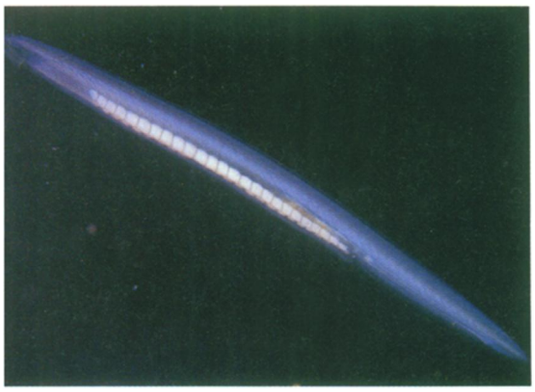
Vertebrates' Cousin Shares Key Genes



M. Dale Stokes/Scripps

Male adult amphioxus (1.5 inches long) from the sands of Tampa Bay, Fla.

Whether a scientist or a romantic, one cannot help but marvel at the incredible diversity of Earth's organisms. Worms seem nothing like elephants; eagles bear little resemblance to octopuses. Yet research reported this week reveals how nature improvises with certain genetic material, called homeobox (hox) genes, to create this variety.

The number and locations of hox genes and their DNA sequences in a wormlike, seemingly headless creature called amphioxus place this animal as a missing link — genetically speaking — between animals with backbones and animals without. Furthermore, the genetic makeup of amphioxus indicates that multiple copies of hox genes and of sets of these genes may drive the evolution of ever more complex animals, says Peter W.H. Holland of the University of Reading in England.

For more than a century, biologists have debated the status of amphioxus as a close relative of vertebrates, basing their arguments on morphological and biochemical studies. While at the University of Oxford in England, Jordi Garcia-Fernández and Peter Holland joined in by tracking down this animal's hox genes. They first found nine hoxlike DNA fragments by using a technique called polymerase chain reaction. Further screening revealed one more, for 10 in all, they report in the Aug. 18 NATURE.

The protein products of hox genes control the activation of other genes, ensuring that various body parts develop in the appropriate places. "These are the blueprint genes," explains Nicholas D. Holland, a zoologist at the Scripps Institution of Oceanography in La Jolla, Calif.

In cells, genes belonging to one chromosome are strung like beads on a necklace, often with other bits of DNA interspersed. In nematodes, a single chromosomal necklace contains all the hox genes. In all the animals now studied, the order of the beads reflects the order in which each gene is expressed along the developing embryo's head-to-tail axis; however, mammals and other vertebrates possess four such chromosomes, each with its own set of hox genes.

To determine whether the amphioxus hox genes lay on one chromosome, Garcia-Fernández carried out a "chromosome walk," a tedious analytical technique for determining the order and position of genes. He and Peter Holland found that, indeed, these genes do cluster. Also, surprisingly, the DNA sequences of these 10 matched closely the sequences of mammalian hox genes, even though the lineages of vertebrates and amphioxus separated 520 million years ago, says Garcia-Fernández, now at the University of Barcelona in Spain. Because mammalian clusters can contain 13 hox genes, the two scientists hope to find three more in amphioxus.

Like nematodes, amphioxus uses a single set of hox genes. But unlike fellow invertebrates' genes, amphioxus' set closely resembles those of vertebrates, says Peter Holland.

The DNA of the modern-day amphioxus does in fact reflect the makeup of the invertebrate ancestor of all vertebrates, comments John W. Pendleton, a molecular biologist at the Oregon Regional Primate Research Center in Beaverton. As a result, "I think the status of amphioxus as an archetypal primitive chordate [an animal possessing a primitive spinal cord and neural tube at some point during its development] will be more accepted," he adds.

In mammals, the hox genes at each position in each of the four sets resemble those at comparable positions in the other sets, suggesting that the multiple sets arose as duplicates of the original, Peter Holland explains. Fish, birds, amphibians, and other vertebrates also have multiple sets. He wonders whether other groups of genes have expanded similarly in vertebrates. Moreover, some hox genes seen in amphioxus look as if they arose first as duplicates of other hox genes.

Thus this discovery in amphioxus indicates that the evolution of more complex organisms proceeded in parallel with the increasing complexity of hox genes. "The idea is that by gene duplication, you could suddenly make really major steps in evolution," Nicholas Holland explains.

Hox genes in particular increase the flexibility of the developmental process. "And development is the currency of evolution," says Pendleton.

"If you fiddle around with genes at [the hox] level, there are all sorts of opportunities for massive and very rapid advances," Nicholas Holland adds.

— E. Pennisi

Large meteorite scar identified in Virginia

If geologist C. Wylie Poag is correct, the Chesapeake Bay owes its existence to an ancient splash.

The U.S. Geological Survey (USGS) researcher from Woods Hole, Mass., and his colleagues have uncovered evidence that a large buried crater underlies the southern section of the bay. According to their theory, a meteorite impact in this spot 35 million years ago determined subsequent river flow in the mid-Atlantic region, causing them to drain toward the present position of the bay.

Poag first uncovered signs of the crash several years ago while studying rock samples pulled up from drilling operations in southern Virginia. The drill cores revealed an unusual layer of jumbled sediments and boulders, called breccias, from the late Eocene period.

Because he was studying a meteorite crater of the same age located off the coast of New Jersey (SN: 11/14/92, p.334), Poag reasoned that the Virginia breccias formed during a tsunami triggered by the same offshore impact. In the late Eocene, eastern Virginia would have been underwater, with the coastline sitting more than 100 kilometers to the west.

Poag changed his mind after examining the results of seismic studies that imaged the rocks beneath the Chesapeake Bay. Oil companies had collected such information by sending seismic waves down into Earth and measuring the vibrations that reflect off buried structures.

These seismic reflection studies revealed a pattern of faults that form concentric circles, similar to a well-known impact crater in Germany, report Poag and his colleagues in the August GEOLOGY. "This shows clearly that there is a large impact crater in the southern part of the Chesapeake Bay," says Poag, who titled his paper "Meteoroid mayhem in Ole Virginny."

Judging from the span of the rings, the USGS geologists calculate that the crater measures 85 kilometers across, filling an area larger than Rhode Island. A structure this size would rank as the largest crater in the United States and among the top 10 known on Earth.

It might also explain a puzzling triangle of impact debris stretching from New Jersey to Texas to Barbados. Within this