The autonomous arms of the octopus

by Kara Rosania

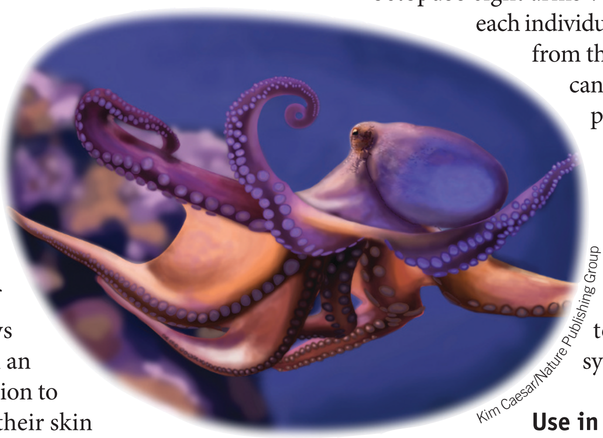
SCIENTIFIC NAME
Octopus vulgaris

TAXONOMY
PHYLUM: Mollusca
CLASS: Cephalopoda
ORDER: Octopoda
FAMILY: Octopodidae

Physical description

The common octopus is a marine, cephalopod mollusk found in the Mediterranean and central Atlantic, preferring to live near the bottom of the ocean[1]. The fearsome creature has a sharp beak, a tongue covered with teeth and a funnel near the side of its head that shoots water. Although they can reach sizes of 2–3 kg, their lack of a skeleton allows them to squeeze their bodies through an opening the size of an orange. In addition to shape-shifting, they can also change their skin color and texture to evade predators, imitate other species or indicate their mood. To do this, they have complex chromatophore organs controlled by their muscles that can translocate pigments and reorient the reflective plates in their skin.

Each of their eight arms contains two rows of suckers, which consist of an upper hollow structure and a disc-like layer of epithelium, connected by a constricted orifice and encircled by a layer of connective tissue[2]. The suckers can taste and feel and are used to grasp, manipulate and investigate objects and to anchor the body to a substrate. To break the hold of the common octopus's suckers requires a quarter ton of force, making the suckers a valuable model for the design of suction cup prototypes. For this purpose, researchers have extensively studied the musculature, sensing properties, surface features, grasping and coordination of octopus suckers[2]. One study found that the grooves that characterize the disc-like portion of a sucker allow it to increase its contact area with the substrate during attachment, distributing low pressure, generated in the hollow structure, to the interface of the two surfaces[2].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Nervous system

Octopuses have the largest nervous systems of any invertebrate, with 500 million neurons distributed throughout the body[3]. Only 40–45 million of these neurons are found in the 40 lobes of the central brain, which surrounds the esophagus. The vertical lobe resembles the vertebrate hippocampus in shape[3] and is thought to underlie similar capabilities as well, including short- and long-term memories, problem-solving skills, discrimination between different shapes and patterns, sensitization, habituation, associative learning and spatial learning. The large optic lobes behind the octopus's eyes are organized into three cortical layers, similar to the vertebrate retina, and contain another 120–180 million neurons[3].

Meanwhile, two-thirds of the neurons (~330 million) are in the octopus's eight arms[3]. This unusual neuronal layout allows each individual arm to act and carry out instructions from the central brain on its own. These arms can use tools, twist off lids and even child-proof caps, withdraw from a noxious stimulus[4] and keep from entangling one another[5]. Many of these feats have been observed in amputated octopus arms, demonstrating how little input from the central brain is needed. Inspired by the octopus, roboticists are working to incorporate decentralized control systems into soft robotic arms[6].

Use in research

The use of octopuses in research has been limited by the ability to maintain the animals in the laboratory. In some ways, octopuses are well-suited to life in captivity, acclimatizing to their aquariums within a few days and often behaving like pets. On the other hand, they have short lifespans, tend to be cannibalistic and have little overlap between generations: both males and females deteriorate and die after breeding.

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4. Hague, T., Florini, M. & Andrews, P.L.R. Preliminary in vitro functional evidence for reflex responses to noxious stimuli in the arms of Octopus vulgaris. *J. Exp. Mar. Biol. Ecol.* **447**, 100–105 (2013).
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