Scientists discover evolutionary origin of fins, limbs

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Performance on the dance floor may not always show it, but people are rarely born with two left feet. We have genes that instruct our arms and legs to grow in the right places and point in the right directions. They also provide for the spaces between our fingers and toes and every other formative detail of our limbs.

Evolutionarily speaking, the genetic instructions used to construct and position our limbs were being perfected more than half a billion years ago in fishes, not along the sides of the body where the fins that preceded human arms and legs sprouted, but at the midline that runs along the backbone and belly.

This midline — think of the dorsal, tail and anal fins of a fish — is where the genetic template to produce fins originated, about 100 million years before paired fins evolved and about 200 million years before paired fins evolved into limbs, according to University of Florida genetics researchers. The findings, published online today in the journal *Nature*, also provide insight into the evolutionary history of genes involved in human birth defects.

“Given that paired fins made their evolutionary debut at a particular location on the sides of the body, intuitively one would think the genetic tools for fin development would be brought together in that place,” said developmental biologist Martin Cohn, an associate professor with the UF departments of zoology and anatomy and cell biology and a member of the UF Genetics Institute. “We’ve discovered that the genetic circuitry

for building limbs first appeared in an entirely different place — the midline of the animal."

The appearance of paired fins on the sides of early vertebrates was a major evolutionary innovation toward fin — and eventually limb — locomotion, Cohn said. The earliest fishes lacked paired fins, similar to the modern-day lamprey — a species of jawless fish with a dorsal fin and tail but no side fins — considered by biologists to share many features with the ancestor of all vertebrates.

"The emergence of paired appendages was a critical event in the evolution of vertebrates," Cohn said. "The fossil record provides clear evidence that the first fins evolved along the midline. The sequence of evolutionary events leading to the origin of limbs has been known for some time, but only now are we deciphering how these events occurred at a molecular genetic level."

Researchers isolated genes from the spotted catshark, a type of slow-moving shark from the eastern Atlantic Ocean. By studying the activity of a dozen genes in shark embryos, they determined shark median fin development is associated with the presence of genes such as HoxD, Fgf8 and Tbx18, which are vital in the development of human limbs.

They also used molecular markers for different cell types to determine which cells give rise to the median fins, finding that they arise from the same cells that form the vertebrae. These same genes dictate the emergence of symmetrical pairs of fins on the animal sides, showing a shared developmental mechanism in completely different locations, according to Renata Freitas and GuangJun Zhang, co-authors of the paper and graduate students in UF's zoology department.

Extending their genetic analysis to the lamprey — a living relic from the time before fish had paired fins — researchers found the same genetic

cues in place.

“That we see these same mechanisms operating in lamprey fins tells us they must have been assembled in the median fins first, and later in evolution this entire genetic program was simply reutilized in a new position to build the first paired fins,” Cohn said. “It tells us our own arms and legs have their evolutionary roots in the dorsal, caudal and anal fins of our fishy ancestors.”

Many of these genetic mechanisms are involved in human birth defects, which provide insight into the evolutionary history of genes and their functions.

“Knowing that many of these genes are responsible for limb defects in humans is intriguing,” Cohn said. “What we’ve done is identify where those developmental pathways originated during our evolutionary past and how they became involved in limb development.”

Learning the mechanics of development enriches our understanding of evolution, according to Ann Campbell Burke, an associate professor of biology at Wesleyan University who was not connected with the study.

“Using modern molecular techniques, this confirms in a lovely way an idea that’s been around for over 100 years about how paired fins may have evolved in the first place,” Burke said. “To translate a 19th century observation about fin development into modern molecular data is a great thing for science. It has become increasingly important to understand developmental processes in our attempts to understand evolution.”

Source: University of Florida