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Long-Term Tracking Reveals that the Upside-Down Jellyfish Has a Sleep-Like State

ABSTRACT:
Long-term behavioral tracking is an invaluable tool for investigating the full diversity of behaviors an animal can perform, especially when applied to understudied, non-traditional model organisms. We looked within the phylum Cnidaria, which diverged from Metazoa prior to the Cambrian explosion. Any shared characteristics between Cnidarians and humans represent deep evolutionary homology as their last common ancestor lived over 600 million years ago. Cnidaria are one of the earliest animal phyla to have evolved neurons, which organize into diffuse nerve nets. Cnidarian jellyfish Cassiopea, commonly known as the upside-down jellyfish, live in shallow waters and pulse for critical functions, e.g., gathering food, eliminating waste, and dispersing gametes. We built a long-term recording and tracking system to quantify the pulsation rate of Cassiopea. In this system we record jellyfish pulsing behavior at 15 fps followed by automated pulse counting based on changes in pixel intensity of the jellyfish in the relaxed vs contracted state. We tracked behavior over several days, with a 12/12 hr light-dark cycle. Remarkably, we found that Cassiopea display three hallmark behaviors of sleep: a reversible quiescent state, rebound after sleep deprivation, and reduced responsiveness to stimuli during the quiescent state. Beyond behavior, we found evidence for molecular conservation in sleep regulation. Melatonin is a known regulator of sleep across animals. We found that jellyfish pulsed less in the presence of melatonin, and resumed normal pulsation when melatonin is removed from the seawater. Sleep is common among vertebrates, and has been found in insects and worms. The discovery of sleep in a Cnidarian shifts the hypothesized root of sleep earlier in the phylogenetic tree, and raises the possibility that sleep is ancestral in the animal lineage. Development and application of tools for interrogating Cassiopea's primitive nervous system (i.e. whole animal imaging and staining) could shed light on the evolution of sleep.