Jaw first emerged for breathing

By Jon Mallatt, WSU researcher

PULLMAN, Wash. - The main significance of our paper is what a remarkable, three-dimensionally preserved fossil fish head from 325 million years ago tells about evolution. It belongs to the most primitive of the non-bony “cartilage” fishes and is related to today’s sharks. However, it has a gill skeleton like that of the bony fishes, such as trout, sturgeons, gar fish and perch.

This helps us to reconstruct the very first jawed fish, which must have existed earlier than the cartilage- and bony fishes, but for which we have no fossil evidence. That is, the first jawed fish from perhaps 400 million years ago must have been somewhat less like a shark and more like a bony fish than scientists had thought, when they previously had used today’s living fish to reconstruct this ancestor. Only fossils could reveal this surprising new fact about our ancient forefathers, as my collaborators Alan Pradel and John Maisey have emphasized.

My contribution, on the other hand, was to decide what this fossil “shark” tells about the origin and evolution of jaws in the vertebrate animals (fish). The first fish had no jaws and were probably filter feeders, but the appearance of these mouth parts, for biting and grasping prey animals, was revolutionary. It let the early jawed vertebrates become predators high in the food chain of the ancient oceans, rivers, and lakes and eventually on land.

Jaws led to many different ways of obtaining and processing food, including slicing, chewing, crushing and even to all kinds of plant-eating by herbivores. Jaws helped the vertebrates to diversify into the many kinds of fishes, amphibians, reptiles, birds and mammals, and to become one of the most successful animal groups, producing earth’s largest animals (whales, elephants, dinosaurs), as well as humans. Without this evolutionary leap, we would not be here.

My theory of jaw evolution, which I developed in the 1990s, was built on a “classical” idea from the 1870s, a time not long after scientists first started thinking about evolution and how animals evolved. The classical idea was that the jaw originally was the first in a series of five or six gill bars, then it became specialized for biting for feeding. This idea arose because the jaw, although larger, resembles the gill bars in certain ways.

Opponents of this idea, however, say that no known jawed fish has a jaw that exactly resembles a gill bar or supports a gill (only a gill-like “false gill”). Yet the jaw of the new shark fossil resembles the gill bars behind it more closely than in any fish ever discovered.

Gill bars support gills for ventilation (the fish's version of breathing), and my own modification of the classical idea was that the jaw enlarged from a gill arch as a breathing structure, not originally as an eating structure. I proposed that this early "breathing jaw" flexed like a closing jackknife to shut the mouth whenever the ancestral fish exhaled, so that the breathing water would only leave through the gill pores and not regurgitate out through the mouth.

Soon this big jaw was used to grasp and hold prey animals while forcefully closing the mouth, so it had changed to a feeding jaw. The resemblance of the jaw to an enlarged gill bar in this newly discovered shark fossil supports my theory.

My ventilatory theory of the origin of jaws, along with the new shark fossil, tells how our hyperactive, heavy-breathing fish ancestors went from harmless filter feeders that could quickly outswim vicious sea scorpions and rapacious proto-squids, to become fast, top predators of the oceans by 400-300 million years ago.