ANIMAL SENTIENCE
AN INTERDISCIPLINARY JOURNAL ON ANIMAL FEELING

Pellis, Sergio M. (2019) The 'Thing' from this world. *Animal Sentience* 26(9)

DOI: 10.51291/2377-7478.1482

The 'Thing' from this world

Commentary on **Mather** on *Octopus Mind*

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Abstract: Science progresses by making contrasts, and the living world is a gold mine of contrasts. Often disciplines become victims by focusing on too narrow a slice of that diversity, leading to a myopic view of how nature works. The relationships between the brain and behavior have been intensively studied in vertebrates, especially mammals, and we have become complacent in our assumptions about how behavior is constructed. As the target article by Mather (2019) shows, the relationship between the brain and behavior in octopuses forces us to reevaluate some of those assumptions.

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1. Introduction. One of my favorite science fiction movies as a teenager was Howard Hawke's 1951 classic 'The Thing from Another World'. What I found intriguing was that the humanoid-looking invader from space was a plant. As the lead scientist states, 'no blood in the arm, no animal tissue at all' and the journalist replies, 'sounds like you are describing some form of super carrot?' What was most unsettling about the 'Thing' was that it overturned my understanding of what it takes to behave like an animal. There are obvious mechanical problems left unresolved by the film in how a carrot can move about without muscles and coordinate its actions without a nervous system. But, decades later, we have come to know that plants have some surprising capabilities in monitoring their surroundings and interacting with the world — including 'socially' with other plants (e.g., Karban, 2015; Trewavas, 2015). Plants can, indeed, do some things that were once thought to be unique to animals. It is often the juxtaposition of a system we think we know well with one that is alien that enables us to overcome biases and see the world from a new vantage point.

Despite the important role of cephalopods in characterizing the structure and function of neurons (Young, 1939), much of our current understanding of the neuroscience that underlies animal behavior is dominated by studies with vertebrates, especially mammals (Kolb & Whishaw, 2015). Octopuses have a radically different body design — a bilaterally organized head/body and a radially organized array of eight arms — and are capable of many of the behaviors that are typical of vertebrates (Mather, 2019). Indeed, the body design of octopuses gives them some unique capabilities that leave us vertebrates in awe! Juxtaposing their behavioral capabilities with what we know in vertebrates serves the function of the 'Thing' in my own biological awakening. Only instead of coming from space, the octopus is the 'Thing' that comes from our own world.

2. Centralized versus peripheral motor control. Mather's target article shows beautifully the many ways the unique design of octopuses affords them novel capabilities and means of navigating the world. The feature that stood out for me was what can be achieved with a motor system that is distributed. Vertebrate nervous systems are not as centralized as once thought. For example, the enteric nervous system, which controls the organs of the gastrointestinal system, has nearly as many neurons as the central nervous system and has a great deal of autonomy in regulating the functions of those organs (Goyal & Hirano, 1996). Similarly, the spinal cord, which is a major conduit by which the brain interacts with the rest of the body, has considerable autonomy via local neural circuits (Stein, 1995). Much of that autonomy is greatly restricted relative to what could be possible. Damage to the lower spinal cord of infant rats only mildly impairs the ability of the hind legs to walk and do so in coordination with the forelimbs. In contrast, with increasing age, the same damage can completely block spinal-generated walking. With age, neurons from the brain gradually overtake the roles of local spinal neural circuits, reducing intrinsic autonomous control (Stelzner, 1986). Centralization comes at the cost of losing local autonomy.

The dual structure of the octopus nervous system, a large bilateral brain and many ganglia distributed radially among the arms, gives these animals the best of both worlds. The brain can set the goal, such as reaching for a crab, and the local neural circuits in the arms take care of how to do so. As the literature reviewed by Mather shows, in some contexts, an octopus relies on constructing motor actions built out of stereotyped components (motor primitives). However, when challenged by contexts that require solutions that cannot rely on retooling the available motor primitives, octopus show a remarkable ability to construct novel action sequences. The autonomy of the arms and the limited need for sensory feedback to be processed centrally frees octopuses to develop local solutions, and thus, novel motor patterns.

3. Conclusion. Although many of the rules that govern the construction of motor patterns in other animals (Pellis et al., 2014) also apply to the octopus (e.g., Mather & Alupay, 2016), the unique organization of the 'Thing' from beneath the seas enables an amazing degree of behavioral flexibility. From a vertebrate perspective, these findings are a major challenge. As a premier example of a mammal with a remarkable degree of behavioral flexibility, we humans may feel cheated that octopuses can do so much with so little. To achieve the degree of flexibility that we have with a much more centralized nervous system has required the addition of much more neural tissue (Jerison, 1973). But adding neural tissue comes with higher maintenance costs (Insler & van Schaik, 2009). Imagine what we could do with that expensive tissue if we had a more distributed, cephalopod-like nervous system. Perhaps the next visitor from space will show us!

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