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## Should fish feel pain? A plant perspective

Commentary on [Key](#) on Fish Pain

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**Abstract:** Key (2016) claims fish that fish do not feel pain because they lack the necessary neuronal architecture: their responses to noxious stimuli, according to Key, are executed automatically without any feelings. However, as pointed out by many of his commentators, this conclusion is not convincing. Plants might provide some clues. Plants are not usually thought to be very active behaviorally, but the evidence suggests otherwise. Moreover, in stressful situations, plants produce numerous chemicals that have painkilling and anesthetic properties. Finally, plants, when treated with anesthetics, cannot execute active behaviors such as touch-induced leaf movements or rapid trap closures after localizing animal prey.

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*“‘I think, therefore I am’ is the statement of an intellectual who underrates toothaches. ‘I feel, therefore I am’ is a truth much more universally valid, and it applies to everything that’s alive....[W]hen someone steps on my foot, only I feel the pain. The basis of the self is not thought but suffering, which is the most fundamental of all feelings.” — Milan Kundera, Immortality (1988)*

Although plants are generally considered passive automata-like organisms, recent research reveals very rich behavior in plants supported by complex electrophysiology with neuron-like cellular and molecular features (Baluška 2010; Baluška and Mancuso 2009a,b; Baluška et al. 2004, 2005, 2006; Brenner et al. 2006). Moreover, plants have also been interpreted as exhibiting their own plant-specific cognition, intelligence, and behavior (Trewavas 2005, 2009, 2014; Trewavas and Baluška 2011; Calvo and Baluška 2015). Plants communicate using a very rich repertoire of volatile chemicals, they manipulate insects and some animals for their own benefit, and some plants such as orchids even show deceptive behavior (Schiestl 2005). All plants use their plant-specific sensory systems to obtain faithful information about the environment and apply their specific problem-solving strategies and behavior to coping with and surviving these stressful situations (Baluška et al. 2006; Trewavas 2005, 2009, 2014; Trewavas and Baluška 2011; Calvo and Baluška 2015).

As Sneddon & Leach (2016) suggest in their commentary on Key (2016), the denial of fish pain is linked to anthropomorphic views that are not supported by experimental evidence. In fact, because of the subjective nature of pain (and of all other feelings), it is not possible to draw any strong conclusions in this respect. We can, however, make indirect inferences on the basis of many measurable parameters, including molecular ones. For example, plants are

known to produce numerous substances that are known to have pain-relieving and mind-altering properties (Kennedy and Wightman 2011; Kennedy 2014). Current thinking is that these substances aid plants in their fight against herbivores. This might be the case with the mind-altering and cognition-enhancing substances, but surely not the pain-relieving ones. It is not in the plant's adaptive interest to invest energy to synthesize these expensive substances just to please animals or humans. It seems more plausible to assume that plants synthesize these substances for their own benefit — especially when the synthesis occurs under conditions of injury or stress.

According to contemporary botany, ethylene is a stress-response hormone in plants (Müller and Munné-Bosch 2015; Yang et al. 2015). Ethylene is also a powerful general anesthetic in animals (Dillard 1930; Campagna et al. 2003). Chauncey Leake synthesized divinyl ether from ethylene to enhance its anesthetic properties (Finer 1965; Mazurek 2007). Stressed plants endogenously produce not only ethylene, but also divinyl ether (Itoh and Howe 2001; Stumpe et al. 2008; Fammartino et al. 2010). Bacteria, fungi, algae and lichens too are known to produce ethylene under stress (Lynch and Harper 1974; Primrose and Dilworth 1976; Chagué et al. 2002). This suggests that ethylene plays a fundamental adaptive role in all living organisms.

A parallel example is caffeine and nectar, which are synthesized by plants for the benefit (to the plant) of their effects on animals, rather than any direct effect on the plants themselves. Recent studies suggest that — for their own benefit — plants add caffeine to their nectar to enhance their pollinators' memory and cognition (Wright et al. 2013; Chittka and Peng 2013; Couvillon et al. 2015). Plants also increase the attractiveness of their nectar with other substances that support pollinator health (Richardson et al. 2015). There are several specific examples of chemical manipulation of ants by plants, for the benefit of plants (Grasso et al. 2015; Heil 2015). It is even beginning to be thought that the evolution of the human brain, too, might have been influenced by plant chemistry (Kennedy and Wightman 2011; Kennedy 2014). Interestingly, fruits — which flowering plants *designed* in their evolution as their organs to be eaten by animals/humans — ripen (i.e., become attractive via their special tastes, aromas, nutritive and health-relevant values, colors and shapes) under the actions of ethylene (Chaves and de Mello-Farias 2006; Barry and Giovannoni 2007). In some plants, unripe fruits can even be poisonous, suggesting that plants can actively prevent consumption of such unripe fruits via toxic chemicals (Lev-Yadun et al. 2009). Similarly, toxic nectar deters possible nectar thieves (Stephenson 1981).

Of course, it would be very difficult to prove that pain-relieving and anesthetic substances are relieving pain in plants themselves. But there have been very relevant findings concerning the neuronal roles of neurotransmitters in plants. Plants synthesize almost all known neurotransmitters. It was formerly assumed that in plants these substances do not play a role in signaling and cell-cell communication anything like the role they play in animal brains. This view has been changing dramatically in recent years. Glutamate signaling is now well recognized in plants. Recent studies have shown that the chemistry and actions of glutamate receptors are similar in plants and animals (Forde 2014; Weiland et al. 2016). GABA receptors have likewise been found recently in plants (Ramesh et al. 2015; Žárský 2015). Neuron-like GABA and glutamate signaling controls (at least) root growth and behavior as well as plant

sexual reproduction (Forde 2014; Biancucci et al. 2015; Ramesh et al. 2015; Žárský 2015; Weiland et al. 2016).

Plant roots are very active organs, searching for mineral nutrients and water in the darkness of an underground environment. Their apices are equipped with a sensory root cap and neuron-like transition zones with numerous neuron-like features (Baluška et al. 2004, 2009; Baluška and Mancuso 2013). Recent studies reveal that roots show preferences and negative responses in their growth patterns (Yokawa et al. 2014a). They avoid or escape vigorously if exposed to light or dangerous salt stress areas (Burbach et al. 2012; Yokawa et al. 2011, 2014a, 2014b; Yokawa and Baluška 2015). This phenomenon opens the possibility that plant roots could have a plant-specific version of negative feelings that help them avoid or escape dangerous situations. This should perhaps not be surprising in view of the fact that all organisms need to be able to recognize danger and perform a proper response to minimize the negative effects of injury or stress.

So, do plants have something like plant-specific consciousness? Of course it is impossible to draw any strong conclusions on this question. But, as with the neuron-like chemistry and the synthesis of mind-altering substances discussed above, indirect evidence does suggest the possibility of such a phenomenon in plants (Trewavas and Baluška 2011). The endogenous production of anesthetics like ethylene and ethyl-ether, and of numerous substances that have pain-killing properties in humans and animals, especially when stressed, is compatible with the possibility of some plant-specific form of pain or negative experience. Indeed, plants are also sensitive to exogenous anesthetics (Bernard 1878; Grémiaux et al. 2014), even to man-made compounds that plants never encountered in their evolution, such as xenon, halothane, ketamine and lidocaine (Milne and Beamish 1999; De Luccia 2012). The touch-induced closing of *Mimosa* leaves and the snapping of *Dionea* and *Drosera* traps are blocked if these plants are treated with exogenous anesthetics. Whatever it is that is switched off and on by adding or removing these compounds, it is also present in plants. Already in 1878, Claude Bernard stated that “what is alive must sense and can be anesthetized, the rest is dead.” He thereby proposed sensitivity to anesthetics as a prime criterion of life (Bernard 1878; Grémiaux et al. 2014).

The perception of negative or stressful conditions through pain-like states — and consciousness itself — may be essential for any organism to be able to navigate in the complex and often dangerous physical environment. This internal, subjective compass (as represented by pain) and the ability to process and act upon it (via consciousness) may be what allowed the survival and evolution of organisms on Earth.

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