Using simple nervous systems to investigate the neural basis of behavior

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The human brain is remarkable, both in the sense that it helps us with a lifetime of decisions and memories, but also that it allows us to contemplate how the brain itself works. One concludes, however, pretty quickly that the human brain is quite complicated. The brain has an estimated 10^{11} neurons, and more than a thousand times more connections. How these neurons and connections work together in systems is a grand challenge in the neurosciences.

Fortunately, we can use organisms with simpler nervous systems to understand basic principles of nervous system function. For example, the first insights into the generation of nerve cell action potentials were determined in a squid giant neuron. Principles derived from these neurons are incorporated into most or all computational models used today. Thus, one expects lessons learned in simpler nervous systems to have application in more complex organisms, including humans.

A successful approach in understanding nervous system function is to examine the role that different neural systems play in regulating behavior. Broadly speaking these include processes that support sensory encoding, motor activity, and multisensory and sensory-motor integration.

Animals have developed sensory systems to sense the world around them. Audition and temperature perception are two of a few of the sensory modalities that are critical for communication and detecting ideal environments. Katydid hearing systems solve perceptual problems that are common to all hearing systems, such as the recognition of complex temporal patterns, or the detection of important signals in noisy backgrounds. Remarkably, katydids solve these problems with a sensory system encompassing only few neurons. In other studies, the ability to sense temperatures has been addressed in the fruit fly *Drosophila*. One can differentiate between neural systems important for sensing relatively cool and warm temperatures.

Motor systems are critical for several animal behaviors, from regulating gut activity to locomotion. Studies of nervous system ganglia in the crab and lobster have identified principles of nerve cell interactions and modulation. Furthermore, mechanisms regulating brain circuits that initiate swimming behavior in the lamprey tell us that they are similar in a wide variety of vertebrates. Finally, one can begin to understand cellular mechanisms of nervous system regeneration after spinal cord injury in simpler vertebrates that are able to behaviorally recover following such injuries.

Multisensory and sensory-motor integration provide essential elements for plasticity in the nervous system. The trigeminal system in the lamprey provide a starting point to determine how sensory inputs feed into brain locomotor command systems to initiate behavior. Also, plasticity underlying longer-lived changes in behavior with learning can be addressed in studies of memory formation. In *Drosophila*, several molecular and neural systems underlying multiple forms of memory have been identified, including implications of cAMP / PKA activity and serotonin reinforcement.

Thus, one can use relatively simple organisms, from insects and crustaceans to lamprey, in determining principles of nervous system function. Results at the sensory, motor, and integrative levels are expected to influence our understanding of more complex systems.