New fossils illuminate the evolution of land vertebrates from fish

By Walter Gilberti
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A major fossil discovery at a site in northern Canada has provided compelling evidence of the evolutionary transition from ancient fish to the first tetrapods—four-legged terrestrial vertebrates that include amphibians, reptiles, birds and mammals.

According to two reports published in the April 6 edition of the journal *Nature*, a team led by Neil Shubin of the University of Chicago, Edward Daeshcler of the Academy of Natural Sciences and Farish Jenkins of Harvard has uncovered a number of well-preserved specimens in the sediments of an ancient streambed in what is now the southern part of Ellesmere Island in the Canadian Arctic. The fossils have been given the genus/species designation *Tiktaalik roseae*, the genus name meaning "large shallow water fish" in the language of the indigenous people of Canada's Nunavut Territory.

The stratigraphic position of the specimens places them as having lived during the early part of the Late Devonian Period (385-359 million years ago), very near to the point beyond which one begins to find true tetrapods in the fossil record. During the ensuing period, the Carboniferous, amphibians would become the dominant land vertebrates, but would later relinquish this dominance, as animals more fully adapted to a terrestrial existence, the reptiles, evolved from one or more amphibian populations.

What is so extraordinary about this latest find is both the number of specimens uncovered and their completeness. While vertebrate paleontologists have long known that amphibians (the first tetrapods) evolved from sarcopterygians (lobe-finned fish), there persisted a paucity of fossil evidence, especially at the point of transition between the fish-like ancestors of amphibians and true tetrapods. Up until now, the closest ancestor to the first tetrapods, *Acanthostega* and the well-known (to any students of vertebrate evolution) *Ichthyostega*, had been the predatory fish-like ancestor to amphibians, *Panderichthys*, whose fossil remains, dating from the Middle Devonian, were uncovered in Latvia.

The discovery of *Tiktaalik* has changed this situation in one fell swoop, effectively bridging a so-called "gap" in the fossil record seized upon by the creationist opponents of Darwinian evolution. The authors describe the find as "a remarkable intermediate between *Panderichthys* and early tetrapods. The material provides opportunities to assess the morphological and functional changes associated with the origin of tetrapods" ("A Devonian tetrapod-like fish and the evolution of the tetrapod body plan," *Nature*, April 6, 2006).

Other paleontologists liken the significance of this discovery to that of the famous *Archaeopteryx*, the fossil widely acknowledged to be the ancestor of modern birds.

The creationists' claim that no transitional species have been discovered that demonstrate macro-evolution—the appearance of new species from pre-existing forms, or of new species that exhibit characteristics that signify the emergence of a totally new taxonomic category (Class Mammalia from Class Reptilia, for example)—is amply refuted by the fossil record alone. The clear evolutionary progression of modern whales from more primitive forms, including a fully terrestrial carnivore, the evolution of the horse from a small dog-like mammal with toes rather than hooves, and the emergence of mammal-like reptiles called therapsids, clearly the ancestors of the mammalian line, are just a few examples.

The discovery of *Tiktaalik*, however, has the creationists gasping for breath. Duane Gish, commenting on the find for the Institute for Creation Research, in San Diego, California, declared: "This alleged transitional fish will have to be evaluated carefully." Sticking to his guns, Gish added that he still finds evolution "questionable because paleontologists have yet to discover any transitional fossils between complex invertebrates and fish, and this destroys the whole evolutionary story."

So, for the creationists, it's on to the next alleged gap in the theory. Having retreated from his fish/amphibian position, Mr. Gish will set up a new skirmish line at the invertebrate-vertebrate boundary, until, of course, the inevitable happens and conclusive evidence of transitional creatures somewhere within the Cambrian/Ordovician timeline is discovered. The ability of these purveyors of creationist nonsense to continue their assault on the theory of evolution and the scientific world-view is aided in no small measure by the promulgation of religious ideology by the Bush administration, the Christian right and the Vatican.

The importance of this latest fossil discovery is that it is a tangible confirmation of an undeniable evolutionary lineage

that is easily comprehensible by anyone. According to Michael Novacek, a paleontologist at the American Museum of Natural History in New York City, the discovery puts to rest the evolutionary link between fish and amphibians. “Based on what we already know, we have a very strong reason to think tetrapods evolved from lineages of fishes. This may be a critical phase in that transition that we haven’t had before. A good fossil cuts through a lot of scientific argument.”

Tiktaalik roseae is clearly a transitional form in that it contains morphological features that anticipate the colonization of terrestrial ecosystems by vertebrates. In fact, the fossil evidence indicates that this organism may have periodically ventured onto the land, a likely necessity for *Tiktaalik* suggested by the paleo-geography of the area.

The fossils reveal a large organism, ranging from four to nine feet in length. Its head is flat and protruding, very un-fishlike, and more suggestive of a crocodilian. Its eyes are decidedly dorsal (towards the top of the head) in position, an indication that this animal was as much interested in what was happening above the water’s surface as beneath it.

There is also clear fossil evidence that *Tiktaalik’s* neck was mobile, allowing the independent movement of the head. Fish have to undulate their spines to move their heads. A mobile neck is a defining tetrapod characteristic, an indication that *Tiktaalik* may have already been engaging in certain eating behaviors characteristic of tetrapods.

Tiktaalik’s fins contain incipient limb bones, but lack any indication of digits (fingers and toes). Nevertheless, the emergence of a clearly defined fin skeleton means that *Tiktaalik* needed substrate support, not for swimming, but for walking along the muddy bottoms of the shallow waterways it inhabited. Other skeletal changes involve a strengthening of its backbone, and the beginning of a ventral (downward) orientation of the rib cage, an indication that *Tiktaalik* was sometimes moving in the open air where the lack of buoyancy and the increased pull of gravity would pose problems for any fish-like organism.

Perhaps the most interesting features of this organism relate to possible changes in the way it respired. Fish breathe by gulping water, which then passes through their featherlike gills where oxygen is taken in and carbon dioxide given off. The waste water is then expelled through the external gill aperture, which in some fish is used as a locomotive device to move them quickly forward.

Tiktaalik, then, was a creature that was in the process of shedding its fishlike characteristics in favor of a terrestrial existence, and one of the essential preconditions for this transformation had to be the ability to extract oxygen from air rather than from water. Whether or not this organism had primitive lungs and was capable of inhaling and exhaling like other land vertebrates remains an open question. But, from a morphological standpoint, *Tiktaalik* was well on its way to doing this.

It should be noted that most paleontologists and comparative anatomists believe that lungs appeared long before the emergence of terrestrial vertebrates. In fact, the evolution of the swim bladder in bony fish, a device that allows these creatures to alter their depth in water without having to swim, is widely thought to have evolved from primitive lungs. So the issue for the emergence of tetrapods is not so much the re-emergence of lungs, but the ancillary structural changes that would make their use more effective.

The discovery of fossils like *Tiktaalik* always raises important conceptual and philosophical questions. To call this fossil discovery a “missing link” is certainly not without justification. But the term must be used guardedly since it can imply a teleological, as well as a purely linear, conception of the evolutionary process. It is tempting to view organisms such as *Tiktaalik* as simply the stepping-stones in the inevitable emergence of land vertebrates, culminating ultimately in ourselves.

Tiktaalik may or may not be a direct ancestor to the first amphibians. There could possibly be a number of similar species crawling around in the Devonian mud. Evolution does not take place in a straight line. There are always branchings. With each new adaptation or exaptation, structures that had evolved to carry out particular functions suddenly, under the pressure of natural selection, fulfill completely new roles, leading to the spread (adaptive radiation) of whole new groups of organisms. The previously mentioned evolution of the swim bladder in bony fish is a prime example of this process.

Is it correct, then, to consider *Tiktaalik* a transitional form? Certainly. But it was also a distinct species, adapted to a particular habitat, and filling a particular ecological niche in the time in which it lived. There is an essential duality in the species concept. A particular species dialectically embodies both moment and relation, which is to say that a species is a distinct reproductively isolated breeding population, while it is also in a constant state of transformation and interaction with its environment.

This is at the heart of any understanding of the process of evolution. A fossil, in essence, is a still photograph of a dynamic and complex process. Just as many still photographs combine to form a moving picture, so does the enriching of the fossil record increasingly illuminate the changes over time of various lineages of organisms. The discovery of the *Tiktaalik* fossil will certainly give us a deeper understanding of this process.