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Neurobiology of motivated behaviors

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The International Society of Zoological Sciences (ISZS) successfully organized its 9th International Symposium on “Response and adaptation of animals to extreme environments.” With the generous support from the ISZS and its symposium sponsors, we took the opportunity to organize a scientific session on “Neurobiology of motivated behaviors.” This successful session and subsequent contributions from our speakers and others have resulted in this special issue of *Integrative Zoology* on the “Neurobiology of motivated behaviors.”

Motivated behaviors are goal-directed behaviors that are essential for most species’ survival and reproductive success. Seeking food or a mate, caring for its offspring and looking for appetitive stimuli (e.g. palatable food, social interactions or even drugs of abuse) are all behaviors that exhibit plasticity throughout an individual’s lifetime to permit adaptation to environmental changes. The brain structures and mechanisms mediating these behaviors show convergence and divergence in the animal kingdom. As discussed by Dr. Young and his colleague in their review, variations in social behaviors among different species allow a better understanding into the neurogenetic mechanisms behind behavioral diversity (Johnson & Young 2018). Dr. Young also stresses the limitations of using traditional laboratory animal models and discusses the benefit of using new diverse species systems to investigate social behavioral diversity and the underlying mechanisms by utilizing combined modern research tools in genetics, genomics, neuroscience and computation.

In numerous species, oxytocin (OT) is a peptide that plays a major role in mediating social behaviors. The structure of this peptide is highly conserved among mammals, but recent evidence shows that New World monkeys have at least 6 OT variants. In their review, Dr. French and colleagues discuss the consequences of these OT variants on cellular functioning and social behaviors in marmoset monkeys (Mustoe et al. 2018). At the OT receptor (OTR) level, numerous polymorphisms have been reported in humans, and it has been suggested that these polymorphisms are associated with different levels of prosocial behaviors. However, as discussed in Dr. Su and her colleague’s contribution (Wu & Su 2018), situational factors (e.g. sociability towards in-group members *vs* out-group individuals) were usually not taken into account when examining social behaviors. Dr. Su shows that certain polymorphisms of OTR and social behaviors are, indeed, dependent on the recipient identity and, therefore, on the situational factors. Dr. Ogawa and her colleagues show that OT and OTR-deficient male mice exhibit severe deficits in longterm social preference of other males, likely due to deficits in social recognition (Tsuda et al. 2018). They also demonstrate

an important contribution of estrogen and its receptors in regulating social preference in this new behavioral paradigm.

In mice also, Dr. Kikusui and his colleagues showed that female mice, when given a choice, will exhibit both sexual and social partner preference for the vocalizing males over non-vocalizing ones, indicating that ultrasonic vocalizations in males may serve as courtship song and enhance reproductive success (Nomoto et al. 2018). In a study in socially monogamous mandarin voles (*Microtus mandarinus*) that display bi-parental behaviors, Dr. Tai and his colleagues show that the hormones prolactin and testosterone play a role not only in the initiation of male parental behaviors but also on spines plasticity in the medial prefrontal cortex in the brain of new father voles (Wang et al. 2018). In light of the recent heated debate that followed a *Nature* report showing that hippocampal neurogenesis is almost absent in the human adult brain (Sorrells et al. 2018), the timely review by Dr. Jorgensen describes what has been reported so far in both humans and other mammalian species on the role that neurogenesis plays in various motivated behaviors (Jorgensen 2018).

In most species, early life experiences shape social behaviors and physiology of the individual and its descendants, and in numerous circumstances the effects can be transmitted epigenetically to further generations. In their contribution to this section, Dr. Wei and his colleagues show that predator odors in pregnant Brandt's voles (*Lasiopodomys brandtii*) have severe consequences on the growth, physiology and foraging behaviors of the descendants, making them potentially an easy prey for predators (Gu et al. 2018). Dr. Ophir and his colleague examined the brain distribution of OTR and vasopressin receptors (V1aR) in prairie voles (*Microtus ochrogaster*) that were raised with or without a father and after weaning were housed either individually or with same-sex siblings (Hiura & Ophir 2018). Their findings show that the expression of the peptides is sex-specific and rearing-specific, suggesting that biological sex and the experiences during development shape the brain and social behaviors. Dr. Thomas Curtis and his colleagues examined the effects of an exposure to an environmental stressor, mercury, during early life on adult social behaviors (Chen et al. 2018). Surprisingly, Dr. Curtis did not detect any alterations in affiliative behaviors in adult prairie voles exposed to mercury.

Eating represents another highly complex and regulated motivated behavior. Dr. Eckel and her colleague review the mechanism controlling homeostatic and hedonic eating and the potential role of inflammation in mediating the effects that high-fat diet have on energy metabolism (Butler & Eckel 2018). Dr. Zhao and his colleagues show that striped hamsters (*Cricetulus barabensis*) in their natural environment and particularly in the summer do not store food and feed mainly on plants and are, therefore, on food restriction (Wen et al. 2018). Their data show that individual differences in metabolic rates may determine how hamsters will physiologically and behaviorally respond to changes in food availability in their environment.

L-methionine is an essential amino acid that we obtain mostly from dietary sources. L-methionine is an important methyl donor. Dr. Kabbaj and his colleagues show that chronic treatment with L-methionine can reduce rats' addiction to cocaine and this decrease is likely the result of inhibition of a neuronal pathway projecting from the medial prefrontal cortex to

the nucleus accumbens: an important pathway in mediating motivated behaviors (Wright et al. 2018). Finally, Dr. Kathleen Curtis and her colleague show that estrogen-enhanced locomotor activity in a running wheel is associated with greater dopamine release in the nucleus accumbens, which likely makes a running wheel rewarding (Espinosa & Curtis 2018). This nicely reflects the idea that increased activity during the conducive state of reproduction is rewarding and can maximize reproductive success.

Overall, we believe that this comprehensive set of review and research articles will help shed light on very important topics related to motivated behaviors. We hope that this volume will help the readers of *Integrative Zoology* become familiar with ways to examine motivated behaviors and to appreciate the importance of examining these behaviors and their underlying physiological and neural mechanisms in various and diverse animal species.

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