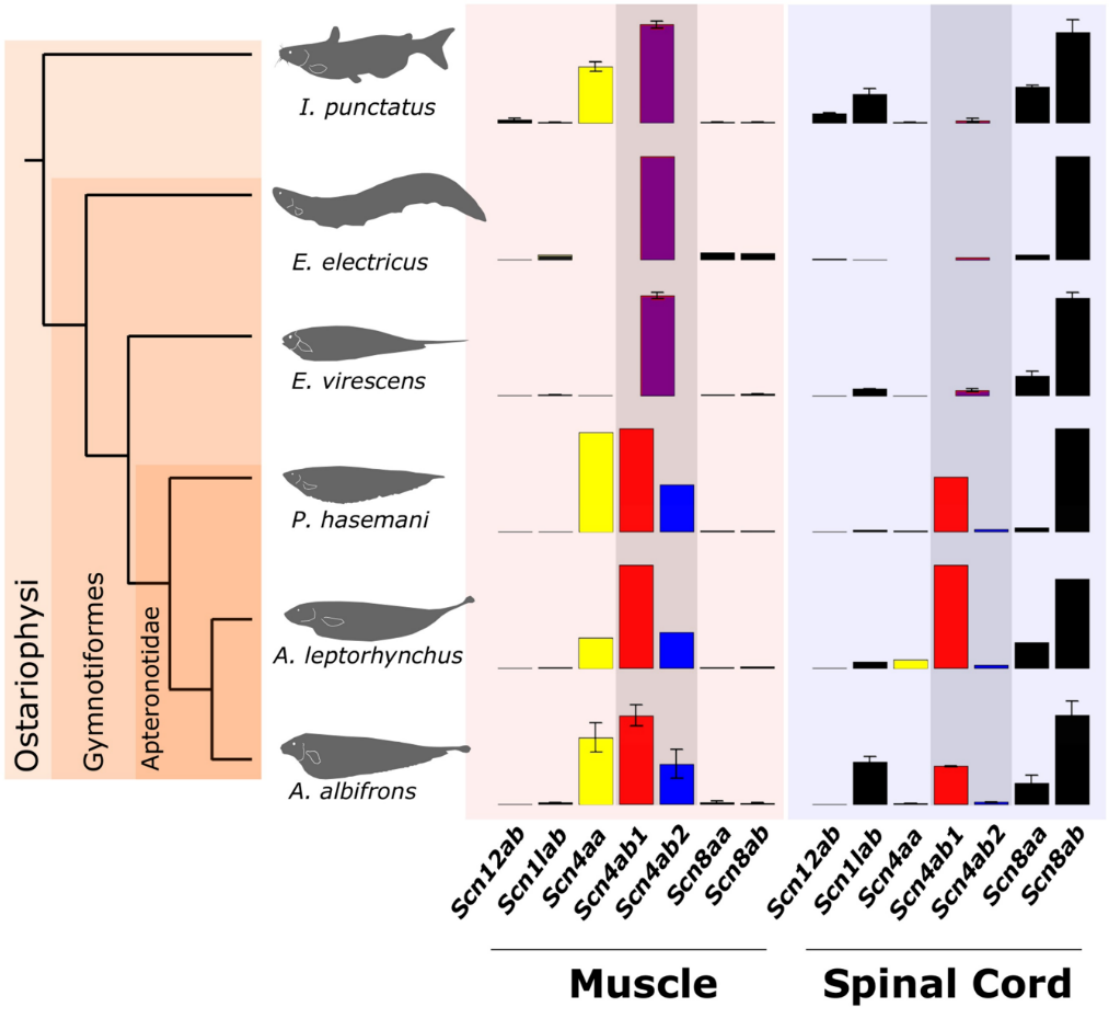

Caption: *The phylogenetic tree on the left shows the evolutionary relationships among three types of fish: nonelectric fish (*I. punctatus*), electric fish with electric organs derived from muscle tissue (*E. electricus*,* E. virescens*), and electric fish with electric organs derived from spinal neurons (*P. hasemani*,* A. leptorhynchus*,* A. albifrons*). The graphs on the right show each species' expression of different voltage-gated sodium channel genes. Gene expression was measured in both muscle tissue and the spinal cord; error bars represent one standard deviation from the mean (n = 3). The genes represented by black bars are* scn12ab*,* scn1lab*,* scn8aa*, and* scn8ab*. The genes represented by colored bars, which are all derived from a gene called* scn4a*, are* scn4aa *(yellow),* scn4ab *(purple),* scn4ab1 *(red), and* scn4ab2 *(blue).*

OBSERVATIONS, NOTES & QUESTIONS

BACKGROUND INFORMATION	BIG IDEAS, NOTES & QUESTIONS
All animals, including humans, have cells that generate electrical signals called action potentials. Action potentials are used by neurons (nerve cells), muscle cells, and other cells for communication and intracellular signaling. Fast pulses or waves of action potentials can be produced by certain types of fish, called electric fish. These fish use the resulting electrical signals for a variety of functions, including navigating their environments and communicating with other electric fish. A few kinds of electric fish, such as electric eels, can even generate electricity that is powerful enough to defend against predators or stun prey. Electric fish produce electrical signals via a specialized organ called the electric organ, which is derived from cells that can generate action potentials. In most electric fish, the electric organ is derived from muscle tissue. In one group of electric fish, the Apteronotids, or ghost knifefishes, the electric organ is derived from spinal neurons instead. Voltage-gated sodium channels, which control the flow of sodium ions in and out of cells, are a group of proteins that play an important role in generating action potentials. Muscle cells, neurons, and electric organs all use sodium channel proteins to generate action potentials. However, electric organs can generate action potentials much faster than normal muscle cells and neurons can. The electric organs of the Apteronotids in particular can generate sustained electrical signals up to 1,800 Hz (oscillations per second), faster than those of the neurons found in any other organisms. How do electric organs generate such fast action potentials? This ability may have evolved through the duplication and mutation of certain sodium channel genes. When genes are duplicated, one copy can maintain the function of the original gene, while the other copy can mutate freely. Over millions of years, sodium channel genes have been duplicated many times to generate a family of genes that are closely related. Electric fish have multiple sodium channel genes derived from a gene called *scn4a*, which is usually expressed in the muscles of vertebrates. Early in the evolution of fish, *scn4a* was duplicated into two different genes, *scn4aa* and *scn4ab*. In the Apteronotids, *scn4ab* was further duplicated into two more genes, *scn4ab1* and *scn4ab2*. Over time, some of these genes accumulated mutations that led to new functions. Scientists investigated how changes in these sodium channel genes may have contributed to the evolution of electric organs in electric fish. The scientists measured the expression of several sodium channel genes, including the *scn4a*-derived genes, in three groups of fish. The first group was fish with electric organs derived from spinal neurons. This group was represented by three Apteronotid species: *P. hasemani, A. leptorhynchus,* and *A. albifrons*. The second group was fish with electric organs derived from muscle tissue. This group was represented by two species: the electric eel *E. electricus* and the glass knifefish *E. virescens*. The third and final group was nonelectric fish, which was represented by one species: the channel catfish *I. punctatus*.	