Palaeontologists evaluate fossil color reconstruction methods to propose new study framework

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A pristine specimen of the feathered dinosaur *Anchiornis huxleyi* showing its color patterns. Melanin was first identified from an animal from this species. Credit: Xiaoli Wang

Dr. Michael Pittman of the Vertebrate Palaeontology Laboratory, Department of Earth Sciences, The University of Hong Kong led an international study with his Ph.D. student Mr Arindam Roy that evaluates fossil color reconstruction methods to propose a new study framework that improves and expands current practice. The paper was

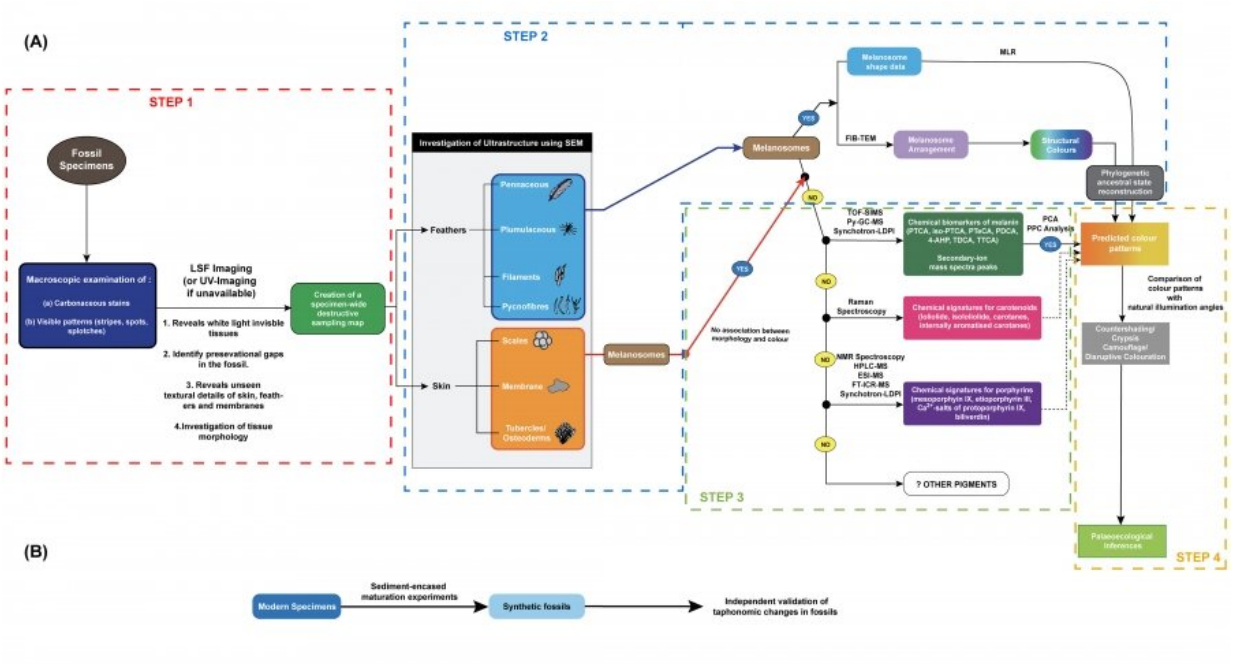
recently published in the journal *Biological Reviews*.

"People are fascinated by the color and pattern of dinosaurs and other extinct animals because these aspects can tell you so much about an animal. Just think of a zebra and a peacock. We evaluated everything we know about fossil and modern animal color and used that knowledge to propose a framework to improve how we reconstruct fossil color in the future." said Dr. Pittman.

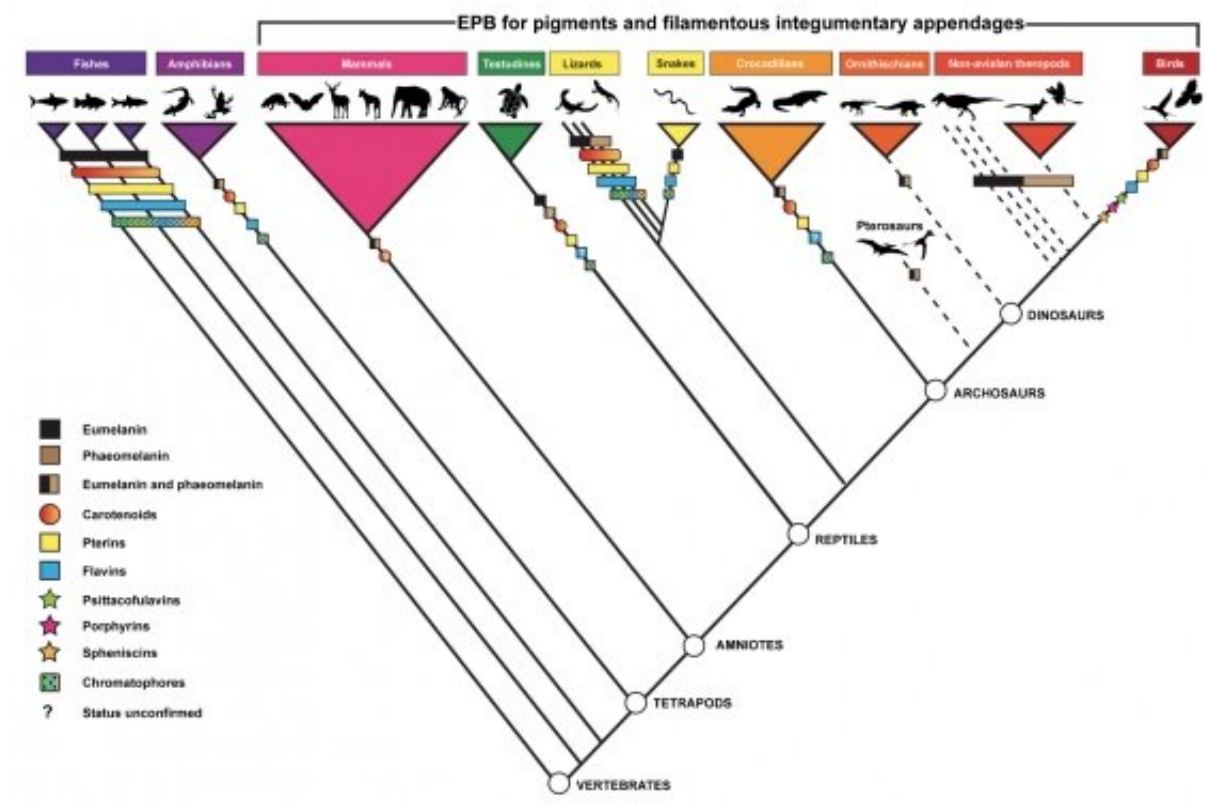
color and patterns are critical to understanding the life, ecology, physiology and behavior of animals. These colors are produced when light interacts with pigments and the structure of animal tissue. Common naturally-occurring animal pigments include melanin, carotenoids, porphyrins pterins, flavins and psittacofulvins which produce colors ranging from black and gray to yellow, orange and green.

Feathered dinosaur fossils instrumental to understanding the origin of birds were the first animal fossils to yield evidence of melanin, the color pigment we also have in our eyes and hair. In the last ten years, color patterns have been reconstructed in over 30 fossil animals including birds, non-avialan dinosaurs and mammals, providing a unique opportunity to test ecological and behavioral hypotheses that were previously out of reach. Unfortunately, our knowledge of other pigments is scarce in the fossil record as these non-melanin pigments are more difficult to fossilize. This incomplete knowledge and the lack of a standard study approach have been prevailing challenges to the reconstruction of color in fossil animals.

A life reconstruction of the feathered dinosaur *Anchiornis huxleyi* based on fossil evidence of its color and patterning. This evidence included inferences about melanin pigments. Credit: HKU MOOC / Julius T Csotonyi / Michael Pittman.



(A) New framework for reconstructing fossil colour in animals. Solid lines indicate confirmed steps; dashed lines indicate potentially useful steps that deserve further investigation. (B) Sediment-encased maturation is method of producing artificial fossils that helps to better understand how fossils are preserved. Abbreviations: ESI-MS, electrospray ionisation mass spectrometry; FIB-TEM, focused ion beam-transmission electron microscopy; FT-ICR-MS, Fourier-transform ion cyclotron resonance mass spectrometry; HPLC-MS, high performance liquid chromatography; LSF, Laser-Stimulated Fluorescence; MLR, multinomial logistic regression; NMR, nuclear magnetic resonance; PCA, principal components analysis; PPC, peak probability contrast; Py-GC-MS, pyrolysis-gas chromatography-mass spectroscopy; synchotron-LDPI, laser desorption-ionisation; TDCA, thiazole-4,5-dicarboxylic acid; TOF-SIMS, time of flight secondary-ion mass spectroscopy; UV, ultra-violet light.



Credit: The University of Hong Kong

Co-author Dr. Evan Saitta of the Field Museum of Natural History, Chicago, U.S. said, "We are in the golden age of multidisciplinary techniques in palaeontology. This is the first comprehensive study that not only critically evaluates the currently available methods, but also provides a reliable and repeatable framework that covers all vertebrate pigment systems not just melanin alone."

The new paleocolor reconstruction framework proposed by Dr. Michael Pittman, Mr Arindam Roy and their international team comprises four main steps: (1) Map the known or suspected extent of preserved color and patterns in the specimen; (2) Search for pigment-bearing microstructures using electron microscopy e.g. microstructure shape can

be used to identify melanin-based colors like black, gray and brown); (3) If melanin-based colors are not detected, use high-end chemical analysis techniques to detect biomarkers of other pigments (4) Use reconstructed colors and patterns to test fundamental hypotheses related to animal physiology, ecology and behavior. The new framework overcomes past challenges by incorporating the chemical signatures of different pigments, large and small-scale anatomical details visible in fossils as well as the potential for different pigments to fossilize. This framework provides background context for the evolution of color-producing mechanisms and is expected to encourage future efforts to reconstruct color in more fossil animals including non-dinosaur reptiles and mammals.

Mr Roy, the study's first author and a Hong Kong Ph.D. Fellow said, "I am really excited by the course we have charted in this review study as I will be tackling many of the key issues we identified during my Ph.D. studies at HKU."

More information: Arindam Roy et al, Recent advances in amniote palaeocolour reconstruction and a framework for future research, *Biological Reviews* (2019). DOI: 10.1111/brv.12552

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