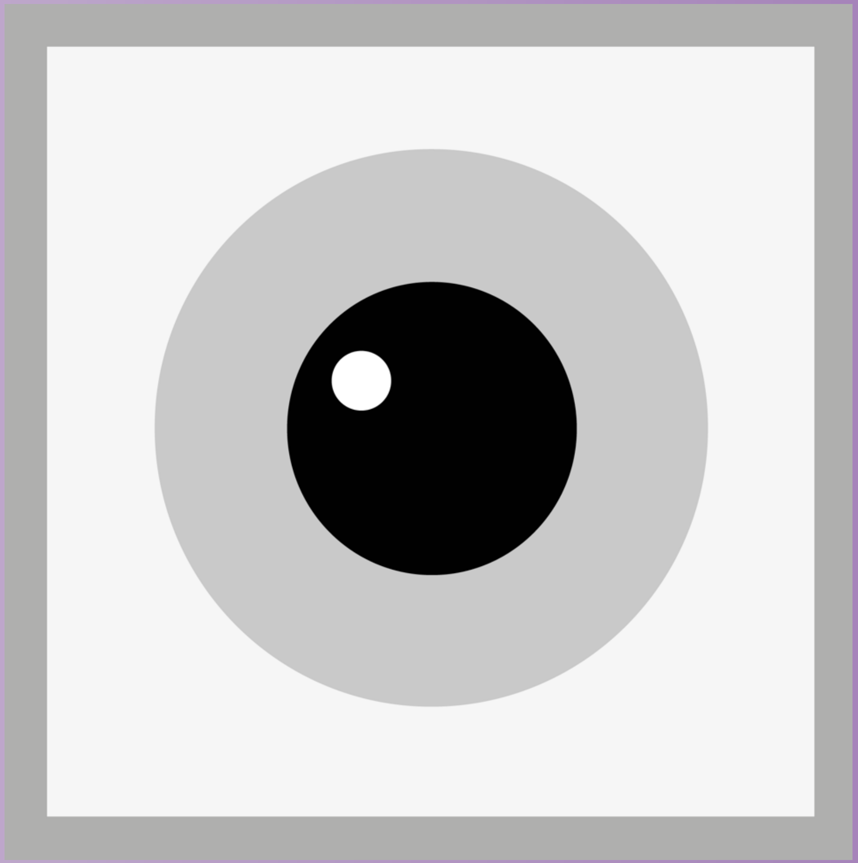
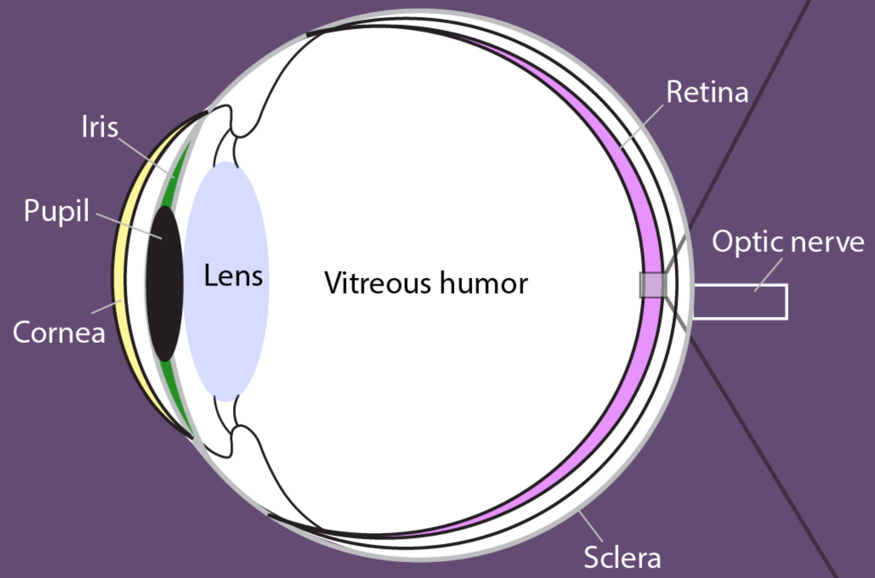
# RetINaBox

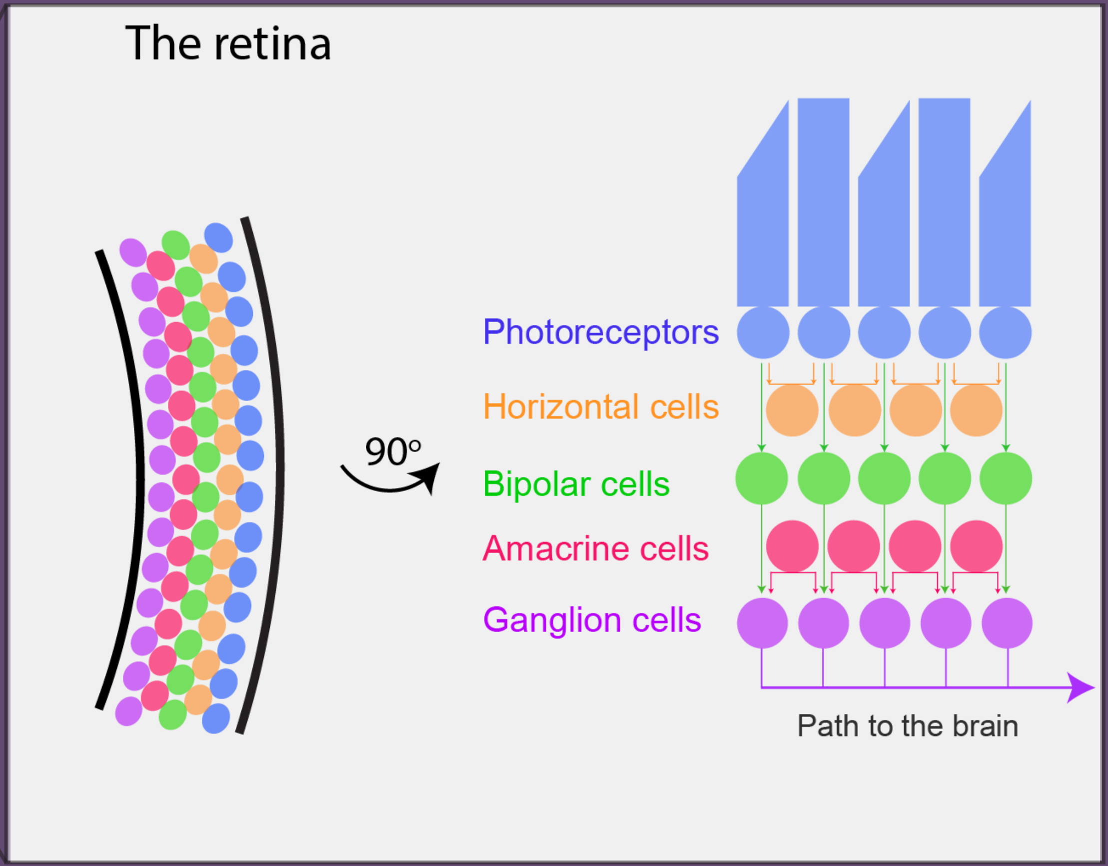
Lesson Plans



# How do we see?

## The retina



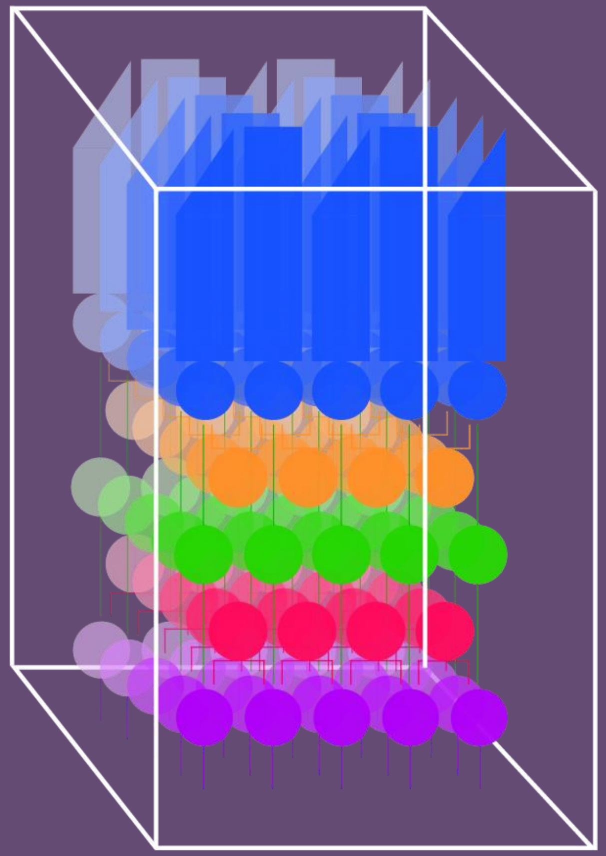



# How do we see?

## The retina

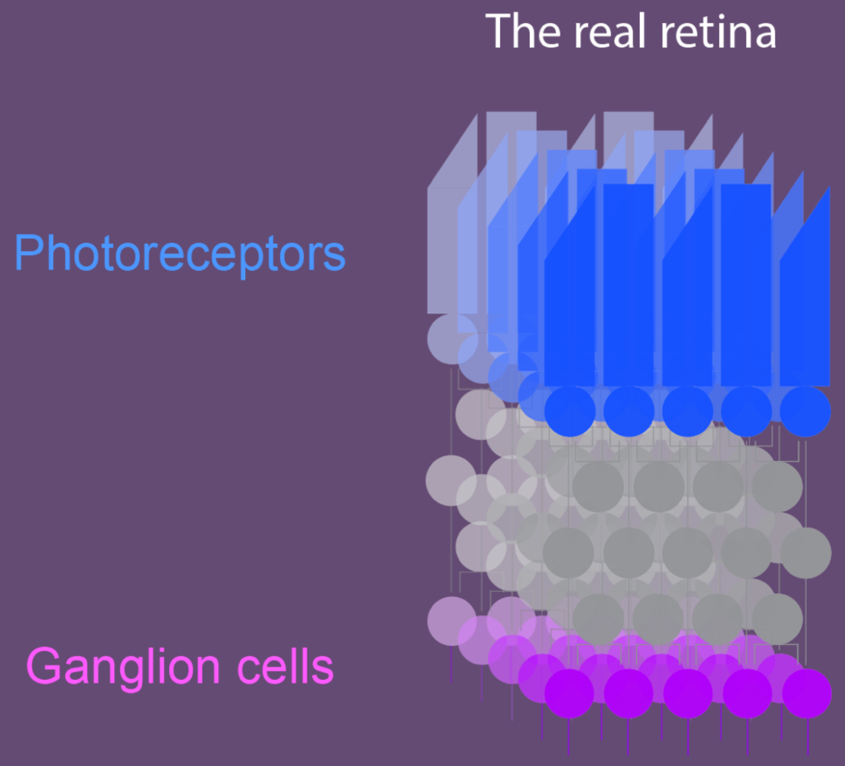
Photoreceptors are arranged in a dense 3D arrangement.

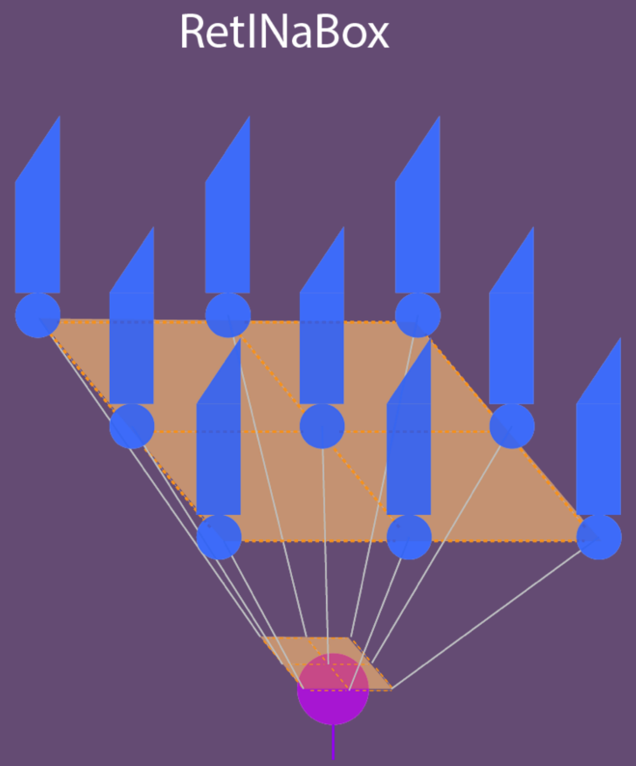
Within a given retinal layer, cells form a 2D mosaic.



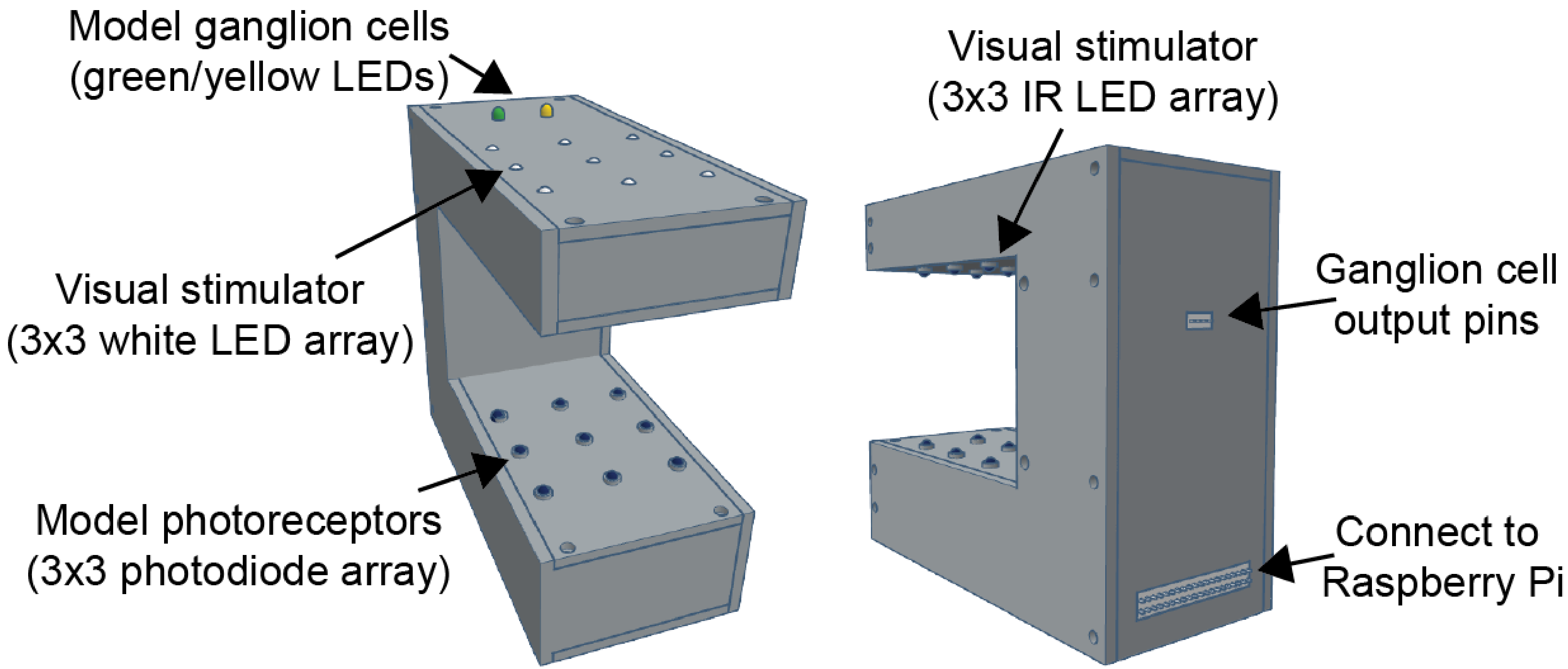
# How do we see?

## The retina

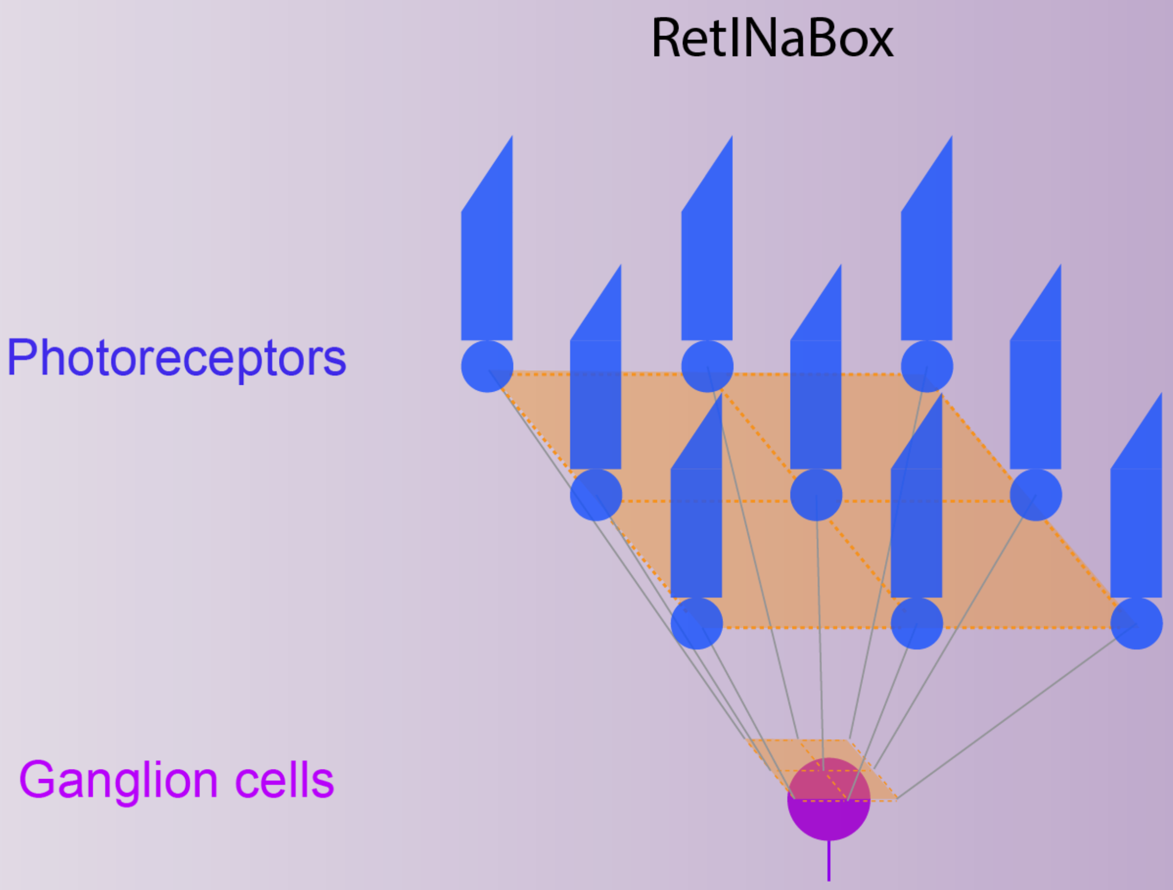


# RetINaBox


Model ganglion cells
(green/yellow LEDs)
Visual stimulator
(3x3 white LED array)
Model photoreceptors
(3x3 photodiode array)
Visual stimulator
(3x3 IR LED array)
Ganglion cell
output pins
Connect to
Raspberry Pi

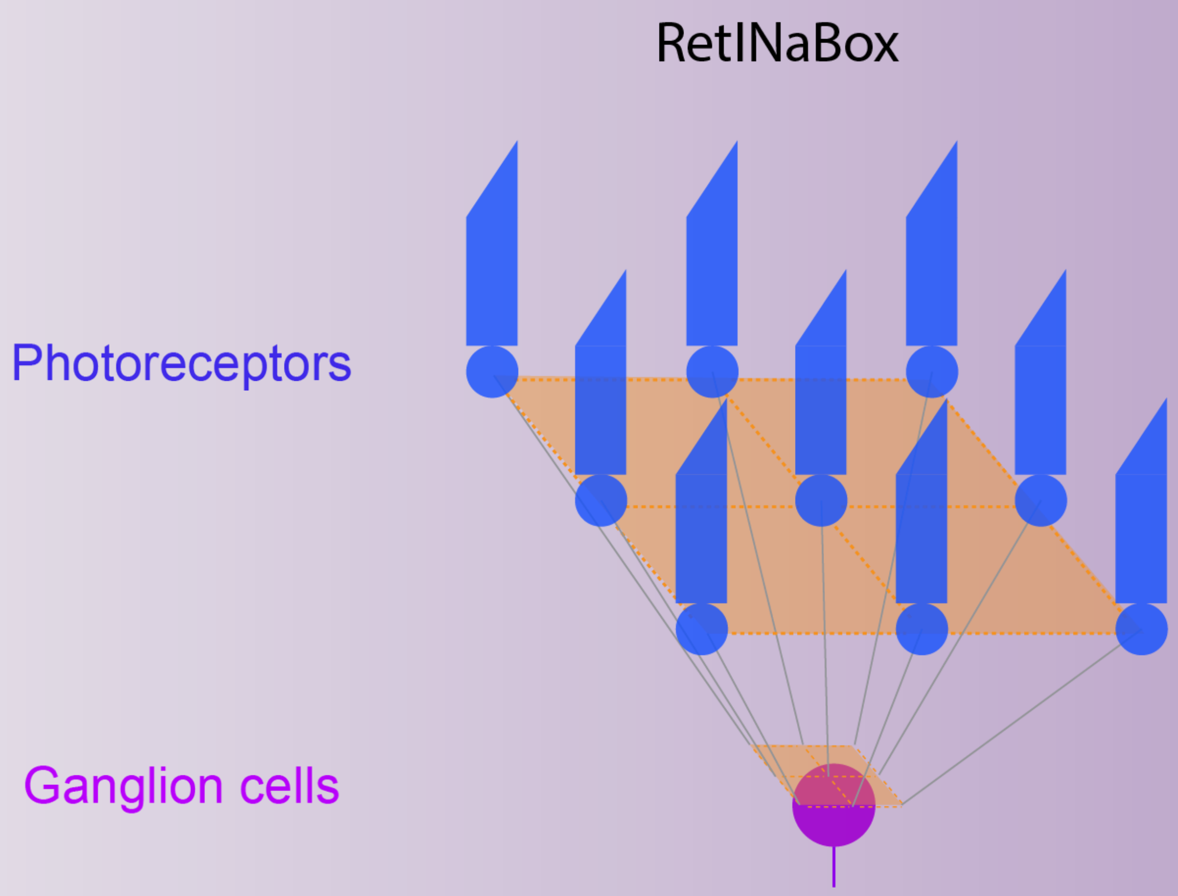
# RetINaBox




Each ganglion cell responds when it receives positive inputs from a sufficient number of photoreceptors.

Each photoreceptor can connect to either or both ganglion cells.

# RetINaBox




For each photoreceptor, you get to set:

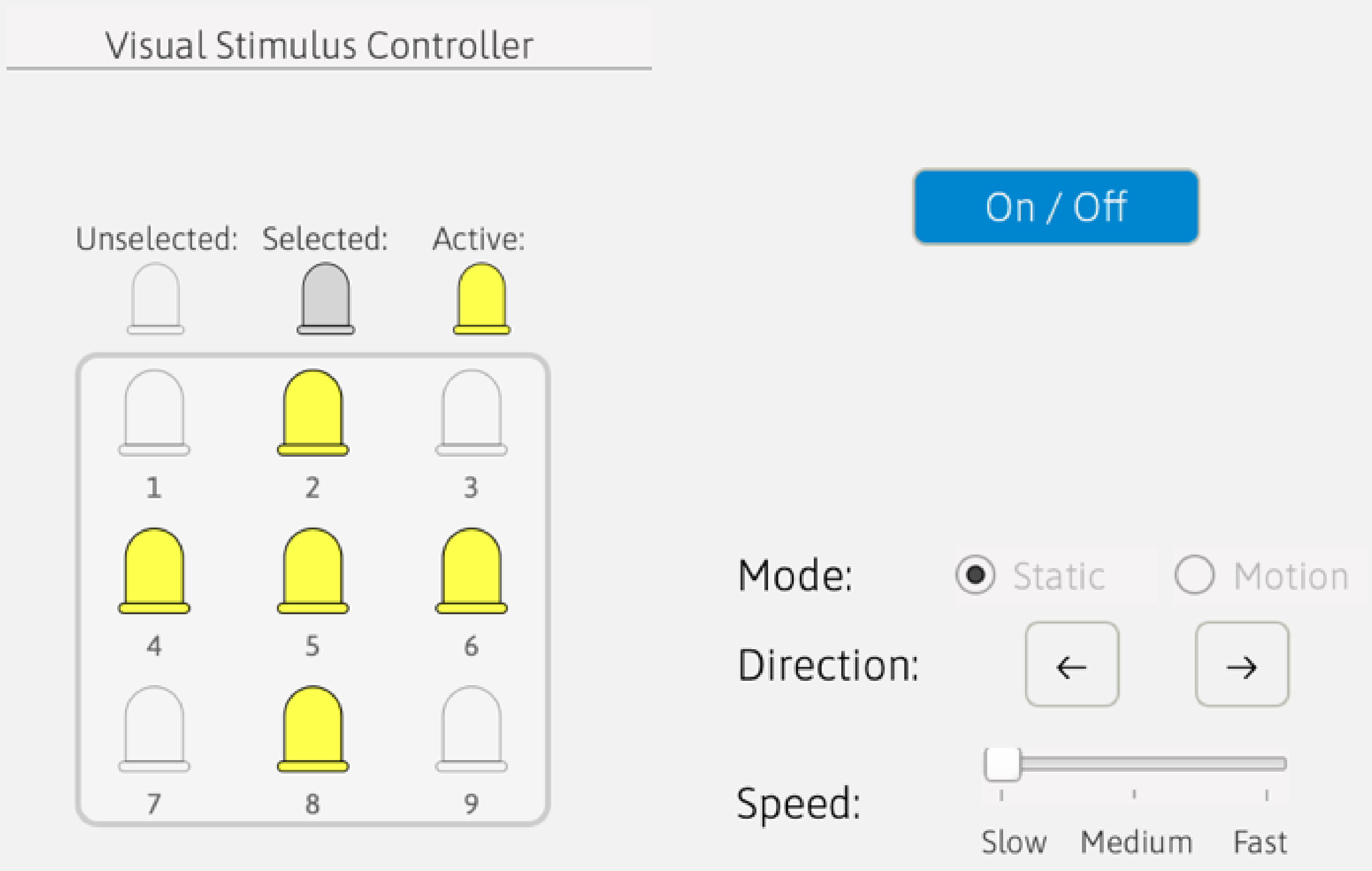
- Polarity
- Time delay

For each ganglion cell, you get to set:

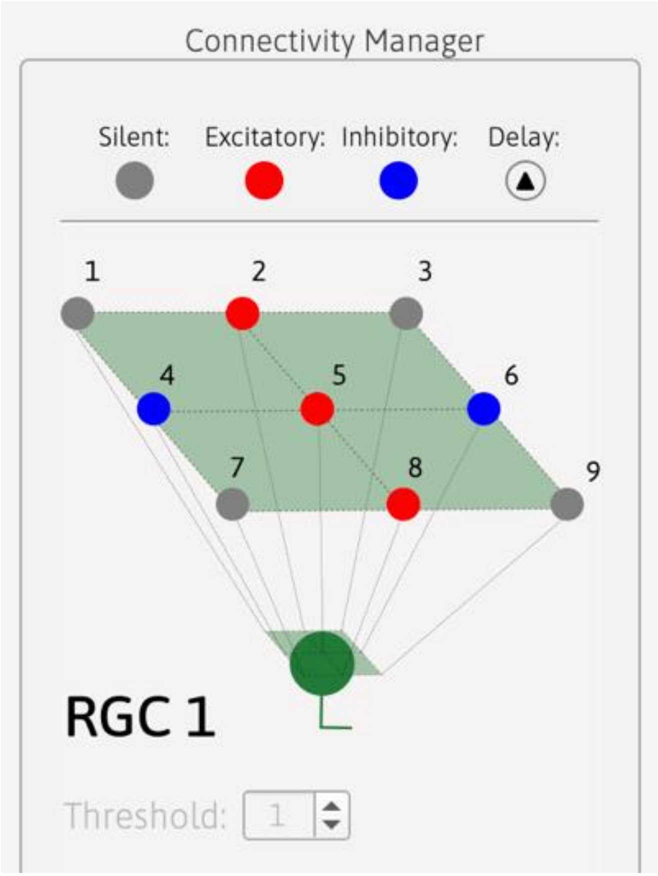
- Threshold

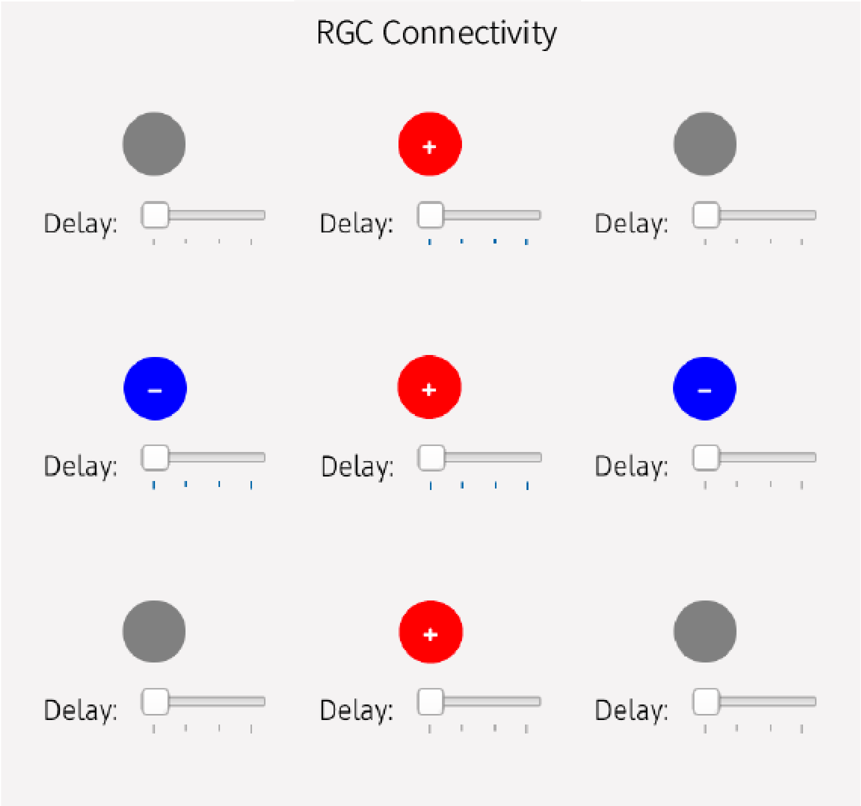
# RetINaBox Graphical User Inerface (GUI)

# Visual Stimulus Controller



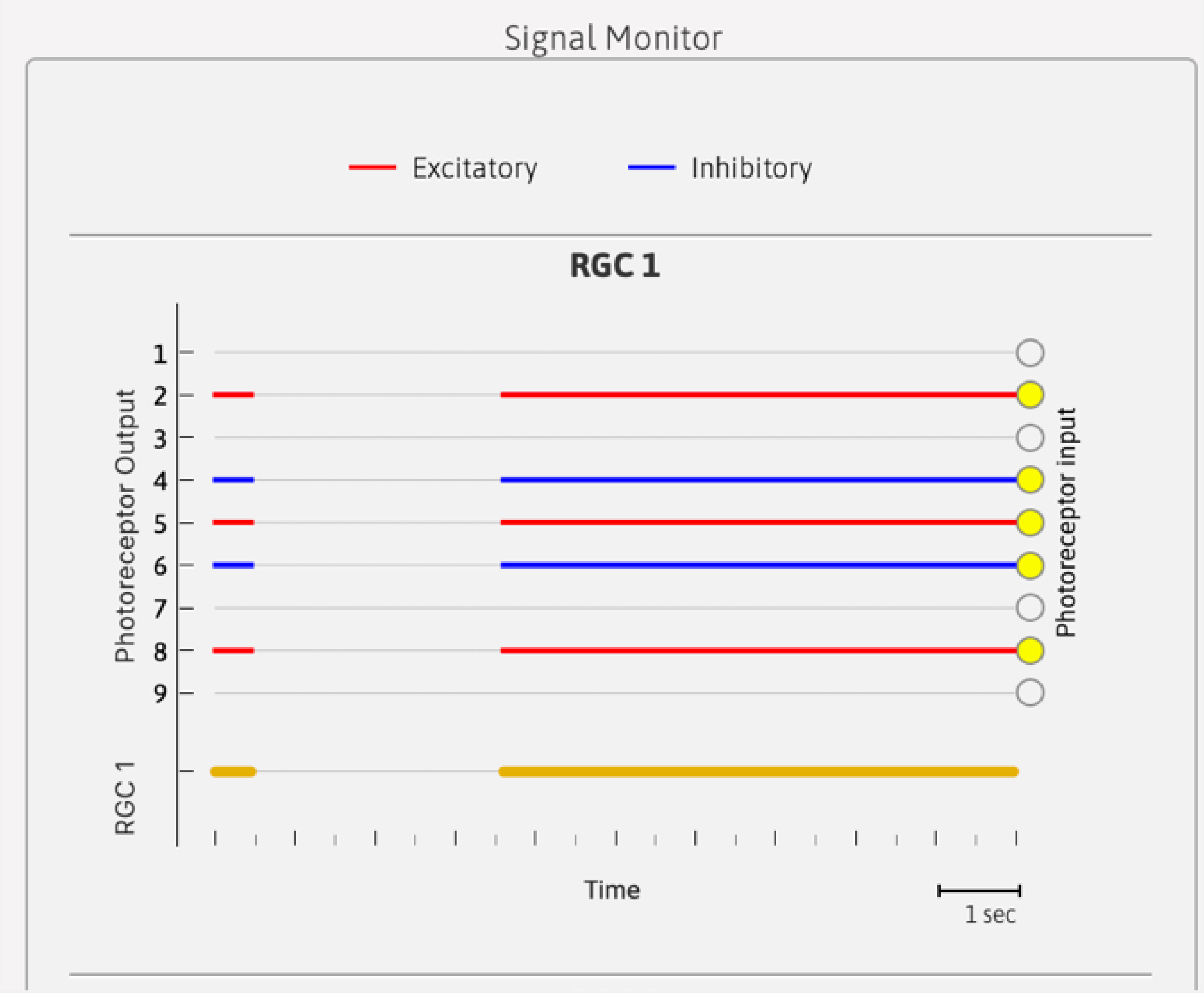
# Connectivity Manager




RGC threshold = 3

# Signal Monitor



# Objectives

## Build

Build simple circuits that mimic retinal ganglion cell with different visual preferences

## Test

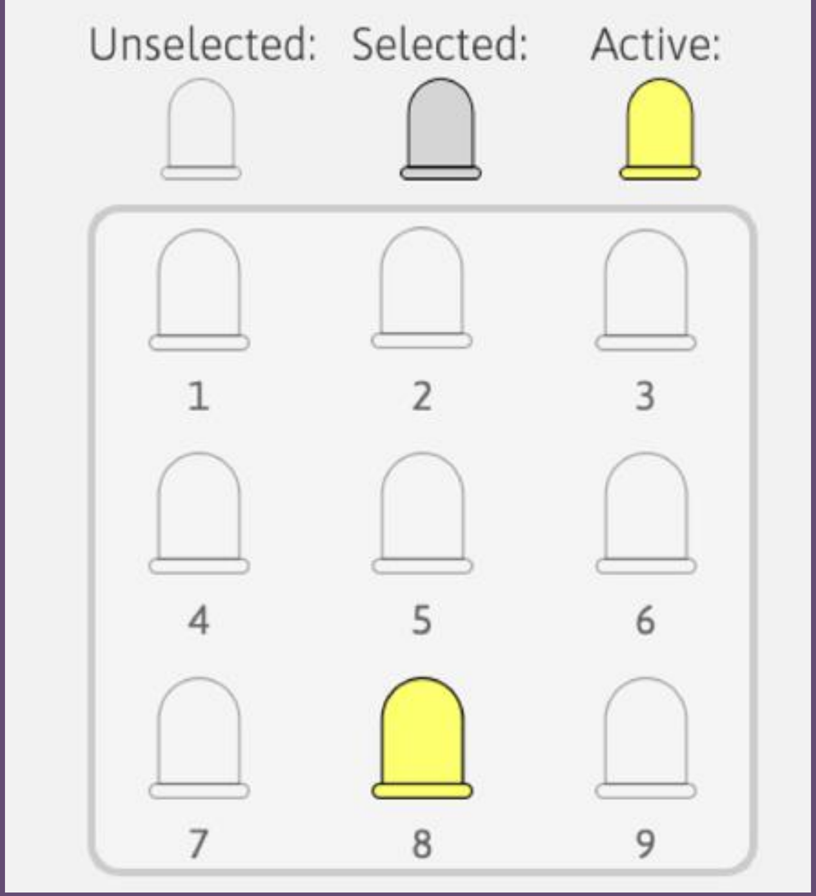
Test your circuit by activating different LEDs to check the ganglion cell's selectivity

## Real-world stimulation

Use the Visual Stimulus Tool to see how robust your circuit is

# Testing your circuits

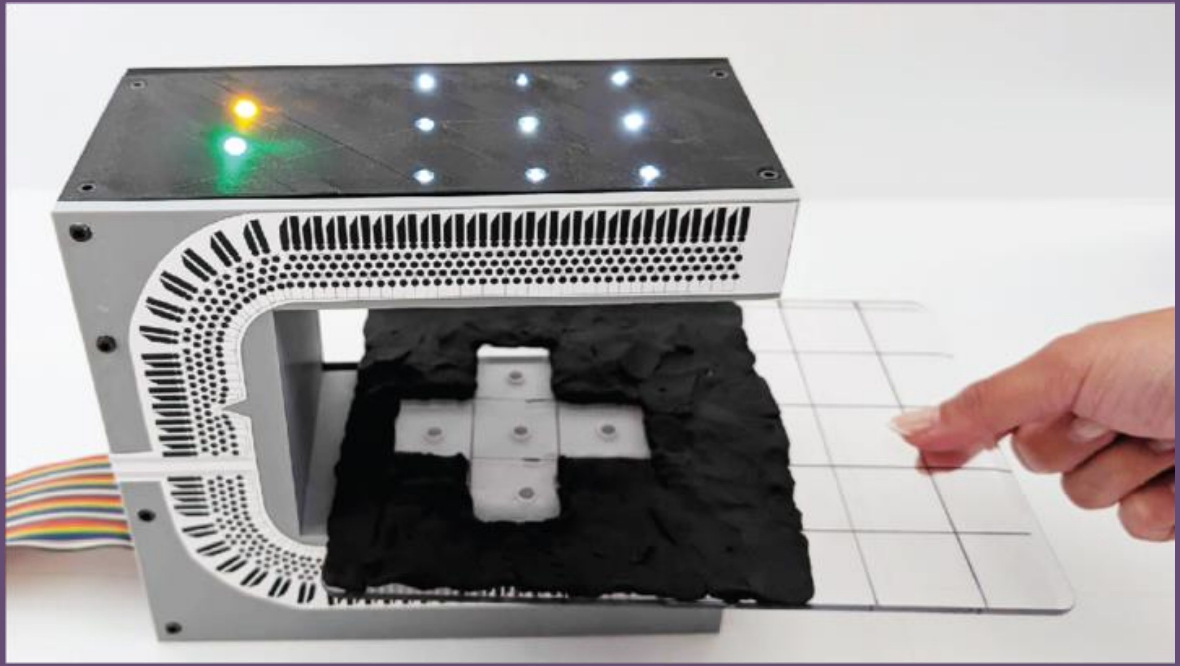
**LED activation**: manually activate different combinations of LEDs in the Visual Stimulus Controller  to stimulate photoreceptors



# Testing your circuits

Turn on the entire LED array

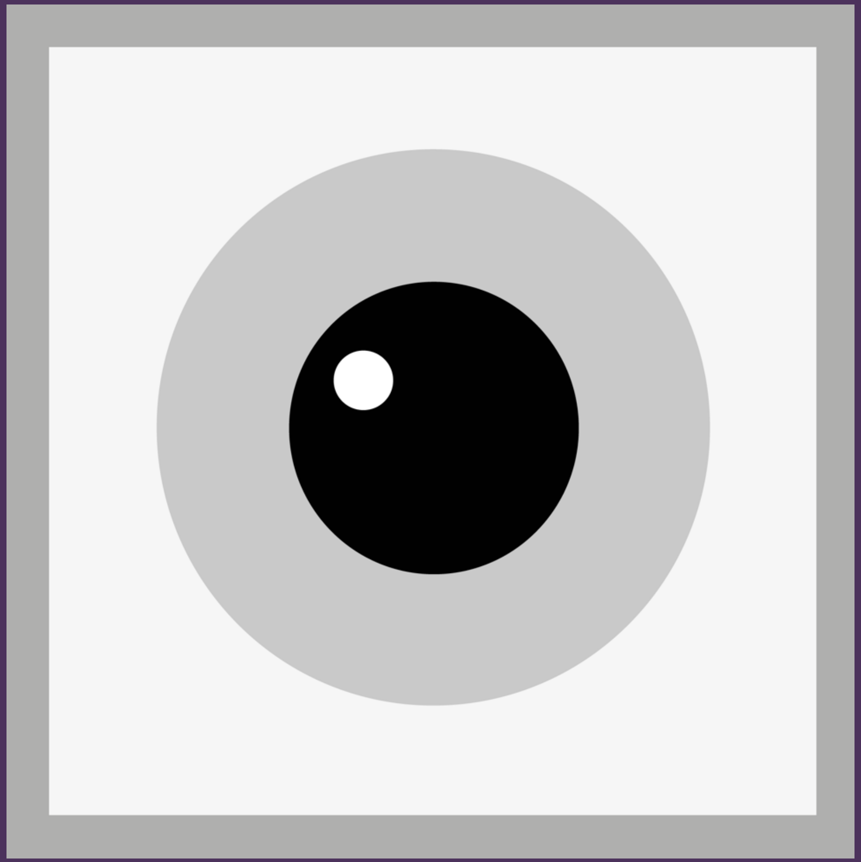
Use the **Visual Stimulus Tool** (modeling clay on a clear plastic  board) or your hands to deliver patterned visual stimuli



# Lesson 1

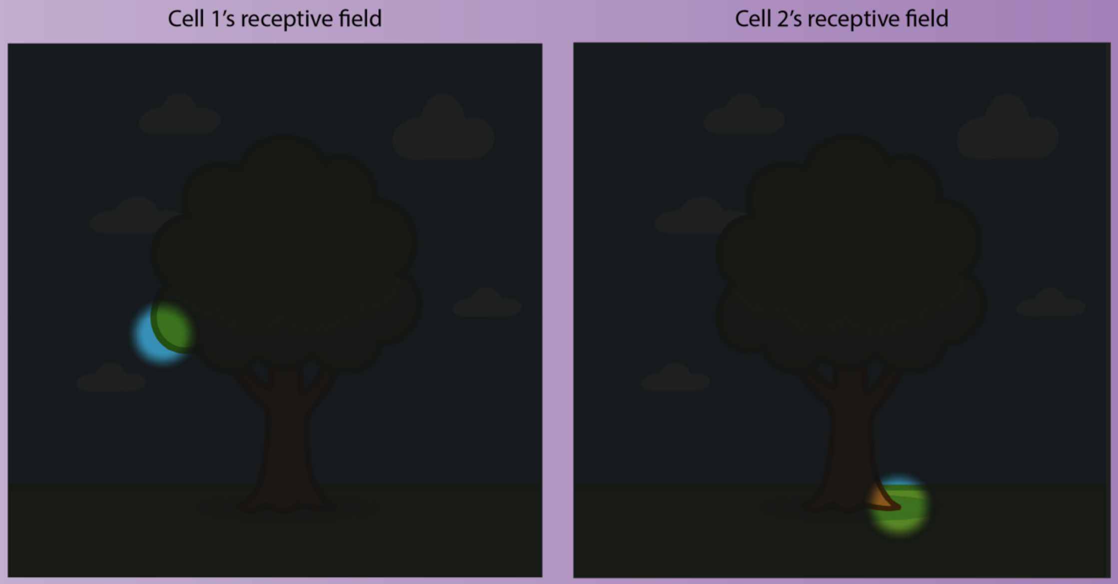
## Center-Surround

How does your visual system know *what* to focus on in the world?



# Receptive fields

Each visual neuron has a receptive field: a specific region of the retina (and therefore, of the visual world) where changes in light intensity can alter that neuron's activity.



## Center-surround tuning

Neurons with center-surround tuning respond to luminance contrast in their receptive field (i.e., when one part of the receptive field is bright while another is dark).

Different neurons can have different sized receptive fields, meaning that different visual neurons prefer objects of different sizes in the visual field

This is useful for both **locating objects** and knowing **how big** they are in the world

# Activity 1

Build a spot detector with an ON-center/OFF-surround receptive field (activated by light in the center of the receptive field but inhibited by light in the surrounding area)

# Activity 2

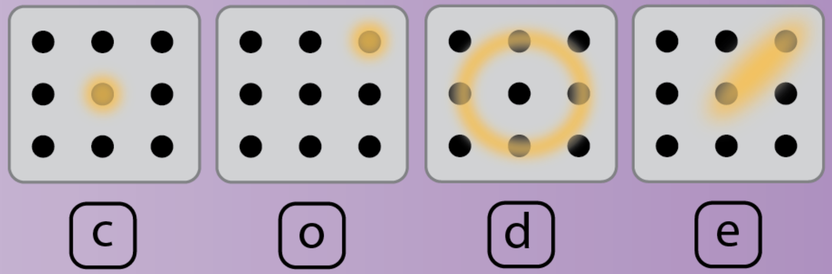
Build a second spot detector with a different receptive field location

# Activity 3

Build two spot detectors with preferences for spots of different sizes

# Challenge

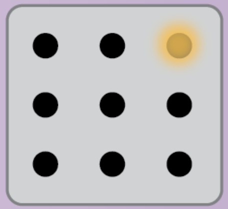
## Codebreaking with center surround receptive fields



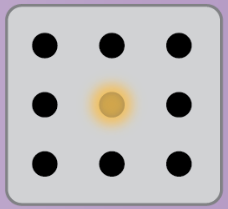

To begin the challenge:
Lessons > Lesson 1 > Code Breaker

### Cipher

**RGC1**
Preferred visual stimulus



**RGC2**
Preferred visual stimulus



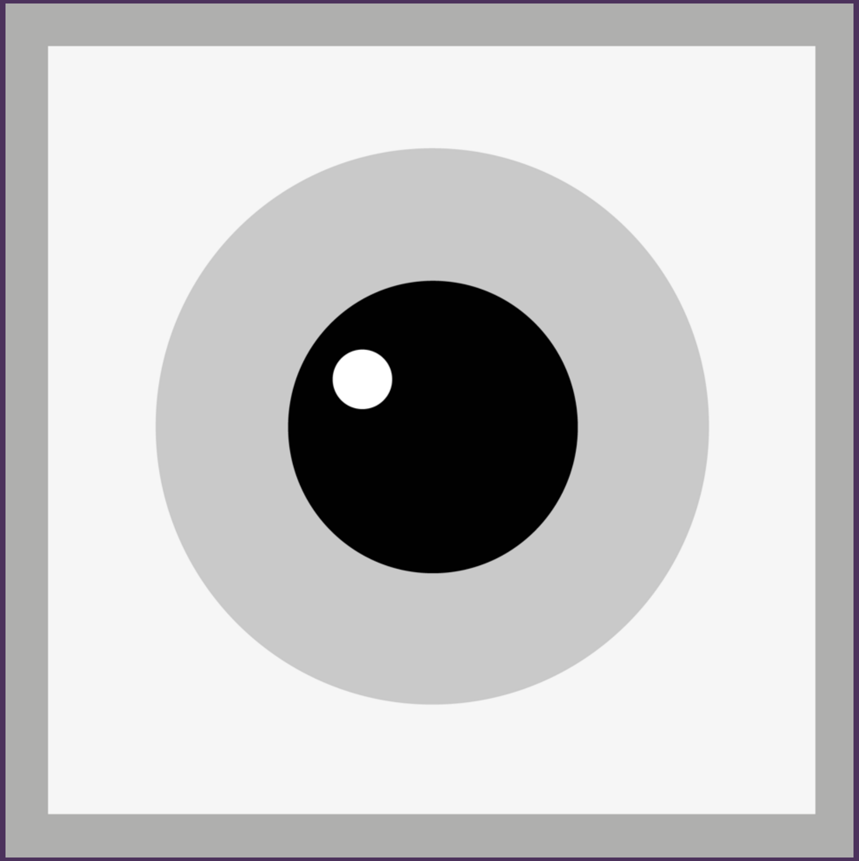
**RetINaBox Output**

| RGC1 | RGC2 | | |
|---|---|---|---|
| 0 | 0 | = | D |
| 1 | 0 | = | O |
| 0 | 1 | = | C |
| 1 | 1 | = | E |

# Lesson 2

## Orientation Selectivity

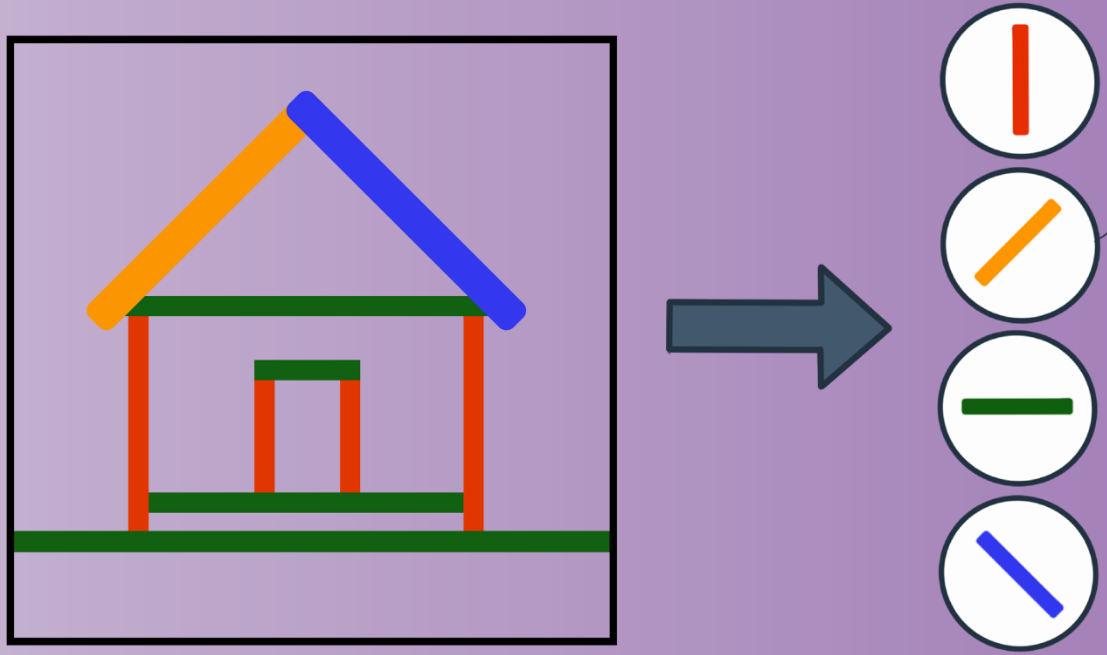
How do we *recognize* objects in the world?



# Orientation selectivity

Our visual system isn't simply a collection of pixel detectors with center surround receptive fields.

Objects in our visual field can be decomposed into a set of edges/lines of different orientations and positions.



# Orientation selectivity

Luckily, our retina also has cells that **combine receptive fields** from multiple neurons with spatially adjacent receptive field centers.

This can generate neurons that are selective to **edges or lines** of **specific orientations** within their receptive fields.

# Activity 1

Build a ganglion cell that detects a vertical line

# Activity 2

Build a second ganglion cell that detects a diagonal line

# Activity 3

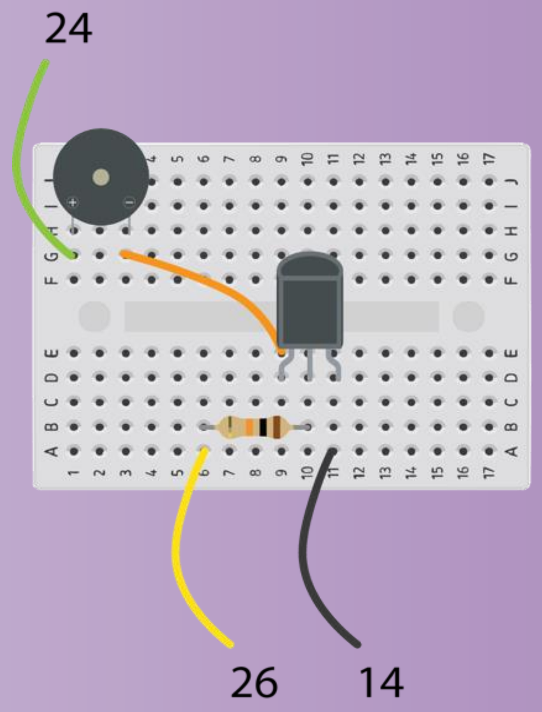
Build two ganglion cells that detect vertical lines of different thicknesses

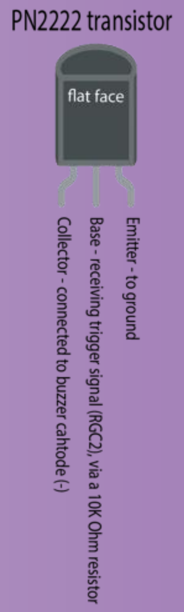
# Challenge

## Build a shape detector with orientation selective receptive fields

Combine the outputs of two orientation selective ganglion cells to detect a shape arising from the combination of two lines.

The buzzer should only sound when you present your target shape (i.e., both ganglion cells activated).



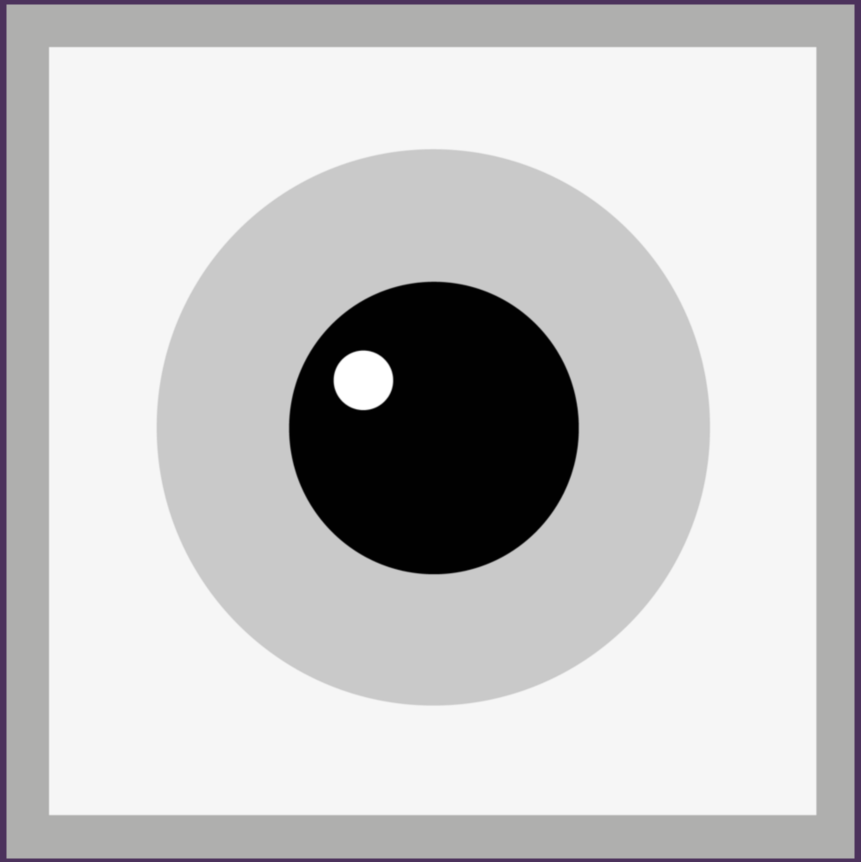




Once you've built the buzzer circuit (RetINaBox User Manual, page 14-15), connect the outputs of the two ganglion cells (the 3.3V digital out pins on the back of RetINaBox) and one of the grounds, to the buzzer circuit.

# Lesson 3

## Direction Selectivity

How do we know *if* and *how* objects are moving relative to us?



# Activity 1

Build a leftward motion direction-selective ganglion cell

# Activity 2

Build a rightward motion direction-selective ganglion cell

# Activity 3

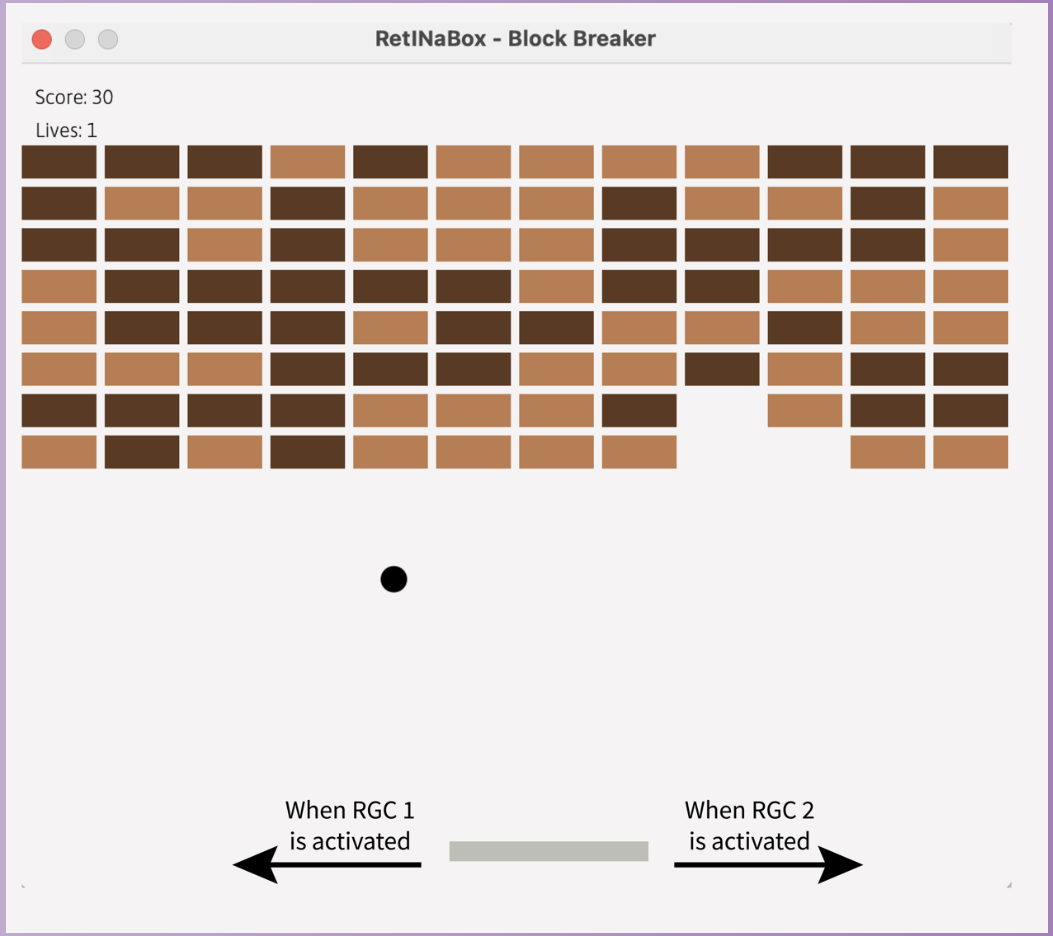
Build fast vs. slow motion preferring direction selective ganglion cells

# Challenge

## Block Breaker

Players move a paddle to bounce a ball to break several rows of bricks. The goal is to clear all the bricks without letting the ball drop.

Your task is to configure two ganglion cells with opposite direction selectivity and use them as the input controls for the game inside the RetINaBox GUI.

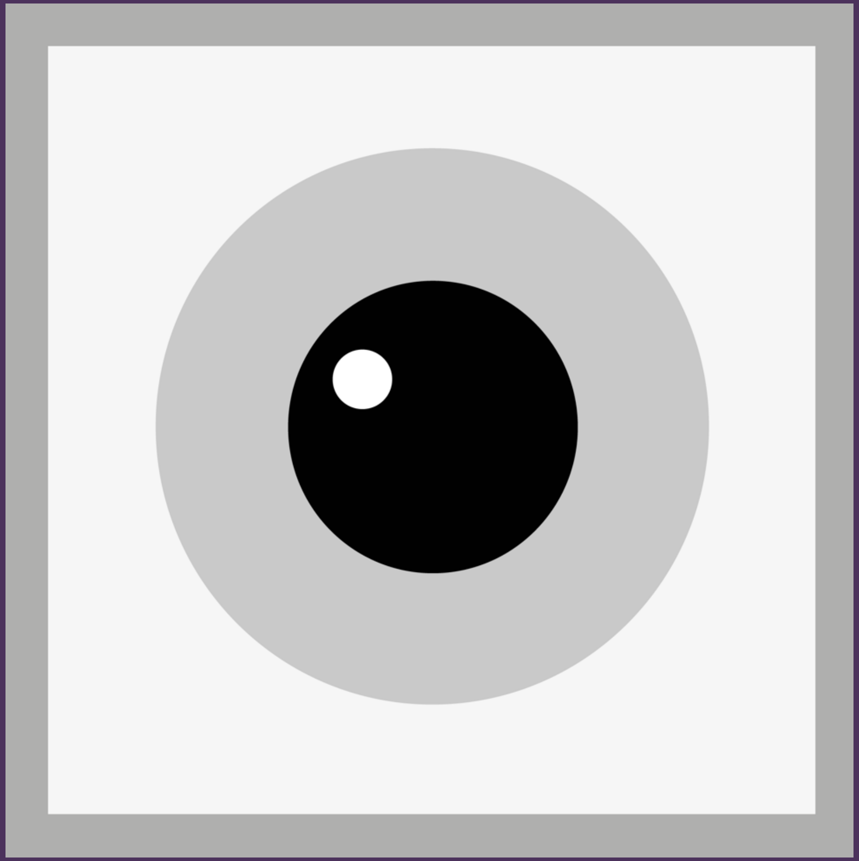



Lessons > Lesson 3 > Block Breaker)

# Lesson 4

## Discovery Mode

It's your turn discover which visual stimuli best activate visual neurons and discover what circuit connectivity properties underlie such feature selectivity.

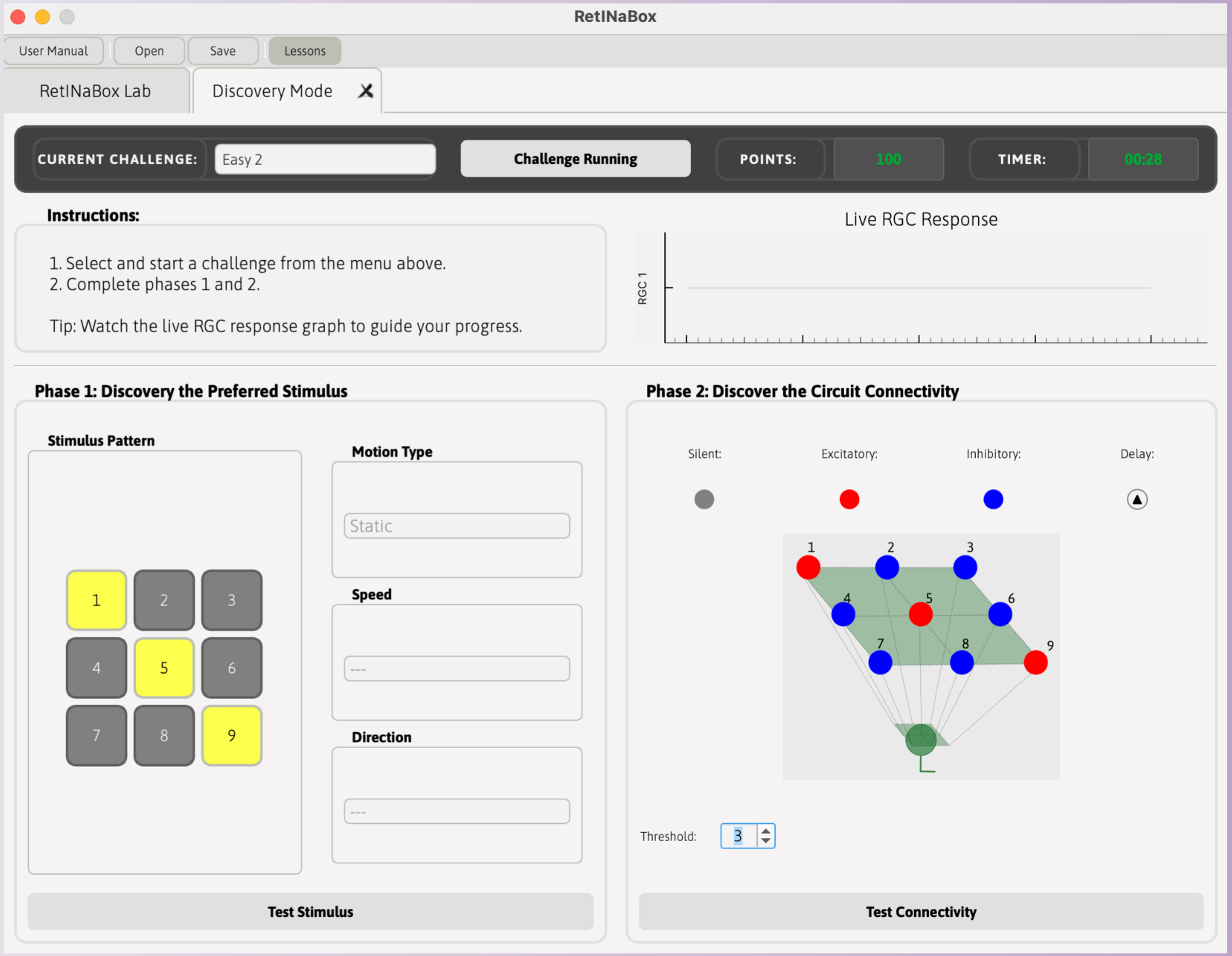


In Discovery Mode, there are three levels of difficulty (**Easy, Medium, Hard**), each with their own set of challenges.

For each challenge, you'll start with 100 points. Incorrect answers cost you 5 points.

Your goal is to complete each challenge with the highest score possible.

From the Menu tab, navigate to 'Discovery Mode' (Lessons > Lesson 4 > Discovery Mode). Then, select a mystery circuit from the drop-down menu.




## Phase 1: Discover the Preferred Stimulus

Figure out **what** each ganglion cell responds to (i.e., a specific shape, or a direction of motion, etc.).

## Phase 2: Discovery the Circuit Connectivity

Figure out **how** the ganglion cell obtains this selectivity.

# Thank You!

Developed by the
Trenholm Lab at McGill University

Solutions and additional details are available in the Lesson Plan.

Instructions for setting up hardware and software are available in the RetINaBox User Manual

Code and materials: https://github.com/Trenholm-Lab/RetINaBox

*For a more detailed overview of the retina and the visual system, visit theopenbrain.org*