Evolutionary shifts in the developmental control of neuron number

Supervisory team:
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Project description:

Brain size varies massively across species, often largely explained by variation in the production of neurons during development. Although we have some knowledge of the developmental mechanisms controlling neuron production in certain well studied species, we are only beginning to explore how these developmental mechanisms change to facilitate the evolution of neuron number. Understanding the proximate basis of neural variation is critical for diverse questions in evolutionary neuroscience, from identifying potential constraints and trade-offs in brain evolution, to explore relationships between neural traits and behavioural variation.

This project aims to tackle these questions using Heliconiini, a diverse tribe of Neotropical butterflies, as a study system. We have recently shown that one region of the brain that has particular importance in learning and memory, the mushroom bodies, varies by over 25X across Heliconiini butterflies. This extreme variation is driven by a massive expansion in the number of Kenyon cells, neurons that form the mushroom body. We now want to understand how this variation in Kenyon cell number is determined by changes in the developmental control of neurogenesis across species.

The primary goals of the project are to test the role of four processes, all of which could alter cell production, in shaping Kenyon cell number across Heliconiini: i) increased neuroblast number at the onset of neurogenesis, ii) accelerated cell-cycle rates during neurogenesis, iii) extension in the duration of neurogenesis, iv) reduced or delayed patterns of apoptosis of neuroblasts. This work will be performed by comparing patterns of development across species which vary in Kenyon cell in known ways. It will form the foundation of our understanding of how Kenyon cell neurogenesis varies across species. Subsequent work will use this foundation to study the functional effects of candidate genes identified by our lab as regulators of mushroom body evolution.

The project will suit a highly motivated student interested in integrating different approaches to understanding behavioural variation. In addition to core DTP training, they will receive guidance in experimental design, immunohistochemistry and imaging techniques, comparative methods, and genomics. The project will involve periods of fieldwork in the Smithsonian Tropical Research Institute's insectaries in Gamboa, Panama, which is the centre of a large international community working on Heliconius butterflies.

Background reading: Montgomery, S.H., Merrill, R.M. and Ott, S.R., 2016. Brain composition in Heliconius butterflies, posteclosion growth and experience-dependent neuropil plasticity. Journal of Comparative Neurology, 524(9), pp.1747-1769. Couto, A., Wainwright, J.B., Morris, B.J. and Montgomery, S.H., 2020. Linking ecological specialisation to adaptations in butterfly brains and sensory systems. Current opinion in insect science. Farris, S.M., 2015. Evolution of brain elaboration. Philosophical Transactions of the Royal Society B: Biological Sciences, 370(1684), p.20150054.