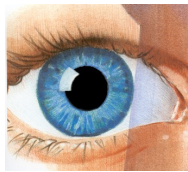


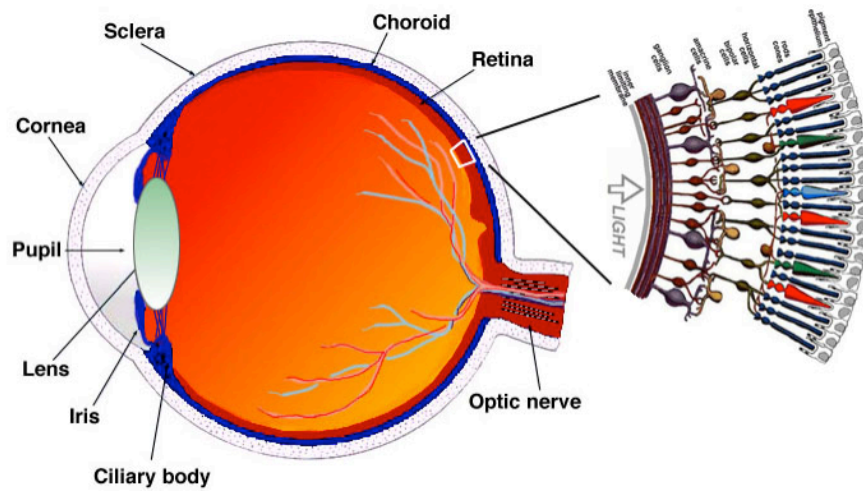
## Early Processing in Biological Vision

Analyzing intensity changes  
in the retinal image



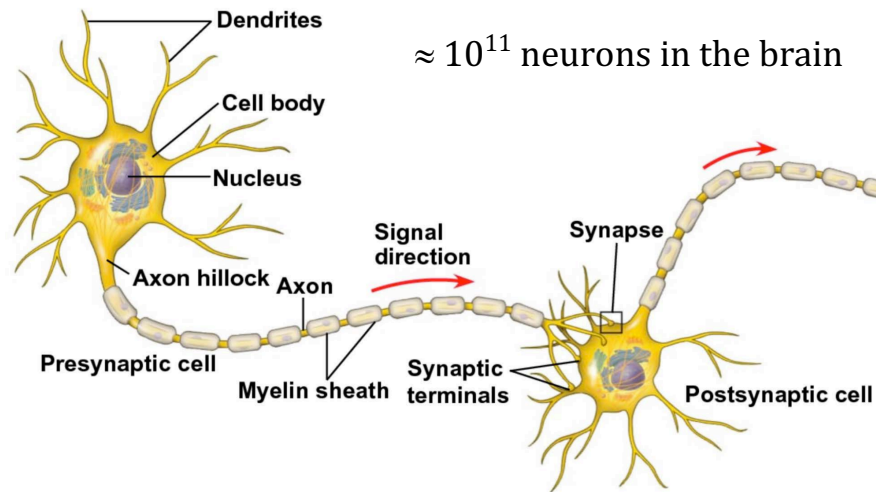
**CS332 Visual Processing**  
Department of Computer Science  
Wellesley College

## Human eye



**Retina:** rods & cones → retinal ganglion cells

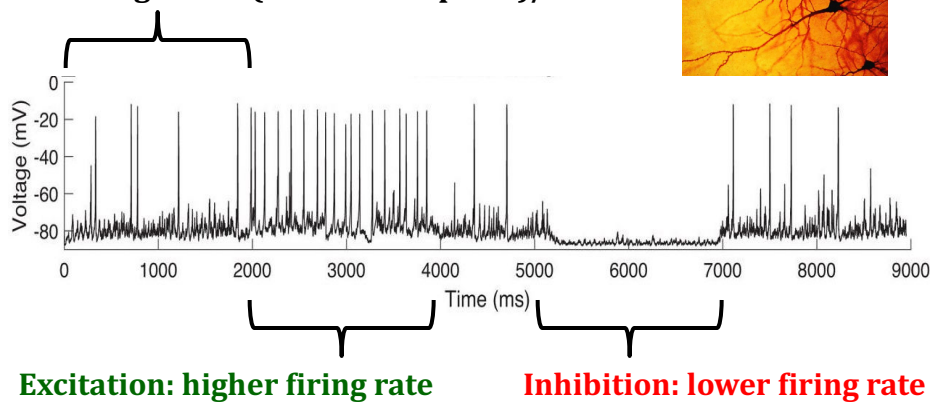
## Structure of a neuron



1-3

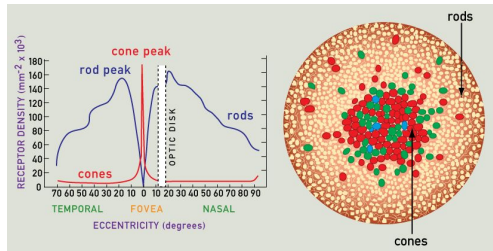
## Neural signals

Firing rate = (number of spikes)/time



1-4

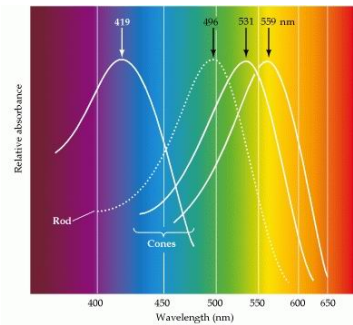
## Rods and cones in the retina



fovea:

- central 2° visual angle
- ≈ 250 receptors across

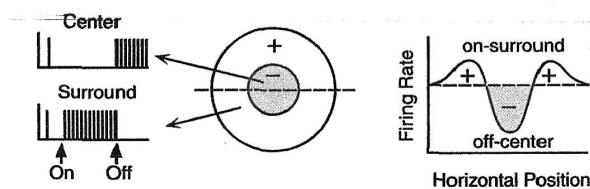
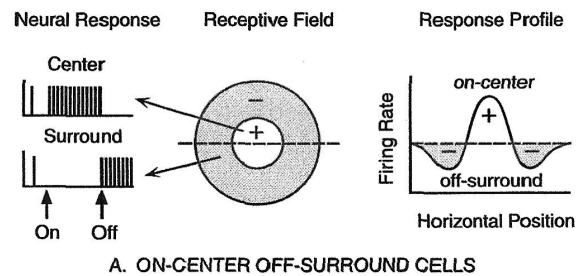
(Relative) absorption spectra for S (short), M (medium), & L (long) wavelength cones



1-6

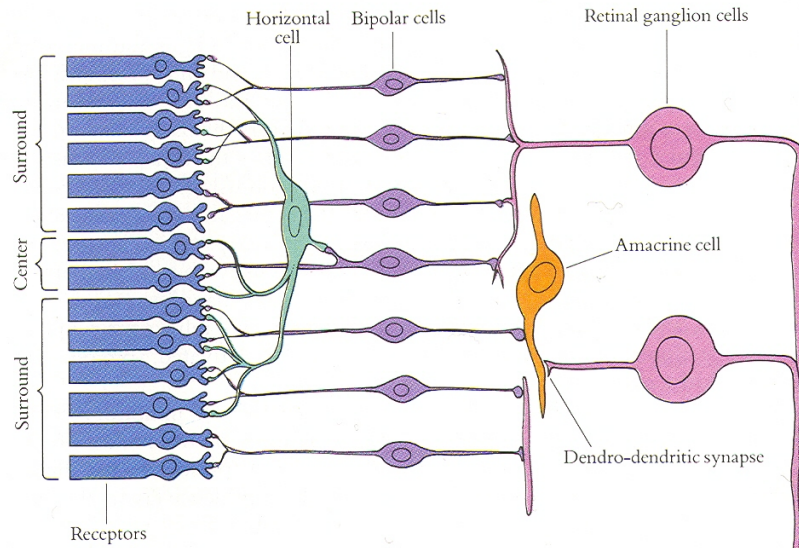
## Retinal ganglion cells

**receptive fields** exhibit a *center-surround structure*, whose cross-section is the difference of two Gaussians

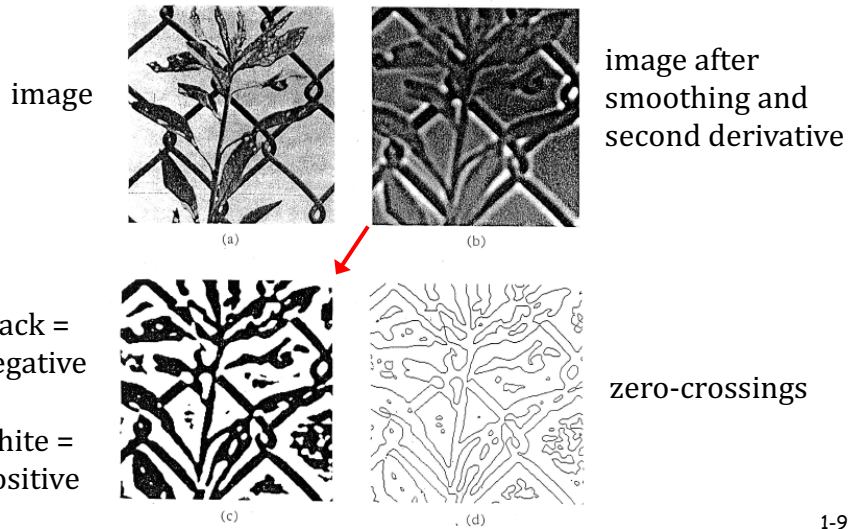


1-7

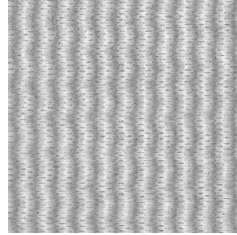
## Processing within the retina



## Analyzing intensity changes in a 2D image



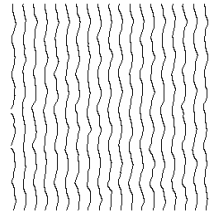
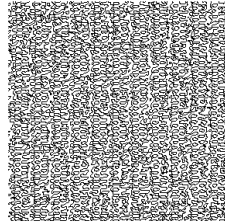
## Detecting intensity changes at multiple scales



### human vision:

- multiple receptive field sizes in the same region of the visual field
- receptive field sizes increase with eccentricity (distance from the center of the eye)

small  $\sigma$

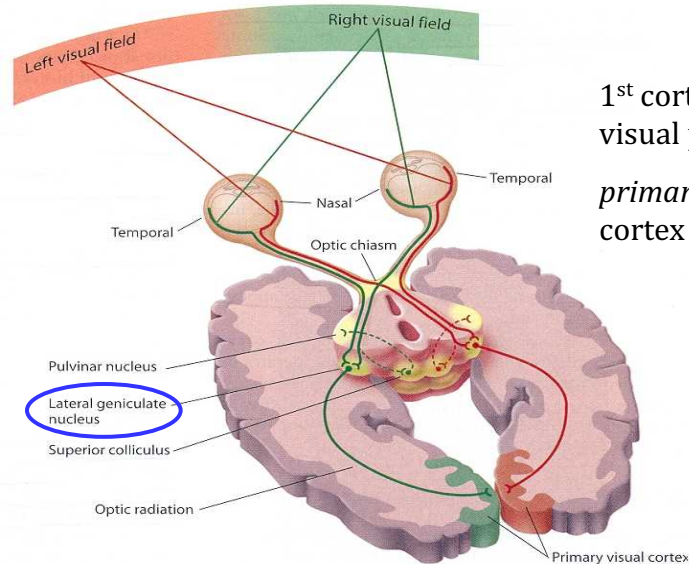


large  $\sigma$

zero-crossings of convolutions of image  
with  $\nabla^2 G$  operators

1-10

## Projection from the retina



1<sup>st</sup> cortical stage of  
visual processing:

*primary* visual  
cortex (area V1)

1-11

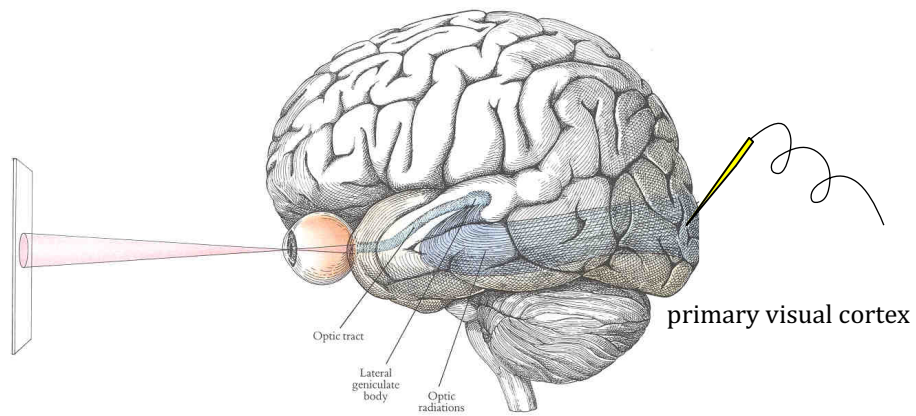
## Mapping cortical receptive fields



David Hubel & Torsten Wiesel  
1981 Nobel Prize

1-12

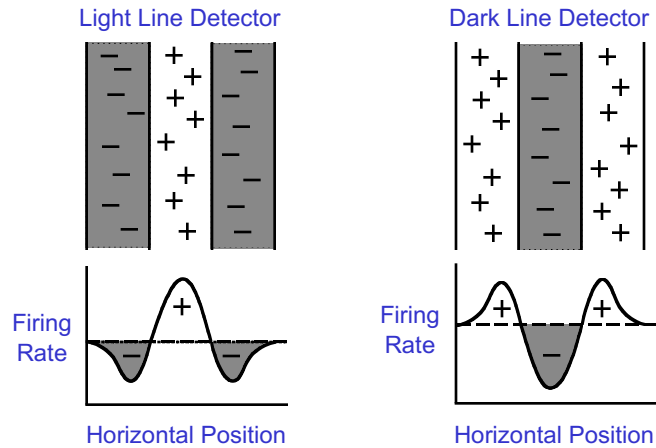
## Single-cell recording from visual cortex



Hubel & Wiesel identified 3 basic cell types:  
simple, complex, hypercomplex cells

1-13

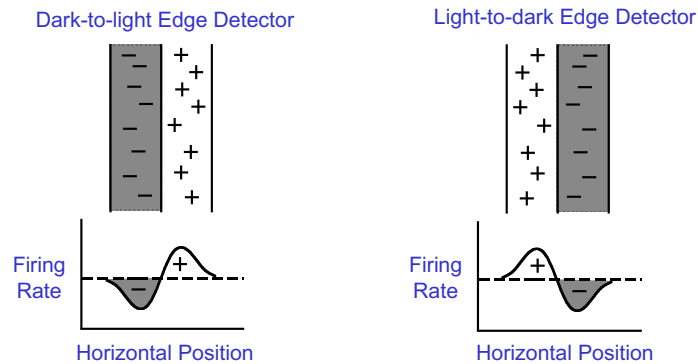
## Some simple cells respond best to lines...



... of a particular contrast sign, orientation, position

1-14

## Some simple cells respond best to edges



Again, of a particular contrast sign, orientation, position

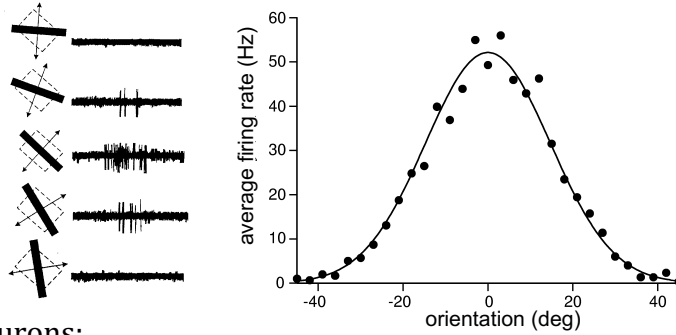
large receptive fields → coarse spatial structure

small receptive fields → fine spatial structure

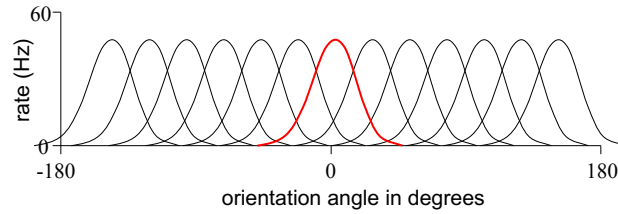
1-

## Tuning Curves in Primary Visual Cortex

Single neuron:

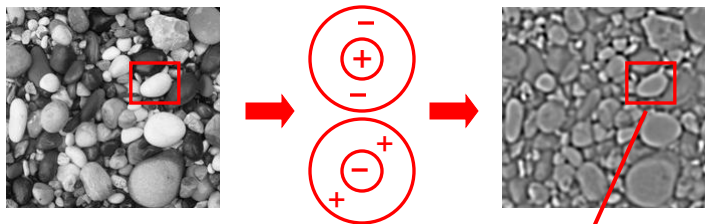


Many neurons:



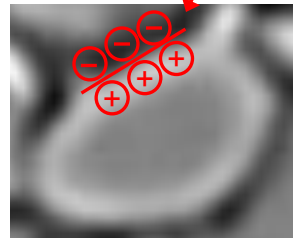
1-16

## Detection of intensity edges



Simple cells appear to detect edges *and* lines

Many complex cells are also selective for stereo disparity and motion



1-17