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Strolling Salamanders Provide Clues on How Animals Evolved to Move from Water to Land

November 30, 2015

KNOXVILLE—Around 390 million years ago, the first vertebrate animals moved from water onto land, necessitating changes in their musculoskeletal systems to permit a terrestrial life. Forelimbs and hind limbs of the first tetrapods evolved to support more weight. But what specific mechanisms drove changes in bone function?

Scientists use the tiger salamander to investigate the stresses that early tetrapods experienced as they moved from water to land. *Credit: Todd Pierson*

The tiger salamander might provide some clues. A new study from a team of scientists from the National Institute for Mathematical and Biological Synthesis (NIMBioS) and Clemson University evaluates what mechanisms drive diversity in bone function, providing new insight into the evolution of how tetrapods—the earliest four-legged vertebrate animals—took their first steps on land.

In this Science Minute from NIMBioS, Dr. Sandy Kawano explains how living salamanders provide insights into modeling how early stem tetrapods moved on land. *Credit: NIMBioS*

In order to understand the biology of fossilized animals, researchers often turn to living animals with similarities that help model how extinct animals moved. Salamanders are particularly good organisms for studying how locomotion onto land evolved, as their anatomy and ecology is similar to the earliest tetrapods.

Bones must regularly withstand a variety of different forces, or "loads," from both the contraction of muscles and from interaction with the environment. Limb bones in particular must accommodate some of the highest forces. Fossil records suggest that the forelimb and hind limb may have had different functions for walking on land, but the specific mechanisms that contributed to these differences are less known. The researchers wanted to test what factors could have driven diversity in skeletal design in the evolution of early tetrapods.

The mechanics of bone loading in the salamanders were tested in a variety of ways, including filming the salamanders as they walked across a custom-built platform that measured forces on the limb bones. A comparison of forelimbs and hind limbs and an analysis of limb joints were conducted. Mathematical models were used to evaluate how the limb bones were able to withstand the physical demands of walking on land. To assure a good test, salamanders that turned, stopped or fell on the platform or walked diagonally, for example, were excluded from the study.

The study found that the forelimbs, compared to the hind limbs, had lower yield stresses, higher mechanical hardness, and a greater ability to withstand loads higher than normal.

"These results offer new perspectives in modeling how tetrapods may have taken their first steps onto land, by considering the unique contributions of both the forelimbs and hind limbs, " said lead author Sandy Kawano, a postdoctoral fellow at NIMBioS.

To evaluate 3D movements, the salamander was filmed walking across a custom-built platform that measured the forces on the limb bones. *Credit: Kawano and Rick Blob/Clemson University*

Citation: Kawano SM et al. Comparative limb bone loading in the humerus and femur of the tiger salamander *Ambystoma tigrinum*: Testing the 'mixed-chain' hypothesis for skeletal safety factors. *Journal of Experimental Biology*. [Online]

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CONTACT:
Sandy Kawano, NIMBioS, +1-865-974-4980, skawano@nimbios.org
Catherine Crawley, NIMBioS, +1-865-974-9350, ccrawley@nimbios.org

NIMBioS
1122 Volunteer Blvd., Suite 106
University of Tennessee
Knoxville, TN 37996-3410
PH: (865) 974-9334
FAX: (865) 974-9300
Contact NIMBioS

NIMBioS is supported by the National Science Foundation through NSF Award #DBI-1300426, with additional support from The University of Tennessee, Knoxville. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.