MICROSCOPY TODAY

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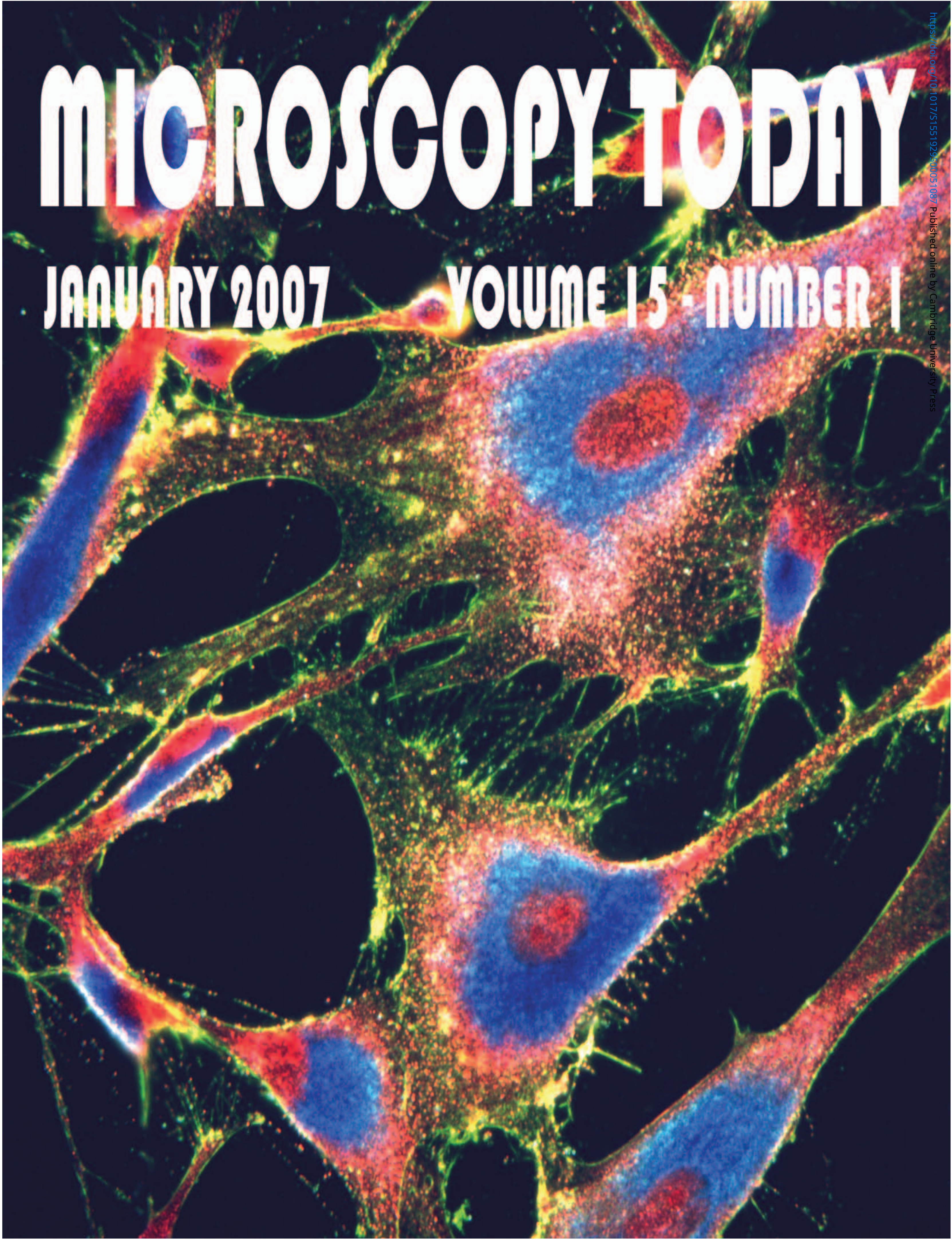

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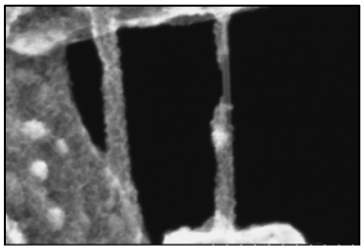
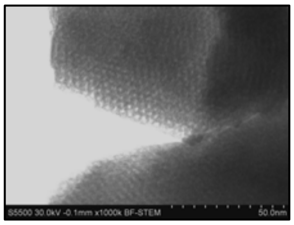
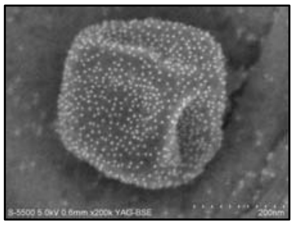


X1000k, 30.0kV Single Walled Nanotube



X1000k, 30.0kV Mesoporous Silica



X200k, 5.0kV Immuno Labeling

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Why Penguin Beaks are Sexy!

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It is well known that birds frequently attract mates by a ritual display of feathers or other ornaments. The colors for these displays are either derived from pigments, such as carotenoids, or photonic crystalline arrangements near the surface of the skin, feathers, or other ornaments. Add to this the fact that many birds can perceive light in the near-ultraviolet end of the visible spectrum and the range for these visual displays is extended. In a spectrophotometric and microscopic study by Birgitta Dresp and Keith Langley,[2] it was demonstrated that a unique arrangement of crystal-like structures near the surface of the beak horn of the King penguin (Aptenodytes patagonicus) most likely accounts for a photonic effect that probably plays a role in their mating rituals.

The beak of a King penguin is black, with an oval plate, called the beak horn, on its side. The beak horn is an oval structure about 8 cm long and 1.5 cm wide and 0.35 mm thick. It is molted annually, and these molted beak horns were collected on Possession Island (46° South, about 1,000 km from the coast of Antarctica and 2,350 km south of Madagascar). To the human eye they are yellow-orange in color and this is almost certainly due to carotenoids in the deeper layers. They also appear to have a pinkish-violet tint. In reflectance spectra, a peak was found around 370 nm, in the near-ultraviolet range. When the top layers were gradually scraped off, this reflectance peak was maintained until a certain depth had been scraped away. These and other experiments suggested that the region nearest the surface, which must be at least 10 microns thick to be reflective, is probably responsible for this reflectance and that it is not reinforced by deeper structures. This would play a role in nature when a beak horn was partially damaged, it would still have the same appearance.

Histologic examination revealed an appearance vaguely resembling mammalian keratinized stratified squamous epithelium. Nuclei were absent from the uppermost layers. Mammalian keratins consist mainly of α-keratin whereas hard integument structures in birds (feathers, scales, etc.) are mostly composed of β-keratins, which form fine filaments with a twisted β-sheet structure. Dresp and Langley referred to an upper region, central region (with layers of cells), and a lower region (containing compact, clear, flat cellular profiles. It was when the upper region had been completely scraped away that the near-ultraviolet reflectance was lost. The central and lower regions are apparently the regenerative layers that maintain the structure for a year.

Examination by transmission electron microscopy revealed interconnected structures in the upper region. These consisted of layers (up to 40) of folded double membranes arranged in microstructures. Between these microstructures were filaments about 3.5 nm in diameter, which correlates with β-keratin filaments. These filaments apparently formed the scaffolding for the microstructures. The spacing between the folded membranes was around 130 nm. Bragg's Law ($n\lambda=2d\sin\theta$, where the relevant parameters are the diffracted wavelength λ, d is the distance between layers in the periodic array, and n is an integer) predicts the reflected wavelength to be about 378 nm, remarkably close to the experimentally measured value of 370 nm! This also elegantly illustrates the power of transmission electron microscopy to predict tissue properties.

Dresp and Langley concluded that coherent light scattering from the King penguin beak horn is caused by sunlight reflected from the microstructures they discovered. Whereas other studies have shown reflectance in the near-ultraviolet to be caused by photonic structures present in feathers and other structures, nothing like the microstructures seen in this study have been described previously. Also, this is the first time this has been characterized in beak tissue of any bird. It is certainly tempting to conclude that this unique structure in the beak horn of the King penguin plays a key role in the courtship behavior of this bird. ■

[1] The author gratefully acknowledges Drs. Keith Langley and Birgitta Dresp for reviewing this article.

[2] Dresp, B. and K. Langley, Fine structural dependence of ultraviolet reflections in the king penguin beak horn, *The Anatomical Record* Part A 288A:213-222, 2006.

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ABOUT THE COVER

This is an image of cultured fibroblasts that were subsequently stained with safranin and β X-gal containing ferrocyanide. The sample was imaged using a BX-51 and 40x objective. The microscope was equipped with a CytoViva™ illuminator and a CytoViva Dual Mode Fluorescence™ module, which allowed simultaneous observation of both the fluorescently labeled and unlabeled structures (www.CytoViva.com). The image was captured with a Dage XL digital camera. The samples were provided by Dr. Doug Martin of the Scott-Ritchey Research Center, College of Veterinary Medicine, Auburn University, AL.