The colour of ancient life

Fossils provide evidence of ancient life, including the colour of insects, reptiles, birds and mammals as old as hundreds of millions of years. Researchers in the ANICOLEVO project are applying high-tech methods to analyse fossils and gain new insights into how colour has evolved over deep time, as Dr Maria McNamara explains.

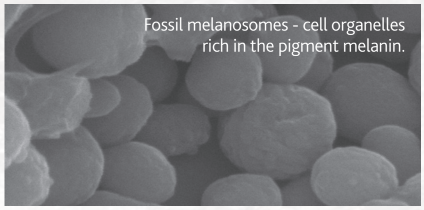
Many of us think of palaeontology as a descriptive discipline, in which researchers collect and describe fossils to build a deeper picture of ancient life. This is not the only way to study palaeontology however, and as the Principal Investigator of the ANICOLEVO project, Dr Maria McNamara is applying sophisticated techniques to study both the microstructure and chemistry of fossils. "We aim to find evidence of colour in animals, and to understand how colour has evolved over deep time," she outlines. This includes using synchrotron X-ray fluorescence and X-ray absorption spectroscopy to analyse metal distributions in fossils. A key focus of her group's work are fossils that preserve evidence of melanin, a pigment best known for its role in determining skin colour. "We can map metals across the surfaces of fossils, and understand how the metals are bound to the organic material, which is effectively polymerized and degraded melanin. This chemical information helps us understand which metals are more likely to have been present in life, in turn shedding light on the functions of melanin long ago," explains Dr McNamara.

Melanin

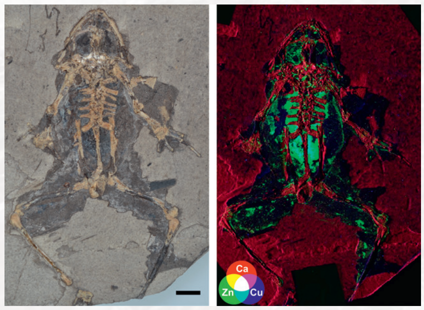
This research is grounded in a comprehensive analysis of extant animals. Part of the project involves characterising melanin in modern vertebrates to provide a solid basis for comparison. "Melanin is synthesised by melanosomes, tiny cell organelles that we all have in our hair and skin," says Dr McNamara. From a chemical point of view, there are two main types of melanin, eumelanin and phaeomelanin. "These two forms of melanin are produced in different ways and have different optical effects. They also have quite different effects on the body," continues Dr McNamara. "Phaeomelanin actually seems to be quite damaging. There's a debate about why vertebrates evolved phaeomelanin if it has negative effects. It's useful for visual signalling, especially camouflage, but there's clearly an evolutionary trade-off. There are lots of unanswered questions about when and why different types of melanin evolved."

The project team are analysing fossils dating back to the Carboniferous period from a variety of localities, including ancient lake environments and river systems, to address these types of questions. One major finding relates to the colours of ancient organisms. "Most fossils don't preserve the full complement of colour-producing cells in the skin. We have shown that minerals can form an accurate 3-D template of the original tissue, and in those cases you can preserve all colour-producing cells. That's when you can reconstruct fossil colour with confidence," says Dr McNamara. Another key finding relates to the distribution of melanin in the body. "Surprisingly, we showed that internal melanosomes are actually very widespread. We found them in every single internal tissue and organ, in modern amphibians, reptiles, birds and mammals, plus in their fossil ancestors. Obviously melanin doesn't just colour our integument, but also has some cryptic and pretty important physiological functions."

Dr McNamara and her colleagues have also used melanosomes to shed light on the affinities of enigmatic fossils. "For instance, there has been a lot of debate over the last few years about the classification of an ancient fossil called *Tullimonstrum*, which is about 300 million years old. It's been interpreted as being everything from a mollusc, to a vertebrate, to an arthropod," she outlines. "It contains layers of differently-shaped melanosomes in its eyes, which was thought to be a uniquely vertebrate characteristic. We found melanosomes, however, in the eyes of modern squid and their relatives. What's more, the chemistry of *Tullimonstrum's* eye melanosomes suggests a closer affinity to invertebrates after all."



Fossil melanosomes - cell organelles rich in the pigment melanin.



Mapping trace elements associated with fossil melanosomes to identify melanosomes in the skin and internal organs using synchrotron-X-ray fluorescence.

Fossil snake skin preserved with high ultrastructural fidelity in three dimensions, including details of preserved chromatophores (prominent globules in this image).

Modern analytical techniques can reveal chemical and microstructural information on pigments and other coloration mechanisms in fossils tens to hundreds of years old, helping us understand the evolution of colour and its functions through deep time.

ANICOLEVO

Animal coloration through deep time: evolutionary novelty, homology and taphonomy

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