1. Early processing in human vision

- Light
- Retina
- Optic nerve
- LGN
- Primary visual cortex
- Neural signal

2. Rods vs. cones

- Cones:
  - Sensitive to color
  - Operate in daylight
  - Adapt quickly to changing light

- Rods:
  - Not sensitive to color
  - Operate at low light levels
  - Adapt slowly to changing light

In the night sky:
Why do stars appear to disappear when you look directly at them?
Why do all stars look white?

3. Retinal ganglion cells

- Receptive fields have center-surround structure
- Cross-section ~ difference of two Gaussians

4. Emergence of center-surround receptive field

- Direct excitation of bipolar cell from photoreceptors
- Inhibition of bipolar cell via horizontal cell
- Resulting bipolar cell response
Analyzing intensity changes in a 2D image

image after smoothing & second derivative convolution with $V^2G$ operator

~ convolution of the retinal image is passed up the optic nerve
• on-center cells carry positive part
• off-center cells carry negative part

Measuring neural activity

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)
Spatial frequency decomposition

Any real signal, such as $I(x)$, can be described as the sum of sinusoidal waves of different frequency, amplitude, and phase.

Fourier Transform

Two ways to describe 1D or 2D signals

Spatial frequency channels

‘Low’ spatial frequency filters encode coarse luminance variations in the world (e.g. large objects, overall shape).

‘High’ spatial frequency filters respond to the fine spatial structure of the world (e.g. small objects, detail).

Spatial frequency channels” in human vision

Hybrid images combine the low spatial frequencies of one picture with the high spatial frequencies of another.

Hybrid images @ MIT Gallery: http://olivalab.mit.edu/hybrid_gallery/gallery.html

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Spatial frequency channels” in human vision

Campbell & Robson, 1968
Orientation tuning curves

Single neuron:

[Graph showing orientation tuning curve with preferred orientation marked]

Many neurons:

[Graph showing orientation tuning curves for multiple neurons]

Visual acuity and hyperacuity

Two-point or two-line acuity:
How far apart do the dots or bars need to be, before we can tell that there are two?

about 1° of visual arc

Vernier acuity:
How much relative shift in the horizontal direction is needed to tell if it's shifted left or right?

about 5-6" of visual arc