**The question or problem, and why it is important**

We aim to integrate artificial and biological neural network computation starting in the simple animal C. elegans. To achieve this, we will design a closed-loop system where an artificial network can receive input from an animal and send outputs to its nervous system. Artificial networks can receive information about the animal through a camera. They can send signals directly to its nervous system with optogenetics, in which animals are genetically modified so that their neurons can be quickly switched on or off with light. We will use this setup to see whether neural subcircuits and their functions can be replaced or augmented by a learning computer algorithm.

By building and studying integrated artificial-biological neural networks, we will learn about how the artificial and biological pieces interact with and adapt to each other. We also want to compare the solutions that both kinds of learning algorithms find when solving biologically relevant problems and see how they might differ. This project will build on the Ramanathan Lab’s previous work in identifying key control neurons in C. elegans nervous systems, combining it with modern tools in bioengineering and machine learning.

**The approach to be taken**

We will use a tractable biological system – the soil-dwelling nematode C. elegans – to demonstrate a viable path towards our long-term goal. C. elegans is highly amenable to genetic modification and optical manipulation. The 300 neurons and 6000 synapses are compact, yet can execute sophisticated search programs to locate bacteria or mates, do associative learning to avoid or pursue biochemical targets, and trigger stress-resistant long-lived states in dire conditions.

We first identify neurons that are responsible for some desired behavior. The goal is to replace or augment the functionality of those neurons. For replacement, we can give a computational agent control over the key neurons and have it learn to reproduce the behavior. For augmentation, we can design our own target behavior for the agent to learn and expand the repertoire of animal behaviors. In both methods, the agent will use reinforcement learning. Reinforcement learning is a field of machine learning that attempts to maximize rewards collected over time by exploration and interaction with an environment.

Our preliminary work shows that

**The potential impact of the proposed work:**

Practical impacts of the work:

* Steps toward replacing lost function
* Steps toward adding new functionality
* Algorithmic understanding by comparing results of learning