Evolution of learning and memory circuits

Supervisory team:
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Project description:
Evolutionary innovation and refinement of neural systems underpins the diversity of behaviour across animal life. By considering natural variation in neural systems, we can begin to understand how new or enhanced behaviours are underpinned at the network level. The diversity and tractability of insects make them particularly well-suited to integrative studies of brain evolution. One of the most variable structures in the insect brain are the mushroom bodies, major integration centres which receive input from primary sensory areas, and play a critical role in associative learning and memory.

Learning can have important ecological effects, providing mechanisms to adapt to changes in resource availability, facilitating range expansion, and optimising reproductive behaviours. This is of particular importance for long lived species such as Heliconius butterflies. This unique genus actively collects and digests pollen, providing an adult source of essential amino acids, which other Heliconiini lack. This dietary innovation is accompanied by the evolution of trap-line foraging, where individuals learn foraging routes between resources with high spatial and temporal fidelity, which they exploit for many weeks or months, suggesting they are dependent on an enhanced capacity for visually orientated spatial memory. We have recently shown that mushroom bodies are highly variable across Heliconiini, being 4 times larger than in their close relatives (Couto et al. Nat Comms. 2023). This extreme volumetric variation among Heliconiini mushroom bodies is explained by massive increases in the number of mushroom body neurons. Together with evidence for conserved synaptic densities, we hypothesise that selection for circuit replication may play a major role in mushroom body evolution in this tribe. This would be consistent with models that suggest information storage capacity increases logarithmically with neuron number. However, we also observe several traits that suggest a degree of circuit modification which suggests a degree of both local and global circuit refinement.

This project will test these hypotheses, by developing whole brain views of circuit variation in morphologically variable species. You will combine new methods to characterise whole brain projectomics to reconstruct patterns of connectivity within and between brain regions, and overlap these data with information from the molecular identity of cell types. The project would suit a student with an interest in high throughput neuroanatomy, image analysis and a desire to develop excellent programming and computational skills. You will be supported to develop extensive expertise in insect neurobiology, imaging and image analysis, and quantitative analysis of cell and network morphologies.

Our aim as the SWBio DTP is to support students from a range of backgrounds and circumstances. Where needed, we will work with you to take into consideration reasonable project adaptations (for example to support caring responsibilities, disabilities, other significant personal circumstances) as well as flexible working and part-time study requests, to enable greater access to a PhD. All our supervisors support us with this aim, so please feel comfortable in discussing further with the listed PhD project supervisor to see what is feasible.