Objective
The objective of this research was to study how nonlocal coupling affects the formation of patterns and chimera states in networks of neurons.

Background
- Systems of neurons can exhibit excitatory and oscillatory behavior. An example of excitatory behavior is neuron action potential, and an example of oscillatory behavior is the firing of neurons in a periodic manner.
- We use the Wiener-Rosenbluth model and FitzHugh-Nagumo (FHN) models to study how nonlocal coupling affects pattern formation in excitatory and oscillatory systems, respectively.
- We model a network of neurons with a square grid, and apply WR and FHN equations to it.
- In excitatory systems, we will explore how nonlocal coupling affects spiral wave formation. In oscillatory systems, we will determine how the Levy walk model and the two layer model affect chimera formation.

Motivation
- Experiments have found that in the brain there are mixed regions of synchronous and asynchronous neural activity. These states, called chimeras, have been found to increase efficiency in the brain [4].
- Research suggests that epileptic seizures occur when chimeras states form in synchronous regions and then collapse [1].
- It is believed that stabilizing chimeras in the brain can reduce epileptic seizures.
- Here we study simple models describing network of neurons that are capable of reproducing chimera states. We explore the role of nonlocal coupling in stabilizing these patterns, with the hope that our results can guide research into epileptic seizures.

FitzHugh-Nagumo Model
- The FHN model is a simplified, dynamical, two-dimensional version of the Hodgkin-Huxley model, which models neuron behavior as an electrical circuit.
- FHN consists of a voltage-like variable, $u$, that exhibits excitatory behavior and a recovery variable, $v$, that provides a negative feedback.
- Based on the parameters, the FHN model can exhibit excitatory or oscillatory behavior. However, we will only look at the oscillatory case. This occurs when the parameter $a$ in the equations below is less than 1.
- Using the Poincaré-Bendixson Theorem, we can prove that when $a < 1$, the system has a limit cycle and therefore displays oscillatory behavior.

Oscillatory System

Levy-Type Coupling
- Thinking of the steps in a random walk as connections between two different locations gives us a way for incorporating nonlocal coupling into our FHN model.
- The Levy flights model is an extension of the random walk model used to represent foraging behavior in animals, or anomalous diffusion of molecules [7].
- The step-lengths follow a heavy-tailed probability distribution, which means that there is no characteristic length for the size of these random steps [7].
- Heavy-tailed distributions follow a power law, so long length steps are less likely than short steps. Similarly for the FHN model, neighbors that are farther away from a cell do not influence a cell as much as the neighbors that are closer.

Conclusion/Future Works
- Recent research has found that chimera states can be synchronized in different regions of the brain using the corpus callosum as a medium [cite source].
- We chose to create a two layer grid of FHN oscillators which acts similar to the corpus callosum. The bottom layer has nonlocal interlayer and intralayer coupling, while the top layer contains only nonlocal interlayer coupling.
- We found that chimera states emerged when $\phi$ is approximately in the range (1.3,1.9) for the case ($R=19, N=50, \sigma=.10, T = 100$).

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