Receptive Field Mapping

A standard approach in sensory physiology is to measure the patterns of stimulation an individual neuron is responsive to – for example, testing where light has to fall in the eye in order to trigger responses in a visual cell. Characterizing these stimulus profiles or "receptive fields" is important because it helps reveal what aspects of the world the neuron is designed to encode. This program simulates the responses of light-sensitive cells in the retina, LGN, and visual cortex, and is designed to give a flavor of what is involved in using single-unit recording to map out the receptive fields of visual cells. Light falling outside the receptive field generally does not affect the cell, while a stimulus within the receptive field can either excite the cell (increasing the number of action potentials) or inhibit the firing. The total response thus depends on the net effects of the excitation and inhibition. All cells also have a set of "preferred stimuli" that they respond best to, and varying the stimulus within the receptive field can be used to measure the "tuning function" or "stimulus selectivity" of the cell. In this exercise, you will discover and characterize the receptive fields of a variety of cells at different points along the visual pathway.

Basic cell types:

- Photoreceptors
    - L cones – respond best to long ("reddish") wavelengths
    - M cones – respond best to medium ("greenish") wavelengths
    - S cones – respond best to short ("bluish") wavelengths
    - Rods – respond best to medium-short ("cyan") wavelengths
- Retinal ganglion cells
    - On-center cell – responds to light in the center, inhibitory in the surround
    - Off-center cell – responds to light in the surround, inhibitory in the center
    - +L-M color opponent cell – excitatory red center, inhibitory green surround
    - +M-L color opponent cell – excitatory green center, inhibitory red surround
    - –L+M color opponent cell – inhibitory red center, excitatory green surround (similar to +M-L)
    - –M+L color opponent cell – inhibitory green center, excitatory red surround (similar to +L-M)
    - +S-LM color opponent cell – excitatory blue center, inhibitory red/green surround
- Visual cortex cells
    - Simple cell – excitatory center, inhibitory surround, responds to orientation
    - Complex cell – responds to orientation/movement

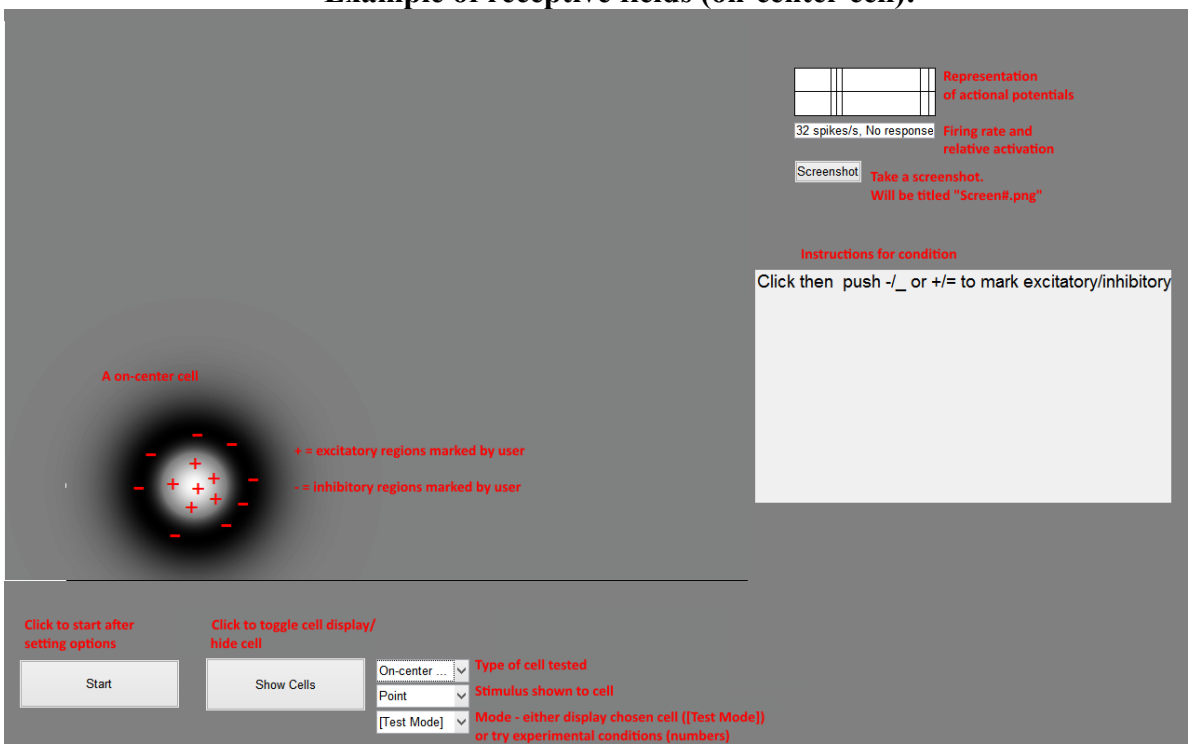
Potential stimuli:

- Point – a 1-pixel region under the crosshairs
- Spot – a circle that measures the region under it; 3 sizes
- Bar – a rectangle that measures the region under it; 3 sizes, 24 angles
- Color stimuli – points that output a specific wavelength
    - Colored lights:
        - 420 Violet
        - 480 Blue
        - 530 Green
        - 580 Yellow
        - 600 Orange
        - 630 Red
    - Stimuli corresponding to the optimum response of the photoreceptors:
        - 448 S cone - Indigo
        - 498 Rod – Blue-green (rods respond best to middle wavelengths, but do not provide a color response)
        - 542 M cone – Yellow-green
        - 570 L cone – Yellowish

Controls (not all are available in each condition):

- F5 – Run program from MATLAB
- Alt+F4 – Quit program (do after completing each step)
- Hover mouse on location – Output action potential rate
- Click – On some systems, you may need to click the form to start recording impulses and marks
- Mark region (based on your choice and may not reflect actual region):
    - Click to start marking
        - or _ key (right of number row) – mark location as inhibitory
    - + or = key (right of number row) – mark location as excitatory
- Delete (not backspace)
    - Delete most recent mark
- Rotate bar stimulus:
    - Q key – rotate counterclockwise by 15 degrees
    - E key – rotate clockwise by 15 degrees
- Increase bar/spot stimulus:
    - Page Up – increase stimulus size
    - Page Down – decrease stimulus size
- Take screenshot
    - ` or ~ key (normally left of number row) (or click button). This will save a file in the working directory that has an incrementing numeral (up to 99).

Example of receptive fields (on-center cell):



Conditions – Set box marked [Test Mode] to the following numbers and answer these questions. After completing each step, make sure you have saved all pertinent information, then close the window and run RF again.

0. [Test Mode]. Set [Cell Type], which constrains [Stimulus]. Try different settings.

Part I: Cells are hidden. Find the location of the cell by only using the activity. Mark regions with + or - based upon the activity under the cursor (light source). Take a screenshot of your marked cell, and describe its properties and regions.

1.

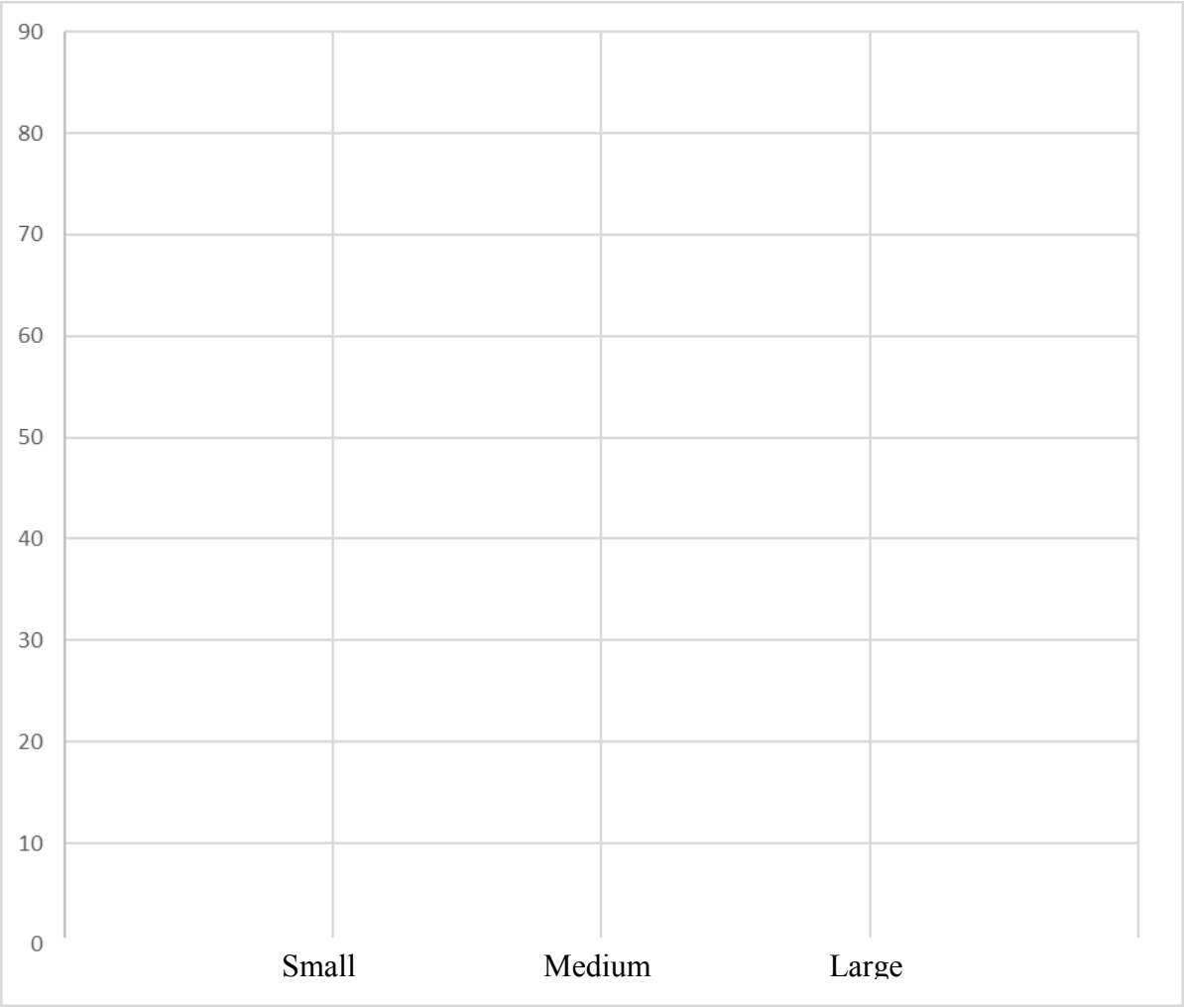
2.

3.

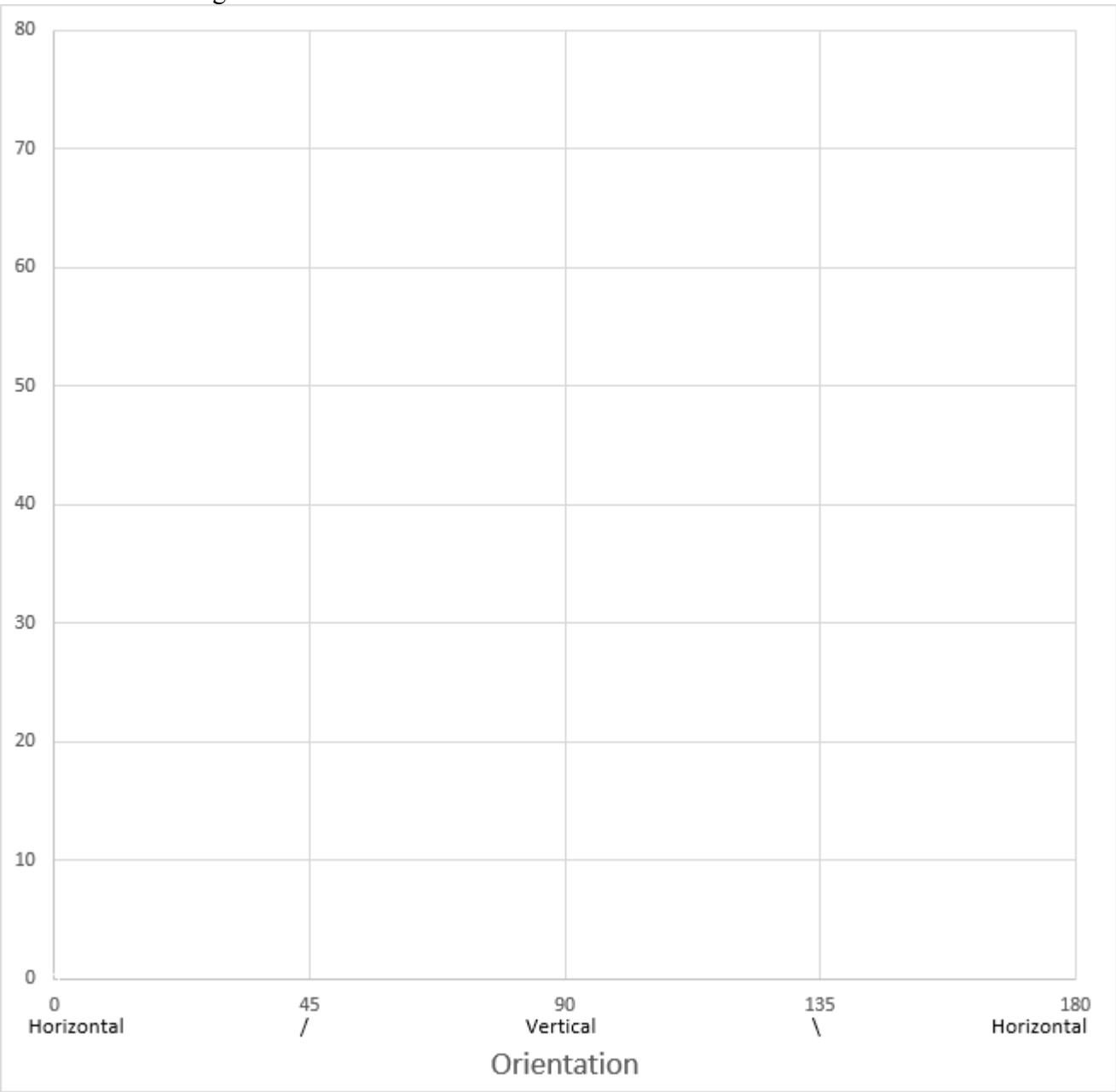
4.

Part II: Cell locations are visible by default, no need to find the location. Use non-point light sources (bar and round spot) to examine the properties of the cell. Describe the pattern of activation and explain why it appears this way.

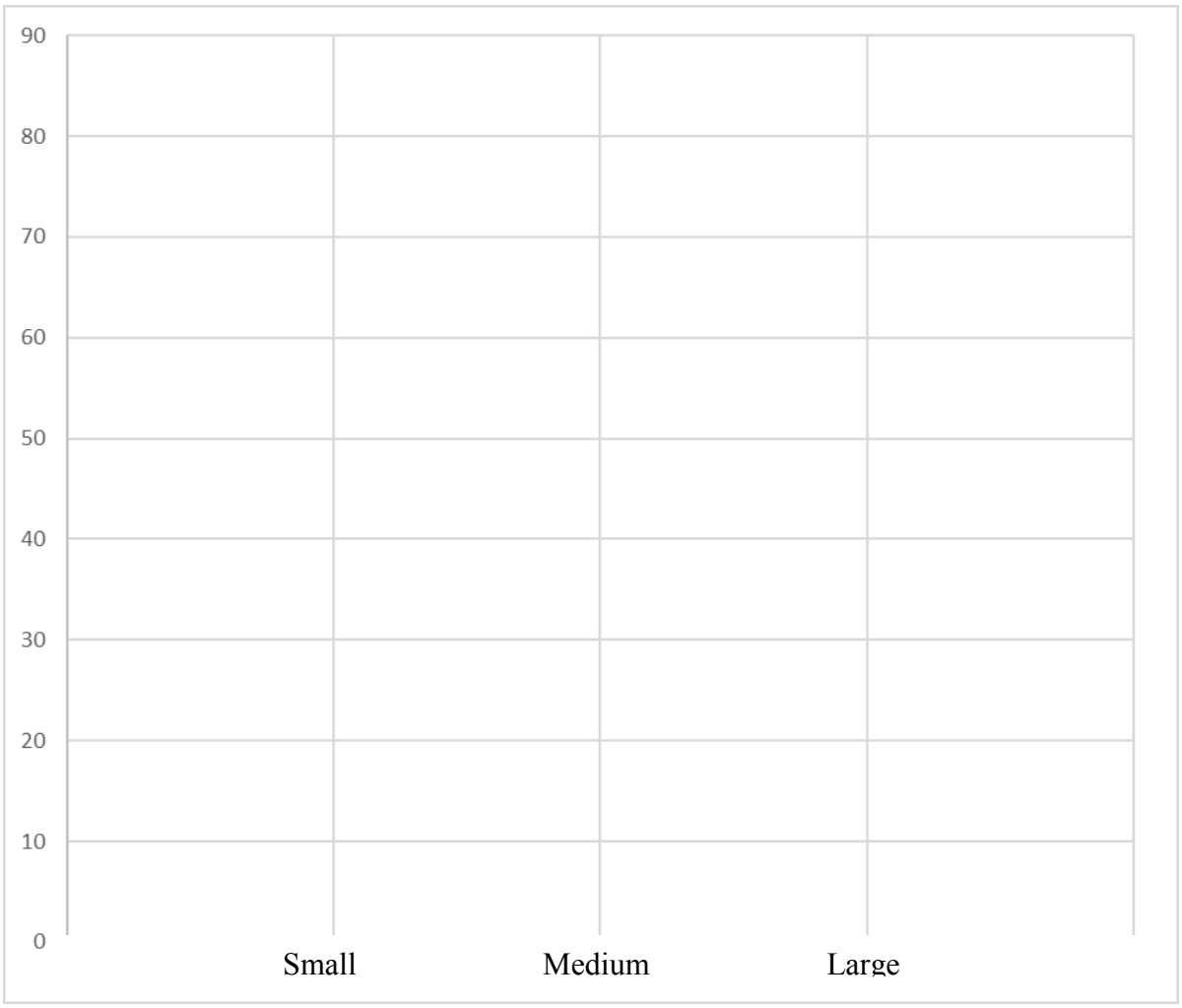
5. On-center cell.
    a) Graph a line for the firing rate (Y axis) to a "Spot" stimulus of different sizes (X axis) centered on the cell.



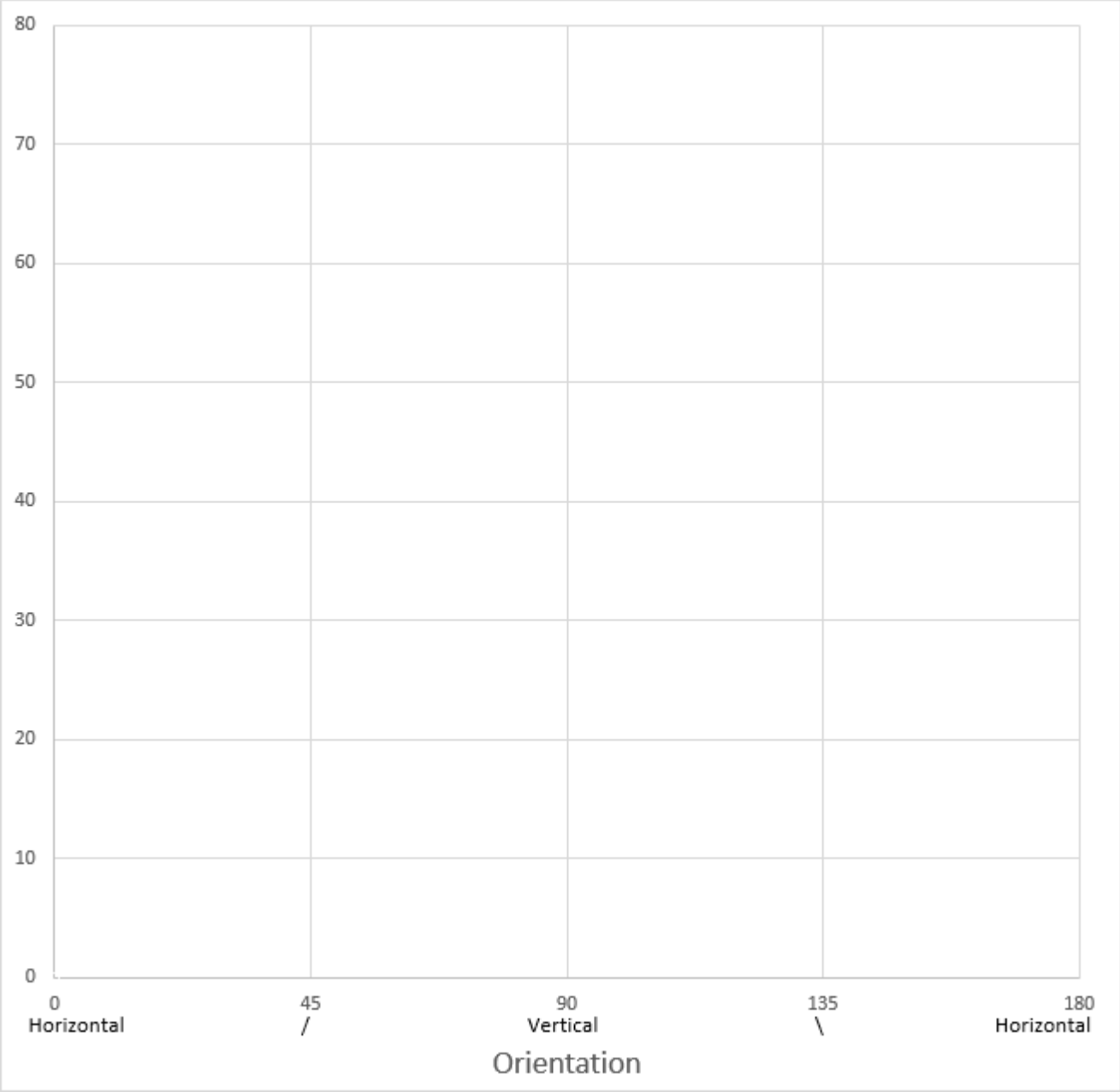
b) Now graph 3 separate lines for 3 sizes of a "Bar" stimulus centered on the cell, while also rotating the bar in at least 45 degree increments.



6) Simple cell. Graph a line for the responses (Y axis) to a stimulus of different orientations (X axis). Use separate lines for each of 3 sizes of the stimulus
    a) Spot stimulus. Graph a line for the firing rate (Y axis) to a "Spot" stimulus of different sizes centerd on the cell (X axis).

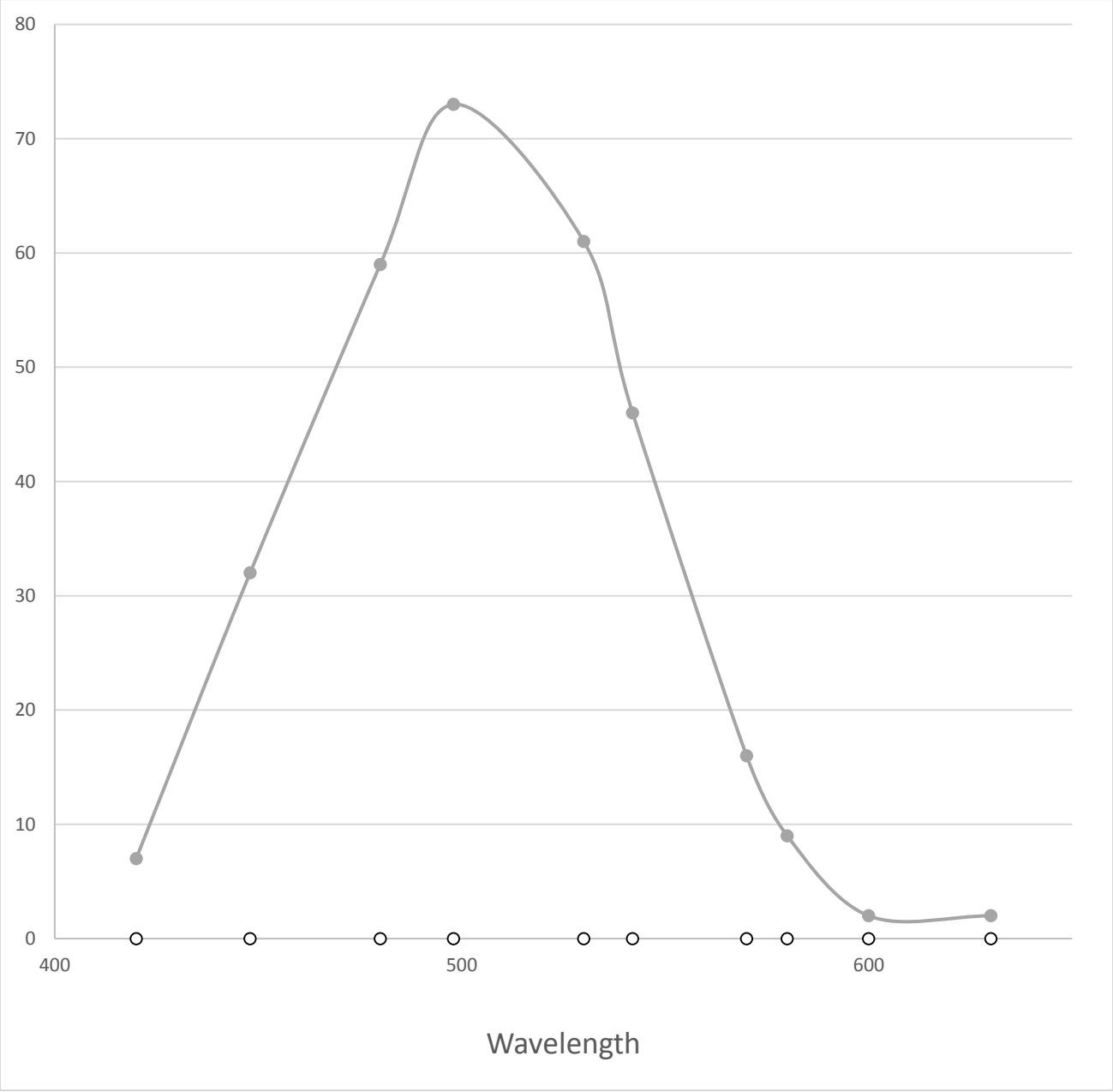


b) Bar stimulus. Graph 1 line for each of the 3 sizes, for 45 degree (or less) increments.



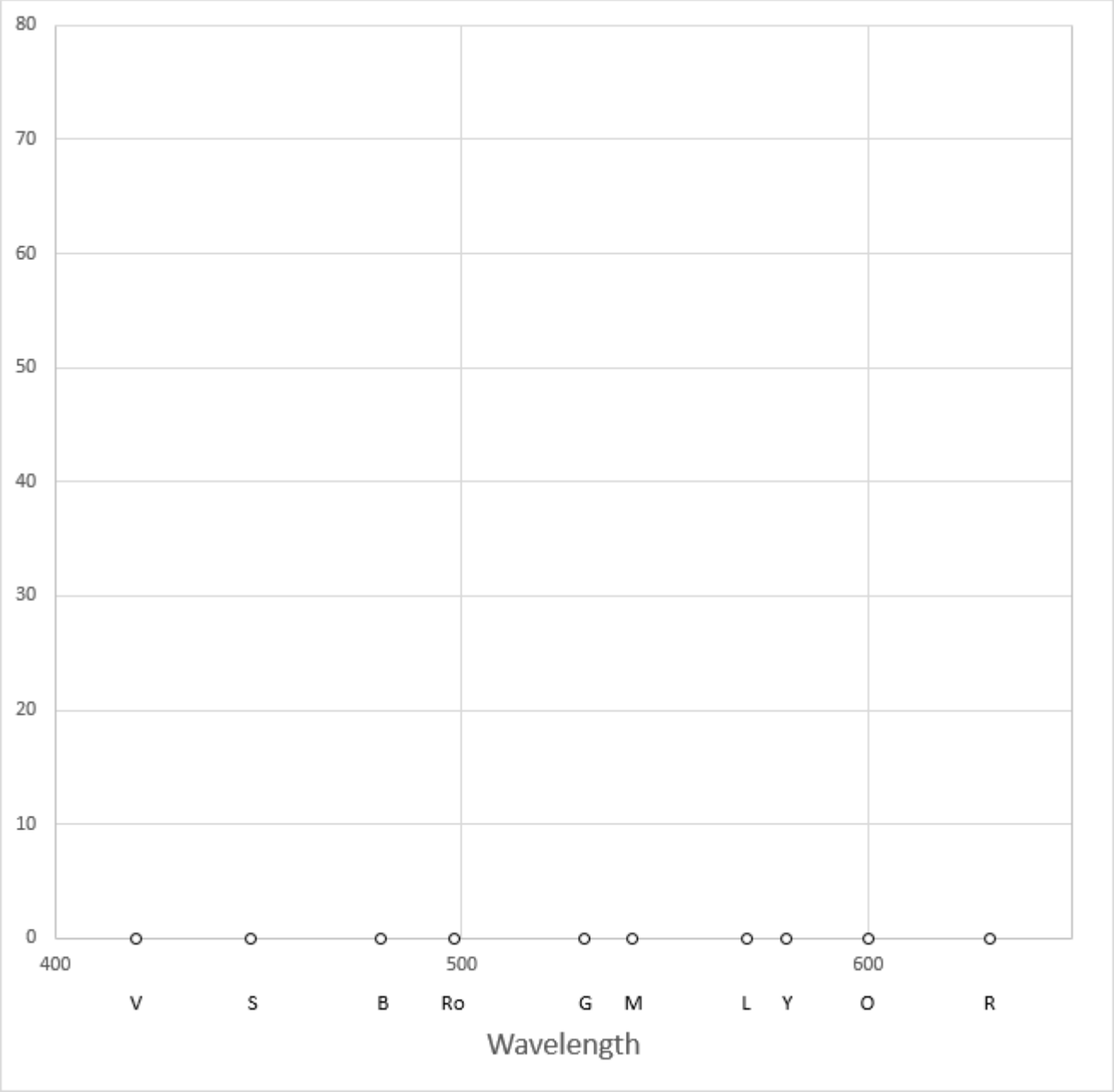
Part III: Color-sensitive photoreceptor cells. Here, the stimulus is a light of specific wavelength that illuminates the entire area, so you will probably need to just click anywhere in the cell window to measure activation. Plot wavelength of light (X axis) vs activation (Y axis) for each question on separate lines. For your convenience, the X axis has the approximate locations of each wavelength of light.

Example: here is the response of a rod cell to various wavelengths of light. Note that even though rods don't provide us with a perception of color, they are still most sensitive to a wavelength of light that we perceive as bluish-green. You should get similar results if you run in Test Mode and select "Rod"



7) L cone. Test response (Y axis) to each chromatic stimulus (X axis).

8) M cone. Test response (Y axis) to each chromatic stimulus (X axis).



Part IV: Color-sensitive retinal ganglion cell/lateral geniculate nucleus on/off cells. Light illuminates the entire screen, so both ON and OFF regions get the same light. Plot wavelength of light (X axis) vs activation (Y axis) for each question on separate lines. For your convenience, the X axis has the approximate locations of each wavelength of light.

9) +L-M cell. Test response (Y axis) to each chromatic stimulus (X axis).

10) +M-L cell. Test response (Y axis) to each chromatic stimulus (X axis).