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Fish's DNA May Explain How Fins Turned to Feet

By NICHOLAS WADE

In the hope of reconstructing a pivotal step in evolution — the colonization of land by fish that learned to walk and breathe air — researchers have decoded the genome of the coelacanth, a prehistoric-looking fish whose form closely resembles those seen in the fossils of 400 million years ago.

Often called a living fossil, the coelacanth (pronounced SEE-luh-canth) was long believed to have fallen extinct 70 million years ago, until a specimen was recognized in a fish market in South Africa in 1938. The coelacanth has fleshy, lobed fins that look somewhat like limbs, as does the lungfish, an air-breathing freshwater fish. The coelacanth and the lungfish have long been battling for the honor of which is closer to the ancestral fish that first used fins to walk on land and give rise to the tetrapods, meaning all the original vertebrates and their descendants, from reptiles and birds to mammals.

The decoding of the coelacanth genome, reported online Wednesday in the journal Nature, is a victory for the lungfish as the closer relative to the first tetrapod. But the coelacanth may have the last laugh because its genome — which, at 2.8 billion units of DNA, is about the same size as a human genome — is decodable, whereas the lungfish genome, a remarkable 100 billion DNA units in length, cannot be cracked with present methods. The coelacanth genome is therefore more likely to shed light on the central evolutionary question of what genetic alterations were needed to change a lobe-finned fish into the first land-dwelling tetrapod.

The idea of decoding the coelacanth genome began six years ago when Chris Amemiya, a biologist at the University of Washington in Seattle, acquired some samples of coelacanth tissue. He asked the Broad Institute of Harvard and M.I.T., a biological research institute in Cambridge, Mass., to decode the DNA and invited experts in evolutionary and developmental biology to help interpret the results.

Dr. Amemiya's team has sifted through the coelacanth's genome for genes that might have helped its cousin species, the ancestor to the first tetrapod, invade dry land years ago. They have found one gene that is related to those that, in animal placenta. Coelacanths have no placenta, but they produce extremely large e blood supply, that hatch inside the mother's body. This gene could have bee land animals into a way of constructing the placenta.

Another helpful preadaptation is a snippet of DNA that enhances the activity of the genes that drive the formation of limbs in the embryo. The Amemiya team focused on the enhancer DNA sequence because it occurred in the coelacanth and animals but not in ordinary fish. They then inserted the coelacanth enhancer DNA into mice.

"It lit up right away and made an almost normal limb," said Neil Shubin, meaning that the coelacanth gene enhancer successfully encouraged the mouse genes to make a limb. Dr. Shubin, a member of the team, is a paleontologist at the University of Chicago.

Present-day coelacanths are ferocious predators that live in a twilight zone about 500 feet deep where light barely penetrates. They lurk in caves during the day and emerge at night to attack surface fish as they descend and deep-sea fish as they rise to the surface. They have no evident need of fins that might help them walk on land.

"This is probably an unusual habitat for this lineage," said Axel Meyer, an evolutionary biologist at the University of Konstanz in Germany and a member of the team. "Other coelacanths lived in more shallow, estuarylike environments 400 million years ago, and you can envisage them using the fins more like walking legs."

The Amemiya team reports evidence that the coelacanth's genes have been evolving more slowly than those of mammals, possibly because of "a static habitat and lack of predators." But its environment must have changed quite considerably over the last 400 million years, Dr. Meyer said. Its principal habitat at present is the caves beneath the Comoro Islands in the Indian Ocean, but since these are extinct volcanoes a mere 5 million to 10 million years old, they must be a quite recent home for the coelacanth.

The Amemiya team does not possess a full coelacanth — these are endangered species — and decoded the genome from tissues obtained from Rosemary Dorrington of Rhodes University in South Africa. Dr. Dorrington supplied DNA kits to the Comoro Islands fishermen who occasionally snag coelacanths by accident. When a coelacanth was captured in 2003, they preserved blood and tissues, which were given to Dr. Dorrington and kept frozen, Dr. Amemiya said.

The specimen was preserved in Moroni, the capital of the Comoro Islands, but Dr. Amemiya has been unable to find out where it is now because of the constant state of civil war in the islands, he said.

Can he be certain, then, that the tissue came from a coelacanth? "Oh, no question," Dr. Amemiya said. "We have DNA from several other coelacanths, from Africa and Indonesia, which is very similar to this one." The one caught in 2003 was identified as a coelacanth by Said Ahamada, a South African expert, Dr. Amemiya said.

Because the original specimen is not available and the DNA sequencing is incomplete, the

Amemiya team does not know its sex.

Lobe-finned fish like the coelacanth and lungfish are known to zoologists as sarcopterygians, meaning fleshy fins. Tetrapods, including people, are descended from this group, and the coelacanth is more closely related to people than to other fish. “Evolutionarily speaking, we are sarcopterygian fish,” Dr. Meyer said.

This article has been revised to reflect the following correction:

Correction: April 17, 2013

An earlier version of this article misidentified the year in which a coelacanth, then believed to be extinct, was recognized in a fish market in South Africa. It was 1938, not 1908.