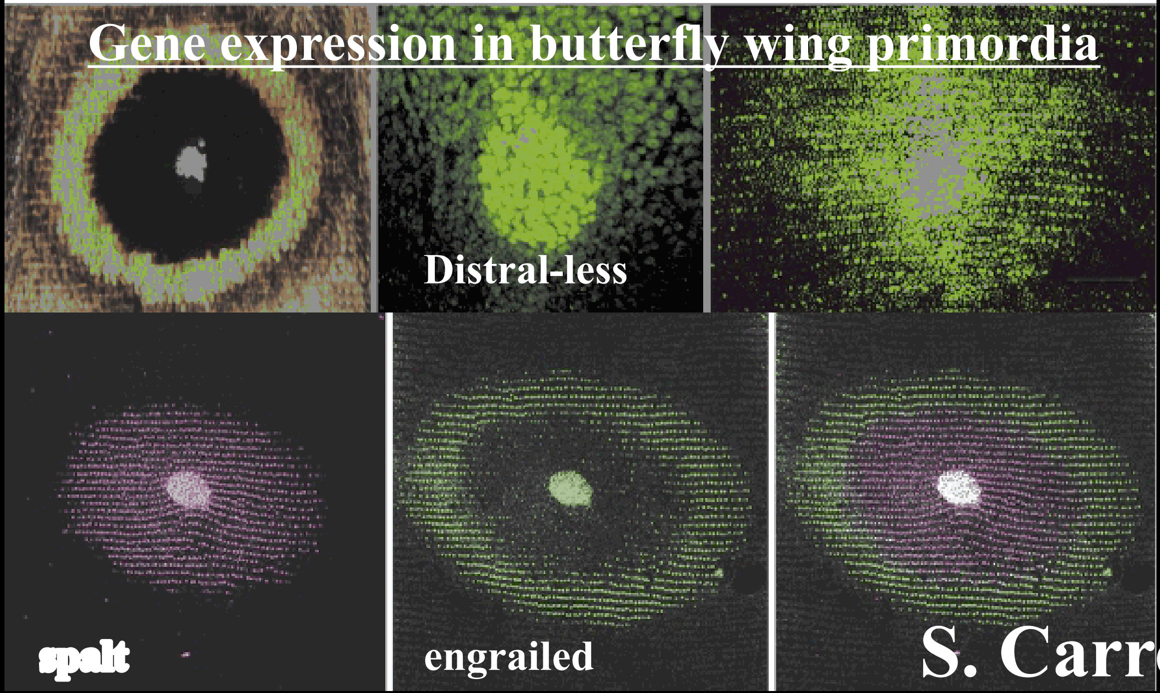
T. Marent, Butterfly: a photographic portrait, 2008

How the Butterfly got its Spots

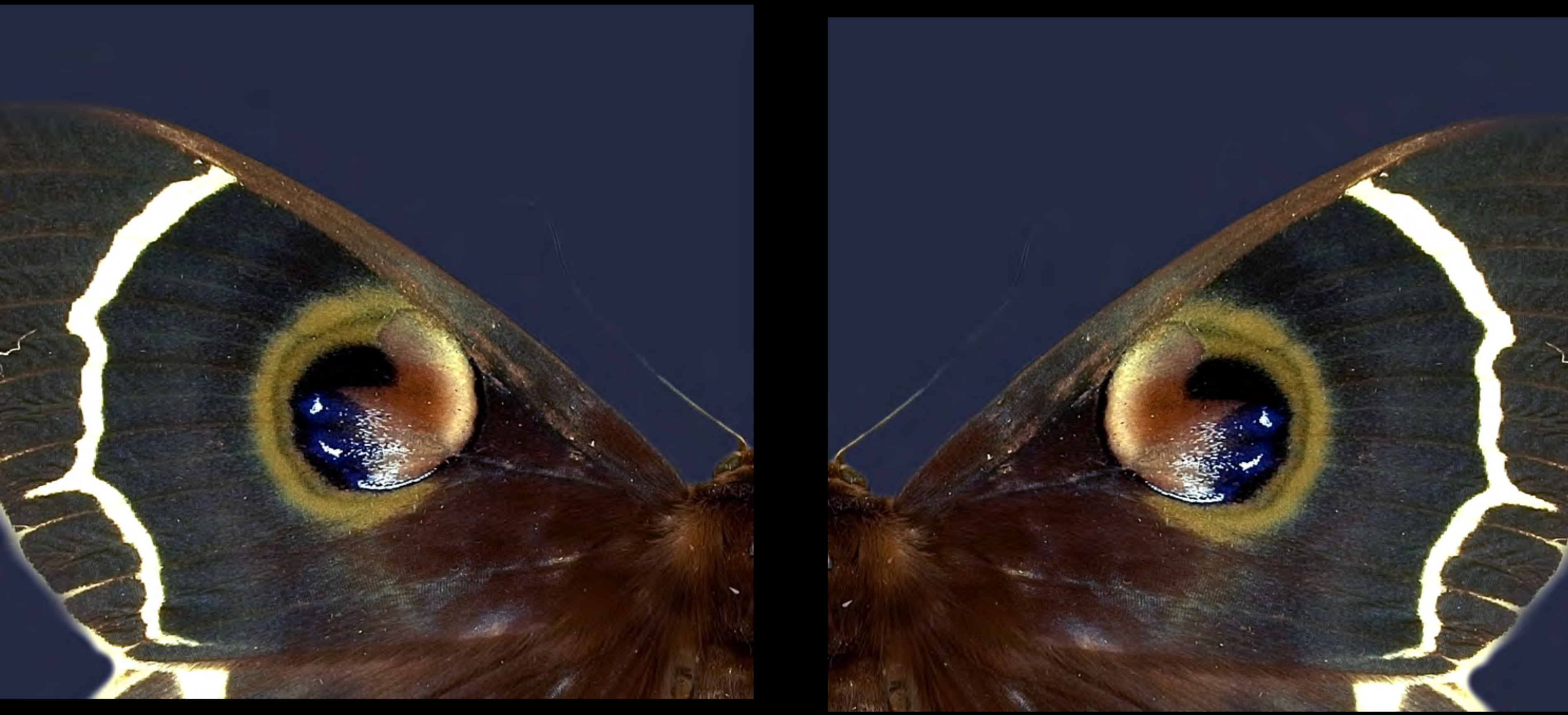


Darwin





S. Carroll



Erebus obscura, photographed by Dr. Norman Day

Replication of ‘original’ painting - creating a mold

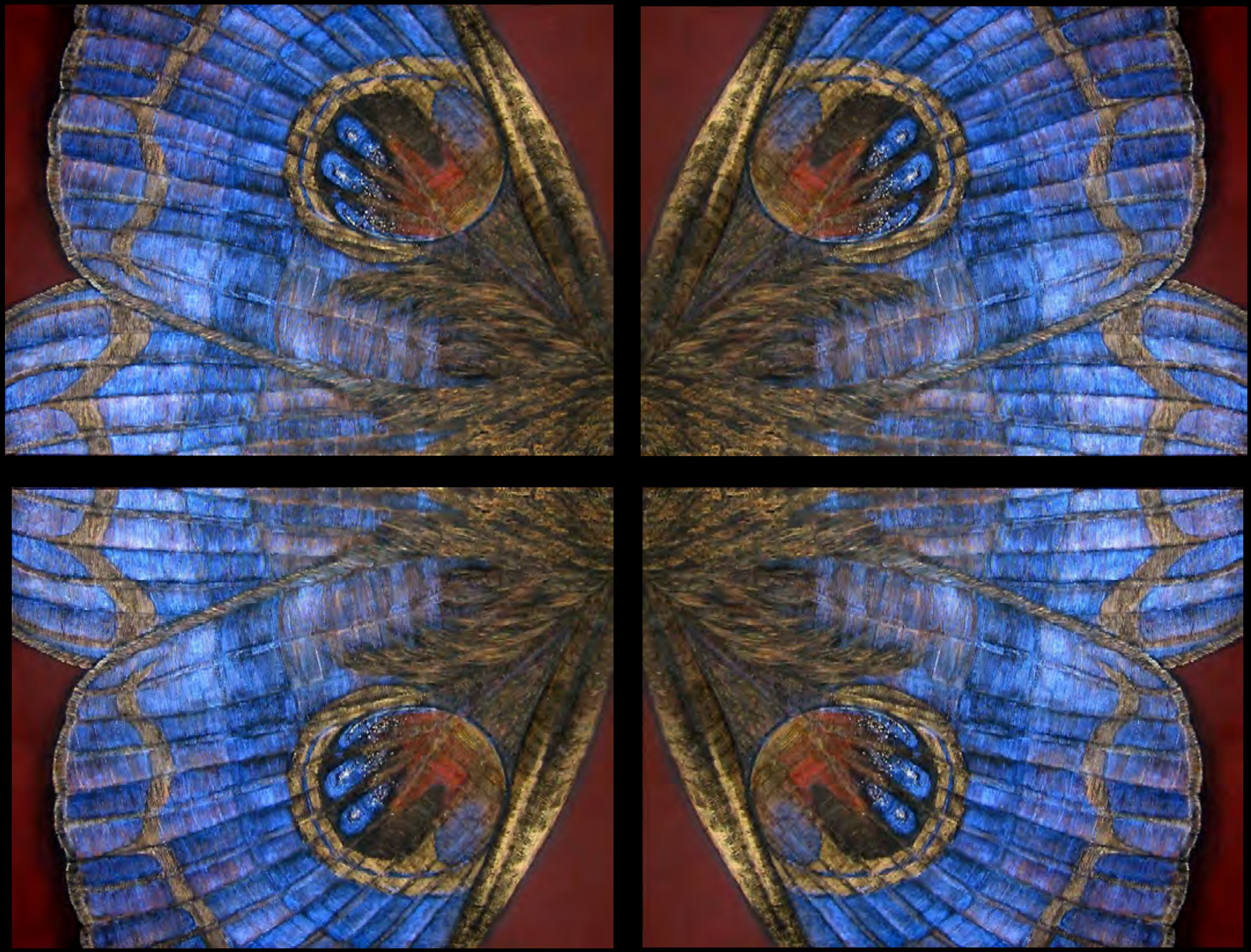


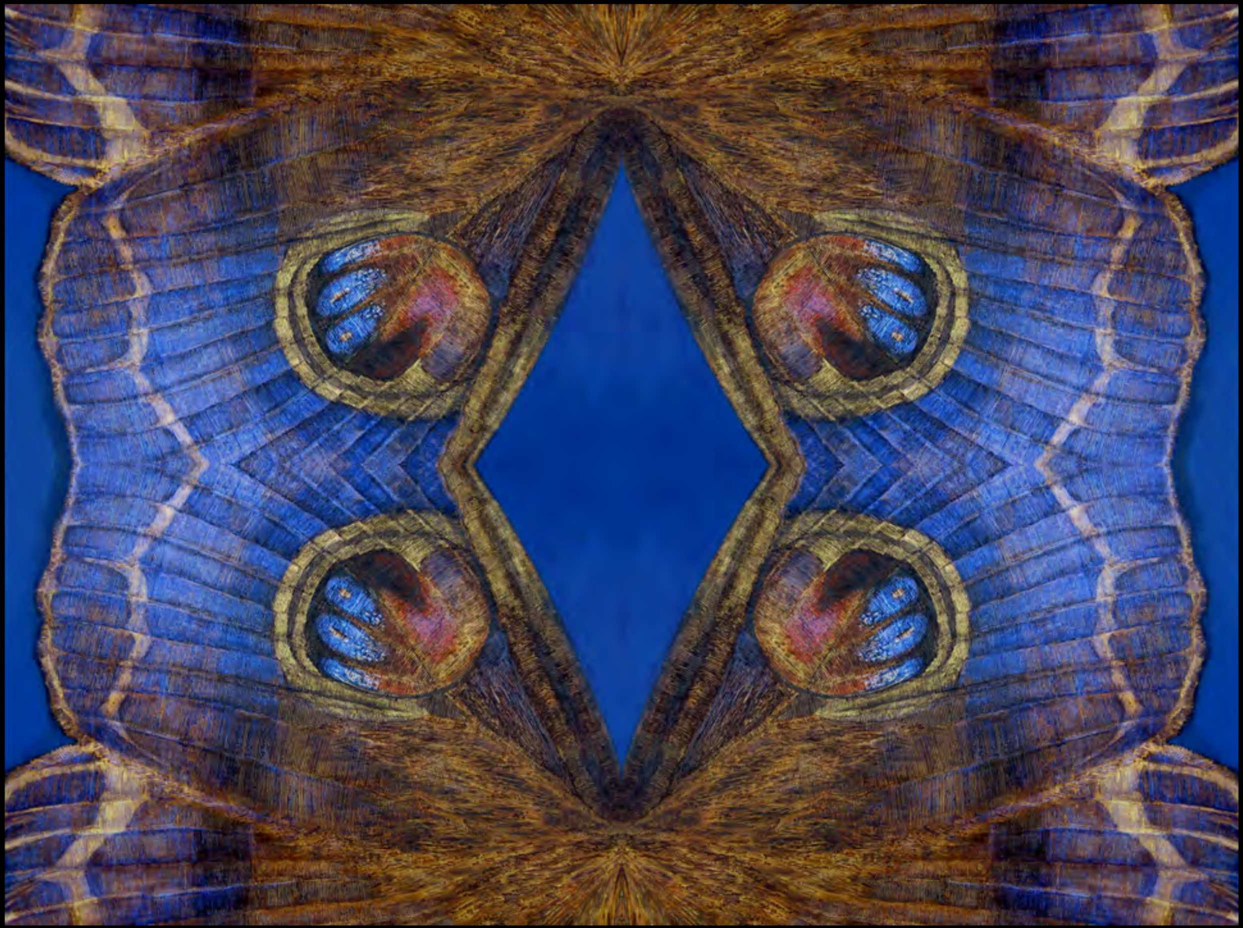
Creating castings of the painting's textured surface

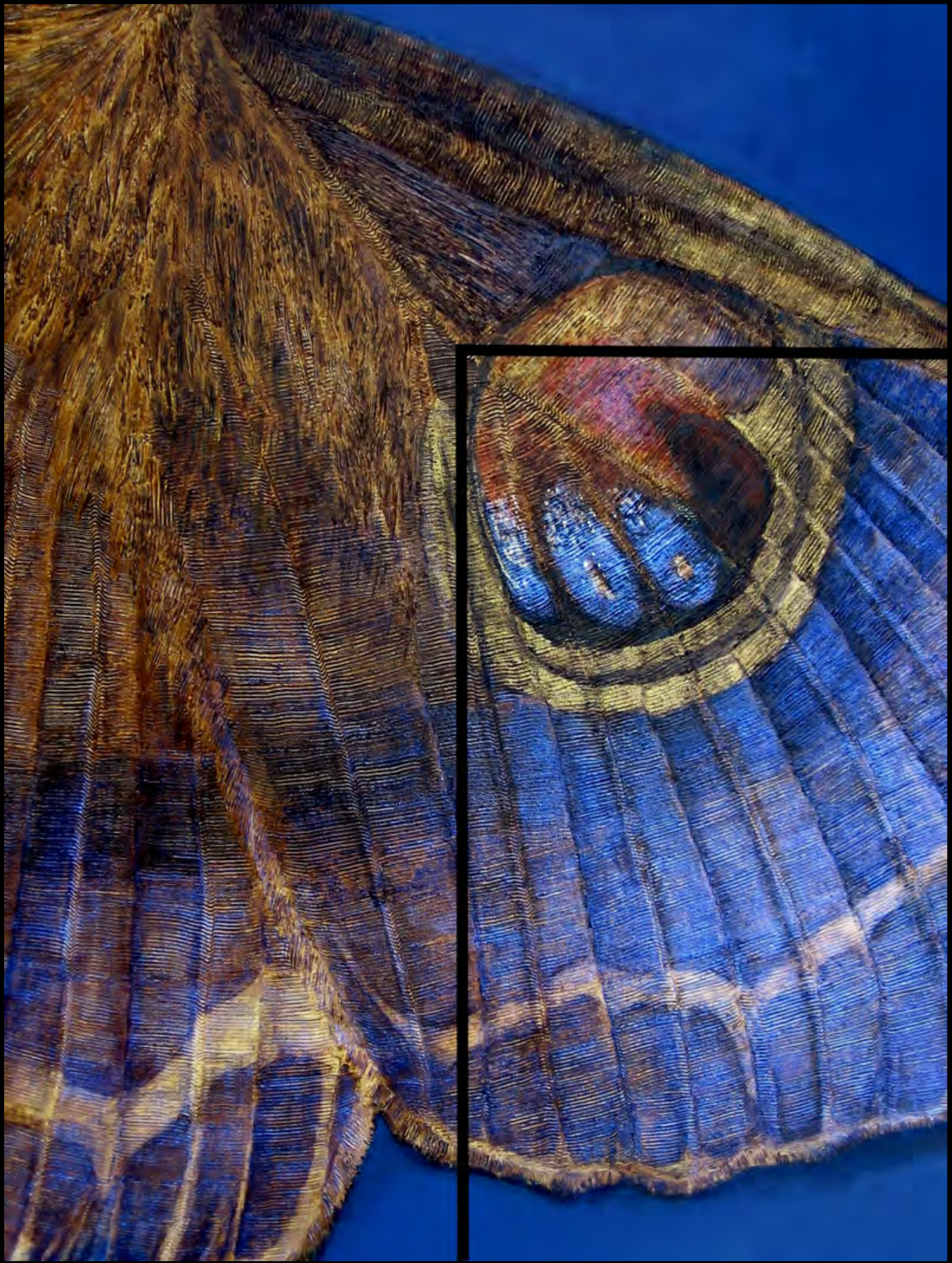

F. Schenk, *Erebus obscura*, mixed media on board, 160 x 190, 2009

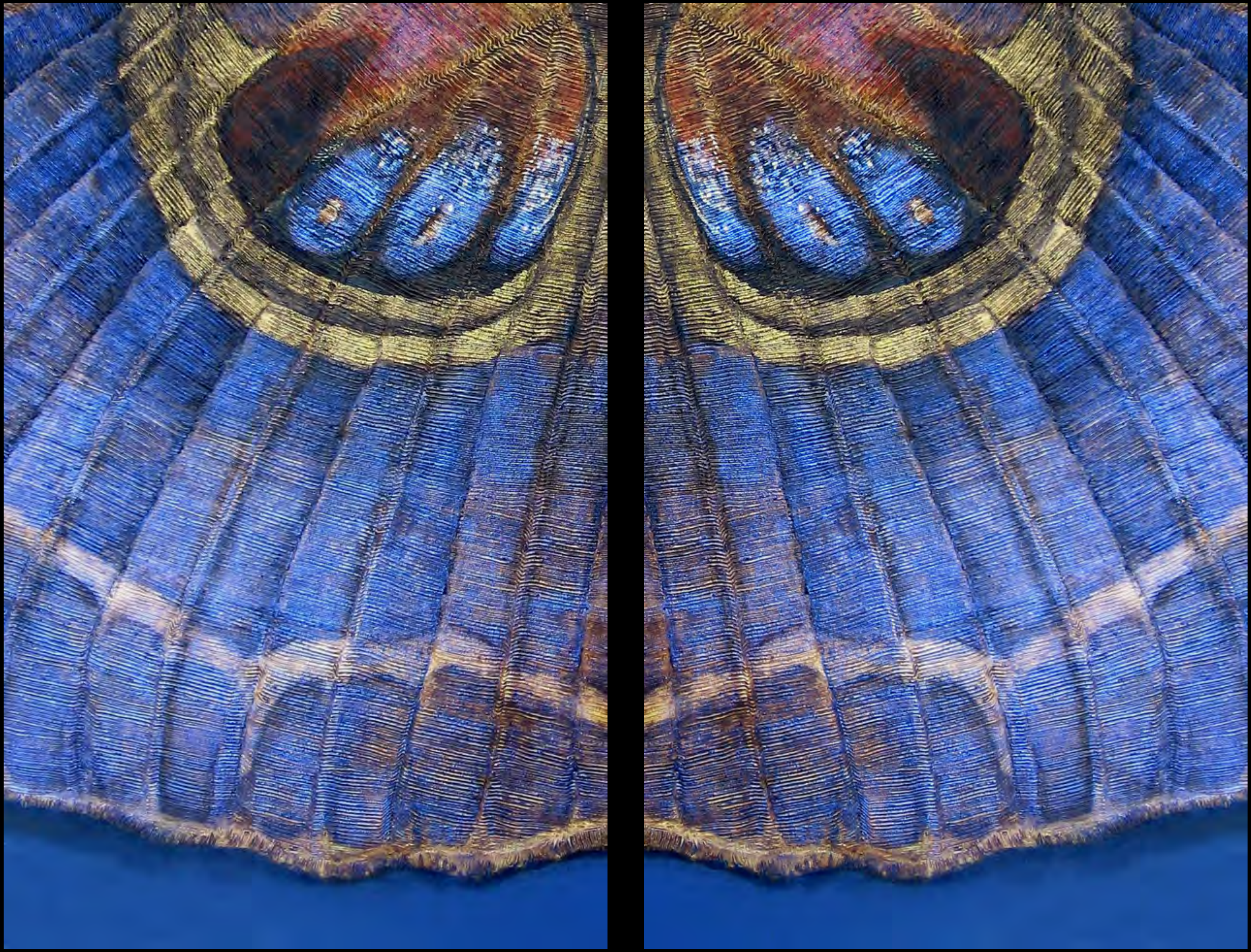
F.Schenk, Erebus obscura, iridescent medium on boards, 3’ x 4’, 2009

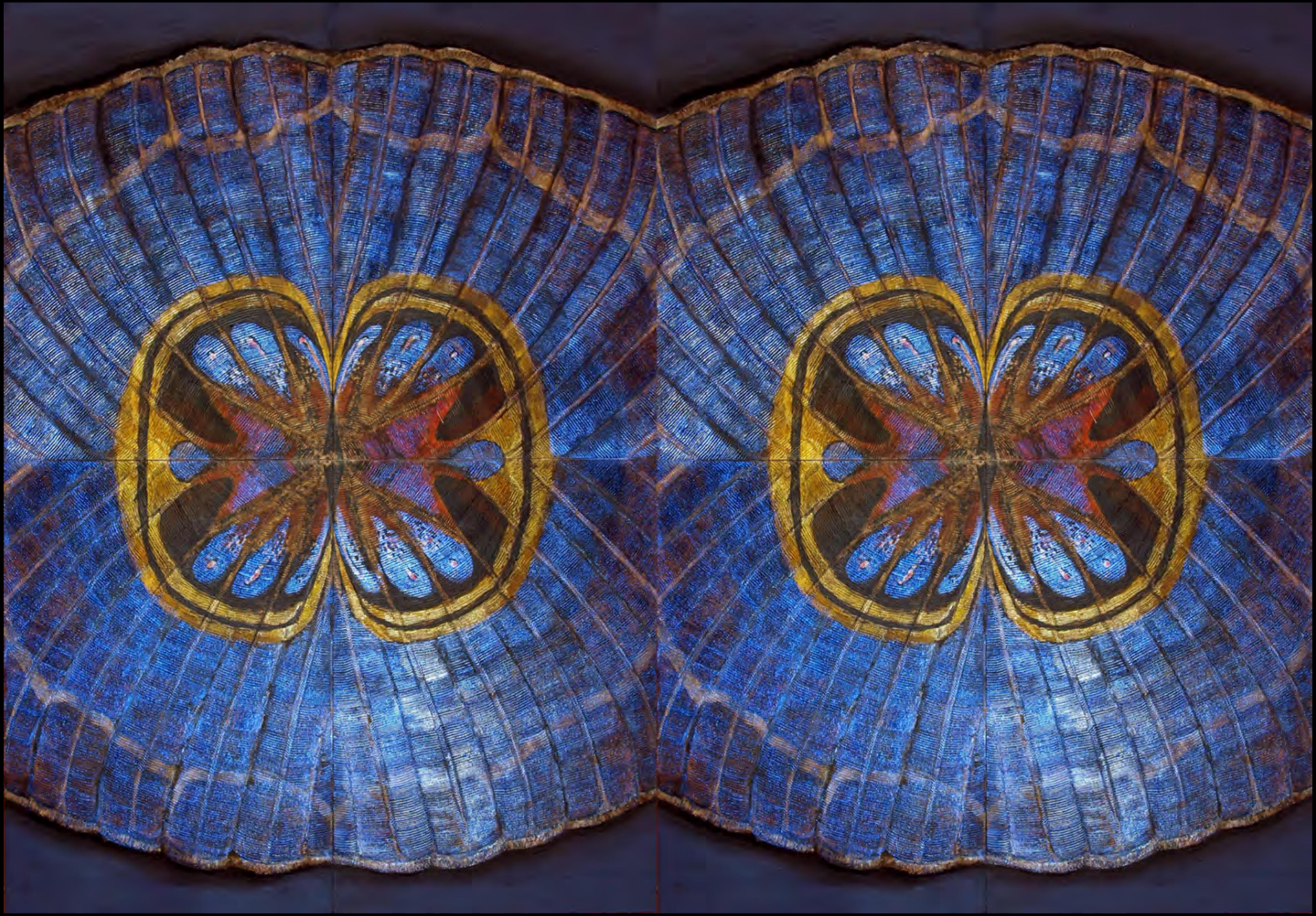
A new species - with 4 eyespots











Biomimetics, Color and the Arts
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