Motor learning is an intricate process whose outcome—a smoothly executed backhand, let’s say—is easy to spot. The underlying cell biological changes, however, are much harder to identify, not least because the neuronal circuitry for almost all behaviors is poorly understood. Trying to understand the molecular and cellular changes that underpin behavioral learning, Du Lac and her team focus on a simple type of learning: How does the brain learn to stabilize an image on the retina and use eye movement to compensate for a moving head? This so called vestibulo-ocular reflex, or VOR, needs to be fast. For clear vision, head movements must be compensated for almost immediately; otherwise, our vision would resemble an undecipherable blur. To achieve the necessary speed, the connection involves only three types of neurons: sensory neurons, which detect head movement; motor neurons directing eye muscles to relax or contract; and neurons in the brainstem that link the two.

To glean meaningful information from in vitro physiological measurements taken from individual neurons, scientists need to know where they fit into the in vivo circuitry. However, unlike the clearly defined layers of the cortex—the brain’s powerful central processing unit responsible for higher functions—the brainstem, which controls automatic functions such as breathing and swallowing, resembles a uniform jumble of neurons, making it difficult to even distinguish between different cell types. To overcome that limitation, Du Lac developed a battery of techniques and tools that allows her to manipulate molecular and genetic components of specific neurons within the VOR circuitry. Recently, she and her team identified two classes of neurons within the VOR circuitry: superfast neurons that rely on glutamate or glycine to transmit signals between cells and can sustain firing rates of up to 600 spikes/second, and GABAergic neurons, which are much slower but still faster than any neuron in the cortex. Their findings demonstrate that these microcircuits are tuned for speed while the whole system is tuned for resilience.

Gaining a better understanding of the neurobiological and molecular mechanisms underlying learning might lead to the development of preventive and therapeutic approaches for strokes, learning and movement disorders, as well as balance problems.

For more information, please visit salk.edu/faculty/dulac.html