Retinal Remodeling

CS 790R Project Status

Kyle McDermott

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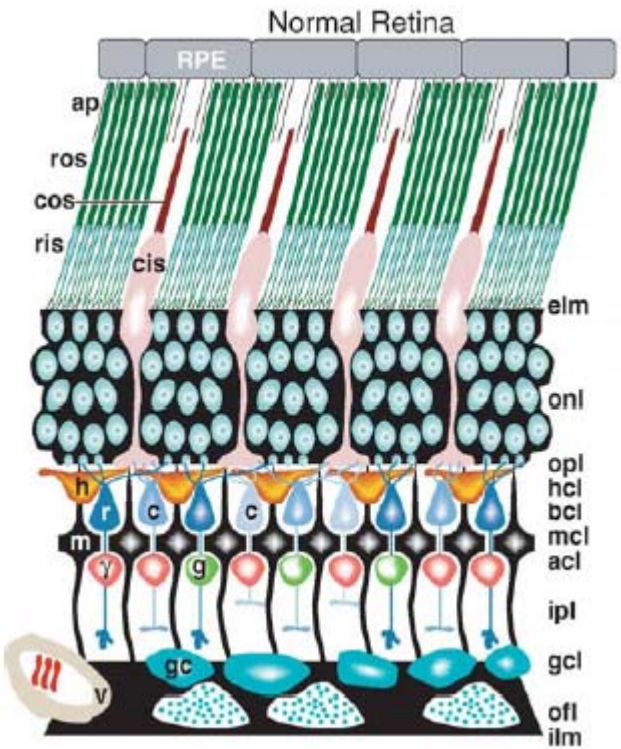
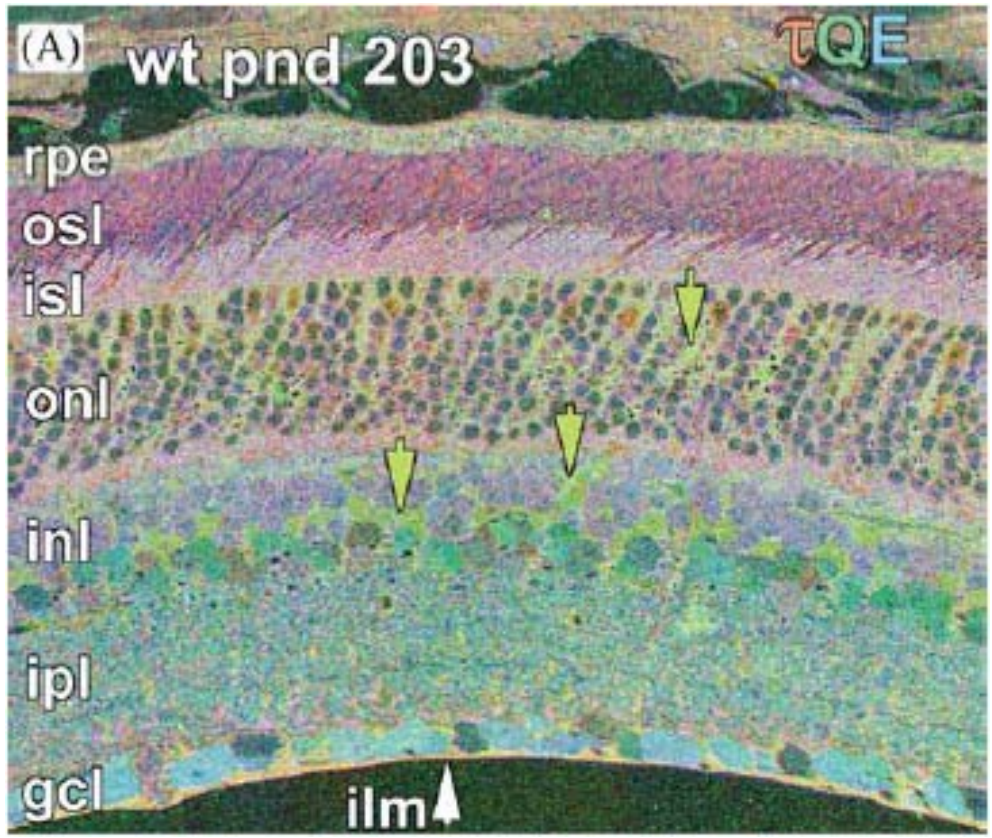
Outline

- The system
  - Retinal degeneration and blindness
  - Retinal remodeling interfering with recovery
- The proposed models
  - Feed-forward neural network
  - Multiple ant colonies
- Methodology
- Implementation

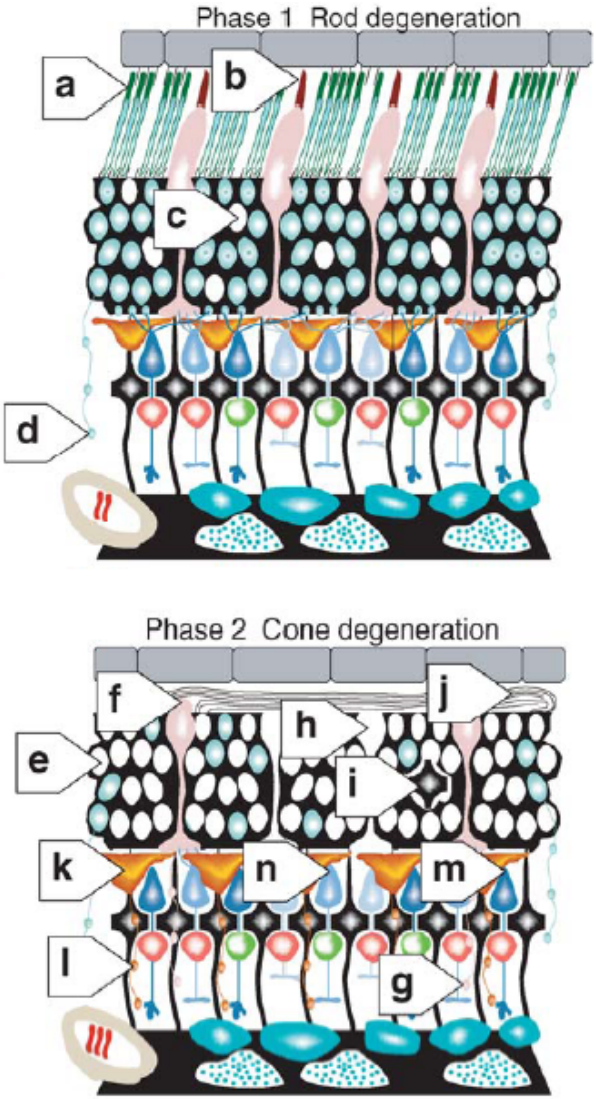
Retina – Layered Neural Network



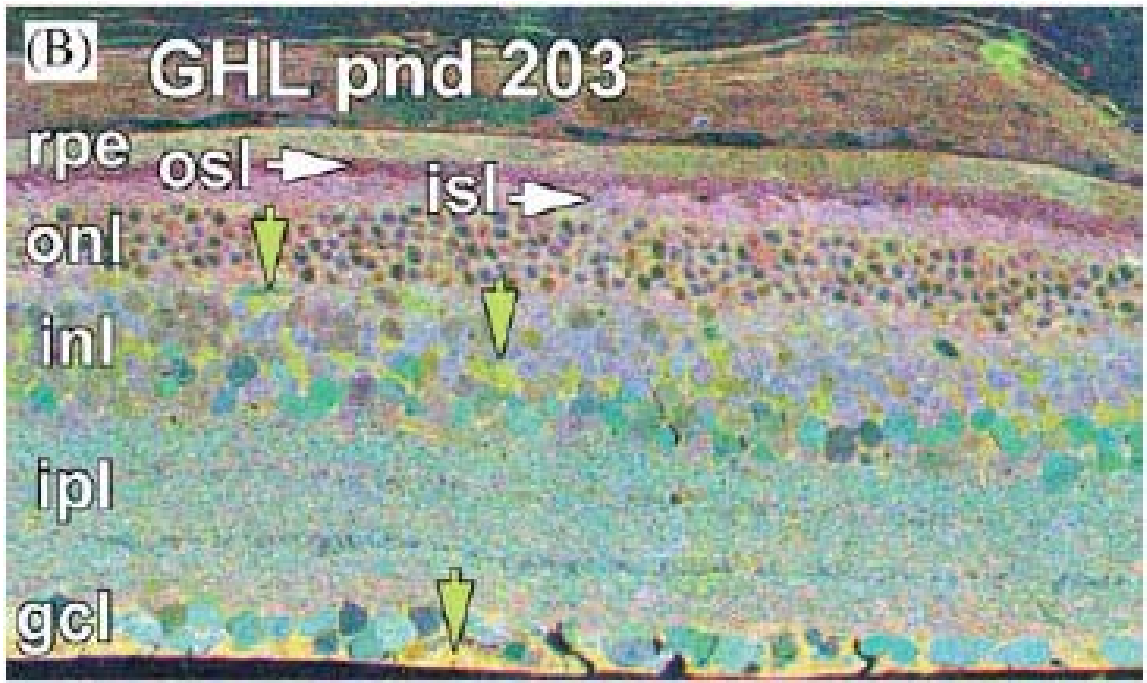


from Marc et al 2003

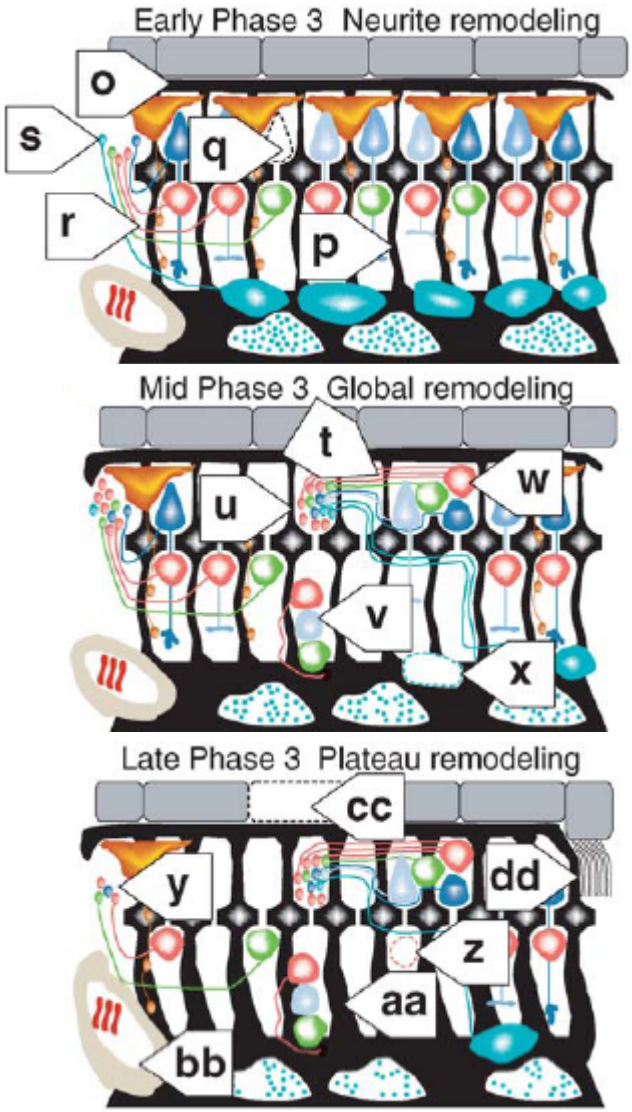
Retina – Receptor Death



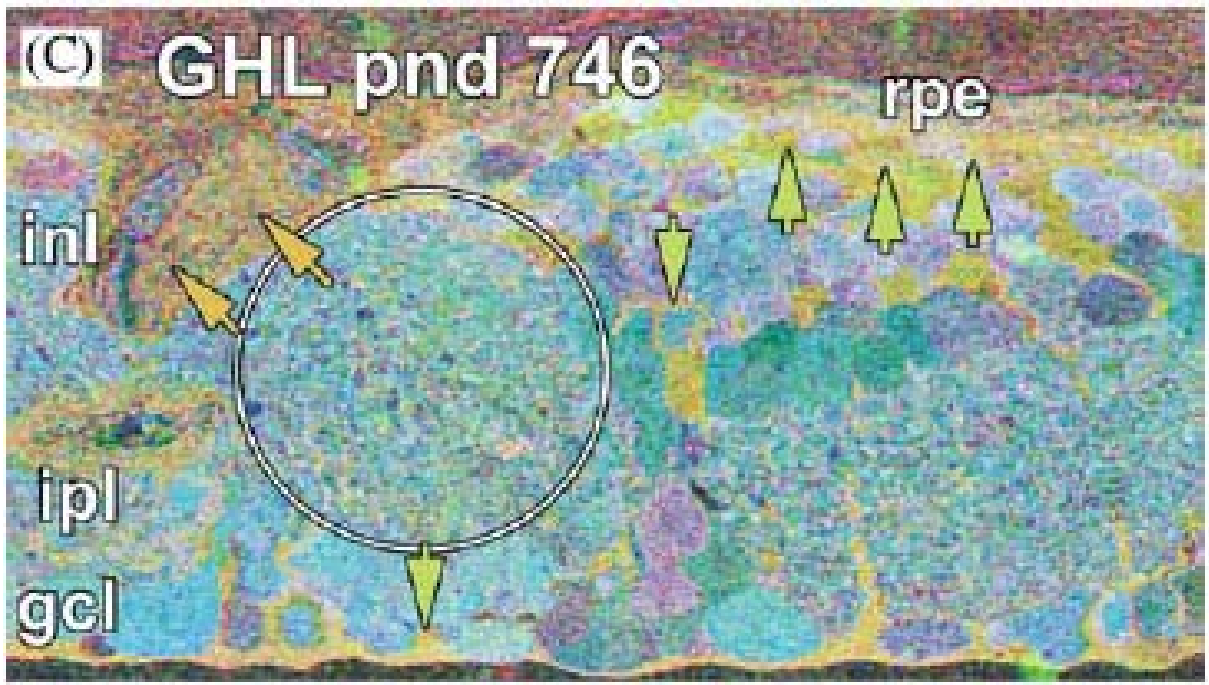
- Rods & cones die
- Sensory & neural (soma's) layers collapse



Retina – Remodeling



- Surviving cells send out new processes
- Cells migrate to other areas



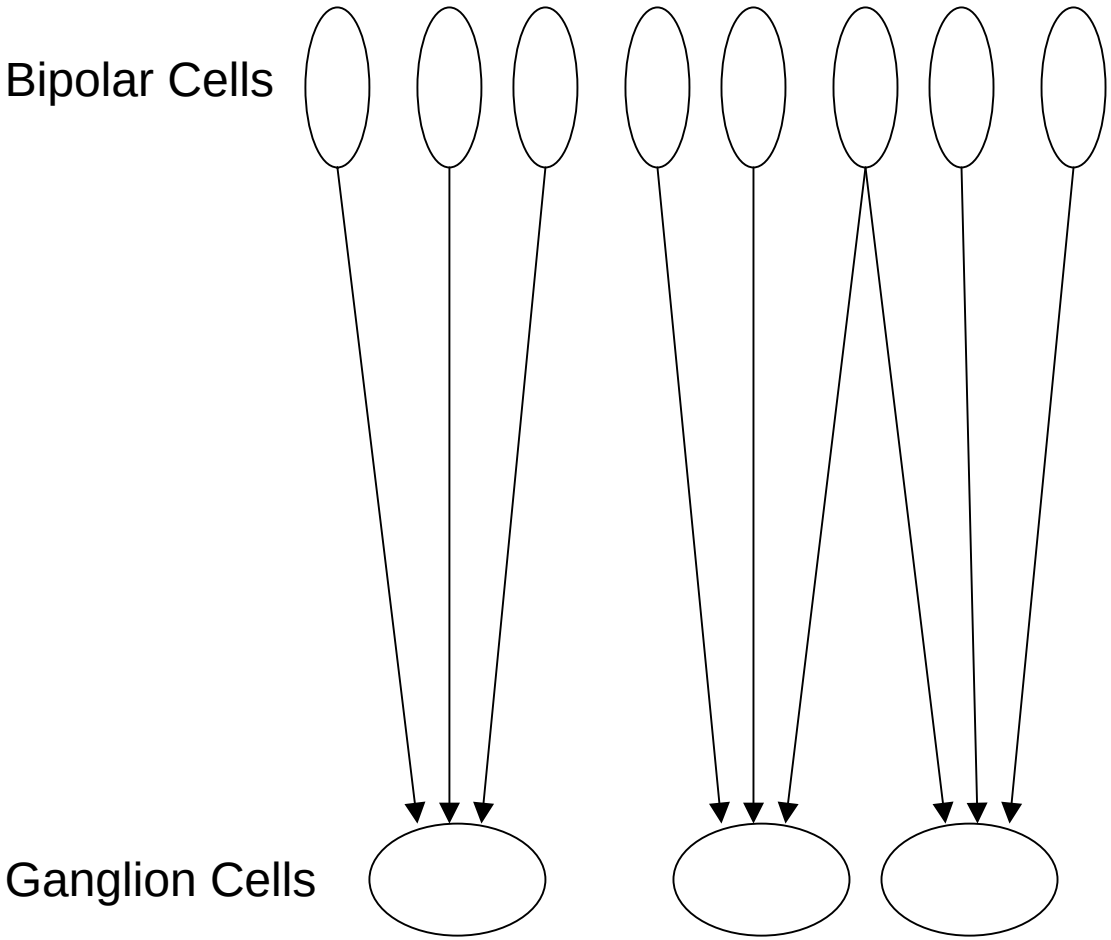
Proposed Model

- Create a layered network to mimic the functioning neural retina
- Use ant foraging model to simulate neurites searching for new input
- Retest remodeled network and compare the output

Proposed Model – Neural Network

- Create a layered network to mimic the functioning neural retina
  - Bipolar and ganglion cell layers operate as feed forward network
  - Horizontal and amacrine cell layers operate as localized attractor network
  - Network will be trained with different objects and/or patterns

Proposed Model – Neural Network

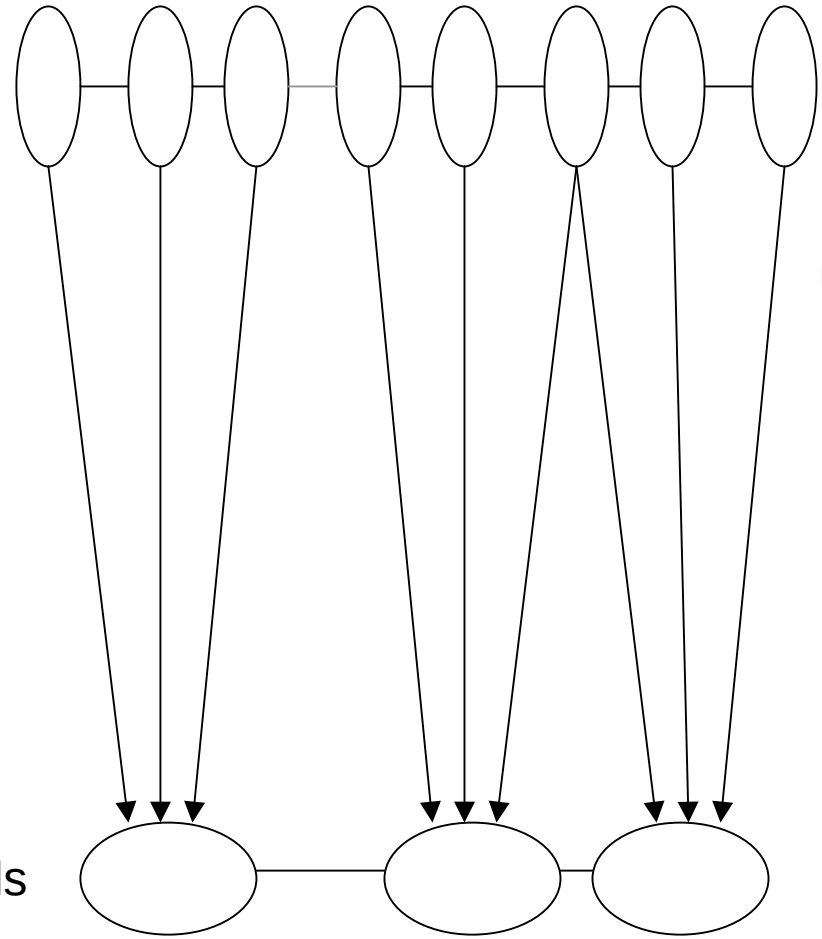


Simplest model

Feed forward network:
Bipolar Cells = Input Layer
Ganglion Cells = Output Layer
Ganglion cell input comes from multiple bipolars

Proposed Model – Neural Network

Bipolar Cells

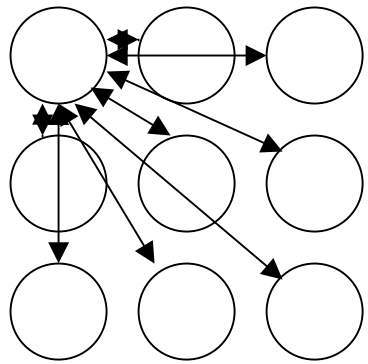


Ganglion Cells

Added complexity

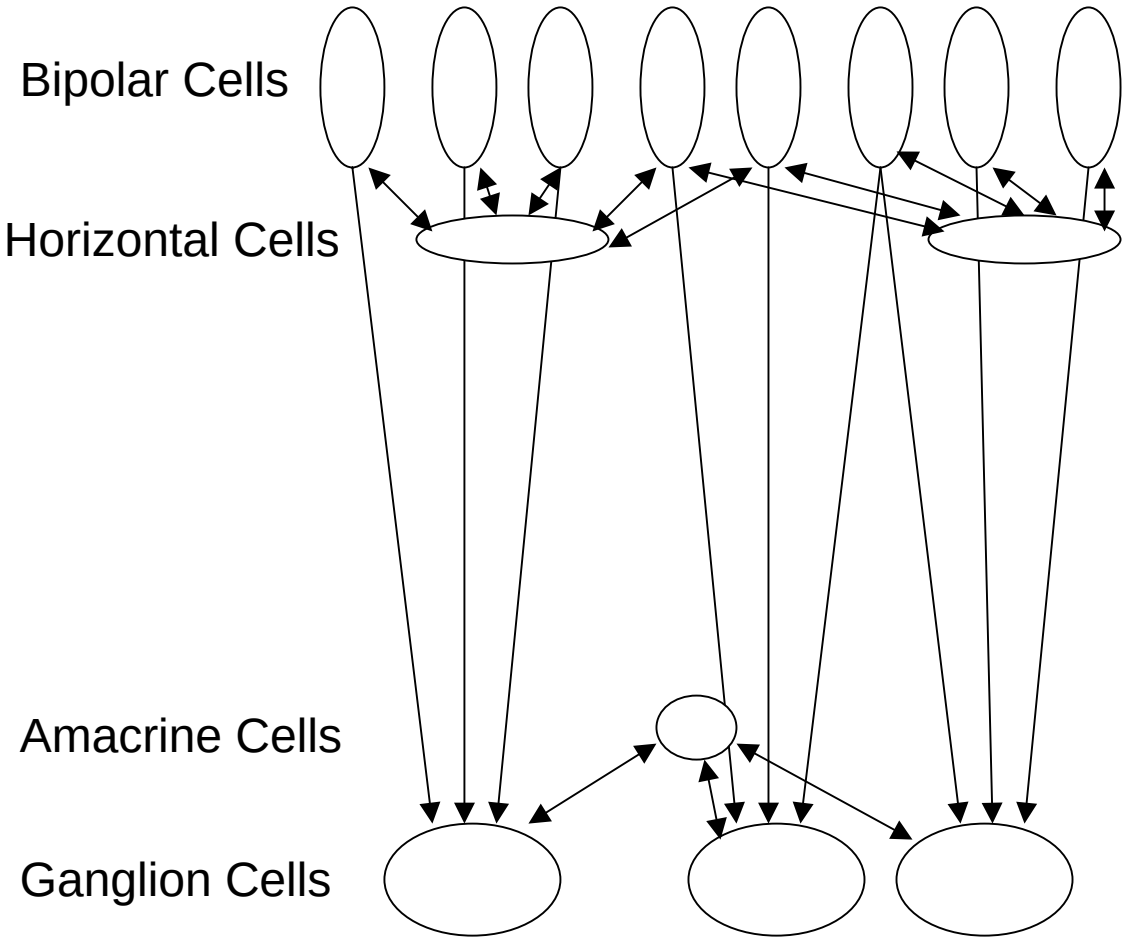
Cells within each layer are interconnected to each other

Repeat for each cell



Top View

Proposed Model – Neural Network

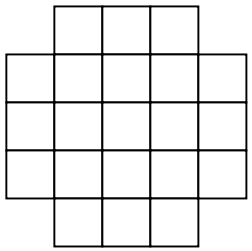
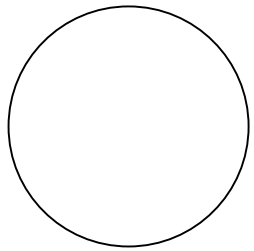
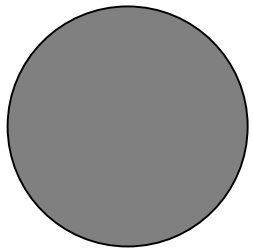
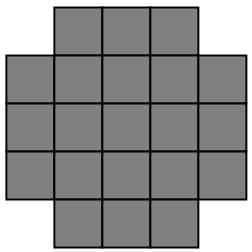
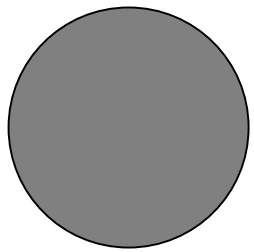
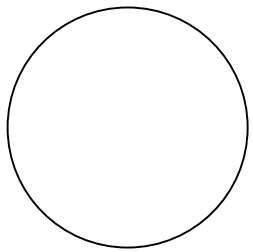
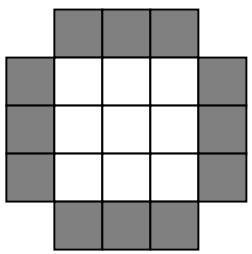
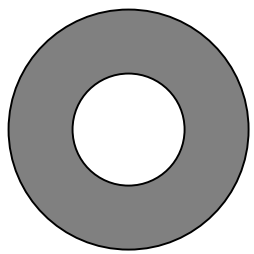
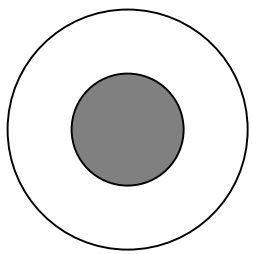


More complexity

Introduce horizontal and amacrine cells for interconnection within layers

Ultimate goal is to simulate receptive fields of the ganglion cells

Proposed Model – Neural Network

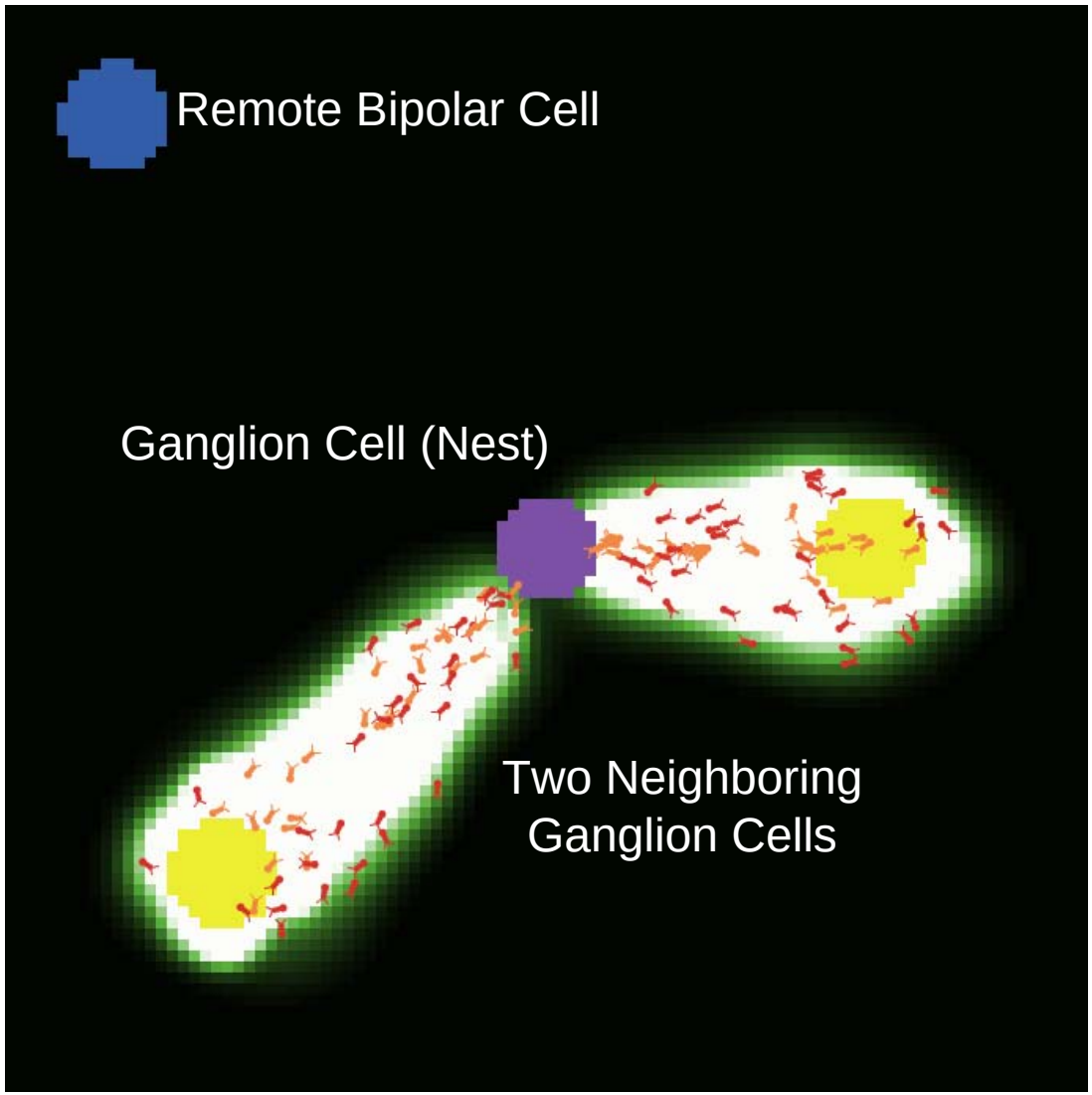
Bipolar Input	Ganglion Cell Behavior	Cell A	Cell B
	On Cell (A) would produce more spikes Off Cell (B) would produce fewer spikes		
	On Cell (A) would produce fewer spikes Off Cell (B) would produce more spikes		
	On center off surround cell (A) would produce more spikes Off center on surround cell (B) would produce fewer spikes		

Add only enough complexity to the neural network layout necessary to create these kinds of receptive fields

Proposed Model – Ant Colonies

- Use ant foraging model to simulate neurites searching for new input
  - Each neuron becomes a nest
  - Ant foragers look for food sources (other neurons of the appropriate type)
  - If a nest can’t bring in food at a minimum rate it will die
  - Ultimately new neuron connections established as the strength of ant trails

Proposed Model – Ant Colonies



- Cells and their established connections decay over time
- New strength is added to connections based on strength of ant trail
- Food at each source (other neurons) does not reduce with consumption by ants but by the decay of the cell
- Cells can remain alive by establishing an equilibrium with each other

Proposed Model – Lost "Potential" Vision

- Retest remodeled network and compare the output
  - Use the same test inputs and observe the outputs
  - Quantify the variation in the outputs
  - Use those numbers to determine time course of the model
  - Adjust parameters to more accurately match the real thing

Implementation

- Randomly position neurons for each layer aiming for specific spatial density
- Establish connections based on rules from the natural system
- Run ant colony simulation with each neuron acting independently
- Compare network output after remodeling
- Tweak parameters

Implementation

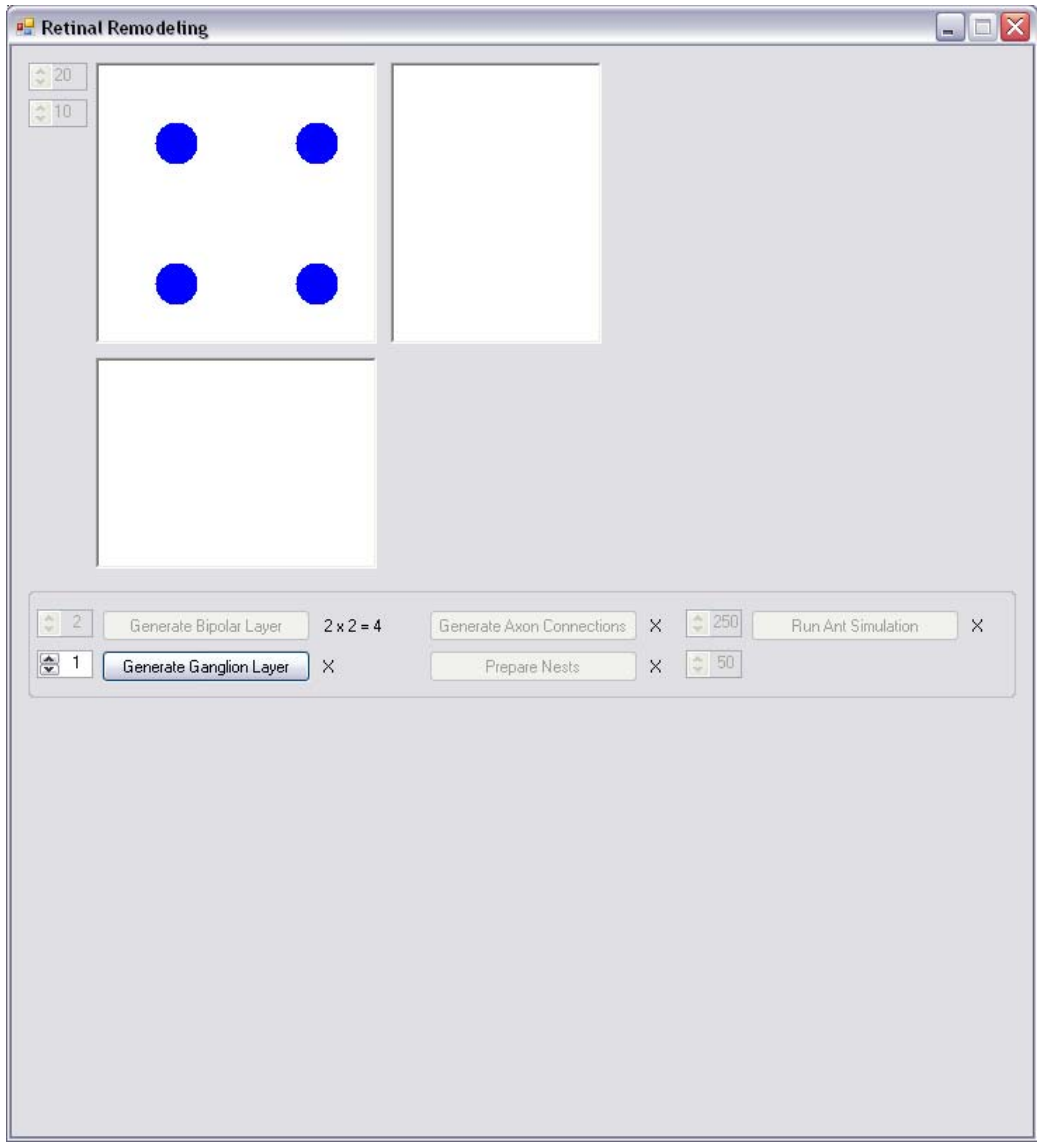
- Language: Visual Basic
  - Existing modules to make things easier – unknown
  - Possibly utilize NetLogo or some other utility for one model and/or the other
- Graphics: Simplistic 2D representations of the actual network
  - Excel: plotting of data
- Input/Output images

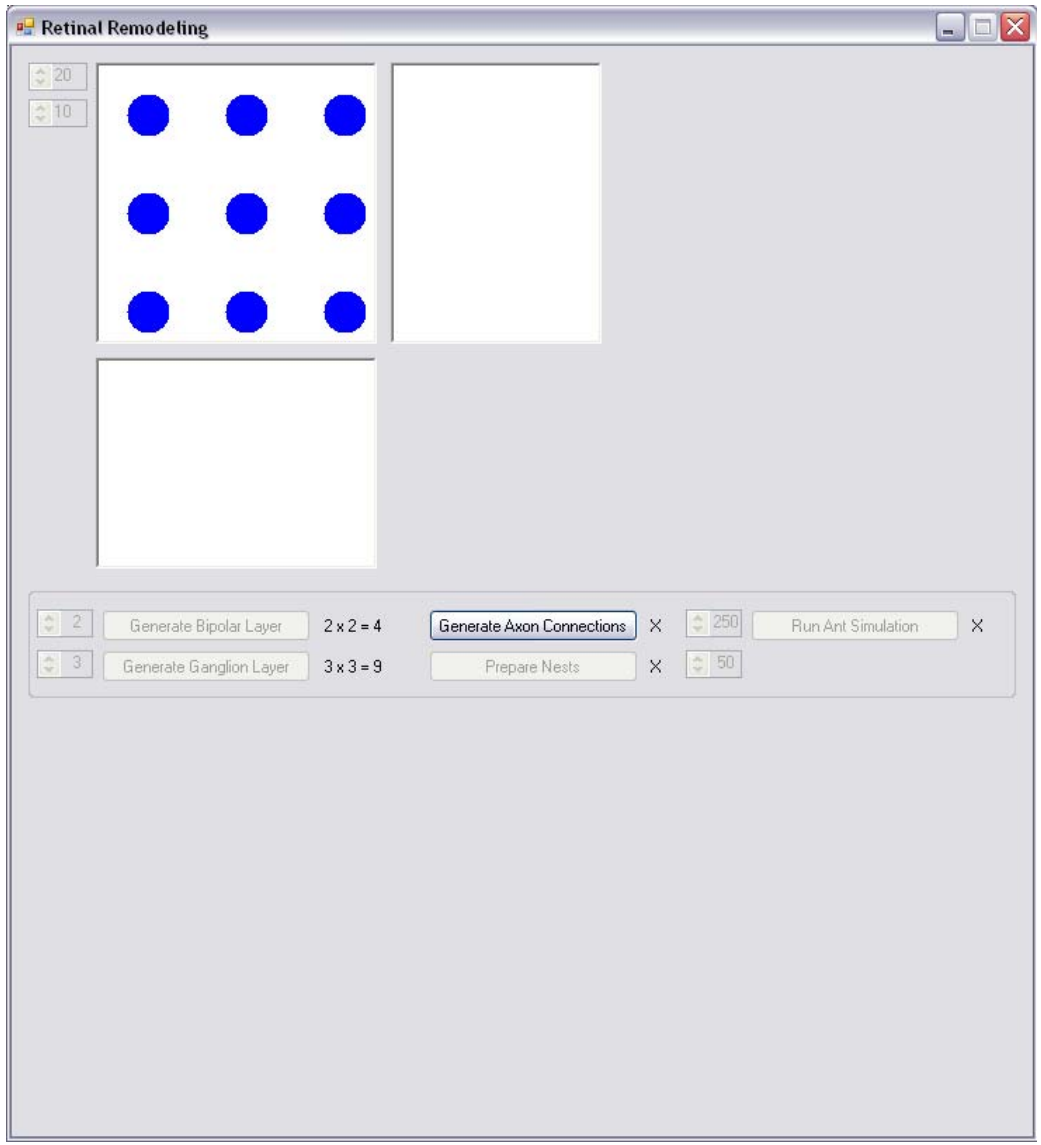
Progress

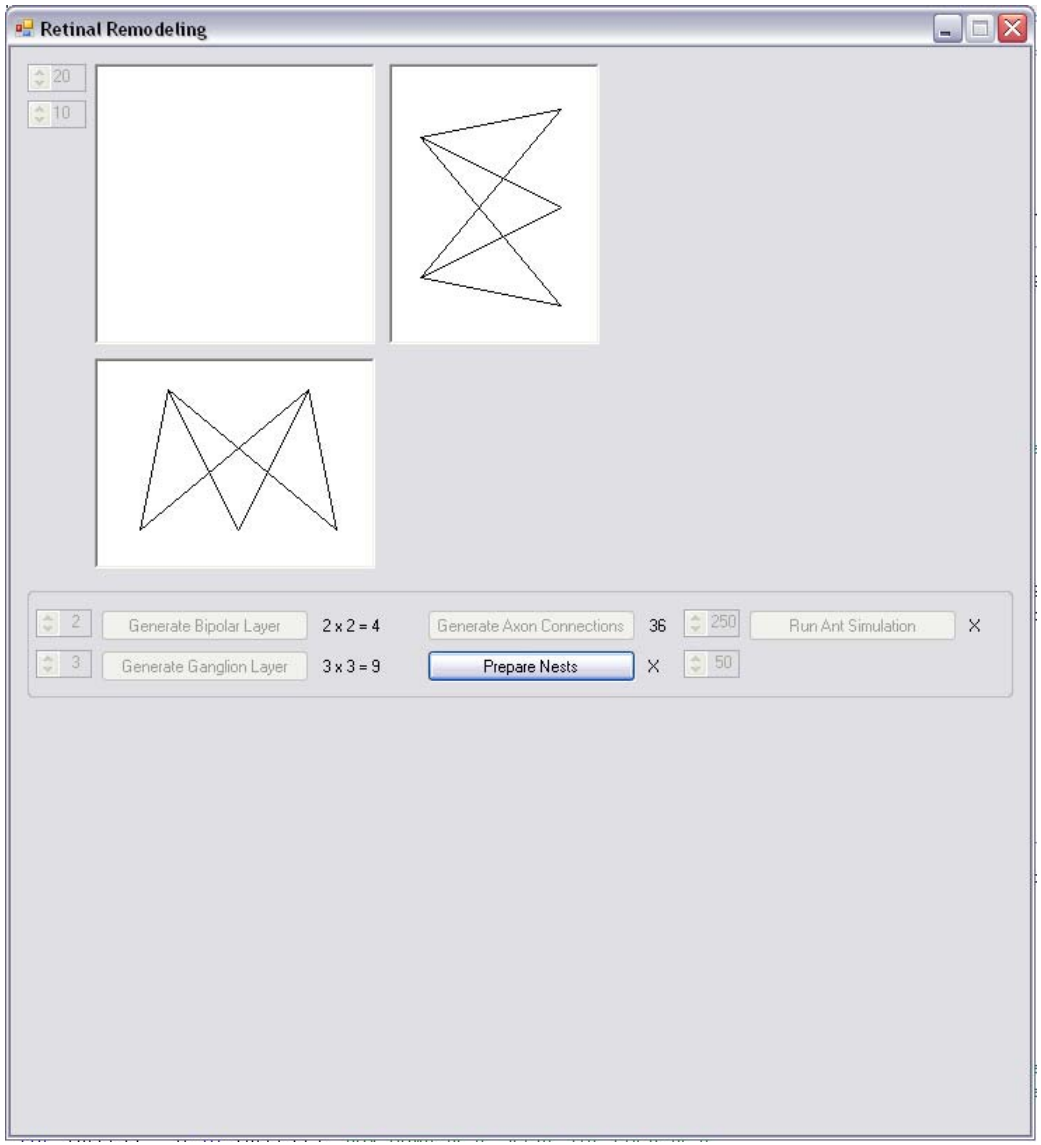
- Physical model
  - Consists of a 3-dimensional space of patches
    - Each patch has a value for each nests' scent
    - Each patch has a value for each nests' ant pheromone which decays over time
  - Each nest occupies a 3x3x3 volume of patches at its location

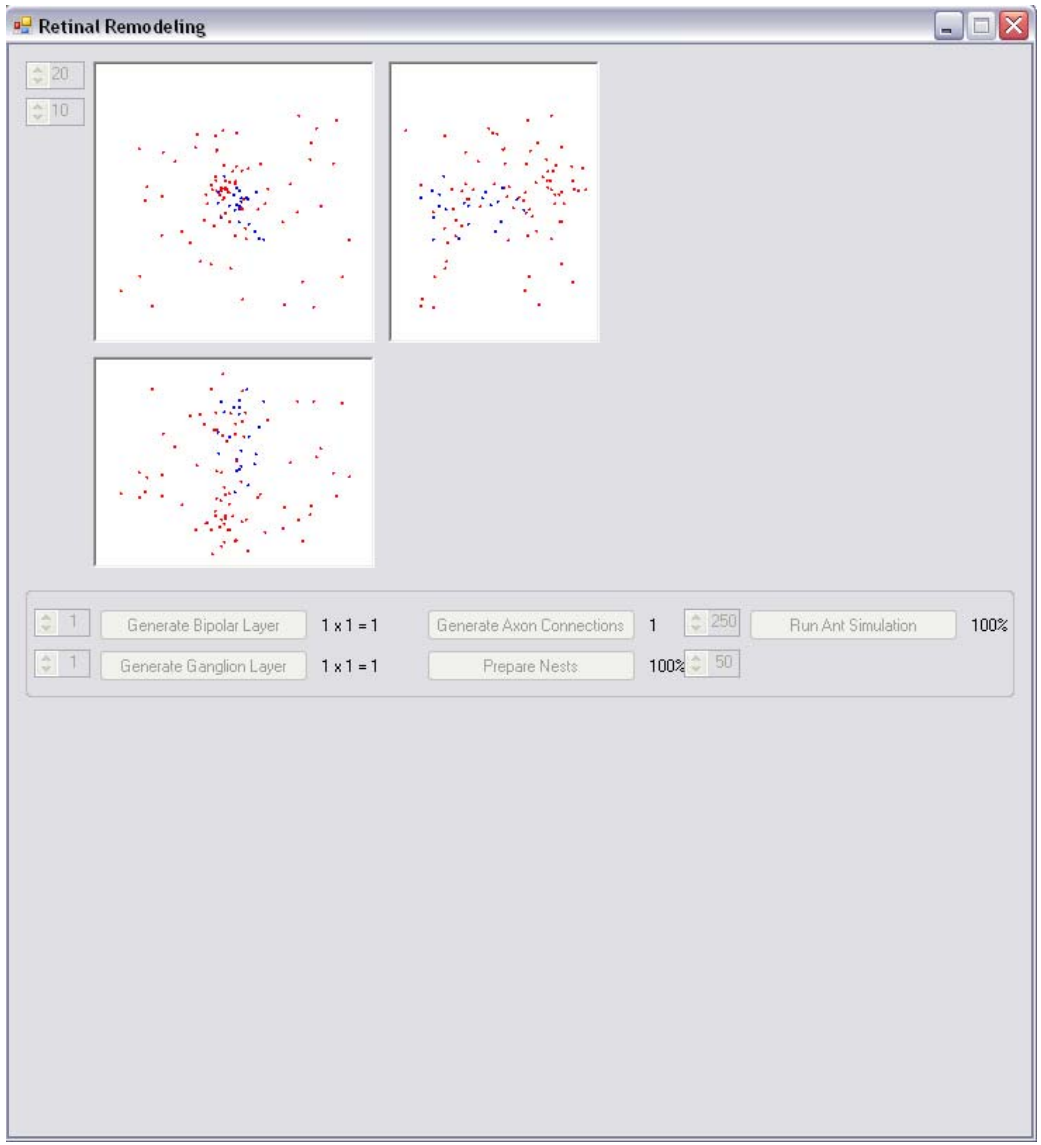
Progress

- Ants move in continuous space within the patches
  - Patches are defined by integer values, ant position by floating point values
  - Each ant searches for food, following pheromone if they find it, and bring food back to the nest when found
  - Ants can get food from any nest other than their home nest, and only follow the pheromone laid by ants from its home nest


Retinal Remodeling
20
10
2
Generate Bipolar Layer
2 x 2 = 4
Generate Axon Connections
X
250
Run Ant Simulation
X
1
Generate Ganglion Layer
X
Prepare Nests
X
50


Retinal Remodeling
20
10
2
Generate Bipolar Layer
2 x 2 = 4
Generate Axon Connections
250
Run Ant Simulation
3
Generate Ganglion Layer
3 x 3 = 9
Prepare Nests
50


Retinal Remodeling
20
10
2
Generate Bipolar Layer
2 x 2 = 4
Generate Axon Connections
36
250
Run Ant Simulation
X
3
Generate Ganglion Layer
3 x 3 = 9
Prepare Nests
X
50


Retinal Remodeling
20
10
1
Generate Bipolar Layer
1 x 1 = 1
Generate Axon Connections
1
250
Run Ant Simulation
100%
1
Generate Ganglion Layer
1 x 1 = 1
Prepare Nests
100%
50

Current Problem

- Nests in the lower z region are getting more food brought to them than those in the upper z region (usually 2x as much)
- This holds for multiple nest configurations in one layer or the other or both
- “Better” ants need to follow the pheromone in positive z direction and go back to the nest in negative z, so if it’s a problem in z . . .

Priorities

- Code in a way to store frames of a movie for each iteration so that multiple runs can be done to test parameter space
  - Additionally, add more quantification for this testing
- Establish pheromone trails at the beginning to draw ants into trails representing axons of healthy retina

Priorities

- Implement decay and retinal remodeling
  - Nest food quality decays over time (nest dies if it reaches zero)
  - Nest food quality decay offset by incoming food brought by its ants
  - Quantify trails in steady state / cut off time to use for image processing through modeled retina
  - Test with hundreds of nests

Questions?