Your Inner Fish … An engaging look at our vertebrate ancestry

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"Your Inner Fish" is a three-part series currently being aired on Public Television (10 pm EST). Narrated by fish paleontologist Neil Shubin and based on his book of the same name, the program explores the evolution of the vertebrate body structure, and how the anatomy of the human body expresses this lineage; first from ancient fish, then extinct reptiles and finally mammals.

The final episode, subtitled "Your Inner Monkey," will air next Wednesday and will no doubt detail and explain the obvious anatomical commonalities between monkeys, apes and humans. With recent developments in comparative genomics, the study of the evolution of life chronicled in every organism's DNA has triggered a revolution in how we classify organisms. In fact, there are scientists who believe some terms that are now perceived as archaic or colloquial, such a "pongid" (a term denoting the great apes) and even "reptile" and Class Aves (birds) need to be replaced in favor of a more scientifically grounded taxonomy.

Shubin is an important figure in this movement. In 2004, he led a team of researchers who uncovered on Canada's Ellesmere Island an amazing trove of extinct sarcopterygians (lobe-finned fish) that were clearly transitional in the evolution of the first tetrapods, four-limbed land vertebrates. The fossil, dubbed *Tiktaalik* in the Inuit tongue, created a sensation. An essential link in the transition from fish to amphibian had been discovered. Shubin declares, "Here was an animal Darwin had predicted."

Presently, Shubin is the Chairman of the Anatomy Department at the University of Chicago, and teaches anatomy to prospective physicians. He quipped that when these medical students discovered that he was not a "real" doctor, they reacted adversely at first, but have since learned that being a "fish paleontologist is a powerful way to teach human anatomy."

In his *On the Origin of Species* published in 1859, Charles Darwin posited the common ancestry of all life, traceable down through the eons of geological time. Darwin's theory of evolution through natural selection became the theoretical foundation of all biology, which would have otherwise remained a disparate science devoid of cohesion.

During the course of the 20th century, Darwin's brilliant work was enhanced by the emerging sciences of genetics and molecular biology, which, in concert with continuing developments in the fields of comparative anatomy, embryology and paleontology, have resulted in what has become known as the "great synthesis" or the "synthetic theory of evolution."

Shubin draws upon all these areas of research in his serious yet light-hearted appreciation of our evolutionary heritage. It is amusing to see Shubin's evolutionary day-dreaming come to life on the Chicago El, as one of the passengers sprouts a hairy tail, another a scaly integument and a projecting tongue, while strange long-extinct tetrapods amble down the aisle.

In fact, our fish ancestry is undeniable. They were the first vertebrates to have a bony skeleton, the first to have their brains encased within a protective cranium. Thus we, that is human beings, can be considered part of the craniate clade. Cladistics is a method of classifying organisms that shows evolutionary lineages according to the appearance of derived traits.

Bony fish or Class Osteichthyes are the first vertebrate group to have evolved two pairs of ventral (underneath) fins. In one group of these fish, their fins evolved into muscular lobes that increasingly served a walking function, perhaps first along the shallow tidal flats, but later, as bony reinforcements appeared to strengthen these fins by establishing new points of connection for the muscles, becoming true limbs for walking on land.

Shubin points out that all tetrapods have limbs that are homologous, that is, they share a common evolutionary history. Our limbs have this common pattern, which can be expressed as "one – two – many – fingers." For example, the formula for the bones of our upper limb would be, starting from the uppermost bone, "one (humerus) – two (radius and ulna) – many (carpals) – fingers (digits). We share this pattern, albeit with specializations (hooves, wings, etc.) that later evolved based on various lifestyles, with frogs, crocodiles, dinosaurs, birds and dogs.

Shubin then turns to comparative embryology. Any student who has taken biology is likely to have encountered the chart comparing the developmental stages of a fish, frog, chicken, rabbit and human embryo, marveling at the commonalities. In the early stages of a human embryo's development there are clearly present pharyngeal pouches (gill slits) and a tail. The early limb buds of the human embryo look more like paddles or fins before they later assume a more recognizable form.

Internally, male and female sex organs first begin forming in a very unlikely position; anteriorly (forward) adjacent to the heart, as in fish, only to migrate further back as the embryo matures. The digestive system in an early human embryo is also a fish-like tube, only later assuming the convoluted character of our extensive digestive apparatus. Shubin quips, "We are jerry-rigged fish!"

I was somewhat disappointed that Shubin's excellent exposition of comparative embryology did not mention its brilliant nineteenth

century anticipation in the work of the great German biologist Ernst Haeckel. Haeckel was one of the foremost evolutionary biologists of his time. He is perhaps best known for his elaboration of what he called the "Biogenetic Law," in which he posited the idea that "ontogeny recapitulates phylogeny," that in the embryonic development of a species one can observe its evolutionary history. Nevertheless, this is a minor weakness, and Shubin presents a compelling case for our evolutionary history.

He then turns to a discussion of the genetic component of the tetrapod limb's extraordinary homology in its evolution. The specific gene, named *Hedgehog*, is, in fact, found in all limbed animals (even insects!), not just in vertebrates. Shubin explains its significance, noting that scientists have for a long time been able to manipulate the timing and appearance of limb structures in chicken embryos even before the genetic mechanism was understood. What has been discovered is "the very basic patterning mechanism forming the same structures."

In part two of the series, "Your Inner Reptile," Shubin explains that many of the characteristics that we take for granted—the presence of skin, hair, teeth and hearing—can be traced to ancient reptiles. However, the basic reptilian line diverged early following the evolution of one of the most important tetrapod innovations, the amniotic egg.

Shubin explains that "375 million years ago life took a critical turn." With the ability to lay an egg with a fluid-surrounded embryo encased in a protective shell, land vertebrates could now begin an adaptive radiation, and occupy virtually all the inhabitable ecological niches on land.

Moreover, Shubin points out that "egg-laying history is written in our genes" and, as it turns out, in our embryology. The human genome contains non-functioning genes that produce yolk protein and a vestigial yolk sac that appears and then vanishes early in our embryonic development.

The divergence of the original amniotes into two distinct groups, the diapsids and synapsids, represented a sea-change in tetrapod evolution. The diapsids, so named because of the presence of two openings at the temporal region of the skull, gave rise to lizards, snakes, dinosaurs and birds. The synapsids, having one temporal opening, gave rise to the bizarre Pelycosaurs—the classic dorsal-sailed Dimetrodon is perhaps the most familiar—and the "mammal-like" reptiles (Therapsids) and true mammals.

Shubin focuses his attention of the synapsids. It was in this group that two of the most important evolutionary developments occurred, the first being the appearance of differentiated teeth with cusped molars that enabled more efficient intake of nutrients by allowing, for the first time, the chewing or mastication of food.

The second innovation involved the evolution of a more acute auditory sense centered on the reduction and migration of two primitive jawbones to form two of the tiny bones of the middle ear of mammals, the incus (anvil) and maleus (hammer). These bones joined the stapes (stirrup), which had, more than one hundred million years earlier, evolved into part of the early tetrapod's hearing apparatus from a bone in the jaws of extinct fish. It should be noted parenthetically that reptiles and birds have only one middle ear bone.

Shubin focuses on the fossil record to show the transition from reptile to mammal. He shows us the complete skull of a Gorgonopsid, a late therapsid from the Permian era, some 270 million years ago. It is a remarkable skull, exhibiting massive canines like a modern carnivore as well as incisors. Clearly it had differentiated teeth, while at the same time showing primitive characteristics like its small brain and extra jawbones.

These animals mostly vanished during the "Great Dying," the mass extinction at the end of the Permian that according to scientists eliminated 80% of all living things on the planet. Enough of the smaller, perhaps burrowing species of these animals survived, however, to evolve into the first mammals, exhibiting another new evolutionary feature—hair.

It is unfortunate that "Your Inner Fish," "Your Inner Reptile," and "Your Inner Monkey" are being aired so late in the evening. Could it be that those who organize the network's programming are being overly sensitive to a possible reaction among creationists to such a clear exposition of the truth of human evolution?

Shubin doesn't bother to answer the creationists, not that he needs to. In his book he echoes Darwin's famous concluding quote from *On the Origin of Species* that begins, "There is a grandeur to this view of life." Shubin writes; "Knowing something about the deep origins of humanity only adds to the remarkable fact of our existence: all our extraordinary capabilities arose from basic components that evolved in ancient fish and other creatures. From common parts came a very unique construction. We are not separate from the rest of the living world; we are a part of it down to our bones."

I urge all readers of the World Socialist Web Site to view the final episode of "Your Inner Fish," subtitled "Your Inner Monkey," this Wednesday night.