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What can fossils tell us about the nervous system's evolution?

Authors:
Russell D. C. Bicknell, John R. Paterson, and others

Associate Editors:
Miranda Wilson and Tanya Dimitrova

Abstract

What can we learn from **fossils**? We can estimate the shape and size of an extinct animal. Anything else? Well, if soft tissues (like the brain or muscles) fossilize, it could tell us how the animal functioned or behaved. Unfortunately, soft tissue decomposes quickly after an animal dies. They aren't preserved as fossils very often.

That's why we felt really lucky when we came across a fossil of an extinct horseshoe crab with a preserved central nervous system (CNS). We discovered that the organization of the CNS in our fossil is the same as in horseshoe crabs living today. It hasn't changed in over 300 million years! We also figured out how our unique fossil might have formed. This could help others discover similar fossils in the future.

Introduction

Have you ever wondered how you feel pain or understand what your eyes see? Your **central nervous system** (CNS) controls and processes those (and many other) functions in your body. It also plays a role in your behavior and how you interact with the world around you. It is basically your brain telling you what to do.

As you can imagine, the CNS in many animals is very complex. One way scientists can study the CNS is by looking at its **morphology**, or the way it is organized. This can provide a lot of information about the way the organism functions.

Paleontologists can look at the CNS in fossils to see how extinct animals might have functioned or behaved. Unfortunately, the CNS is made of a soft material that decays quickly once an animal dies. This means there aren't very many fossils where paleontologists can see

Horseshoe crabs living today are important marine arthropods. This is a baby Atlantic horseshoe crab (*Limulus polyphemus*). **Photo:** Joe Reynolds

the CNS. With this gap in the fossil record, it's hard to understand how the CNS might have evolved in many animals.

One group of animals where this is important is the **arthropods**. Arthropods are one of the most diverse groups of organisms. And they have been around for more than 500 million years! You have probably heard of some of the most popular arthropods like insects, spiders, and crabs.

We wanted to know what changes might have happened in the CNS of arthropods over time. Luckily, we found a fossil of an extinct horseshoe crab where we could see the CNS clearly. We took a closer look at the fossil to:

- learn about the CNS in this extinct arthropod.
- discover the possible **taphonomic processes** that led to the formation of this fossil.

Methods

We looked at the fossil of a *Euproops danae* horseshoe crab that is kept in the Yale Peabody Museum. The fossil was originally discovered near Mazon Creek in Illinois, USA. The animal lived during the Carboniferous period (about 300 million years ago).

We photographed the fossil. Then we used a **scanning electron microscope** to figure out the chemical composition of the minerals and rock making up the fossil.

Results

We found that the CNS looked like a ring with seven paired extensions. These extensions got longer toward the back of the fossil. (Fig. 1)

We found that the CNS was preserved as a white mineral. The mineral contained a lot of aluminum and silicon but not much iron, potassium, or magnesium. We identified it as kaolinite (a type of mineral). It has been seen in other Mazon Creek fossils before.

Figure 1:
This is the fossil of the *Euproops danae* horseshoe crab we studied. The central nervous system (CNS) is outlined by a white box on the fossil. The inset shows a redrawn version of the CNS.

Discussion

Our find is exciting because it is the first time we have been able to examine the complete CNS of an extinct arthropod that lived in freshwater.

The morphology of the CNS in our fossil is very similar to the CNS in horseshoe crabs living today. This means that the organization of the nervous system hasn't changed for at least 300 million years! This extinct horseshoe crab likely functioned and behaved in similar ways to horseshoe crabs alive today.

Usually, soft tissues do not preserve well. This fossil is unique because the CNS is preserved in kaolinite,

which is easy to see. We think this fossil must have formed in three steps.

1. The mineral matrix around the fossil formed very fast. The CNS was likely protected by a thick membrane.
2. The CNS eventually decayed and left a void.
3. The void was filled in with kaolinite. Kaolinite is white in color and makes the CNS easy to see.

We think there may be examples of soft tissues in other Mazon Creek fossils, but they may be hard to recognize. Future studies should look at the color and contours of fossils to help find these preserved tissues.

Conclusion

Fossils give us a snapshot of what happened in the past. Paleontologists can even figure out how organisms functioned and behaved by studying soft tissues like the CNS. It is important to look at fossils so we can understand how organisms have changed over time and how they might change in the future.

If you want to see fossils, you can visit your local natural history museum. Or you can take a trip to an area like Mazon Creek to hunt for your own fossils. If you find something amazing, make sure to share it with your local museum or paleontologist!

Glossary of Key Terms

Arthropods - A group of invertebrates that have their skeleton on the outside (exoskeleton). They also have a segmented body with pairs of limbs that have joints. The group is extremely diverse and includes millions of species. Examples include insects, spiders, and scorpions. They live in almost all kinds of environments.

Central nervous system - A collection of nerves (incl. the brain) that take in sensory information to process and then send signals for the body to respond. It controls both all voluntary movements like walking and talking and all involuntary movements like blinking and breathing. It also controls things like regulating body temperature and blood pressure.

Fossil - the remains or impression of an ancient plant or animal embedded and preserved in rock. Fossils are rocks, not bones or shells from the animal itself.

Morphology - the way something is shaped or organized. Scientists may study a fossil's morphology to determine what the animal looked like in the past.

Paleontologist - A type of scientist who studies the history of life on Earth. They study fossils of plants and animals. They use a range of disciplines including biology, geology, biochemistry, and ecology.

Scanning electron microscope - A type of microscope that scans the surface of an object using a beam of electrons that interact with the surface of the object. The signals produced from this interaction can see features less than 1 nanometer wide. For comparison, a human hair is about 80,000 nanometers wide. A scanning electron microscope can also determine the chemical composition of an object.

Taphonomic process - How an organism decays and becomes fossilized and preserved. It can provide paleontologists with information about why certain organisms fossilize better or why fossils can be found in certain locations and not others.

Check your understanding

1. Why is the central nervous system an important system to study? What types of things does it control?

2. Why is it hard to find fossils of the central nervous system?

3. Describe the taphonomic process (the steps) that likely occurred in the formation of this unique fossil.

4. How similar is the central nervous system of the extinct horseshoe crab to that of horseshoe crabs living today? What information does that tell us about the evolution of horseshoe crabs?

5. Why do you think some organisms change much less over their evolutionary history than others do? In small groups, discuss your ideas with your classmates.

REFERENCES

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