ISTA 352

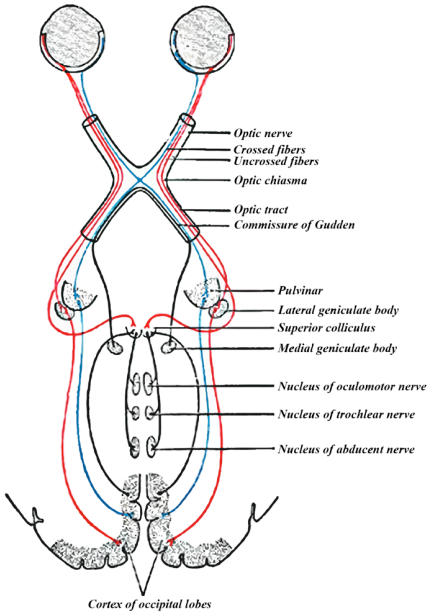
Lecture 7

Human Vision System (HVS)
Light Capture and First Level Processing

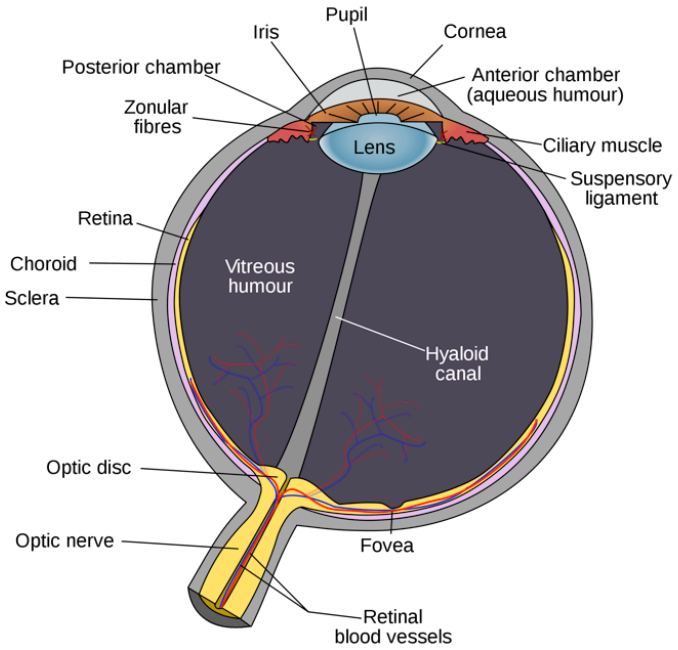
Administrivia

- HW1 due in 68 hours
- Homework questions
  - Email mail list or Kyle (and CC me if you like)
  - Kyle Simek <ksimek@email.arizona.edu>
- Friday bonus lecture 1pm (sharp) in GS 906
  - Demo on "color constancy"
  - Monitor gamma (time permitting)

The HVS

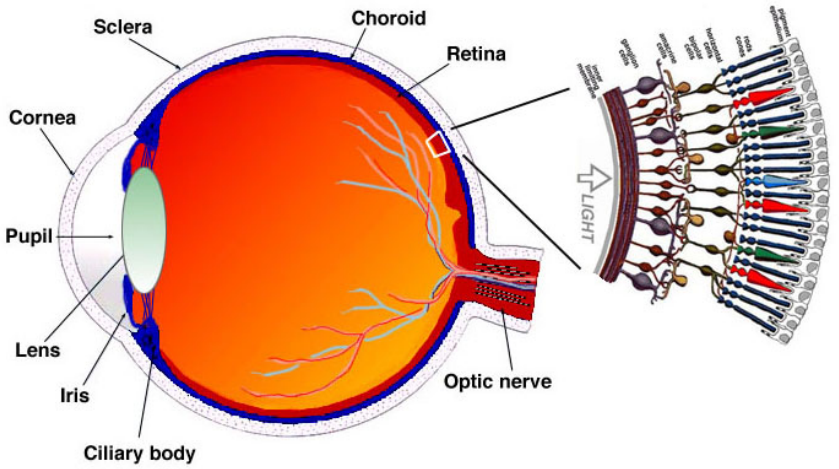


The human eye

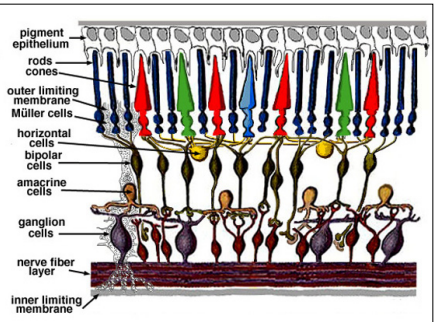


The human eye

- The amount of light entering the eye is a function of the pupil size (controlled by the iris)
  - Camera analog is aperture
  - The range of brightness in nature is huge
    - The ability to handle this is referred to as dynamic range
    - The eye has higher effective dynamic range than most cameras because at a fixed aperture the range is higher, and their range adjusts as a function of what they are looking at.
- Light is sensed on the retina
  - Camera analog is CCD (or other sensor type) chip
  - The flat sensor in a camera has some disadvantages to the spherical one
- The lens accommodates to focus what is being looked at on the retina.



The Retina

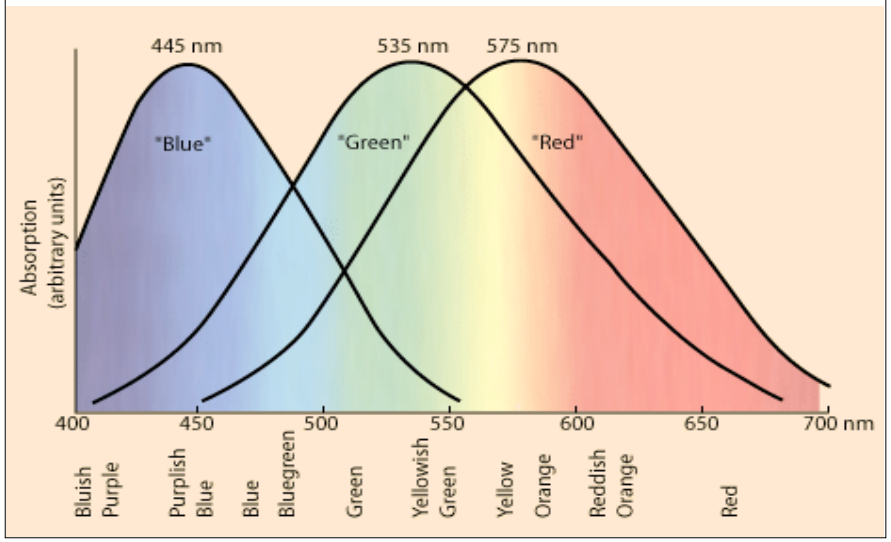


- The retina is an information processing machine
- Sensors (rods and cones) feed into other cells
  - Around 7 million cones
  - 75 to 150 million rods
  - “only” one million nerves in optic nerve bundle

Sensory elements (rods and cones)

- Rods are sensitive to low light
  - Pegged at max and non-informative when it is bright
- Cones only work when there is enough light
  - Night vision is black and white (only one kind of rod)
- Cones carry color
  - People with normal human vision have three types
    - L (long), M (medium), and S (short)
  - Is this fundamental?
    - Consider that cats have 2, most birds have 4, some turtles have 6, ...

Approximate spectra sensitivity for the three cone types

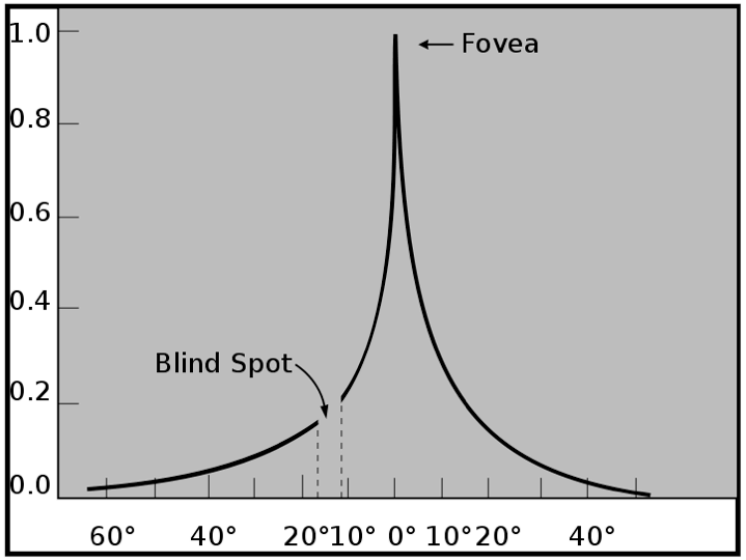


Color vision is linear

- Cone response to photon capture can be modeled in the same we did for camera sensors
  - At the capture level it is linear
  - It is confusing because the automatically adjusting aperture, and down stream processing makes the overall "brightness" response more like a logarithmic function.
- We can use the cone sensitivities to predict whether two spectra will be seen as the same color
- We will lean more about color vision when we study color reproduction

Distribution of rods and cones

- A small central part of the eye (**the fovea**) is especially densely populated with L and M cones (no rods)
  - To see detail when it bright, look straight ahead
  - To see a dim star, don't look directly at it
  - Foveal vision is black and white
- The S cones (blue sensitive) are relatively rare
  - True color vision is fuzzy and inferred
  - Interesting tidbit --- if their were more S cones, the "chromatic aberration" in the eye would be a problem.



The relative acuity of the eye across the field of view

do your

focus
here!

home work

3. 1 4 5 9 2 6 5 3 5 8

3. 1 4 1 5 9 2 6 5 3 5 8 9 7 9

3. 1 4 1 5 9 2 6 5 3 5 8 9 7 9 3 2 3 8 4 6 2 6

3. 1 4 1 5 9 2 6 5 3 5 8 9 7 9 3 2 3 8 4 6 2 6 4 3 3 8 3 2 7

3. 1 4 1 5 9 2 6 5 3 5 8 9 7 9 3 2 3 8 4 6 2 6 4 3 3 8 3 2 7 9 5 0 2 8 8 4 1 9

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3. 1 4 1 5 9 2 6 5 3 5 8 9 7 9 3 2 3 8 4 6 2 6 4 3 3 8 3 2 7 9 5 0 2 8 8 4 1 9 7 1 6 9 3 9

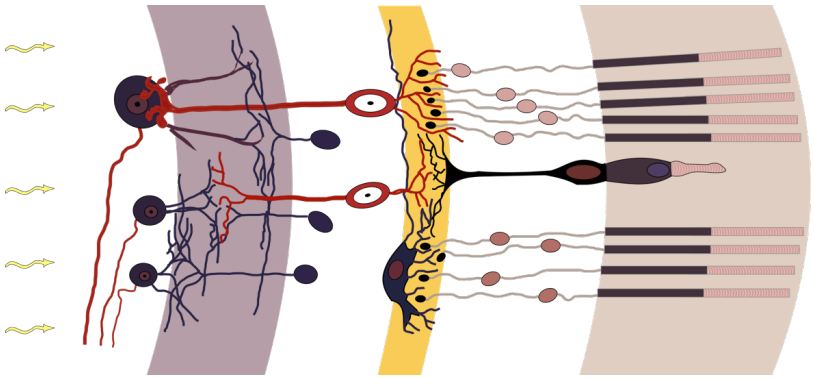
The high resolution illusion

- Despite blind spots, low resolution outside the fovea, very low resolution, we see the world in high resolution!
  - Our brain constructs a high resolution illusion
  - When we need to know a detail, we can look there
  - The eye natural moves to a new fixation point many times a second ("saccades").
  - Motion sensitive cells detect change
  - We still miss a lot more than we think!

From capture to optic nerve

- Recall that there are many more sensors than nerve fibers going from the eye to the back of the brain
- Initial computations aggregate signals and detect change
- Three kinds of differencing operations
  - Center surround cells (respond to edges)
  - Opponent color cells (reduce correlation between color channels)
  - Motion sensitive cells detect temporal differences

Neural organization of the retina

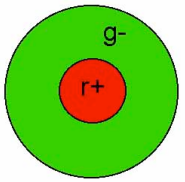


Amacrine and ganglion cells

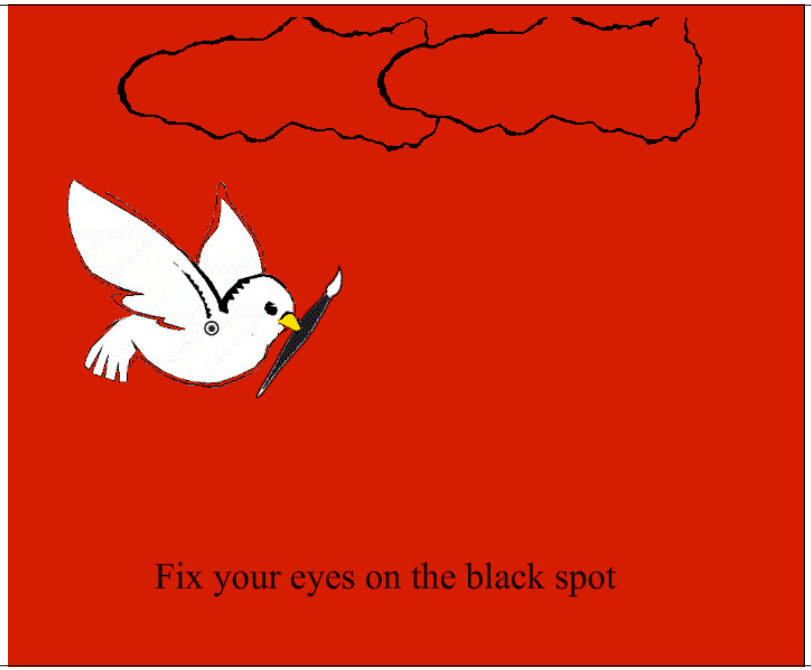
Bipolar and horizontal cells

Center surround and opponency

- A basic arrangement is central cells surrounded by others
- The neuron output is the difference between the signals
  - If the input corresponds to a spatial arrangement, then we have a dot detector
    - e.g. a bipolar cell with surround connections to horizontal cells, center connections to cone
  - If the input corresponds to cone types, then we have color opponent cells
    - implemented in ganglion cells



red-green opponent cell



Motion detection

- Basic detection is based on correlating current signal with delayed signal from nearby sensors.
- More when we study movies