Research links evolution of fins and limbs with that of gills

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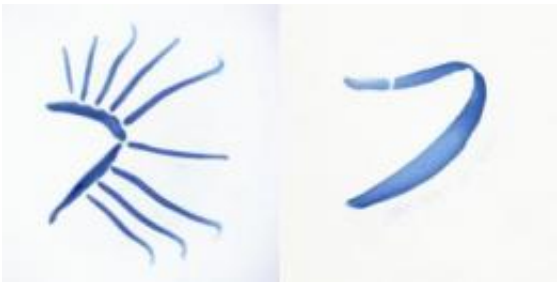

The shark arch gill skeleton (left) shows primitive gill rays that are found only in sharks and other cartilaginous fishes. The gills of other fishes (right) are also arched but lack gill rays. This primitive feature of sharks allowed the researchers to link the developmental genetic program for fins and limbs to the more primitive one for gill rays. Credit: Image by J. Andrew Gillis, University of Chicago

The genetic toolkit that animals use to build fins and limbs is the same genetic toolkit that controls the development of part of the gill skeleton in sharks, according to research to be published in *Proceedings of the National Academy of Sciences* on March 23, 2009, by Andrew Gillis and Neil Shubin of the University of Chicago, and Randall Dahn of Mount Desert Island Biological Laboratory.

"In fact, the skeleton of any appendage off the body of an animal is probably patterned by the developmental genetic program that we have traced back to formation of gills in sharks," said Andrew Gillis, lead

author of the paper and a graduate student in the Department of Organismal Biology and Anatomy at the University of Chicago. "We have pushed back the evolutionary origin of the developmental genetic program that patterns fins and limbs."

This new finding is consistent with an old theory, often discounted in science textbooks, that fins and (later) limbs evolved from the gills of an extinct vertebrate, Gillis added. "A dearth of fossils prevents us from definitely concluding that fins evolved from gills. Nevertheless, this research shows that the genetic architecture of gills, fins and limbs is the same."

The research builds on the breakthrough discovery of the fossil Tiktaalik, a "fish with legs," by Neil Shubin and his colleagues in 2006. "This is another example of how evolution uses common developmental programs to pattern different anatomical structures," said Shubin, who is the senior author on the PNAS paper and Professor and Associate Dean of Organismal and Evolutionary Biology at the University of Chicago. "In this case, shared developmental mechanisms pattern the skeletons of vertebrate gill arches and paired fins."

The research also showed for the first time that the gill arch skeleton of embryonic skates (a living relative of sharks that has gill rays) responds to treatment with the vitamin A derivative retinoic acid in the same way a limb or fin skeleton does: by making a mirror image duplicate of the structure as the embryo develops. According to the researchers, the genetic circuitry that patterns paired appendages (arms, legs and fins) has a deep evolutionary origin that actually predates the origin of paired appendages themselves.

"These findings suggest that when paired appendages appeared, the mechanism used to pattern the skeleton was co-opted from the gills," Gillis said. "Perhaps we should think of shark gills as another type of

vertebrate appendage—one that's patterned in essentially the same way as fins and limbs."

The deep structural, functional, and regulatory similarities between paired appendages and developing gill rays, as well as the antiquity of gills relative to paired appendages, suggest that the signaling network that is induced by retinoic acid had a patterning function in gills before the origin of vertebrate appendages, the research concludes. And this function has been retained in the gill rays of living cartilaginous fishes.

Source: University of Chicago Medical Center