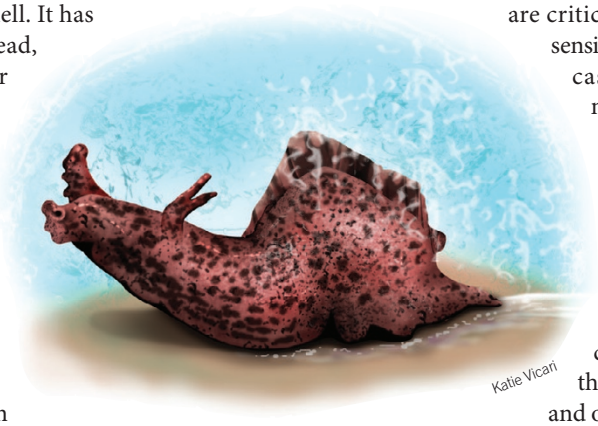
The simplicity of sea slugs

SCIENTIFIC NAME
Aplysia californica

TAXONOMY
PHYLUM: Mollusca
CLASS: Gastropoda
ORDER: Opisthobranchia
FAMILY: Aplysiidae

Physical description

The California brown sea hare, also called a sea slug, is a marine snail that has no external shell. It has two pairs of tentacles on top of the head, one pair near the mouth and the other behind the eyes. The larger anterior tentacles are ear-like and thought to resemble the ears of a hare, giving the creature its name. Its mantle, which covers the gills, has external wing-like extensions, called parapodia, that extend the length of the animal's body up over each side of the back and meet in the center. Sea hares can range from reddish to greenish brown in color, depending on the color of the algae they eat. The herbivorous mollusks tend to be about 20 cm long and 1 kg in weight, though they can grow up to double this size.



History

Aplysia first reached prominence as a research model through the work of neuroscientist Eric Kandel. While studying the cellular underpinnings of learning, Kandel wanted an experimental animal system in which a simple behavior could be modified. Ideally, that behavior should be controlled by only a small number of large and accessible nerve cells, so that the animal's overt behavior could be related to events occurring in the cells that control that behavior. After an extensive search of candidate species, Kandel settled on *Aplysia*, which offered three major advantages: its nervous system was relatively simple, with a small number of cells; the cells are unusually large and accessible, enabling intracellular electrophysiological recording; and many of the cells are individually identifiable[1]. Kandel studied how the gill and siphon withdrawal reflex was modified through a process called habituation, the simplest form of learning, and described the results in a set of papers published in 1970 (refs. 2,3). In his studies of the cells involved in habituation, sensitization and classical conditioning, he found that the efficiency of synapses, the connections between neurons, can be modified, and these changes of synaptic function are central for learning and memory. Kandel was awarded the Nobel Prize in Physiology or Medicine in 2000 for his work.

Research résumé

Researchers continue to explore the chemical underpinnings of memory in *Aplysia*. For instance, it is still not well understood how molecular signaling cascades are temporally and spatially integrated in the neurons that underlie memory processing. Using *Aplysia* as a model system, researchers examined the timing and subcellular location of two signaling molecules, both of which are critical for the formation of memory for sensitization, and found that their signaling cascades coordinate within a single neuron to allow synaptic changes to occur[4]. Another study used *Aplysia* to investigate the processes through which the circadian clock modulates memory formation[5].

Aplysia have been used in other areas of research as well. Sea hares have many defenses, including chemical defenses. When attacked, they secrete two substances, a purple ink and opaline, a whitish liquid that becomes highly viscous upon contact with water. Using spiny lobsters, *Panulirus argus*, as model predators, researchers found that the opaline release by *Aplysia* sticks to the lobsters' antennules, mouthparts and other appendages, physically blocking reception of and response to food odors and allowing *Aplysia* to escape[6].

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2. Pinsker, H., Kupfermann, I., Castellucci, V. & Kandel, E. Habituation and dishabituation of the gill-withdrawal reflex in Aplysia. *Science* **167**, 1740–1742 (1970).
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4. Ye, X., Marina, A. & Carew, T.J. Local synaptic integration of mitogen-activated protein kinase and protein kinase A signaling mediates intermediate-term synaptic facilitation in Aplysia. *Proc. Natl. Acad. Sci. USA* **109**, 18162–18167 (2012).
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6. Love-Chezem, T., Aggio, J.F. & Derby, C.D. Defense through sensory inactivation: sea hare ink reduces sensory and motor responses of spiny lobsters to food odors. *J. Exp. Biol.* **216**, 1364–1372 (2013).