More than 252 million years ago, mammal ancestors became warm-blooded to survive mass extinction

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The skeleton of a therapsid dicynodont Lystrosaurus. Credit: Flickr

Today, mammals and birds are the only true warm-blooded animals. They are called endotherms, meaning they produce their body heat internally.

Endotherm animals are the opposite to ectotherms which get their heat from an external factor like the sun. They are considered "cold-blooded".

The origins of warm-bloodedness in mammals has been a very controversial issue for two reasons. One is that several of the anatomical features thought to be linked to warm-bloodedness have also been found in cold-blooded reptiles. The other is that these characteristics are not always preserved in fossils, giving scientists inconsistent signals about the presence of warm-bloodedness.

Our research helps shed new light on this controversy. We've been able to come up with new insights about how mammals developed a warm-blooded metabolism that may have helped them survive the terrible mass extinction that marked the end of the Permian period, 252 million years ago.

By comparing the ratios of oxygen isotope in fossils we were able to show that a group called the cynodontia – mammal ancestors – acquired warm-bloodedness somewhere during the Late Permian period, which ranged from 259 to 252 million years ago. This makes the origin of mammal endothermy older than what we thought previously.

But our research also shows that the cynodontia were not the only ones to acquire warm-bloodedness. The dicynodontia, which have been considered cold-blooded, also developed this feature independently in the same time period.

Our discovery suggests that climate was the main factor that triggered the evolution of warm-bloodedness in mammals and it's responsible for subsequent mammalian evolutionary success. We argue that triassic dicynodonts and cynodonts were able to survive by already possessing an endothermic metabolism to cope with temperature fluctuations.

Mammalian characteristics

There are several special features that are linked to warm-bloodedness. One is the bones inside the nose and snout, called the turbinates. These bones increase the distance that air travels into the body, allowing it to warm up on the way in. There is also the bony palate which separates the mouth from the nose and allows for continuous breathing, even while eating. Another, which is rarely preserved in the fossil records, is the presence of fur which acts as an insulating layer.

The challenge with evaluating the origins of morphological features is that they aren't from the same time. Some have appeared in some animals earlier than others.

So we took an innovative and unprecedented approach. We looked at the isotopes of oxygen in the bones and teeth of Permo-Triassic mammal-like reptiles known as therapsids. This is an approach that's been used officially to evaluate dinosaurs.

The transition between the Permian and Triassic periods, 252 million years ago, is known as the most devastating mass extinction in Earth's history. Reconstructions of the paleoclimate show that after a cooling trend towards the end of the Permian period, there was an abrupt and intense warming at the Permian-Triassic Boundary.

We took samples of groups of animals from fossil records kept in South Africa, Lesotho, Morocco and China dating to the Permian and Triassic period.

We sampled therapsids and some tetrapods that lived at the same time and at the same place. By doing so we were able to distinguish warm-blooded therapsids from cold-blooded ones, and get closer to pinning down when species evolved to warm-bloodedness.

We found that Permian therapsids and the co-existing tetrapods had similar body temperatures. But, in contrast, analysed therapsids in the Triassic period were warm-blooded.

Both the dicynodonts and cynodonts in the Permian period were cold-blooded while the same groups in the Triassic period were warm-blooded. This means that they acquired their endothermy in the late Permian period.

Understanding that these groups developed their warm-bloodedness during the Late Permian period highlights two important findings.

The first is that they appeared independently – the Permian ancestors of both groups were not warm-blooded. The second is, even if they may have appeared at different times during the Late Permian period, they seem to have been through the same factors of selection by surviving the global climatic variations of the end-Permian.

The "mammal-like reptiles" survived because warm-blooded animals have the capacity to produce their own body heat which allows them to live in colder environments or in areas with huge seasonal temperature contrasts.

At the geological scale, this could mean that endothermic species would have a better chance to survive through important and rapid climate change.

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