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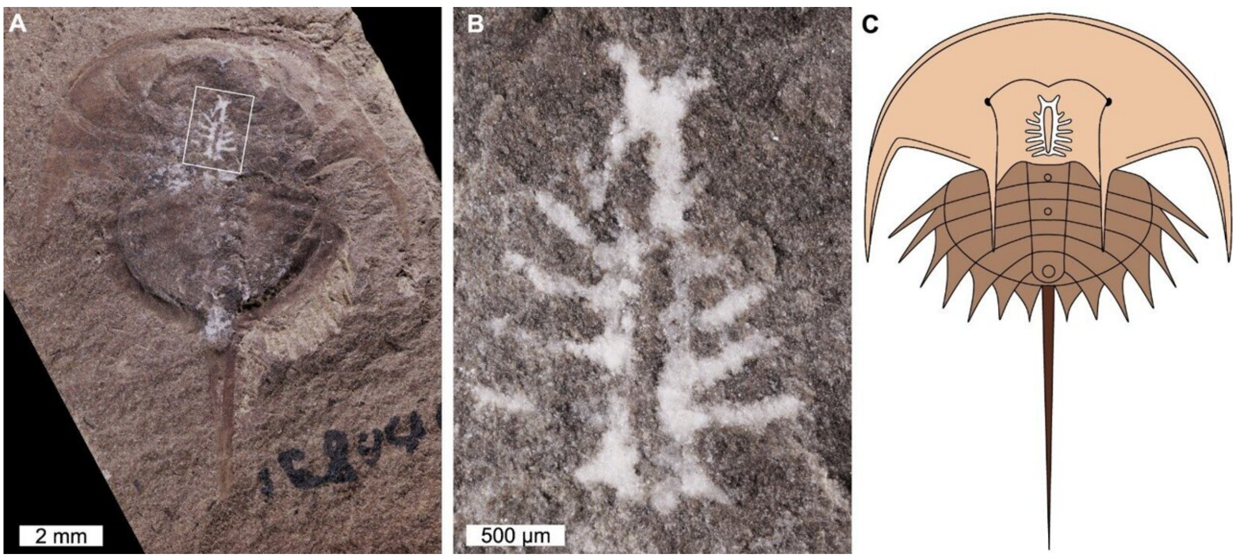
Decoding the secrets of a 310 million-year-old brain

July 27 2021



(A) Specimen of the fossil horseshoe crab Euproops danae from Mazon Creek, Illinois, USA, preserved with its brain intact. (B) Close-up of brain, as indicated by box in image (A). (C) Reconstruction of Euproops danae, including the position and anatomy of the brain. Credit: Russell Bicknell

Unlike bones and shells, which can endure for millions of years, soft tissues are rarely preserved as fossils.

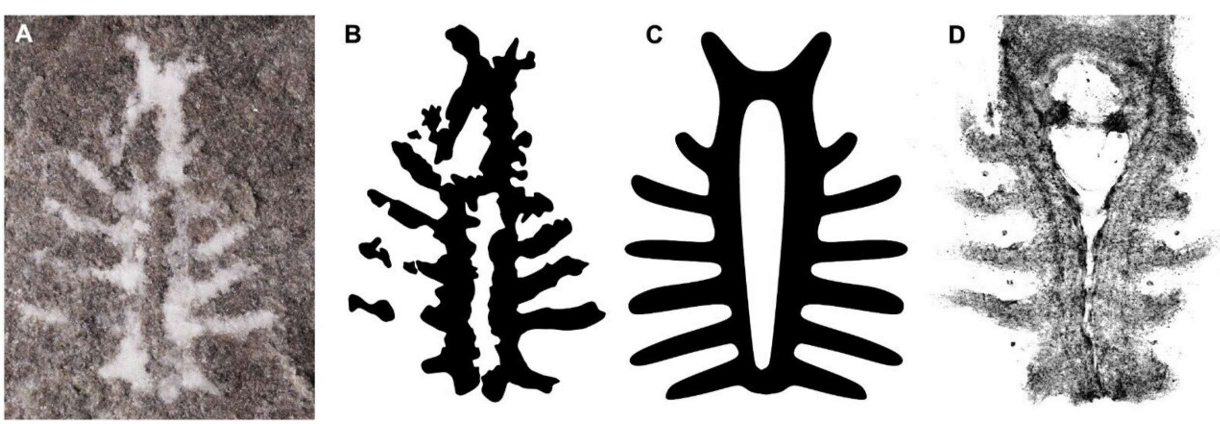
Indeed, the fossil record of animal soft tissues, such as brains and other internal organs, is so limited that there are significant gaps in our understanding of the evolution and fossilization processes of these important anatomical features.

A new study published today in the prestigious journal *Geology* has now closed some of these knowledge gaps. The study—by an international team of scientists, including UNE palaeontologists Dr. Russell Bicknell and Professor John Paterson—describes the delicate brain of an ancient aquatic arthropod and how it was preserved in such remarkable detail.

Lead author, Dr. Bicknell, explains what makes the discovery of a 310-million-year-old horseshoe crab with its brain intact so special.

"Most of our limited knowledge on prehistoric arthropod brains is derived from amber inclusions or Cambrian Burgess Shale-type fossil deposits."

"Amber, or fossilized tree resin, often contains a variety of trapped organisms such as insects, preserving the most intricate details. Using sophisticated imaging technology, scientists are able to study these entombed creatures, including their tiny brains.



(A) The fossil and (B and C) interpretive drawings of the Euproops danae brain, and (D) the brain of a modern juvenile horseshoe crab, Limulus polyphemus.

Credit: Russell Bicknell, (D) and Steffen Harzsch.

"However, we are somewhat limited when studying these particular fossils, as the oldest arthropods in amber only date back to the Triassic Period, around 230 million years ago."

Burgess Shale-type deposits from the Cambrian Period—typically around 500 to 520 million years in age—are much older than the amber and also preserve spectacular brain structures as carbon films in mudstone.

"These Burgess Shale-type fossils are very important as they represent some of the oldest animals on Earth, and can inform us on their origins and earliest evolutionary history," Dr. Bicknell said.

The team's new fossil effectively demonstrates that arthropod brains can be preserved in an entirely different way.

Their specimen of the horseshoe crab, *Euproops danae*, comes from the world-famous Mazon Creek deposit of Illinois in the U.S.. Fossils from this deposit are preserved within concretions made of an iron carbonate mineral called siderite.

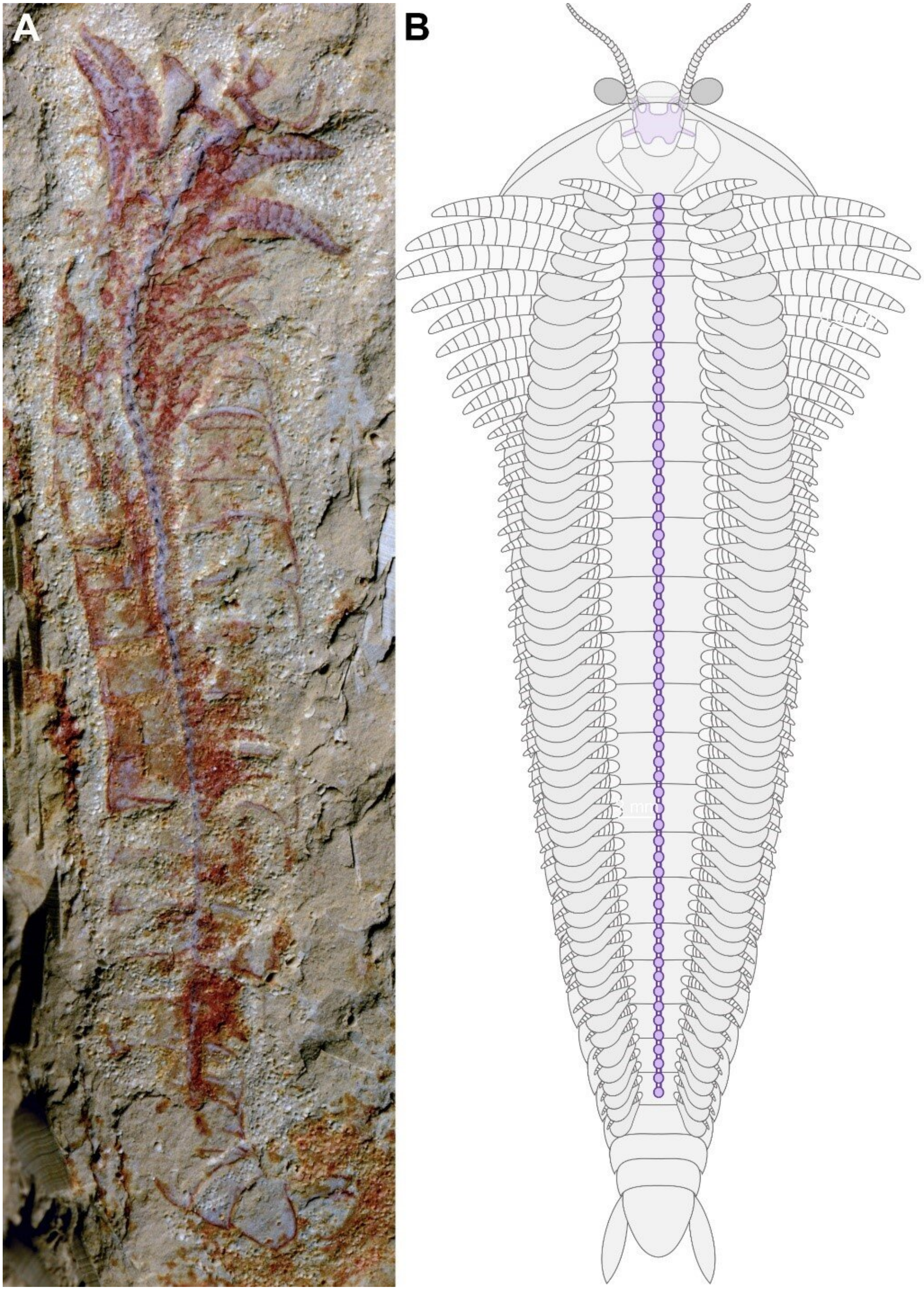
A centipede and a neighbouring ant suspended in roughly 23 million-year-old Mexican amber. Credit: Greg Edgecombe

"We have shown, for the first time, that the Mazon Creek animals were not only molded by the rapid formation of siderite that entombed their entire bodies, but also that the siderite quickly encased their internal soft tissues before they could decompose," co-author Professor Paterson said.

"In our fossil, the brain of *Euproops* is replicated by a white-colored clay mineral called kaolinite. This mineral cast would have formed later within the void left by the brain, long after it had decayed. Without this conspicuous white mineral, we may have never spotted the brain."

The study also reveals that the brain anatomy of horseshoe crabs has remained essentially unchanged throughout most of their evolutionary history.

"The fossil's central nervous system is closely comparable to that of living horseshoe crabs and match up in their arrangement of nerves to the eyes and appendages. It also shows the same central opening for the esophagus to pass through. This is quite remarkable, given the substantial morphological and ecological diversification that has taken place in the group over the intervening 310 million years," Prof. Paterson said.


A
B

The Cambrian arthropod Chengjiangocaris kunmingensis from China. See the bead-like ventral nerve cord preserved in the fossil (A) and its central position in the reconstruction (B). Credit: Javier Ortega-Hernández.

"We have been given a rare glimpse into the prehistoric past, allowing us to further our understanding of the biology and evolution of these long-extinct animals."

The research "Central nervous system of a 310-m.y.-old horseshoe crab: Expanding the taphonomic window for nervous system preservation" was published in *Geology* today.

More information: Russell D.C. Bicknell et al, Central nervous system of a 310-m.y.-old horseshoe crab: Expanding the taphonomic window for nervous system preservation, *Geology* (2021). DOI: 10.1130/G49193.1

Provided by University of New England

Citation: Decoding the secrets of a 310 million-year-old brain (2021, July 27) retrieved 25 April 2024 from https://phys.org/news/2021-07-decoding-secrets-million-year-old-brain.html