The first fossilised heart ever found in a prehistoric animal

April 20 2016, by John Long, Flinders University

This 119 million year old fish, Rhacolepis, is the first fossil to show a 3D preserved heart which gives us a rare window into the early evolution of one of our body's most important organs. Credit: Dr John Maisey, American Museum of Natural History in New York, Author provided

Palaeontologists and the famous Tin Man in The Wizard of Oz were once in search of the same thing: a heart. But in our case, it was the search for a fossilised heart. And now we've found one.

A new discovery, announced today in the journal eLife, shows the perfectly preserved 3D fossilised heart in a 113-119 million-year-old fish from Brazil called *Rhacolepis*.

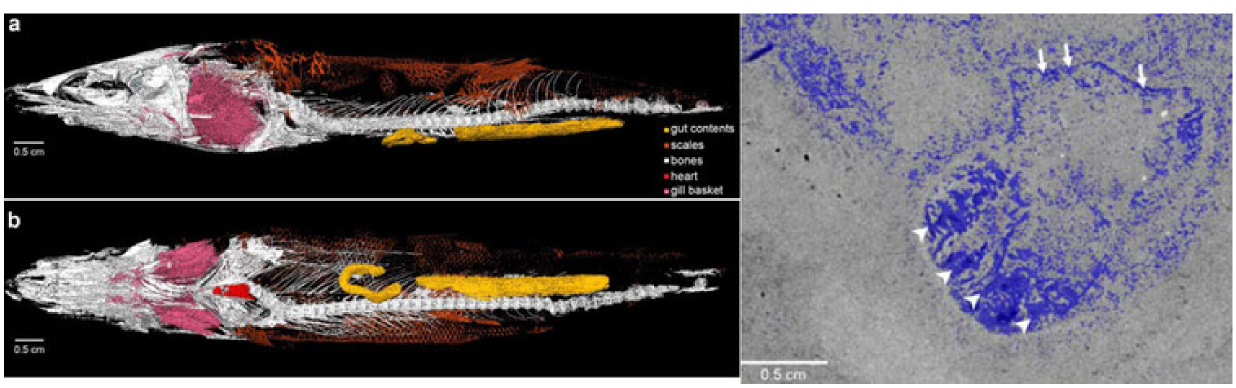
This is the first definite fossilised heart found in any prehistoric animal.

For centuries, the fossil remains of back-boned animals – or vertebrates – were studied primarily from their bones or fossilised footprints. The possibility of finding well-preserved soft tissues in really ancient fossils was widely thought to be impossible.

Soft organic material rapidly decays after death, so organs start breaking down from bacterial interactions almost immediately after an animal has died. Once the body has decayed, what remains can eventually become buried and what's left of the skeleton might one day become a fossil.

Exceptional preservation of fossils

But certain rare fossil deposits, called konservat laggerstätten (meaning "place of storage"), are formed by rapid burial under special chemical conditions. These deposits can preserve a range of soft tissues from the organism.



The fish Rhacolepis imaged by synchrotron tomography showing the heart (left) and a cross-section through the heart showing valves (right, white arrows). Credit: Maldanis et al. (2016)

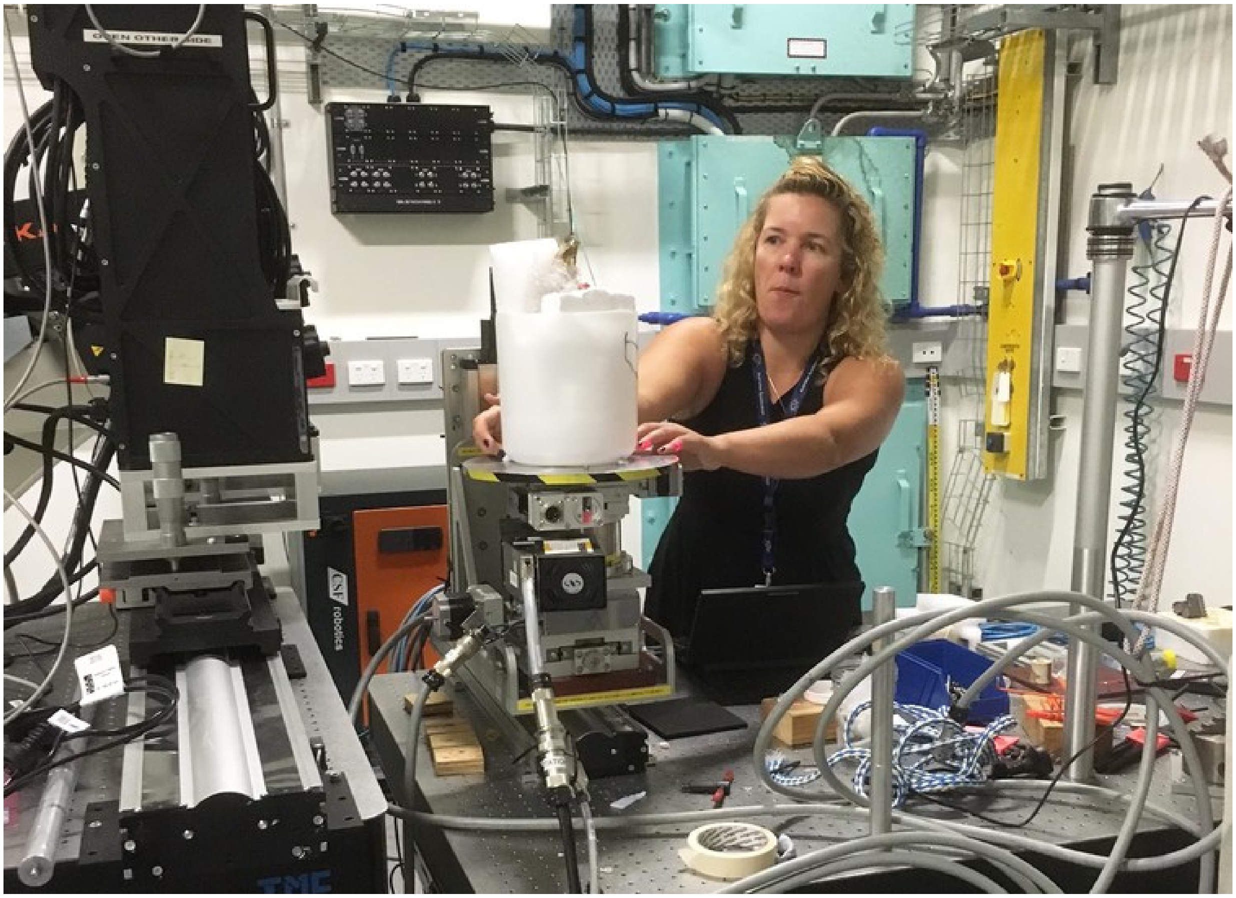
The famous Burgess Shale fossils from British Columbia in Canada show soft-bodied worms and other invertebrate creatures. These were buried by rapid mudslides around 525 million years ago.

The well-preserved fishes from the 113-119 million-year-old Santana Formation of Brazil were among the first vertebrate fossils to show evidence of preserved soft tissues. These include parts of stomachs and bands of muscles.

The discovery of complete soft tissues preserved as whole internal organs in a fossil was a bit of a Holy Grail for palaeontologists. Such finds could contribute to understanding deeper evolutionary patterns as internal soft organs have their own set of specialised features.

Finding a complete fossilised heart in a fish almost 120 million years old was a major breakthrough for José Xavier-Neto of the Brazilian Biosciences National Laboratory, Lara Maldanis of the University of Campinas, Vincent Fernandez of the European Synchotron Radiation Facility and colleagues from across Brazil and Sweden.

Back in 2000, a group of US scientists claimed to have found a heart preserved in a dinosaur nicknamed Willo, a *Thescelosaurus*. But recent work has debunked this claim, showing the cavity of the dinosaur body was infilled by sediment and then impregnated with iron-rich minerals to make the cavity inside look a bit heart-like when imaged by CT scanning.



Setting up a fossil in the Australian Synchrotron's IMBL facility. Fossilised soft organs can be studied using these high-tech imaging methods. Credit: John Long, Flinders University

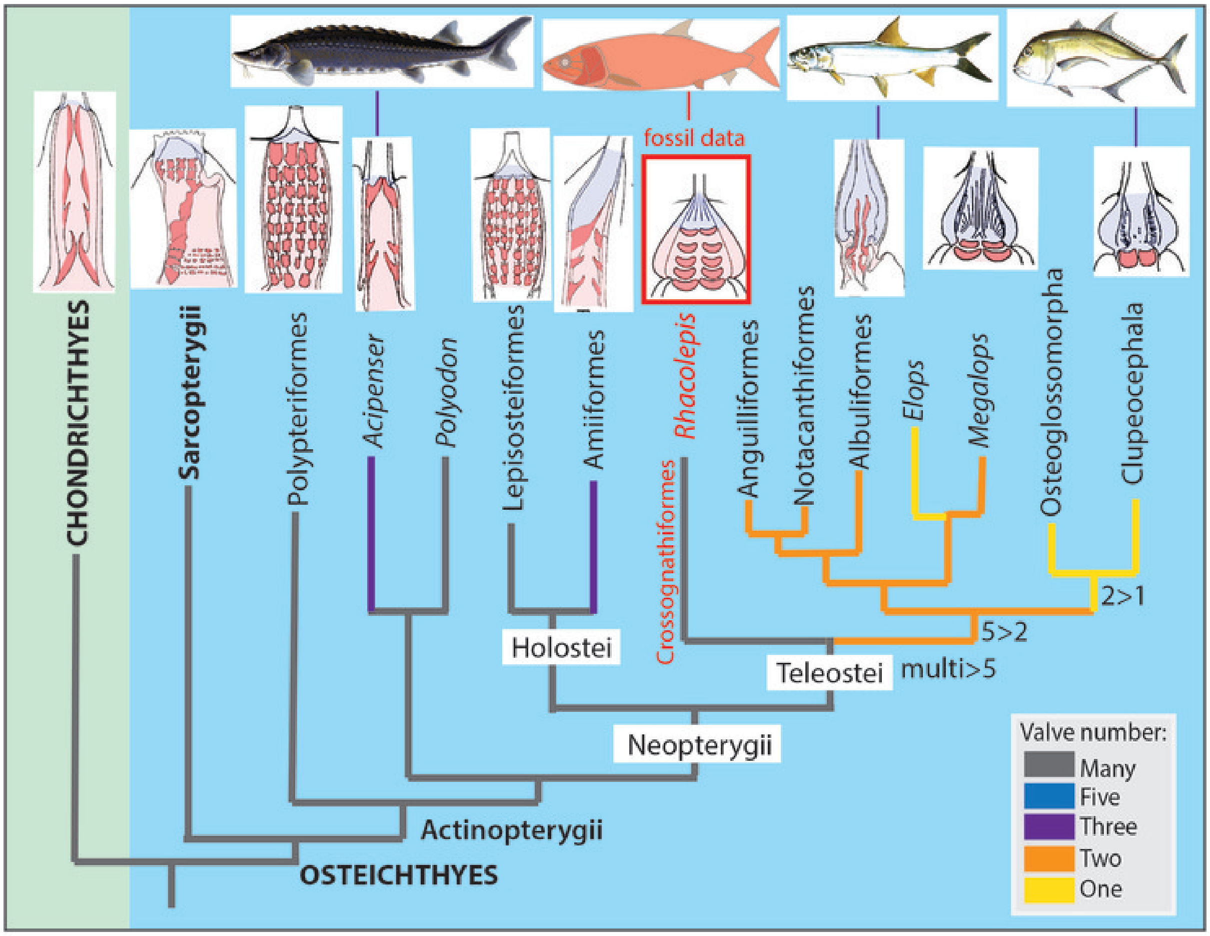
The only other claims for fossilised vertebrate hearts are stains supposedly made by haemoglobin-rich blood found in the region of the fossil where the heart should be. These, along with stains representing possibly the liver, have recently been documented in 390 million-year-old fishes from Scotland.

Digital heart surgery on a fossil

The new discovery was made by imaging a fossil still entombed within its limestone concretion using synchrotron X-ray tomography down to 6µm sections. The heart is then rendered out slice by slice using software to digitally restore the features of the organ.

This method has now been widely applied in palaeontology for the past decade or so to reveal many intricate soft tissue structures in fossils, including the actual preserved brain of a 300 million-year-old fish from North America and actual muscle bundles attached to 380 million-year-old placoderm fishes from Australia.

The *Rhacolepis* heart was digitally restored by tomography and from images studied in cross-sections through the rock. It shows clear detail of the conus arteriosus, or bulb at the top of the heart, which has a pattern of five rows of valves inside it.



The fossil heart data from Rhacolepis shows an intermediate condition between the many-valved types seen in basal ray-finned fishes and the single-valved hearts in modern teleosts. (From Maldanis et al. 2016) Credit: John Long

A detailed comparison with a dissected tarpon heart in the paper shows similar structures in the same relative position as the fossil heart.

The discovery of the fossilised heart is significant in that it shows the valve condition in an early member of the ray-finned fish group. These are the largest group of vertebrates alive today with nearly 30,000 species, and naturally they display a wide range of valve patterns in their hearts.

Some, such as the African reedfish, a very basal member of the ray-finned fishes, has nine rows of valves. But the modern most diverse group of ray-fins, the teleosts, have just a single outflow valve in the heart. In teleosts another structure, the bulbus arteriosus, prevails over the conus arteriosus to dominate outflow of blood from the heart.

Enter our fossil, *Rhacolepis*, a fish belonging to an entirely extinct family, the Pachyrhizodontidae, named after the extinct fish *Pachyrhizodus*. This is a group placed close to the base of the teleosts.

The pattern shown by the fossil seems to represent a good intermediate condition between the most primitive pattern and the most advanced type. In biology, simple patterns often hold more complex hidden meanings.

Within some ray-finned fish groups there is also thought to be a secondary simplification of the valve arrangements. For example, in sturgeons and bowfins there is independent pattern of simplification within the conus arteriosus.

There is also evidence for independent increase in the numbers of valves in some basal ray-fins, like the reedfish *Polypterus*, so interpreting evolutionary patterns from just one data point in time must be open to several explanations.

Nonetheless, for the first time we actually do have a data point to study the anatomy in detail of a fossilised heart in an extinct group of fishes.

The find demonstrates the immense potential for more discoveries of this nature, enabling more discussion of the comparative anatomy of soft organs in extinct organisms and how they have evolved through time.

With increased discoveries like this one, and more detailed knowledge of the soft tissue anatomy of extinct animals, we will one day really get to the heart of understanding the evolution of the first back-boned animals.

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