Biology 11
J. Harwood
Howe Sound Secondary School

Name:

Fish to Amphibians – transitional forms

Amphibians

Ichthyostega
Forelimbs with wrists and digits used for crawling on land

Tiktaalik – aka: fishapod

- 375 million year old fish - recently discovered transitional form (reported April/06).
- Found off Ellesmere Island in the Canadian Arctic.
- Means shallow water fish. Has a limb with wrist, elbow, shoulder and hand.
- Probably crawled on land or at least propped itself up in shallow water to find prey and avoid predators.
- Probably had lungs. Looks like a crocodile except has gills, broad skull, flexible neck, eyes on top of head.

Eusthenopteran
Lung + boney structure like that of all vertebrate limbs

Panderichtyes
Boney structure like that of all vertebrate limbs

Coelacanths – modern

Lung fish - modern

Lobe finned fish
Boney structure like that of all vertebrate limbs
Subclass Sarcopterygii

Ray finned fish
Fin composed of rays or rods, most of the fish we eat
Subclass Actinopterygii

Boney fish
Class Osteichthyes

Assignment: Watch DVD Great Transitions (https://vimeo.com/153551383)

1. What type of selective pressures might force fish onto land? What might have been the selective advantage for a move onto land?

2. Many people suggest that fish developed legs so that they could make the move to land. As an experienced biologist, how would you respond to this idea?

3. Describe what a pre-adaptation is.

4. What were the necessary pre-adaptations for the move from water to land?

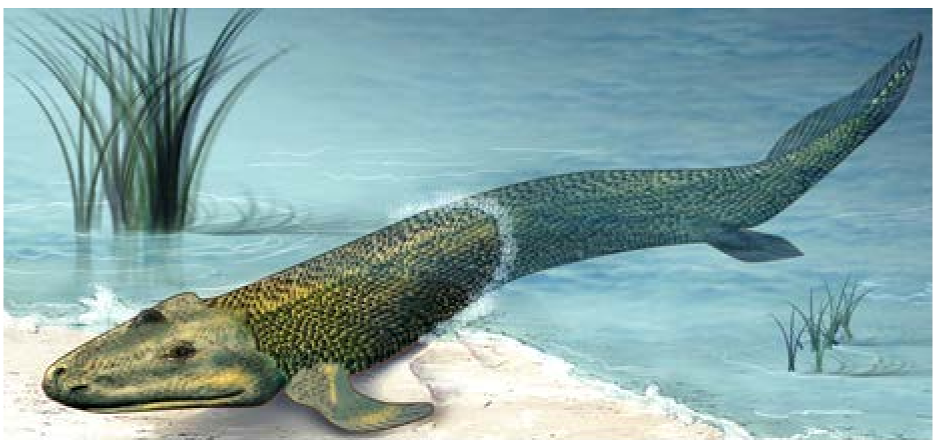
5. Read the article – Our Cousin the Fishapod and complete the attached assignment.

Our Cousin – The Fishapod – Taken from TIME Magazine, April 17, 2006

An ancient fish with primitive fingers fills an evolutionary gap and shows Darwin's theory in action

The V-shaped bone turned out to be the lower jaw of a fish, but not any fish Neil Shubin had ever seen. The University of Chicago paleontologist had been chipping his way through an ancient rock formation in an icy drizzle near Bird Fjord on Canada's Ellesmere Island last July when one of his colleagues pointed to a wall of red siltstone and exclaimed, "What's that?"

That, as Shubin and his colleagues reported last week in a pair of articles in *Nature,* was part of a creature that grew to at least 2.75 m in length and lived some 375 million years ago, just at the point in evolutionary history when fish were giving rise to the four-legged animals known as tetrapods. And indeed, the creature was a little of each, for along with a fish's scales, fangs and gills, it had anatomical features usually found only in animals that spend at least some of their time on land. It is, in short, exactly the sort of transitional animal Darwinian theory predicts, with new physical traits gradually emerging to help it thrive in a novel environment. And it has become scientists' Exhibit A in their long-running debate with creationists and other anti-evolutionists who have been using the lack of such missing-link organisms to argue that Darwin's theory is wrong.



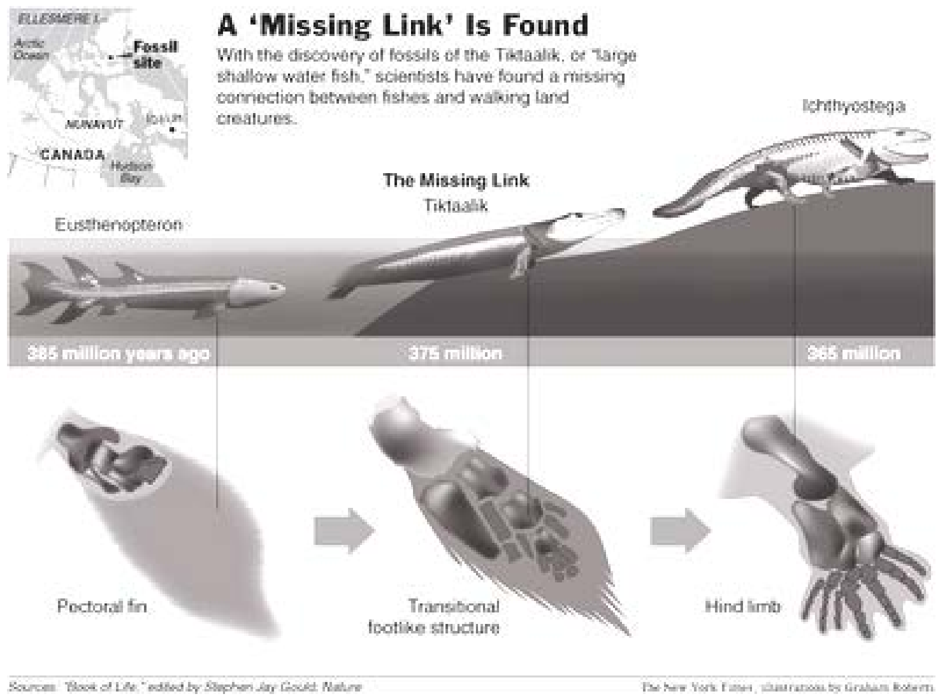
Before Tiktaalik – Lobe finned fish had forelimbs suitable for moving in water but not on land

Tiktaalik – The forelimbs had the beginnings of fingers

After Tiktaalik – Tetrapod forelimbs have wrists and digits used

It will be hard to explain away the "fishapod" as Shubin and his team nicknamed their find. Unlike a true fish, it had a broad skull, a flexible neck, and eyes mounted on the top of its head like a crocodile. It also had a big, interlocking rib cage, suggesting that it had lungs and did at least part of its breathing through them, as well as a trunk strong enough to support itself in the shallows or on land. And most startling of all, when technicians dissected its pectoral fins, they found the beginnings of a tetrapod hand, complete with a primitive version of a wrist and five fingerlike bones. "This is not some archaic branch of the animal kingdom, says Shubin. "This is our branch. You're looking at your great-great-great-great cousin!"

What really fascinates scientists about the fishapod is that it fits so neatly into one of the most exciting chapters in the history of life-when creatures that swam in seas and rivers gave rise to things that walked, ran and crept on land. The fishapod appears to be a crucial link in the long chain that over time led to amphibians, reptiles, dinosaurs, birds and mammals. Indeed, *Tiktaalik roseae,* the official name bestowed on the fishapod (in the language of the local Inuit, *tiktaalik* means "large fish in stream"), falls anatomically between the lobe-finned fish *Panderichthys,* found in Latvia in the 1920s, and primitive tetrapods like *Acanthostega,* whose full fossil was recovered in Greenland not quite two decades ago.



Together, these fossils have, overturned the old picture of the fish-tetrapod transition, which conjured up the image of creatures like the modern lungfish crawling out of water onto land. That picture certainly didn't fit *Acanthostega,* whose short, flimsy legs were ill equipped for terrestrial locomotion. Rather, according to University of Cambridge paleontologist Jennifer Clack, *Acanthostega* was an aquatic creature that used its limbs and lungs to make a living in water. And that scenario makes sense because it sets up conditions for natural selection-the force that powers evolution-to favor transitional life forms like the fishapod, with its funny wrist and five digits encased in the webbing of a fin.

On land, observes Shubin's collaborator Ted Daeschler, chair of vertebrate zoology at Philadelphia's Academy of Natural Sciences, such an appendage would have been worse than useless. But it would have been more than adequate for propping the animal's head above the water so that it could survey its surroundings or for anchoring it underwater as it waited to ambush its prey. The advantage of being able to gulp air through lungs as well as gills would likewise have been immediate, given that the fishapod made its home in warm, shallow waters that were frequently rendered inhospitable by decaying vegetation.

The fishapod was among the pioneering organisms to take advantage of an ecological frontier – the marshy floodplains of large rivers-that opened between 410 million and 356 million years ago during the Devonian period, known as the Age of Fishes. Early in the Devonian, the continents were mostly masses of bare rock with just a fringe of plants "no taller than your ankle" as Daeschler puts it, growing along the wet margins of rivers and streams. By the late Devonian, however, thick vegetation had taken hold in marshes, fens and floodplains, and mosses, ferns and trees had co-alesced into the world's first forests.

Those archaic plants prepared the way for the tetrapods. The plants created new aquatic habitats by stabilizing the banks of rivers and streams. They pumped oxygen into the atmosphere, making the earth habitable for large, air-breathing creatures. And they shed organic debris that formed the basis of a new food chain. Bacteria, fungi and small arthropods (the animal group that includes crustaceans and insects) moved in to feed on the debris; small fish moved in to eat the arthropods; bigger fish moved in to eat the small fish. Among them were the fishapod's lobe-finned ancestors, which found in the vegetation-clogged shallows abundant food and relative safety from predators.

Because characteristics like limb development are governed by powerful families of genes known as Hox genes, the fishapod's curious mix of features intrigues developmental biologists as much as it does paleontologists. Recent experiments on mice by University of Geneva geneticist Denis Duboule and his colleagues, for example, show that Hox genes control limb development in two stages. "Even though the same genes are involved;" says Duboule, "separate processes govern the development of arms and legs and the development of hands and feet."

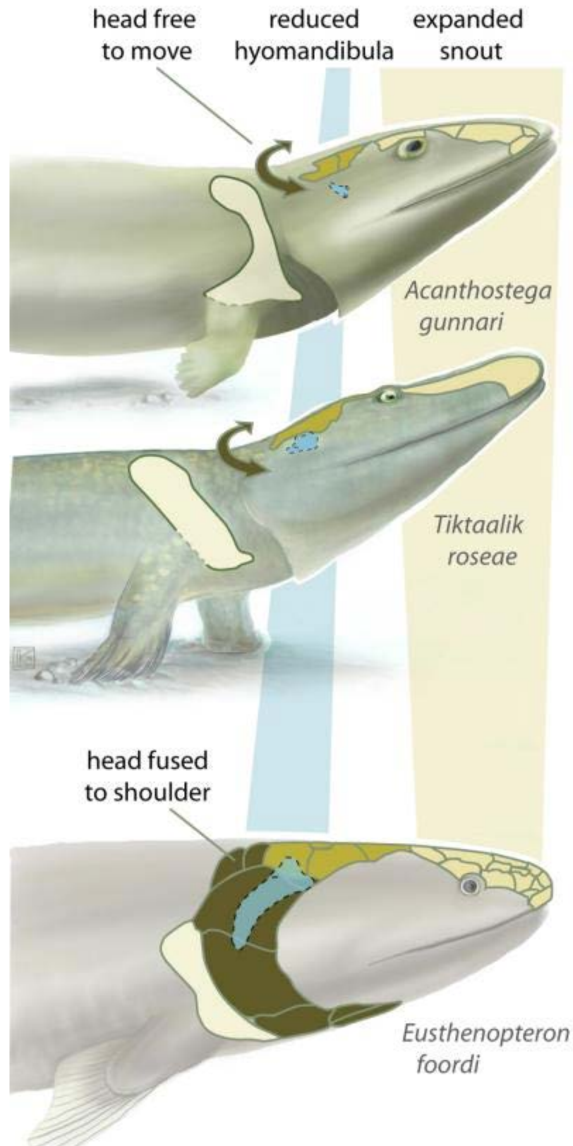
It all depends on how and when the genes are turned on by a segment of DNA that acts like a switch. Fish have a version of that switch too. For example, Zebrafish (ray-finned fish that split off from the lineage that led to lobe-fins early in the Devonian) have only part of the sequence, whereas coelacanths (lobe-fins closely related to lungfish) have a lot more of it. And the fishapod, presumably, had even more.

None of that comes as a surprise to most biologists. Even the scientists who invoke "intelligent design" to explain life's diversity concede that transitional creatures have been showing up in the fossil record for quite some time. "The argument that there are no transitional forms," says Kenneth Miller, a Brown University biologist and staunch defender of evolution, "has been untenable for at least two decades.'

But the lack of missing links is still part of the antievolution rhetoric circulating on the Internet. "Some people will never be convinced," says paleontologist Michael Novacek, provost of science at the American Museum of Natural History in New York City. "But discoveries like this are valuable because there are people who are still undecided about evolution. This gives us an opportunity to educate them." And if not with this discovery, then maybe with the next one. "The fishapod," says Miller, "is one more piece of a rapidly filling jigsaw puzzle. And every couple of years we put another important piece in place."

Darwin Would Have Loved It – Taken from TIME Magazine, April 17, 2006

What his theory predicted – and why it matters



They were once regared as deceptions planted by evil spirits, but fossils eventually came to be recognized as Exhibits A, B and C of the history of life. Those stony specimens are the only direct evidence of what happened in the eons since the first rudimentary cells emerged on Earth some 3.6 billion years ago.

Unfortunately, the fossil record is incomplete, as Charles Darwin himself realized. He surely would have been delighted to see the riveting discoveries made by paleon-tologists in the subsequent century and a half. These new fossils eloquently reinforce his conviction that "endless forms most beautiful and most wonderful have been, and are being, evolved." The iconic winged *Archaeopteryx,* as well as newly described feathered fossils from China, show the transition from dinosaurs to their only living descendants, birds. Fossil whales with limbs demonstrate the evolutionary steps some mammals took to return to the sea.

Now there is new and powerful evidence in *Tiktaalik* for the steps that backboned animals took to crawl out of the sea in the first place. Many who reject evolution in favor of divine creation claim that the fossil record doesn't contain the so-called transitional species anticipated by Darwin's theory. This ancient, walking fish is yet more evidence that such an argument is simply wrong; all sorts of missing links pre-served in exquisite detail have been and will be discovered.

Is the discovery of *Tiktaalik a* pivotal moment that profoundly shifts the balance in the tension between those who accept evolution and those who question it? Probably not. Those who regard creationism as dogma will probably remain unmoved by any manner of scientific evidence. For those who are uncertain, however, the fishapod may be a source of enlightenment, a demonstration that we can recover ancient clues to events clearly predicted by the theory of evolution.

That theory is the framework for all modern biology, from the study of fossils to the mapping of the genome, but it is also profoundly practical in application. Scientists are debating the likelihood and timing of a horrific pandemic caused by avian flu. Those who worry about that possibility and reject evolution live in a world of contradiction. If the H5N1 virus, the infective agent for avian flu, adopts a new lifestyle and moves directly from one human host to another, it would be because it evolved that capacity.

Indeed, evolutionary theory shapes both our health and our future. As Darwin noted, the survival of each species depends on how well it fits into changing environments. We know that ecosystems are changing on a global scale. As documented by the fossil record, some species in the past thrived under new conditions, while others, ill adapted to change, went extinct. Who will be the winners in the hot, deforested, carbon dioxide enveloped world of the future? It won't necessarily be us.

Questions about the "Canadian Fishapod"

1. Where was the fossil found?
2. How old is the fossil?
3. Where do you think the name "fishapod" came from? Why was it called that?
4. What are the fish-like characteristics of this fossil?
5. What are the non-fish-like characteristics of this fossil?
6. There are 2 main categories of bony fish: ray finned and lobe finned. What is inside the lobe and why might it be an advantage for land living?