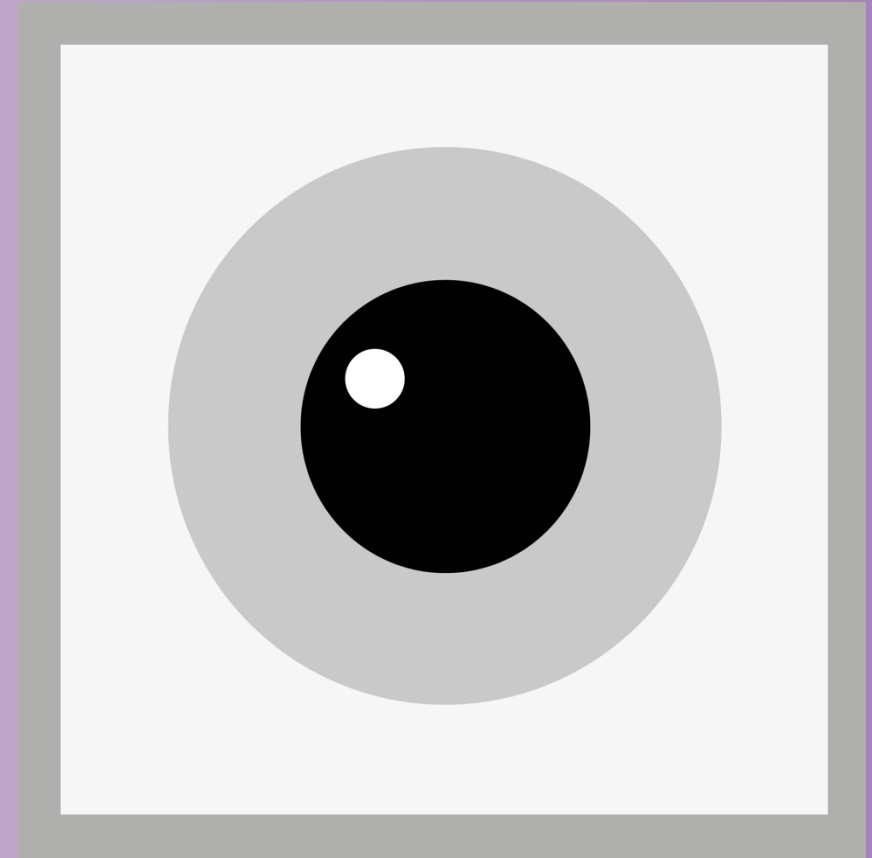


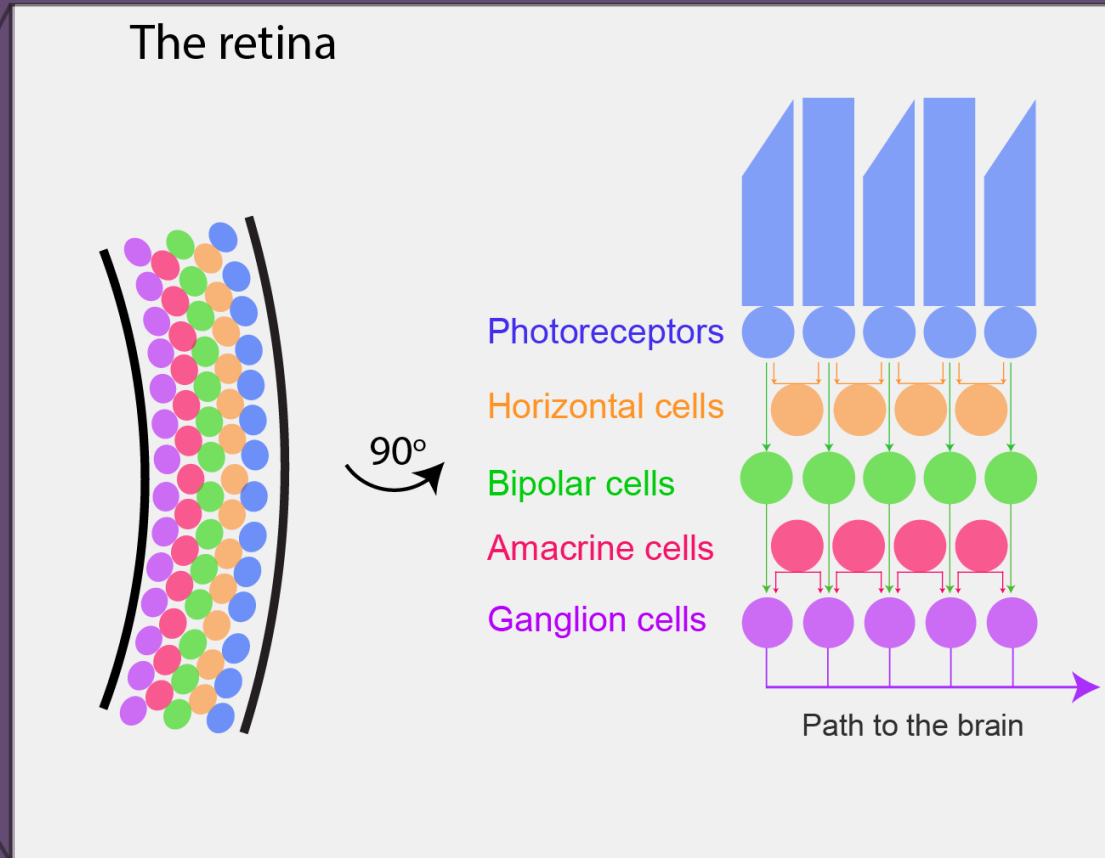
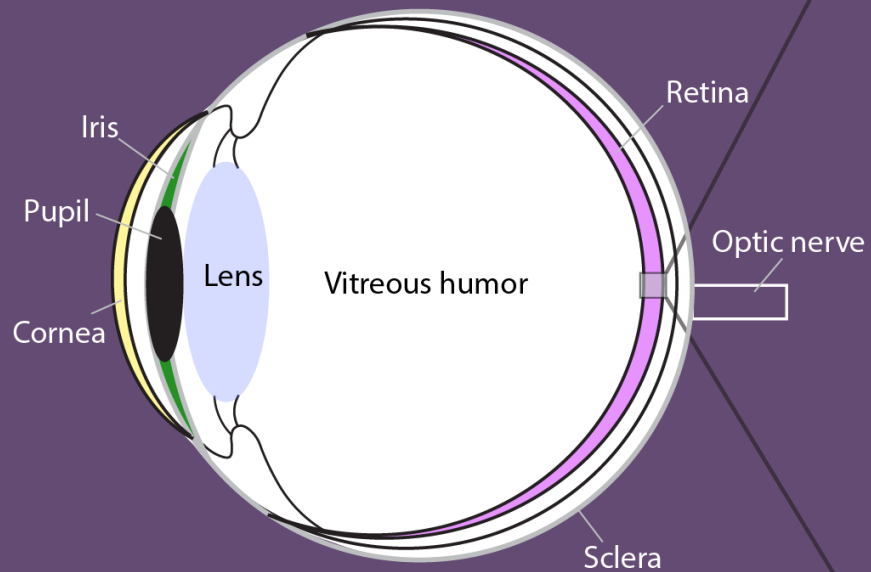
RetINaBox

Lesson Plans



How do we see?

The retina

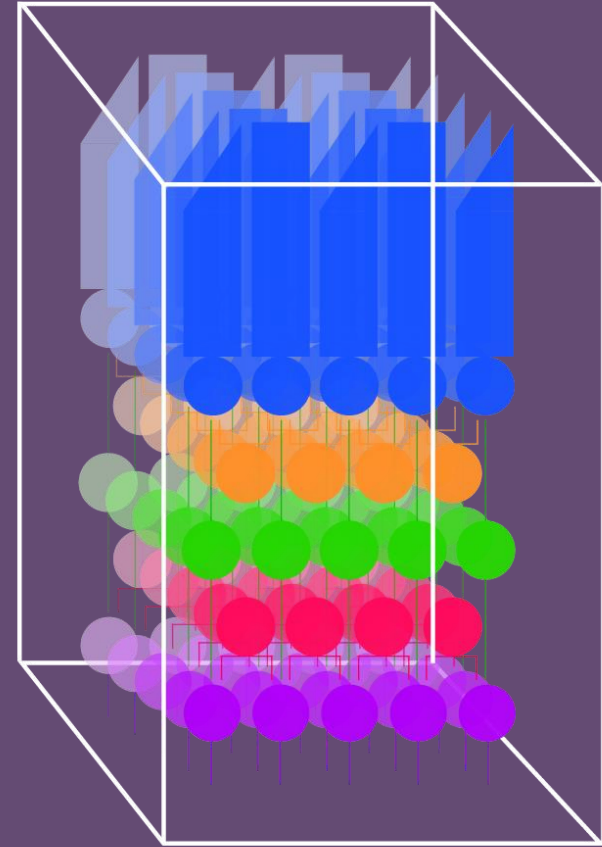


How do we see?

The retina

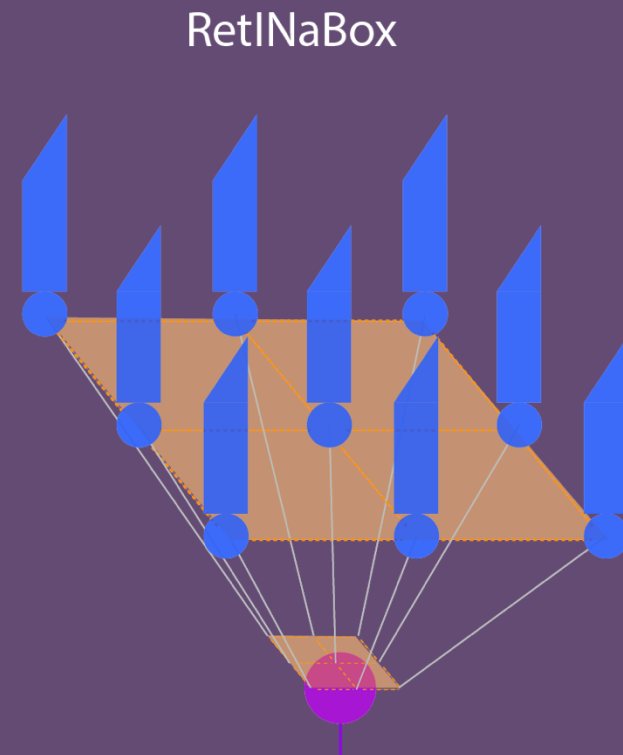
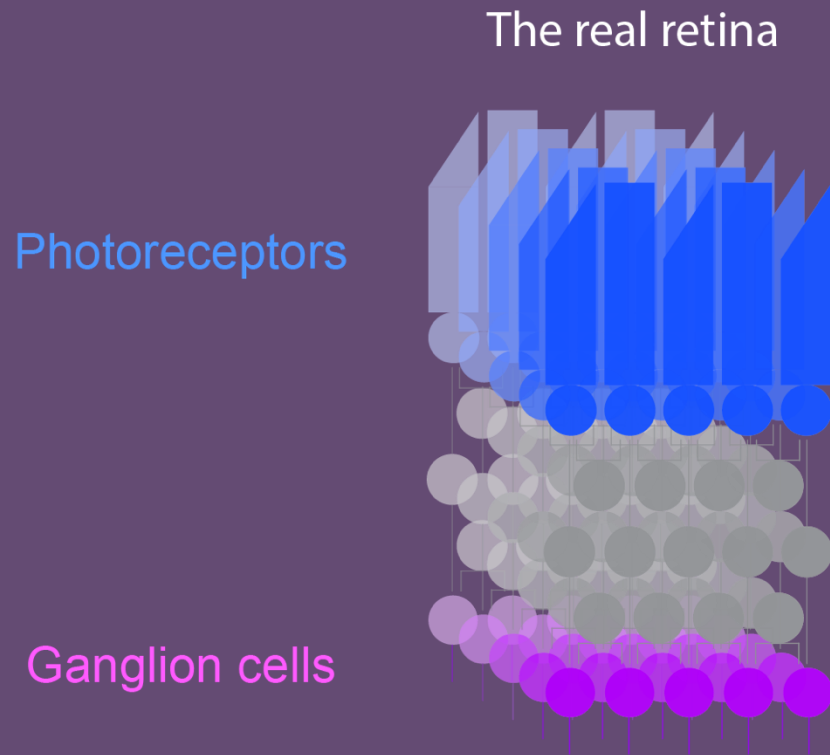
Photoreceptors are arranged in a dense 3D arrangement.

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

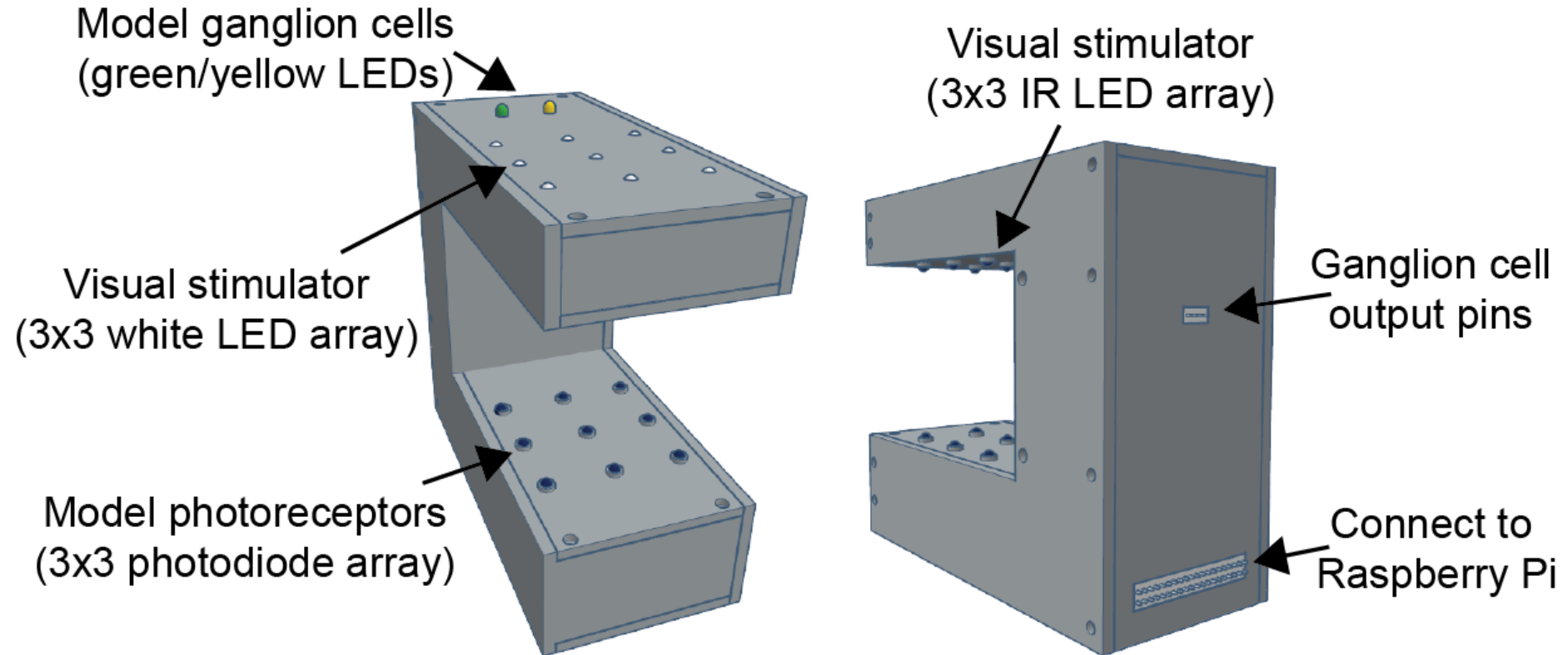


How do we see?

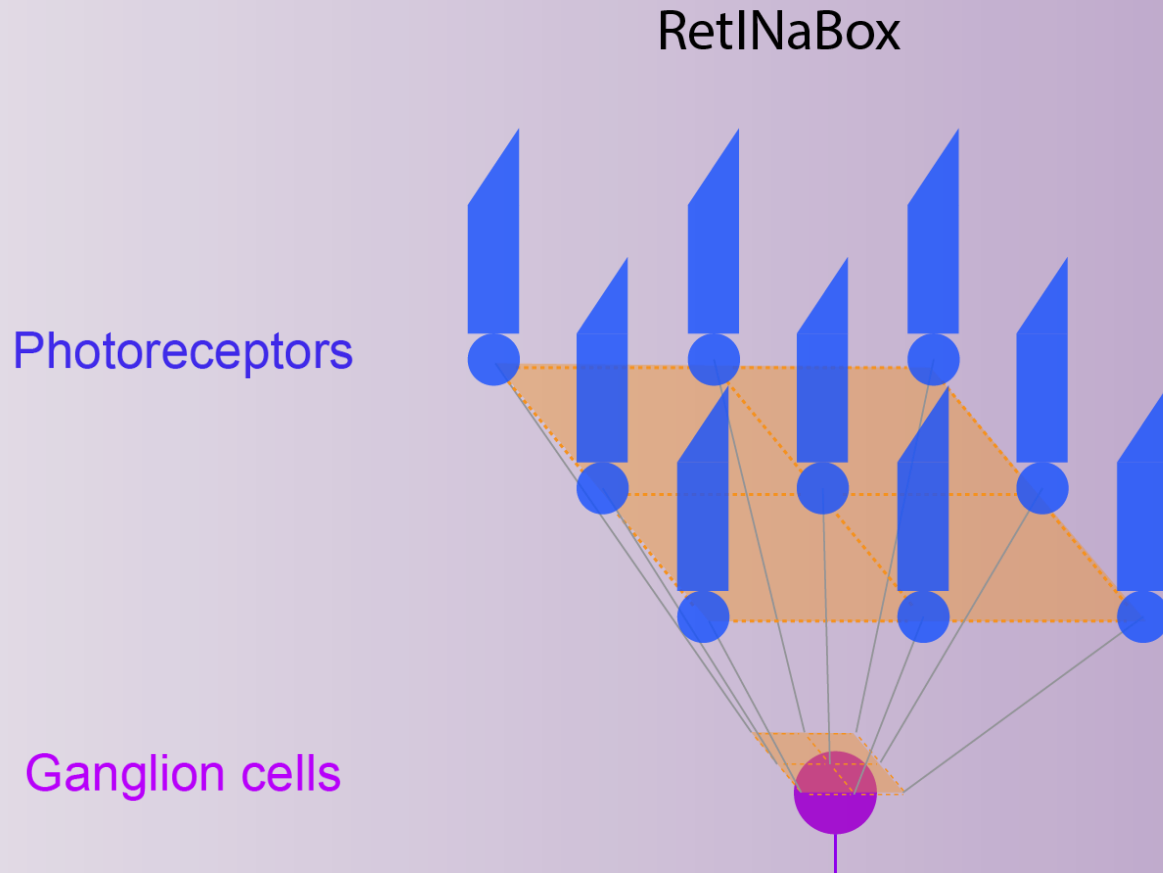
The retina



RetINaBox



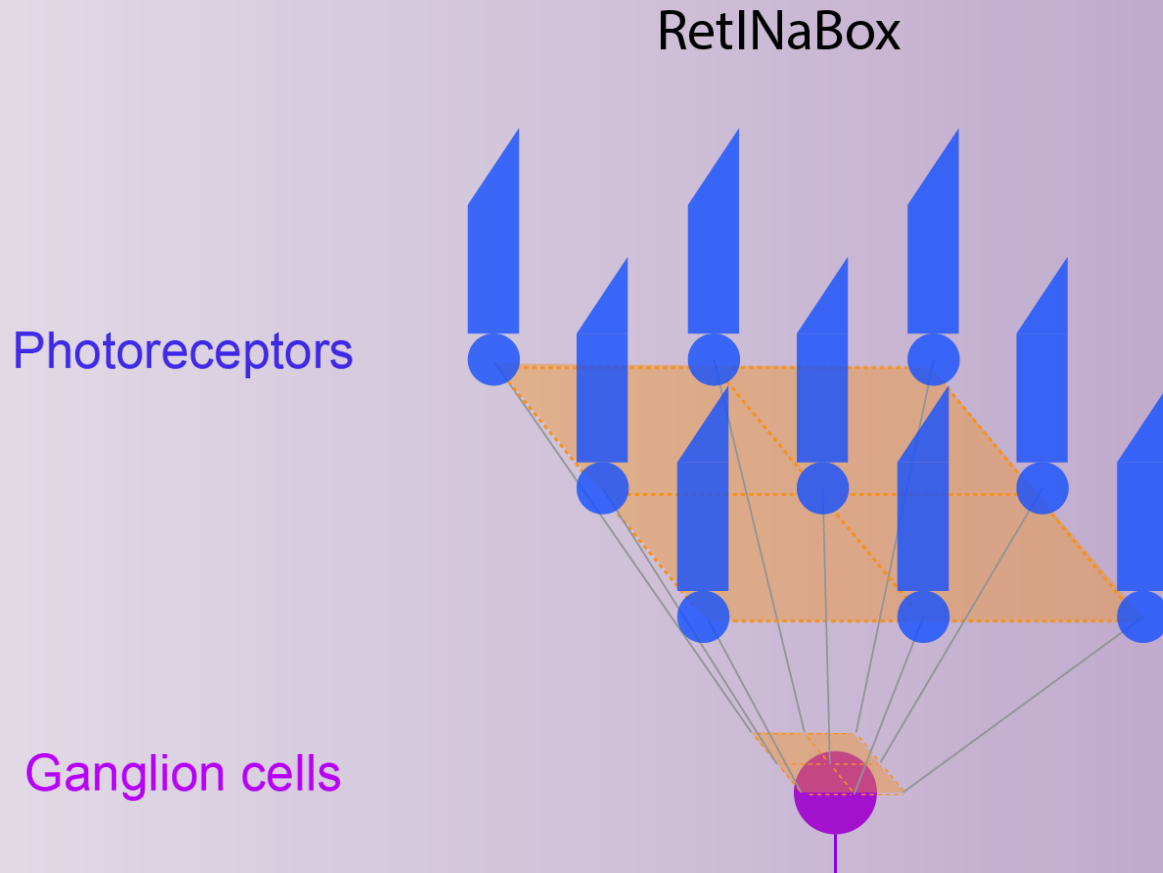
RetINaBox



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 Interface (GUI)



Visual Stimulus Controller

Visual Stimulus Controller

Unselected: Selected: Active:



On / Off

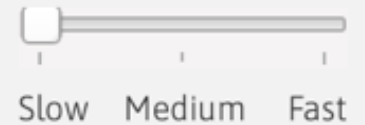
Mode:

☒ Static ☐ Motion

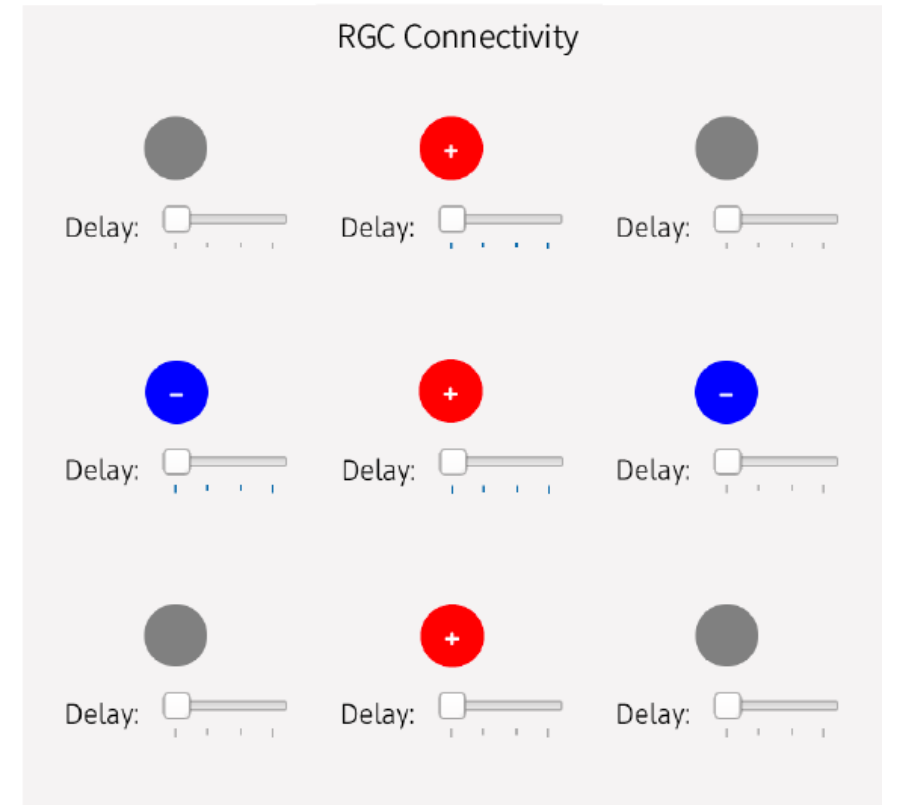
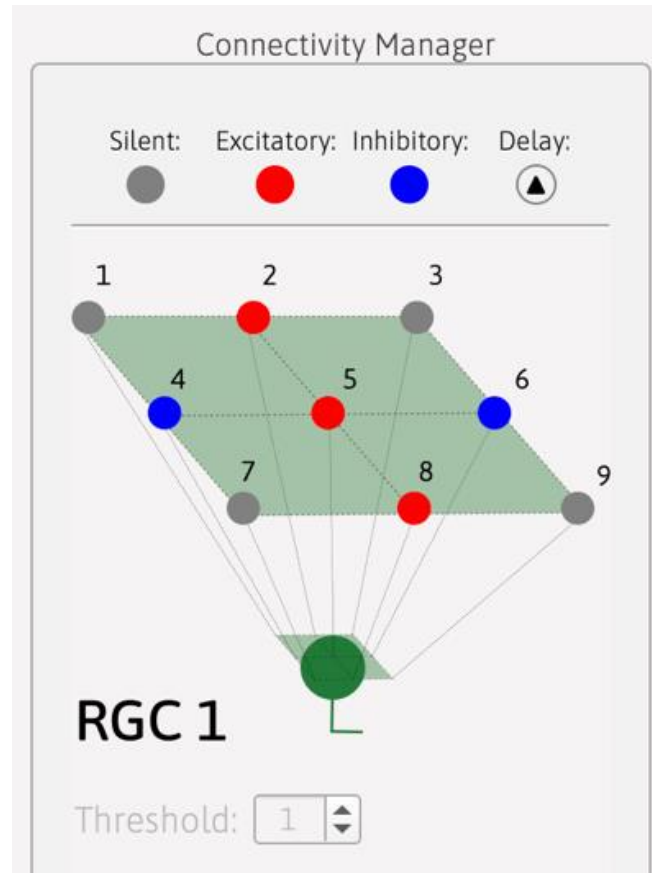
Direction:



Speed:

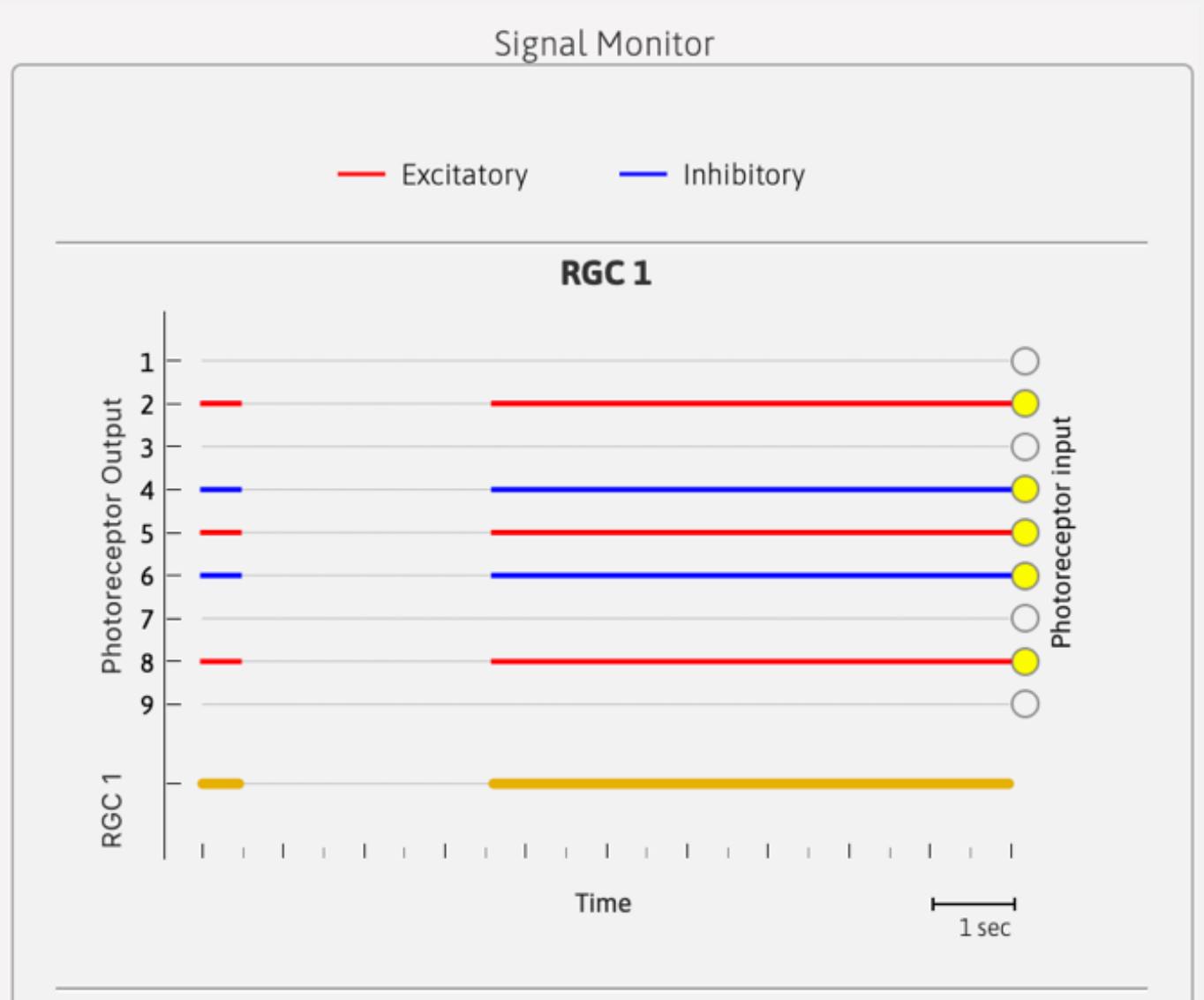


Connectivity Manager



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



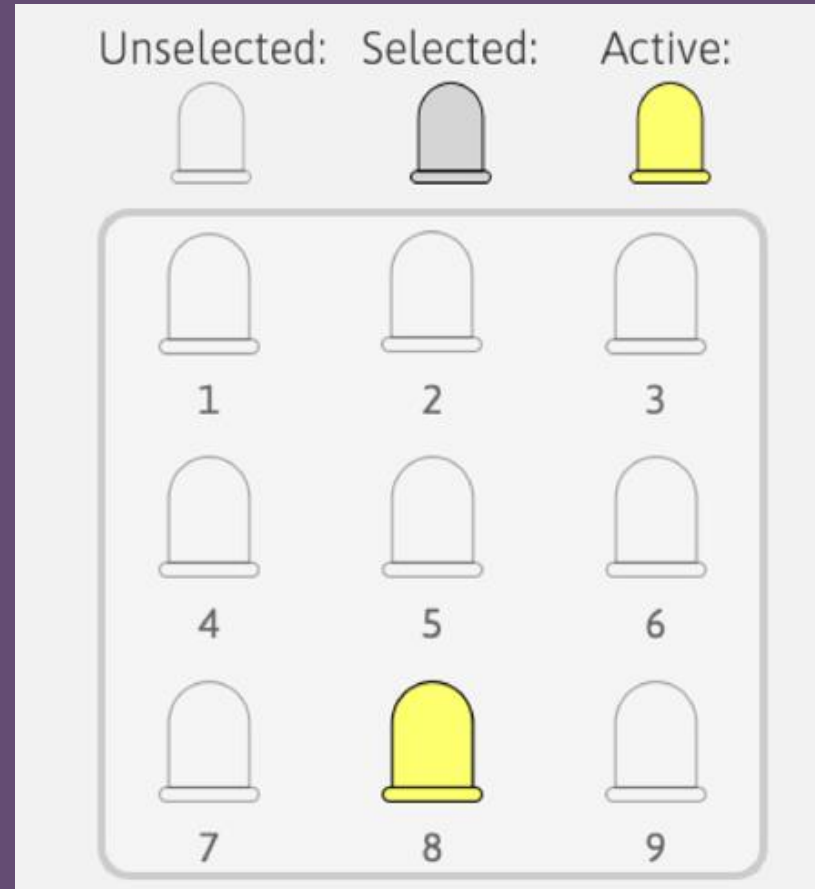
Real-world stimulation

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



Testing your circuits

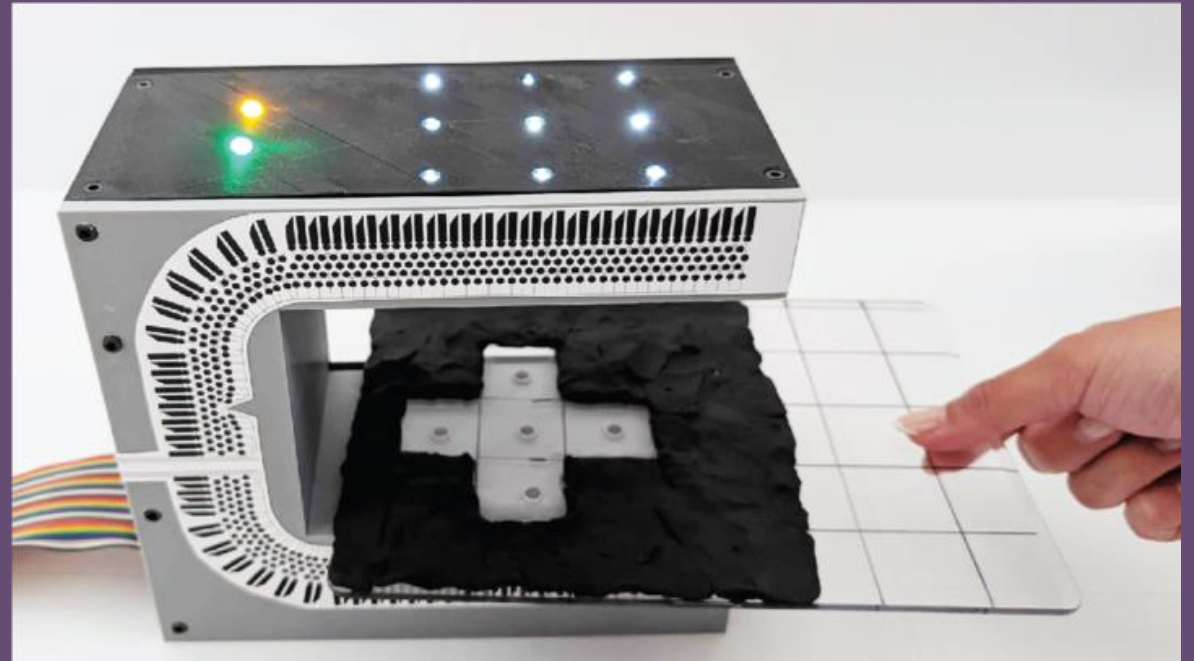
LED activation: manually activate different combinations of LEDs in the Visual Stimulus Controller to stimulate photoreceptors



Testing your circuits

Turn on the entire LED array

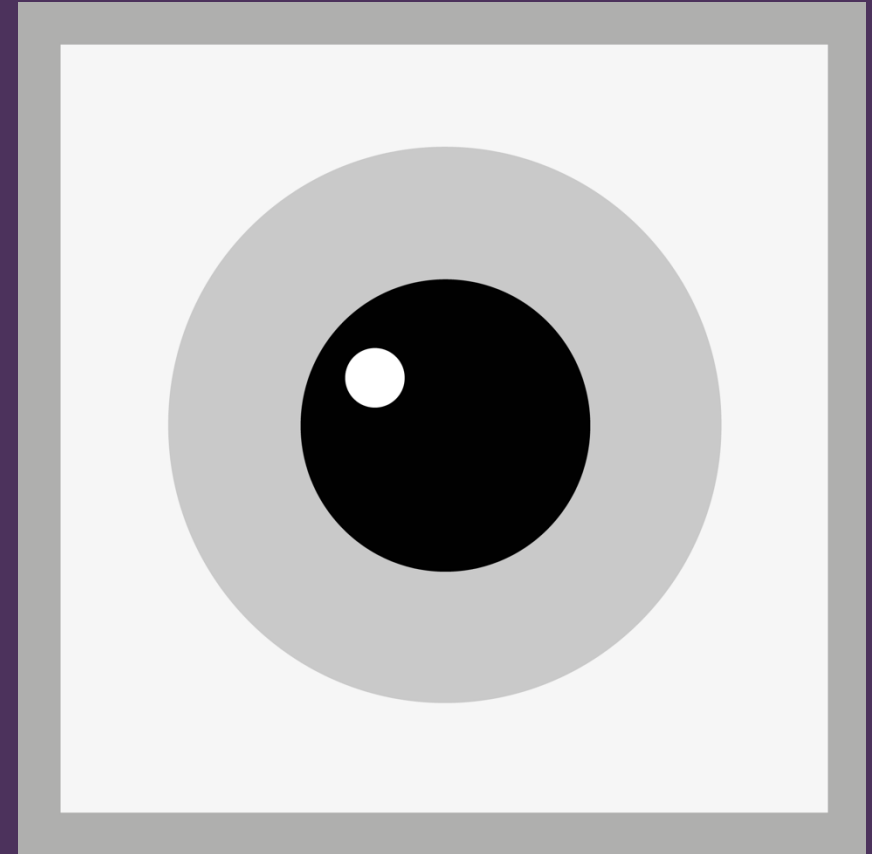
Use the **Visual Stimulus Tool** (modeling clay on a clear plastic board) or your hands to deliver patterned visual stimuli



Lesson 1

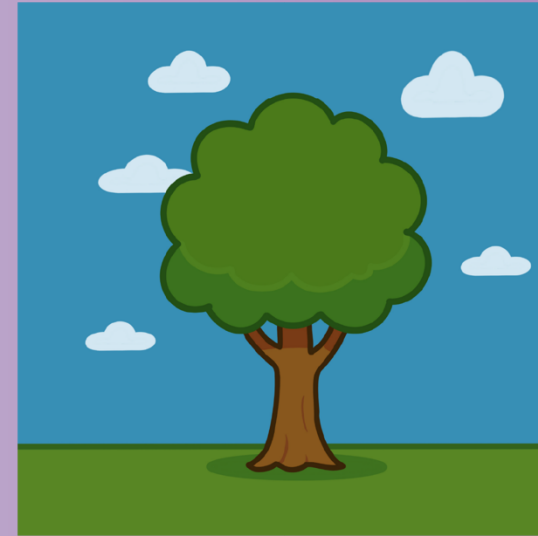
Center-Surround

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

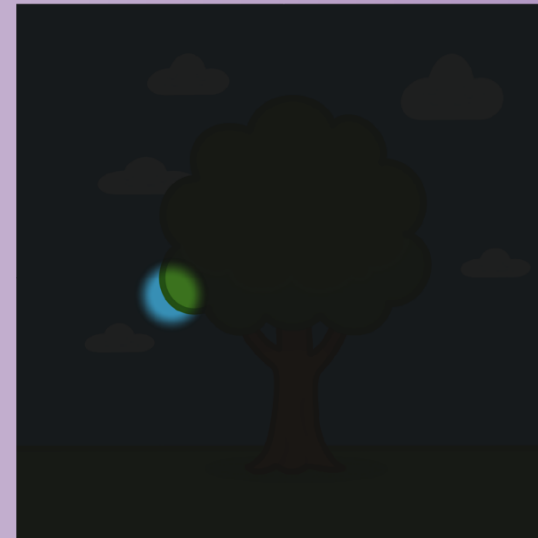


Receptive fields

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.



Cell 1's receptive field




Cell 2's receptive field



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

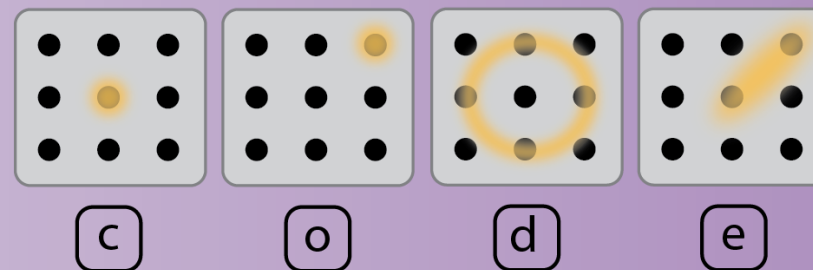
Build a second spot detector
with a different receptive field
location

Activity 3

Build two spot detectors with preferences for spots of different sizes

Challenge

Codebreaking with center surround receptive fields

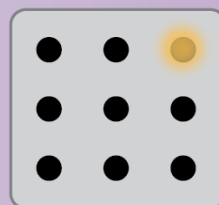


To begin the challenge:
Lessons > Lesson 1 > Code
Breaker

Cipher

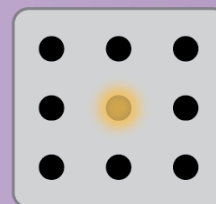
RGC1

Preferred visual stimulus



RGC2

Preferred visual stimulus



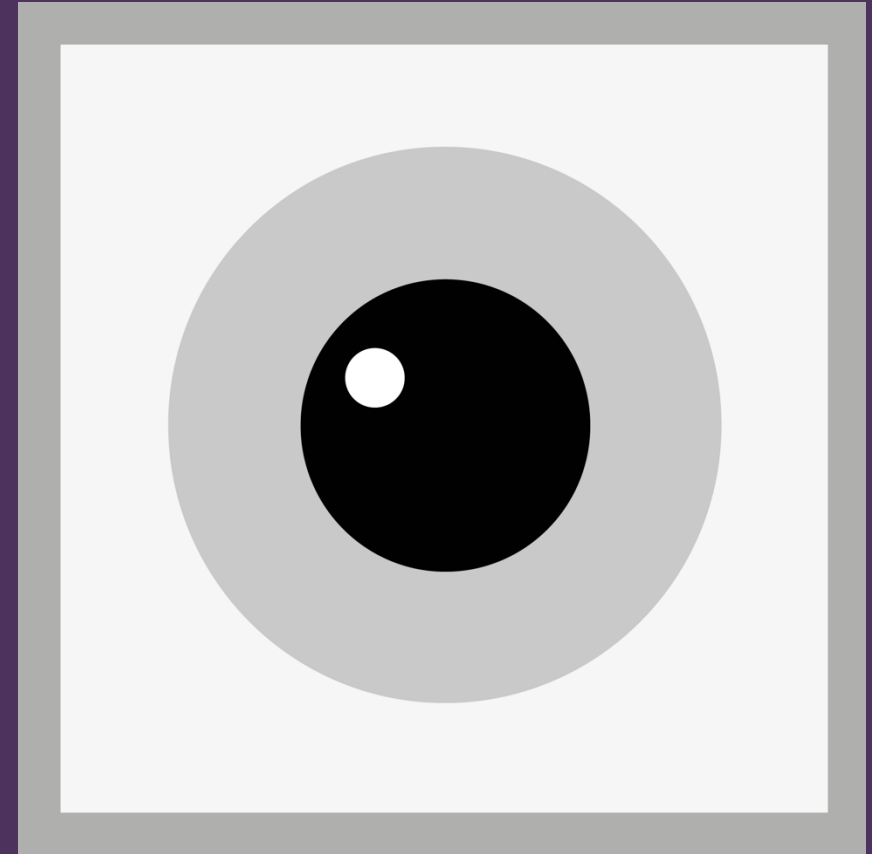
RetINaBox Output

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

Lesson 2

Orientation Selectivity

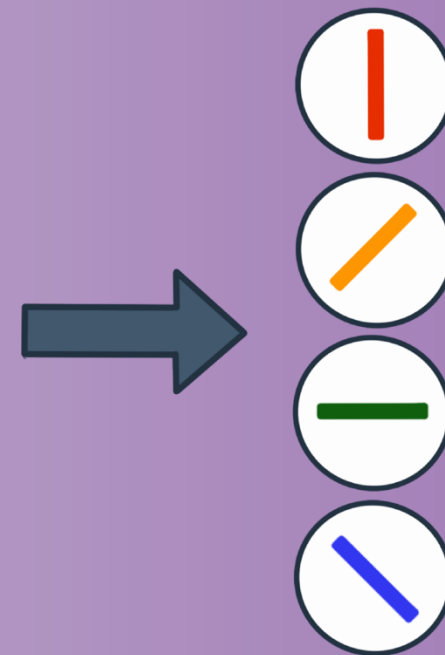
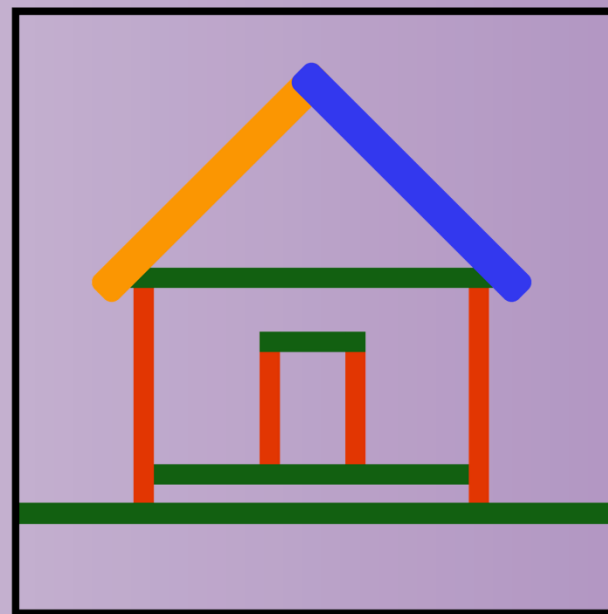
How do we *recognize* objects in the world?



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

The background is a purple gradient. There are three white decorative elements: a line starting from the left edge, going right, then up, then right again, ending in a dot; a line starting from a dot, going right, then up-right, then right again, ending in a dot; and a line starting from the left edge, going right, then up-right, then right again, ending in a dot.

Activity 2

Build a second ganglion cell that detects a diagonal line

Activity 3

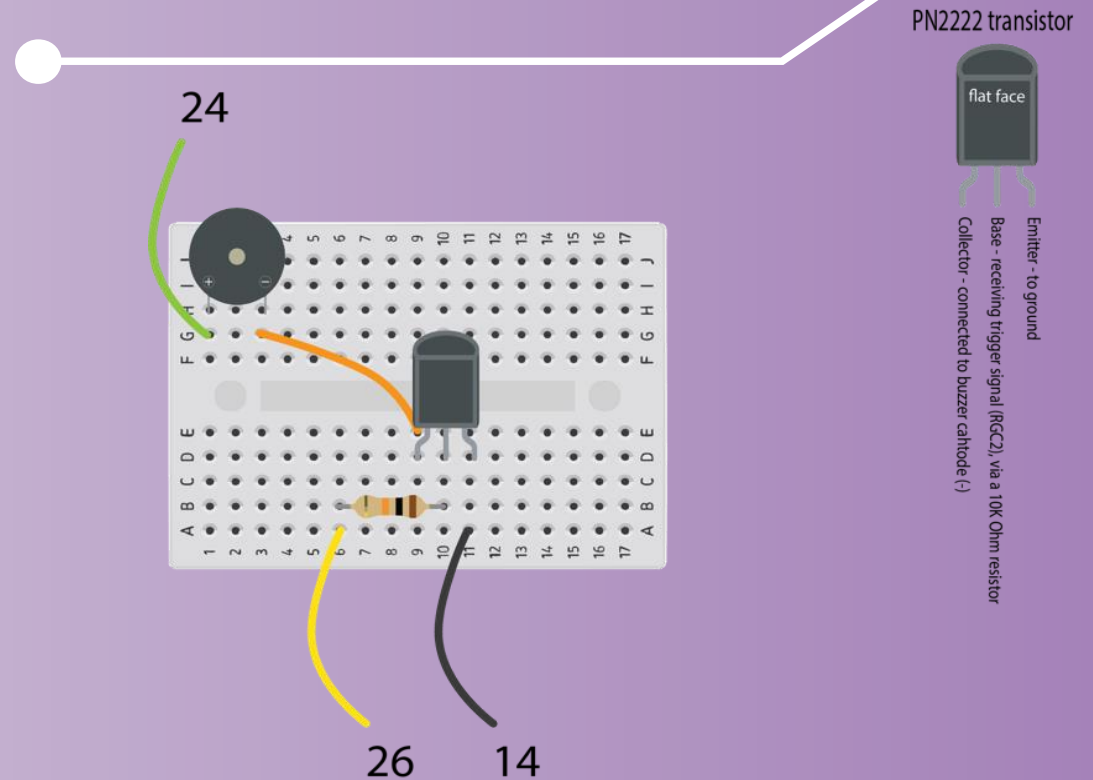
Build two ganglion cells
that detect vertical lines of
different thicknesses

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).

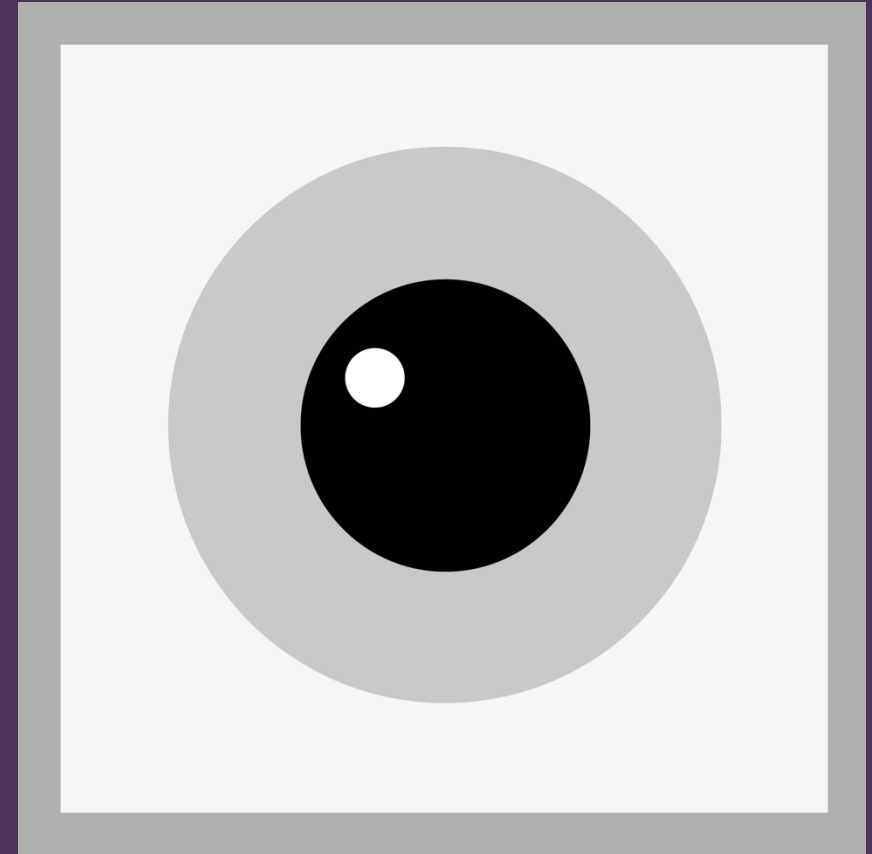


Once you've built the buzzer circuit (RetINaBox User Manual, page 14-15), connect the outputs of the two ganglion cells (the 3.3V digital out pins on the back of RetINaBox) and one of the grounds, to the buzzer circuit.

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

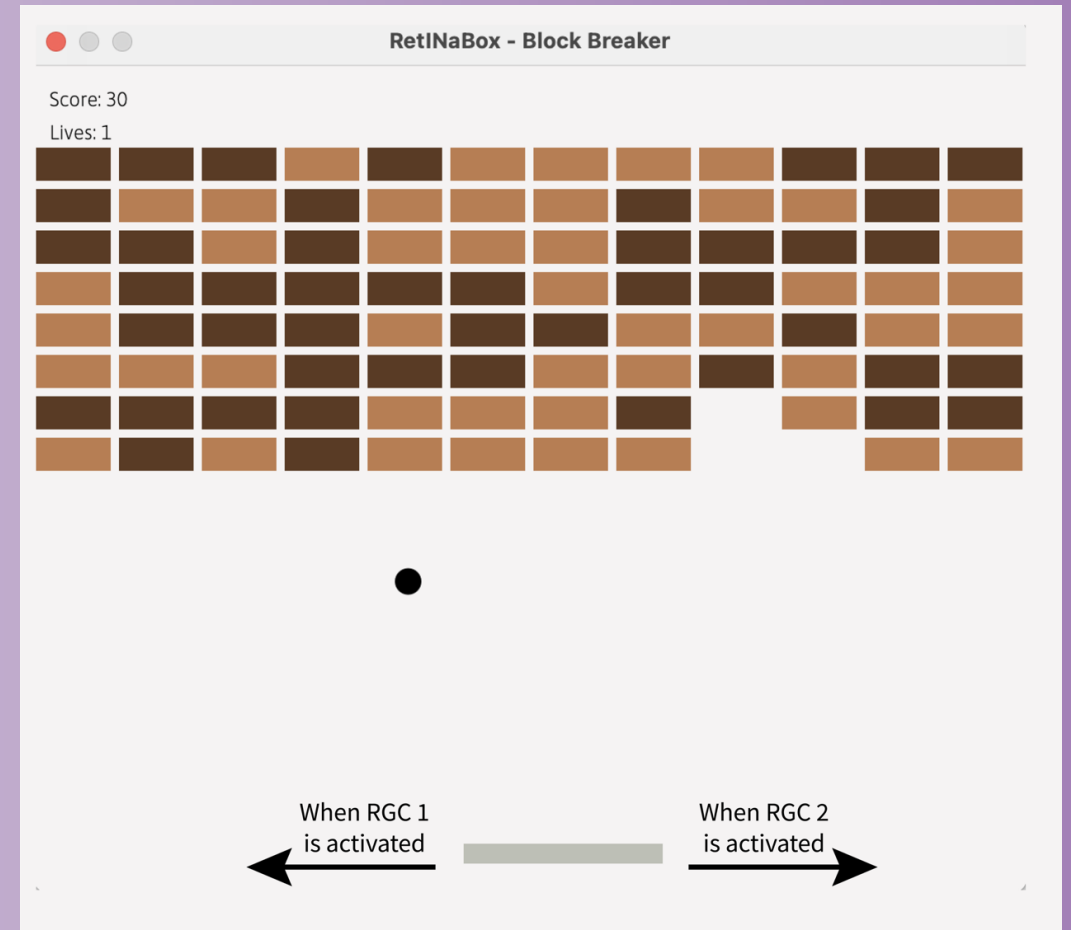
Build fast vs. slow motion
preferring direction selective
ganglion cells

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.

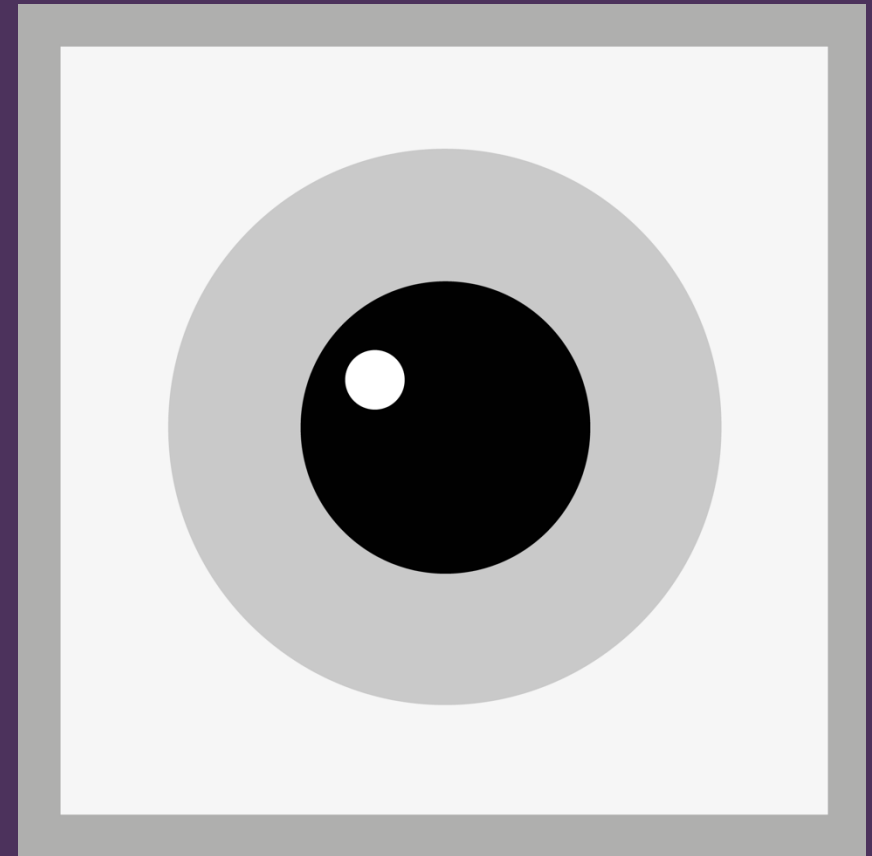
Your task is to configure two ganglion cells with opposite direction selectivity and use them as the input controls for the game inside the RetINaBox GUI.




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.



RetINaBox

User ManualOpenSaveLessons

RetINaBox LabDiscovery Mode

CURRENT CHALLENGE: Easy 2Challenge RunningPOINTS: 100TIMER: 00:20

Instructions:
1. Select and start a challenge from the menu above.
2. Complete phases 1 and 2.

Tip: Watch the live RGC response graph to guide your progress.

Live RGC Response

RGC 1

Phase 1: Discovery the Preferred Stimulus

Stimulus Pattern

123

456

789

Motion Type

Static

Speed

Direction

Test Stimulus

Phase 2: Discover the Circuit Connectivity

Silent:Excitatory:Inhibitory:Delay:

123

456

789

Threshold: 3

Test Connectivity

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.).

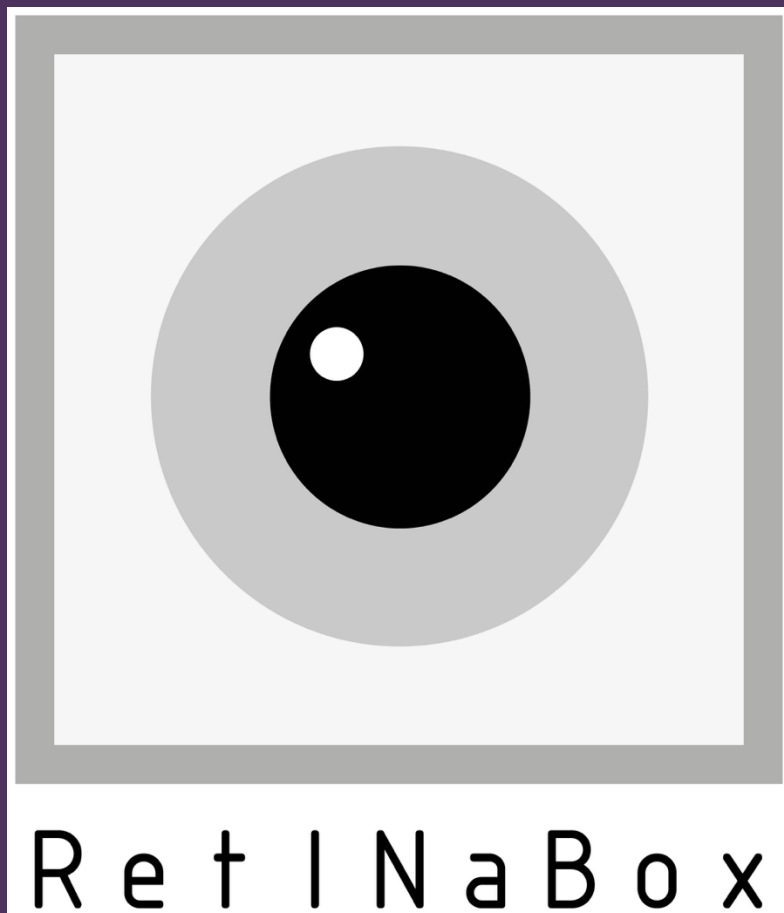
Phase 2: Discovery the Circuit Connectivity

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



Solutions and additional details are available in the Lesson Plan.

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



Thank You!

Developed by the
Trenholm Lab at McGill University



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

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