Computational talents of medical leech provide answers to touchy question

March 2, 1998

Media Contact: Warren R. Froelich, (619) 534-8564, wfroelic@ucsd.edu

COMPUTATIONAL TALENTS OF MEDICAL LEECH PROVIDE ANSWERS TO TOUCHY QUESTION

Despite its unsavory reputation as a bloodsucker, the medical leech is starting to pay big dividends to those interested in how the nervous system performs intricate calculations in response to a stimulus.

In new studies, biologists at the University of California, San Diego have uncovered the complete picture of the neural coding used by the leech as it bends after being touched.

According to these studies, in analyzing which way to bend, the leech applies a formula that represents the basis for the coordinate system used in analytical geometry, revealed in the 16th Century by the French philosopher and mathematician Rene Descartes.

The results not only show that the leech is hundreds of millions of years ahead of Descartes, they also offer the first detailed understanding of how information is processed for a simple behavior, from sensory input to motor response. It's likely to offer insights into touching and other more complex behaviors in higher organisms as well, and potentially what happens when these networks go awry.

"It's an article of faith that the way nervous systems are hooked up to produce behaviors would be the same from one species to another," said William Kristan, a professor of biology at UCSD and co-author, with former UCSD biologist John Lewis, of the new studies. "It's very encouraging, then, that the nerve-cell circuitry we found in the leech was first proposed as a way that monkeys move their arms. Our work allows someone else to ask if what we've found in leeches is true for other systems."

Though the therapeutic excesses of the medicinal leech have generally soiled its reputation, in recent years scientists have learned the creature (scientific name, Hirudo medicinalis) is a natural for studying how nerve cells are connected and how they communicate with one another.

It's been long recognized, for example, that the medicinal leech has large and unusually accessible nerve cells that make them easy to study and probe. Not only are they large, they also are few in number, with each leech housing about 10,000 neurons (compared to about 10 billion in our nervous system). The animal is divided into 32 body segments, with its central nervous system consisting of 32 neuronal bundles, or ganglia, tied together by connective nerves.

Despite their simplicity, the leech does many of the complicated things that other animals do, including crawling, swimming and bending.

"It's big enough to give complicated behaviors, yet small enough that we can track down every cell," said Kristan.

The focus of the UCSD studies, published in recent issues of Nature and The Journal of Neuroscience, is on what's technically called the "leech local bend." Thus, if you touch a leech, it bends at the diametrically opposite point from the touch stimulus.

During the past decade, Kristan and two graduate students, Shawn Lockery (now a faculty member at the University of Oregon) and Lewis (now a postdoctoral fellow at the University of Ottawa), tracked down the neural circuitry that controls bending in the leech. In essence, this network consists of three layers of neurons through which messages are passed back and forth. It includes four sensory neurons on the surface, 10 kinds of motor neurons that control muscle, and a switchboard of about two dozen or more interneurons that's sandwiched between the other two layers.

For their latest work, the UCSD biologists sought to measure sensory activity in this network in response to touch. Four sites, corresponding to mid-regions innervated by the four pressure-sensing nerve cells on the leech's surface, generated the strongest responses. When straight lines are connected to each of these points, they form perpendicular lines similar to those used in the Cartesian coordinate system.

Touching the areas in between these four locations produced a bend centered on the touched, intermediate location, with only a small margin of error. This result shows that the leech takes full advantage of its built-in coordinate system.

Finally, Lewis and Kristan demonstrated how this bending behavior in leeches is calculated. In essence, the activity requires the combined input of the entire neural network, with each member of the network contributing to the final result, the bend.

It's what the neuroscientists refer to as a "population code."

"You could say the system is the ultimate (complete democracy), with everybody having a vote in which direction to take," explained Kristan. "In the end, you let everybody pull in the direction they choose and whichever direction has the strongest pull, that's the way they go."

(March 2, 1998)