

# Using Agent Based Modeling for the Exploration of Self Organizing Neural Networks

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# Overview

- Project Motivation and Goals
- Simulation background
- Design of the Simulation
- Results
- Future Directions

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# Project Motivation

- We were interested in exploring a new approach to self-organizing neural networks
- We required more than simple signaling from the neurons
- We needed to incorporate many different mechanisms into our proposed experiment

# Motivation

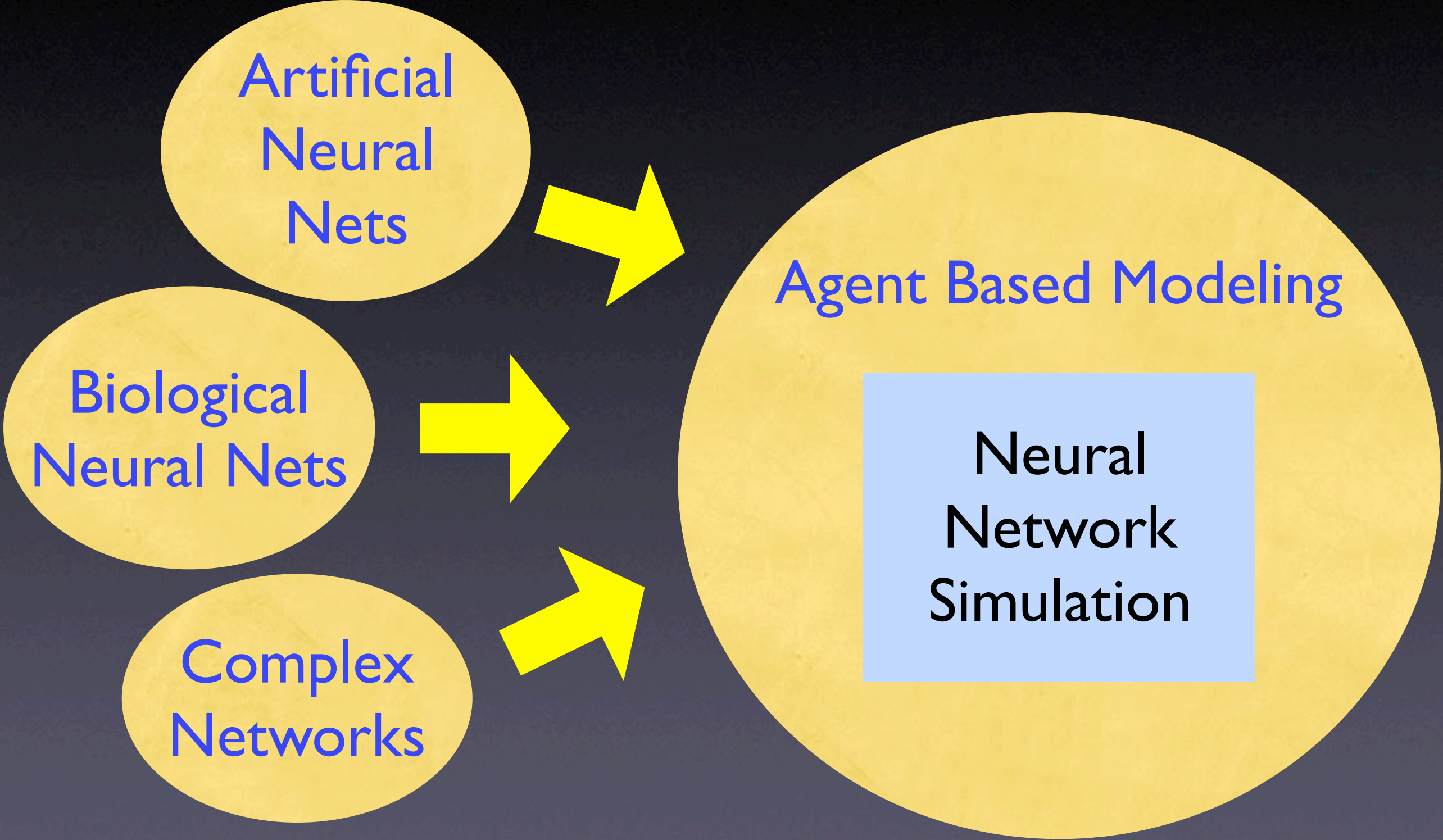
Artificial  
Neural  
Nets

Biological  
Neural Nets

Complex  
Networks

Agent Based Modeling

Neural  
Network  
Simulation



# Project Goals

- Develop an Agent Based Model of a self-organizing neural network
- Model should:
  - Be able to capture important behaviors of the neurons
  - Provide a method of describing the underlying abstract network

# Project Goals

- Must be able to model complex behavior of neurons
- Should be able to support several types of neurons
- The neurons should be able to interact with their environment
- Interaction between neurons should affect global network topology

# Overview

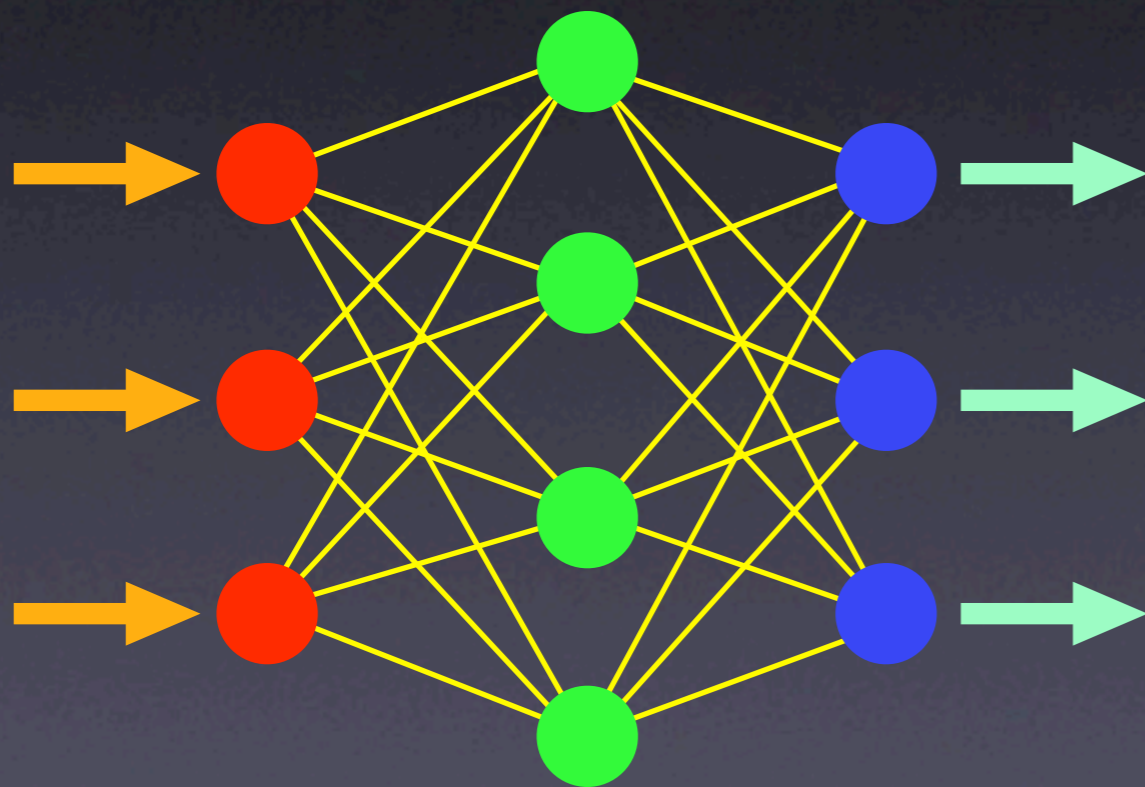
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# Neural Networks

Artificial Neural Network



Biological Neural Network

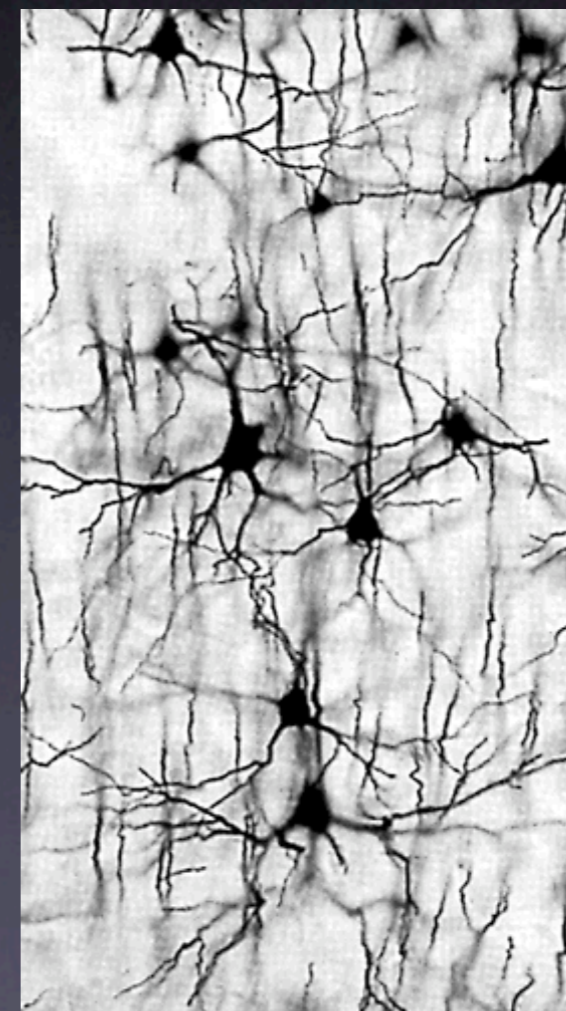


Image courtesy [www.alanturing.net/turing\\_archive/graphics/realneurons.gif](http://www.alanturing.net/turing_archive/graphics/realneurons.gif)

# Neural Networks

Researchers have created biologically accurate models of neurons...



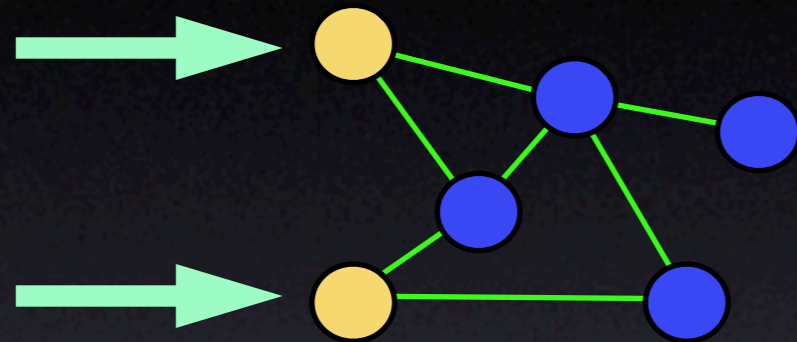
However, ANN topologies aren't as advanced.

Image courtesy <http://whyfiles.org/109stroke/4.html>

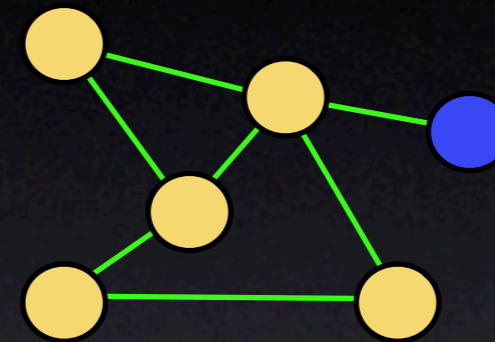
# Biological Mechanisms

- Hebbian learning - reinforcement of connections related to activation
- Neuronal regulation - related to Hebbian learning, maintains synaptic membrane potential
- Pruning - elimination of weak connections, underperforming neurons

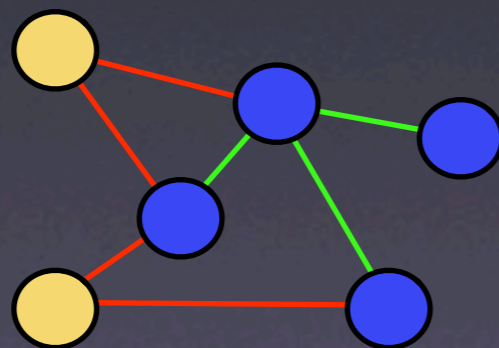
# Hebbian Learning



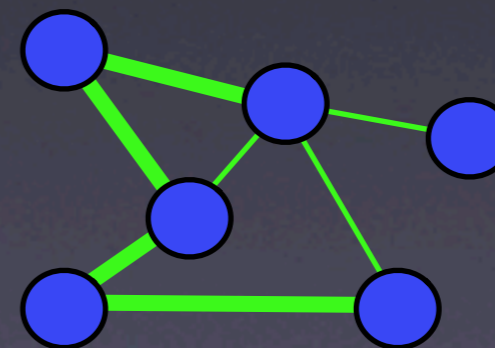
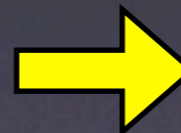
Pattern applied to  
input nodes



Information propagates  
through system



Feedback flows back to  
activating neurons



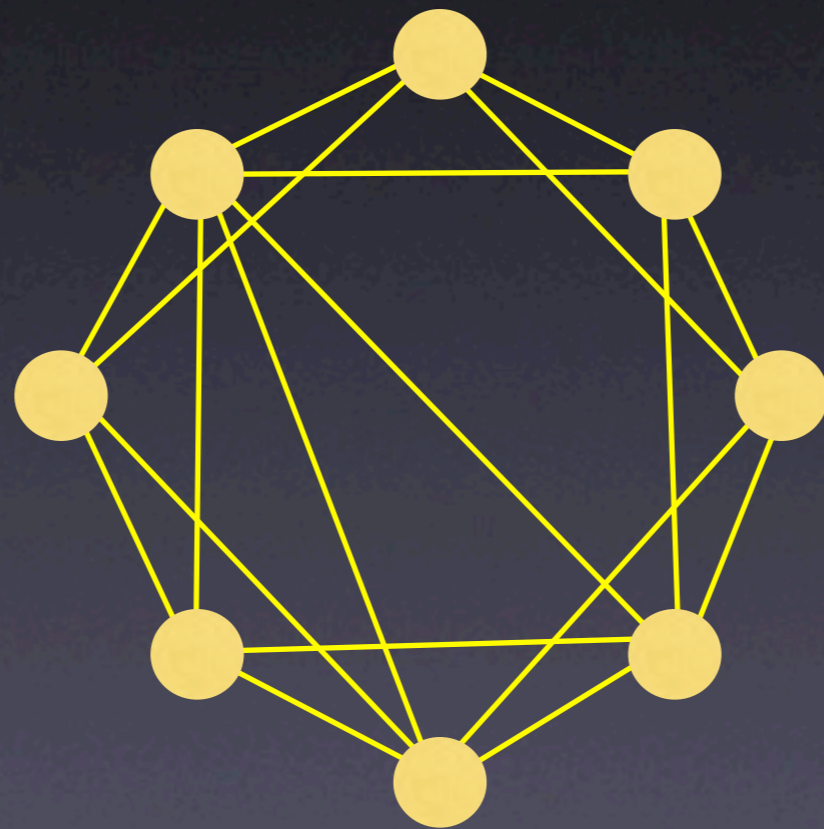
Participating links  
are strengthened

# Complex Networks

- Barabasi style networks - “scale free”, hubs, constructive algorithm
- Watts-Strogatz - clustering, characteristic path length, iterative algorithm for deforming regular graph

# Complex Networks

## Watts-Strogatz Method



# Complex Networks

## Barabasi Method



# Barabasi's Algorithm

- Scale free networks are constructed by adding nodes and edges incrementally, with preferential attachment
- Formulations of the algorithm seem to indicate that fitness information is global
- We attempt to adapt the algorithm to use only local information and preferential attachment

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# Simulation

- Apply/adapt complex network algorithms to neural network domain
- Develop agent-based model, using swarm principles
- Use resulting graph characteristics to drive further iterations of the model

# ABM Toolkit

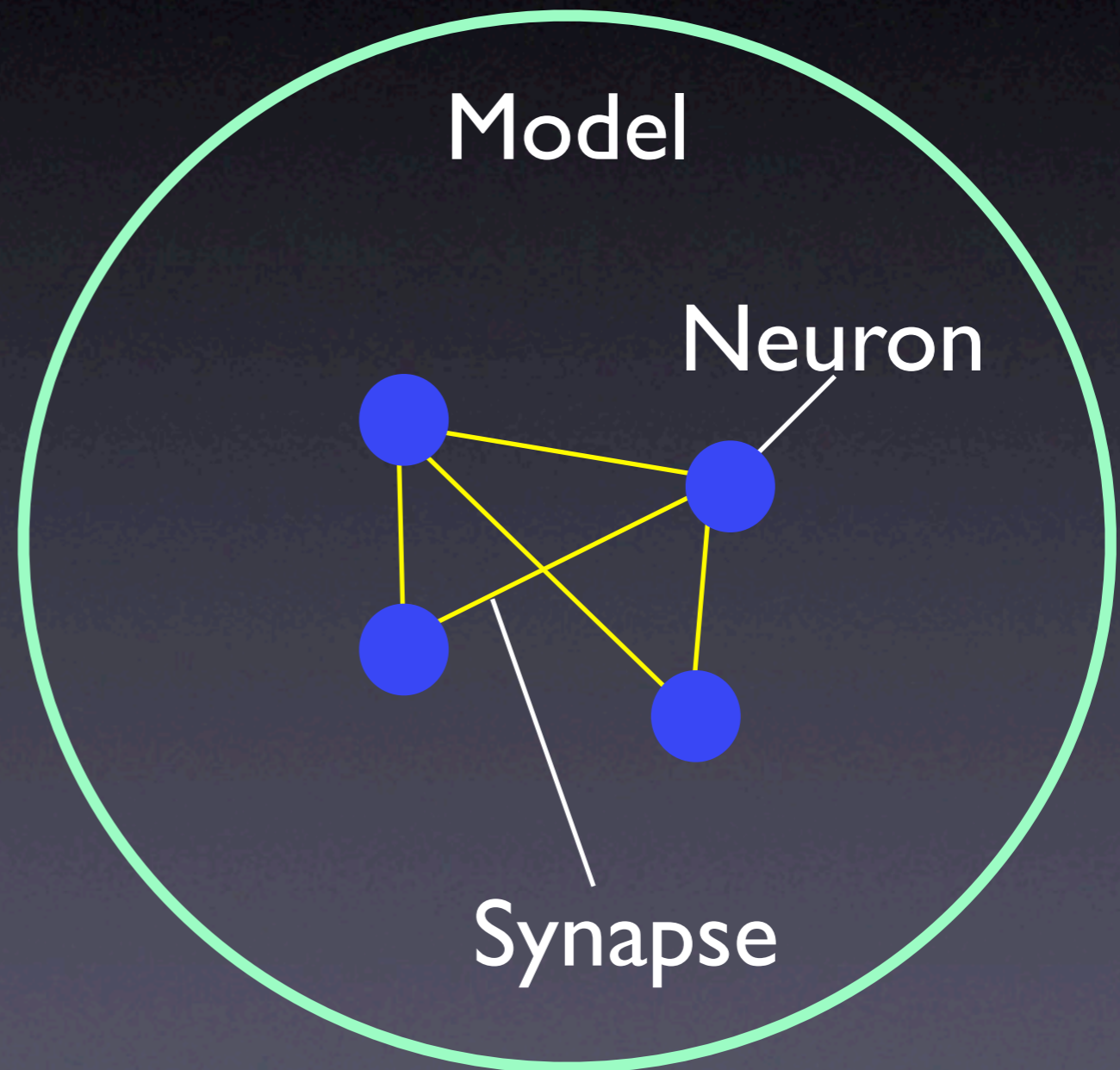
- We use RePast 2.0.2
  - RePast is pure Java
  - Uses a discrete event simulator with double precision scheduler
  - Sophisticated API - visualization tools, batch processing

# Modeling an ANN with ABM

- Model the Neurons as agents
- Placing them on the grid yields physical relationship, important should chemotactic mechanisms be desired
- Scheduling tool allows precise timing of Neuron firing events

# Simulation Overview

- Model class
- Neuron class
- Synapse class



# Model Class

- Creates the neurons, holds setup parameters
- Parameters can be set via dialog box, config file or in the source code
- Creates schedule, places initial and recurring events on the schedule

# Neuron class

- Contains behaviors for what to do when signaled, what to do when receiving feedback
- Subclass of Node class, so can be viewed as the node of a graph
- Maintains connections to other Neurons via Synapse class

# Synapse class

- Has actions for transmitting pulses and feedback
- Subclass of Edge class, can be viewed as a link in a graph
- Each “end” connects to a Neuron, this is a directed connection

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# Results

- Simulation is in a deployable state, with data output as adjacency matrices and/or computed statistics
- Simulation runs on all available architectures (Mac, x86 Linux, SPARC Solaris)
- If there is time, a short demonstration...

# Benefits of Our Approach

- Can view simulation as Neurons and Synapses, with spatial relationships, connections
  - This lets us look at higher order behavior and small scale interactions
- Can view it as connection graph with nodes and edges
  - This enables us to focus on details relating to global structure

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# Future Directions

- We believe we have validated the usefulness of a Swarm approach to neural network modeling
- What remains is to use the simulation to explore self-organizing neural networks:
  - Determine which mechanisms are important for the development of a complex network
  - Develop tools to examine parameter space

# Thanks

- Dr. Greg Madey
- Arthur J. Schmitt Foundation