To swim or to struggle: how tadpole motor circuits reconfigure themselves in a fraction of a second

Supervisory team:
Main supervisor: Dr Joel Tabak (University of Exeter)
Second supervisor: Prof Roman Borisyuk (University of Exeter)

Collaborators: Dr Wenchang Li (University of St-Andrews (Coordinator of the BBSRC collaborative grant that funds this project. He and his postdoc will provide data to help build the model, and run experiments to test model predictions))

Host institution: University of Exeter (Streatham)

Project description:

A beautiful ballerina dance can be considered as a continuous chain of motor actions (behaviours) such as jump, forward run, backward run, etc. Neuroscience experiments show that each particular motor behaviour can be characterised by a set of neurons producing a pattern of electrical activity. However, the transitions between each pattern/behaviour are poorly understood. What happens in the neuronal network when the forward run in a dance switches to a backward movement?

In this project, the successful PhD candidate will study young frog tadpoles capable of two rhythmic motor behaviours: forward swimming and backward struggling. In swimming, alternation in neuron activity on each side leads to rapid waves of muscle contraction propagating from head to tail. If held by a predator, or stuck against an obstacle, the tadpole must quickly escape. In that case, it rapidly switches to the struggling behaviour, during which slower, but stronger waves propagate from tail to head, creating a powerful backward movement. This is critical for its survival.

The neuronal network that produces struggling is the same network that produces swimming. When the tadpole is captured by a predator, the continuous stimulation on its skin results in the activation of extra groups of nerve cells while other groups of nerve cells are turned off. This means that the network reconfigures itself automatically to generate a different behaviour.

During this project, you will build a model of the neuronal network in the tadpole spinal cord that supports swimming and struggling. This model will incorporate different types of neurons and will connect these neurons together according to rules that you will define. You will then use the model to determine how changes in sensory stimulation lead to dynamic changes in the activity of the different neuron types. Finally, you will determine how each type of neurons contributes to the transition between swimming and struggling, by conducting numerical experiments with the model. Your results will be tested by our experimental collaborators and you will have a chance to modify your model to account for new data.

Fundamental neuronal mechanisms are highly conserved across vertebrate species. The results you will obtain using tadpole models will be applicable to more complex brain networks in mammals. Your findings will have implications beyond basic neuroscience research: they may be used to better design robots that need to navigate difficult environments without getting stuck.