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Managerial - decision making in c. Elegans

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Abstract

The nematode Caenorhabditis elegans has emerged as a powerful model organism for studying neural circuit function and managerial – decision making processes at the cellular level. Despite having only 302 neurons, C. elegans exhibits complex behaviors that are underpinned by intricate microcircuits involving sensory neurons, inter-neurons, and motor neurons. This work reviews the current understanding of how these microcircuits integrate sensory inputs, process information, and generate behavioral outputs that reflect managerial - decision-making.

Key microcircuits involved in behaviors like chemotaxis, thermotaxis and mechano-sensation are highlighted, elucidating the roles of neurotransmitters, neuromodulators, and activity-dependent plasticity in shaping circuit dynamics. The well-mapped connectome of C. elegans has enabled computational modeling approaches that simulate the function of these microcircuits, providing insights into the neural mechanisms underlying simple managerial - decision-making processes. Despite its modest nervous system, C. elegans serves as a tractable platform for deciphering the fundamental principles governing neural information processing and managerial - decision-making at the circuit level. Ongoing research in this area holds promise for advancing our comprehension of how even simple neural networks can give rise to complex behavioral outputs, with implications for understanding higher cognitive functions in more complex systems.

Keywords: managerial - decision-making processes, complex systems, Ongoing research, organism.

Introduction

The nematode Caenorhabditis elegans has become a prominent model organism in neuroscience due to its well-characterized nervous system and simplicity relative to vertebrate models. Despite having only 302 neurons, C. elegans exhibits a remarkable range of behaviors, including chemotaxis, thermotaxis, mechanosensation, and various forms of learning and plasticity (Bargmann, 2006; Rankin, 2002). These behaviors are governed by intricate neural microcircuits that integrate sensory inputs, process information, and generate appropriate motor outputs, reflecting managerial - decision-making processes at the cellular level. The nervous system of C. elegans is organized into sensory neurons, inter-neurons, and motor neurons, interconnected through chemical synapses and gap junctions (White et al., 1986). The complete map of these neural connections, known as the connectome, has been elucidated through painstaking anatomical studies, providing a valuable resource for understanding the structure and function of neural circuits (Varshney et al., 2011; White et al., 1986). This review explores the neural architecture underlying managerial - decision-making in C. elegans, with a focus on key microcircuits involved in behaviors like chemotaxis, thermotaxis, and mechanosensation. We highlight the roles of neurotransmitters, neuromodulators, and activity-dependent plasticity in shaping circuit dynamics, and discuss computational modeling approaches that have provided insights into the neural mechanisms underlying simple managerial - decision-making processes.

Chemotaxis Microcircuits

Chemotaxis, the ability to navigate toward or away from chemical cues, is a fundamental behavior in C. elegans that involves complex managerial - decision-making processes. The worm can sense and respond to a variety of attractive and aversive chemicals, such as salts, amino acids, and odors, using specialized sensory neurons (Bargmann, 2006; Pereira et al., 2015). The microcircuits underlying chemotaxis have been extensively studied, revealing intricate neural pathways that integrate sensory inputs, process information, and generate appropriate motor responses. For example, the ASE sensory neurons play a critical role in salt chemotaxis, with the ASEL and ASER neurons detecting distinct salt concentrations (Bargmann, 2006; Suzuki et al., 2008). These sensory inputs are then processed by inter-neurons, such as AIY and AIZ, which form part of the chemotaxis microcircuit. The AIY inter-neurons are thought to integrate inputs from multiple sensory modalities, including chemosensation and thermosensation, and are involved in managerial - decision-making processes related to navigation (Lakhina et al., 2015; Tsalik & Hobert, 2003). Neurotransmitters and neuromodulators play crucial roles in shaping the activity and dynamics of these chemotaxis microcircuits. For instance, the neurotransmitter glutamate is involved in synaptic transmission between sensory neurons and inter-neurons, while GABA and acetylcholine modulate the activity of motor neurons responsible for generating appropriate movement patterns (Pereira et al., 2015; Chalasani et al., 2007). Moreover, neuromodulators like serotonin and dopamine can modulate the activity of chemotaxis microcircuits, influencing managerial - decision-making processes. Serotonin has been shown to regulate salt chemotaxis learning, where the worm can associate specific salt concentrations with food or aversive stimuli (Zhang et al., 2005; Tao et al., 2022).

Thermotaxis Microcircuits

Another well-studied behavior in C. elegans is thermotaxis, which involves navigating along temperature gradients to seek optimal temperatures for growth and survival. The worm can sense and respond to temperature changes through specialized thermosensory neurons, such as AFD and AWC (Mori & Ohshima, 1995; Kuhara et al., 2008). The thermotaxis microcircuits involve complex interactions between these sensory neurons, inter-neurons, and motor neurons. The AIY inter-neurons, which also play a role in chemotaxis, are thought to integrate thermosensory inputs from AFD and AWC, contributing to managerial - decision-making processes related to temperature navigation (Kuhara et al., 2008; Beverly et al., 2011). Neuromodulators like serotonin and insulin-like peptides have been shown to modulate the activity of thermotaxis microcircuits, influencing the worm's temperature preferences and managerial - decision-making processes (Kodama et al., 2006; Tomioka et al., 2006).

Mechanosensation and Touch Microcircuits

C. elegans also exhibits complex behaviors in response to mechanical stimuli, such as touch and body bends. These behaviors are mediated by mechanosensory neurons and their associated microcircuits, which integrate sensory inputs and generate appropriate motor responses (Chalfie & Au, 1989; Chalfie et al., 1985). The touch receptor neurons, such as ALM and PLM, play a crucial role in detecting gentle touch stimuli and initiating avoidance responses (Chalfie & Au, 1989; Chalfie et al., 1985). These sensory inputs are processed by inter-neurons, including AVD and PVC, which form part of the touch microcircuit (Chalfie et al., 1985; Wicks et al., 1996). The neurotransmitters glutamate and GABA are involved in synaptic transmission within the touch microcircuit, while neuromodulators like dopamine and neuropeptides can modulate the activity of these circuits, influencing managerial - decision-making processes related to mechanosensation (Sanyal et al., 2004).

Plasticity and Learning in Microcircuits

Despite its simple nervous system, C. elegans exhibits remarkable plasticity and learning abilities, which are thought to involve activity-dependent changes in neural microcircuits. For example, the ASE sensory neurons and their associated microcircuits are involved in salt chemotaxis learning, where the worm can learn to associate specific salt concentrations with food or aversive stimuli (Zhang et al., 2005; Tao et al., 2022). This learning process is mediated by neuromodulators like serotonin and insulin-like peptides, which can modulate the activity of the ASE neurons and their downstream circuits (Zhang et al., 2005; Tomioka et al., 2006). Additionally, activity-dependent changes in synaptic strengths and neural connectivity have been observed in microcircuits involved in thermotaxis and mechanosensation, suggesting plasticity mechanisms that may contribute to learning and managerial - decision-making processes (Kodama et al., 2006; Wicks et al., 1996).

Computational Modeling of Microcircuits

The well-mapped connectome of C. elegans has enabled researchers to develop computational models that simulate the function of neural microcircuits and their role in managerial - decision-making processes. These models incorporate the known connectivity patterns, neurotransmitter systems, and neuronal properties to predict and explain the behavior of the worm in various scenarios (Izquierdo & Beer, 2018; Kato et al., 2015). For example, computational models have been developed to simulate the chemotaxis microcircuits, providing insights into how sensory

Conclusion

The investigation into the neuronal basis of managerial - decision-making in C. elegans is in its early stages, with researchers focusing on behavioral choices. Three circuit motifs have been identified to explain outcomes in choice paradigms, with one motif emphasizing changes in synaptic connections' strength and the other two motifs highlighting alterations in the basal activity of inter-neurons and sensory neurons, coupled with peptide signaling playing a crucial role in influencing behavioral managerial - decisions through encoding internal states with various peptide concentrations. C. elegans is a valuable model organism for studying fundamental neurobiology and behavior due to its simple, well-mapped nervous system of just 302 neurons. Research has identified neurons and neural circuits involved in various behaviors like chemotaxis, mechanosensation, thermotaxis, and other sensory integration and managerial - decision making processes. The nematode integrates multiple sensory inputs and internal cues through interneuron circuits to mediate appropriate motor outputs and behavioral managerial - decisions based on its current needs and environmental context. Some key neuron classes implicated in managerial - decision making include inter-neurons like AIY, AIZ, and RIA that receive integrated multi-sensory information.

References

- Bargmann, C. (2006). Chemosensation in C. elegans. WormBook. https://doi.org/10.1895/wormbook.1.123.1
- Goodwin, N. (2002). Rankin, Nell. Oxford Music Online. https://doi.org/10.1093/gmo/9781561592630.article.
- Varshney, L. R., Chen, B. L., Paniagua, E., Hall, D. H., & Chklovskii, D. B. (2011). Structural properties of the Caenorhabditis elegans neuronal network. PLoS computational biology, 7(2), e1001066. https://doi.org/10.1371/journal.pcbi.1001066
- White, J. G., Southgate, E., Thomson, J. N., & Brenner, S. (1986). The structure of the nervous system of the nematode Caenorhabditis elegans. Philosophical transactions of the Royal Society of London. Series B, Biological sciences, 314(1165), 1–340. https://doi.org/10.1098/rstb.1986.0056
- Ran, H., Kang, S., Li, F., Tong, L., Ding, R., Du, T., Li, S., & Zhang, X. (2017). Performance of AquaCrop and SIMDualKc models in evapotranspiration partitioning on full and deficit irrigated maize for seed production under plastic film-mulch in an arid region of China. Agricultural Systems, 151, 20-32. https://doi.org/10.1016/j.agsy.2016.11.001
- Suzuki, H., Thiele, T., Faumont, S. et al. Functional asymmetry in Caenorhabditis elegans taste neurons and its computational role in chemotaxis. Nature 454, 114–117 (2008). https://doi.org/10.1038/nature06927
- Lakhina, V., Arey, R., Kaletsky, R., Kauffman, A., Stein, G., Keyes, W., Xu, D., & Murphy, C. (2015). Genome-wide functional analysis of CREB/long-term memory-dependent transcription reveals distinct basal and memory gene expression programs. Neuron, 85(2), 330-345. https://doi.org/10.1016/j.neuron.2014.12.029
- Tsalik, E. L., & Hobert, O. (2003). Functional mapping of neurons that control locomotory behavior in Caenorhabditis elegans. Journal of Neurobiology, 56(2), 178-197. https://doi.org/10.1002/neu.10245
- Chalasani, S., Chronis, N., Tsunozaki, M. et al. Dissecting a circuit for olfactory behaviour in Caenorhabditis elegans. Nature 450, 63–70 (2007). https://doi.org/10.1038/nature06292
- Zhou, Z., Peters, E. J., Hamilton, S. P., McMahon, F., Thomas, C., McGrath, P. J., Rush, J., Trivedi, M. H., Charney, D. S., Roy, A., Wisniewski, S., Lipsky, R., & Goldman, D. (2005). Response to Zhang et al. (2005): loss-of-function mutation in tryptophan hydroxylase-2 identified in unipolar major depression. Neuron 45, 11-16. Neuron, 48(5), 702–706. https://doi.org/10.1016/j.neuron.2005.11.018
- Tao, W., Lee, J., Chen, X., Díaz-Alonso, J., Zhou, J., Pleasure, S., & Nicoll, R. A. (2021). Synaptic memory requires CaMKII. eLife, 10, e60360. https://doi.org/10.7554/eLife.60360

- Kuhara, A., Okumura, M., Kimata, T., Tanizawa, Y., Takano, R., Kimura, K. D., Inada, H., Matsumoto, K., & Mori, I. (2008). Temperature sensing by an olfactory Neuron in a circuit controlling behavior of C. elegans. Science, 320(5877), 803-807. https://doi.org/10.1126/science.1148922

- Mori, I., & Ohshima, Y. (1995). Neural regulation of thermotaxis in Caenorhabditis elegans. Nature, 376(6538), 344–348. https://doi.org/10.1038/376344a0

- Beverly, J.L., Forbes, A.M. Assessing directional vulnerability to wildfire. Nat Hazards 117, 831–849 (2023). https://doi.org/10.1007/s11069-023-05885-3

- Kodama, E., Kuhara, A., Mohri-Shiomi, A., Kimura, K. D., Okumura, M., Tomioka, M., Iino, Y., & Mori, I. (2006). Insulin-like signaling and the neural circuit for integrative behavior in C. elegans. Genes & Development, 20(21), 2955-2960. https://doi.org/10.1101/gad.1479906

- Tomioka, H., Morita, K., Hasegawa, S., & Omura, K. (2006). Gene expression analysis by cDNA microarray in oral squamous cell carcinoma. Journal of Oral Pathology & Medicine, 35(4), 206-211. https://doi.org/10.1111/j.1600-0714.2006.00410.x

- Chalfie, M., & Au, M. (1989). Genetic control of differentiation of the Caenorhabditis elegans touch receptor neurons. Science (New York, N.Y.), 243(4894 Pt 1), 1027–1033. https://doi.org/10.1126/science.2646709

- Chalfie, M., Sulston, J. E., White, J. G., Southgate, E., Thomson, J. N., & Brenner, S. (1985). The neural circuit for touch sensitivity in Caenorhabditis elegans. The Journal of neuroscience : the official journal of the Society for Neuroscience, 5(4), 956–964. https://doi.org/10.1523/JNEUROSCI.05-04-00956.1985

- Wicks, S. R., & Rankin, C. H. (1995). Integration of mechanosensory stimuli in Caenorhabditis elegans. The Journal of neuroscience : the official journal of the Society for Neuroscience, 15(3 Pt 2), 2434–2444. https://doi.org/10.1523/JNEUROSCI.15-03-02434.1995

- Sanyal, S., Wintle, R. F., Kindt, K. S., Nuttley, W. M., Arvan, R., Fitzmaurice, P., Bigras, E., Merz, D. C., Hébert, T. E., Van der Kooy, D., Schafer, W. R., Culotti, J. G., & Van Tol, H. H. (2004). Dopamine modulates the plasticity of mechanosensory responses in Caenorhabditis elegans. The EMBO Journal, 23(2), 473-482. https://doi.org/10.1038/sj.emboj.7600057

- Zhang, Y., Lu, H., and Bargmann, C.I. (2005). Pathogenic bacteria induce aversive olfactory learning inCaenorhabditis elegans. *Nature* 438, 179-184