# Sensory Processes

## Welcome to EXP3104

Instructor: Ryan Mears, PhD

August 25, 2017

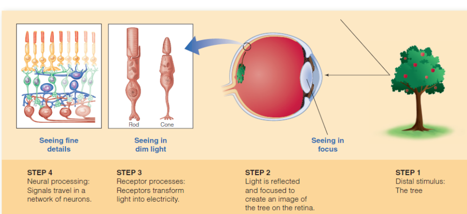


# Chapter 2

## The Beginning of the Perceptual Process



## Starting at the Beginning






# Light, the Eye, and the Visual Receptors

# Light: The Stimulus for Vision

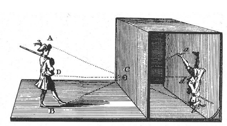
- Electromagnetic spectrum
  - Energy is described by wavelength.
  - Spectrum ranges from short wavelength gamma rays to long wavelength radio waves.
  - Visible spectrum for humans ranges from 400 to 700 nanometers.
  - Most perceived light is reflected light.



# Camera Obscura Principle

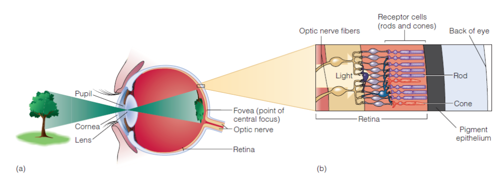


# Camera Obscura Principle





# The Eye



# The Eye

- The eye contains receptors for vision.
- Light enters the eye through the pupil and is focused by the cornea and lens to a sharp image on the retina.
- Rods and cones are the visual receptors in the retina that contain visual pigment.
- The optic nerve carries information from the retina toward the brain.



# The Eye

Differences between rods and cones

- Shape
  - **Rods**: large and cylindrical
  - **Cones**: small and tapered
- Distribution on retina
  - Fovea consists solely of cones.
  - Peripheral retina has both rods and cones.
  - More rods than cones in periphery.



# The Eye

- **Macular degeneration**
  - Fovea and small surrounding area are destroyed.
  - Creates a “blind spot” on retina
  - Most common in older individuals
- **Retinitis pigmentosa**
  - Genetic disease
  - Rods are destroyed first.
  - Foveal cones can also be attacked.
  - Severe cases result in complete blindness.



# The Eye

(a) (b)

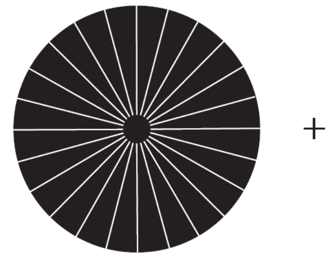
## The Eye

- Number: about 120 million rods and 6 million cones
- **Blind spot**: place where optic nerve leaves the eye

- We don't see it because:
  - One eye covers the blind spot of the other.
  - It is located at edge of the visual field.
  - The brain "fills in" the spot.



## The Eye



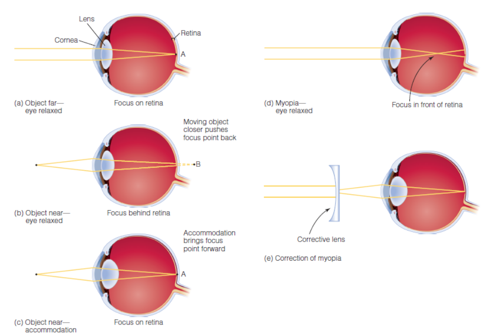


# Focusing Light Onto the Receptors

Describe how the cornea and lens focus the image on the retina.



## Focusing Light Onto the Receptors



## Focusing Light Onto the Receptors

- The cornea, which is fixed, accounts for about 80% of focusing.
- The lens, which adjusts shape for object distance, accounts for the other 20%.
  - **Accommodation** results when ciliary muscles are tightened which causes the lens to thicken.
  - Light rays pass through the lens more sharply and focus **near** objects on retina.



## Focusing Light Onto the Receptors

- The near point occurs when the lens can no longer adjust for close objects.
- **Presbyopia**: “old eye”
  - Distance of near point increases.
  - Due to hardening of lens and weakening of ciliary muscles
  - Corrective lenses are needed for close activities, such as reading.



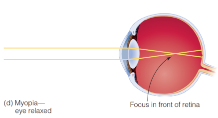
## Focusing Light Onto the Receptors

- **Myopia** or nearsightedness: inability to see distant objects clearly
- Image is focused in front of retina.
- Caused by:
  - *Refractive* myopia: cornea or lens bends too much light.
  - *Axial* myopia: eyeball is too long.



## Focusing Light Onto the Receptors

- **Myopia** or nearsightedness: inability to see distant objects clearly
- Image is focused in front of retina.
- Caused by:
  - *Refractive* myopia: cornea or lens bends too much light.
  - *Axial* myopia: eyeball is too long.



## Focusing Light Onto the Receptors

- **Hyperopia** or farsightedness: inability to see nearby objects clearly
  - Focus point is **behind** the retina.
  - Usually caused by an eyeball that is too **short**
  - Constant accommodation for nearby objects can lead to *eyestrain and headaches*.



## Receptors and Perception

Describe the role of visual pigments in transduction.

Describe the method for measuring dark adaptation, and the overall results.

Discuss the differences between the distribution of the rods and the cones.

Explain why the "blind spot" exists, and why we are not usually aware of it.

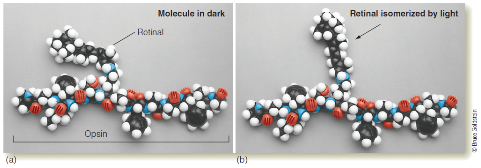


## Transforming of Light Energy Into Electrical Energy

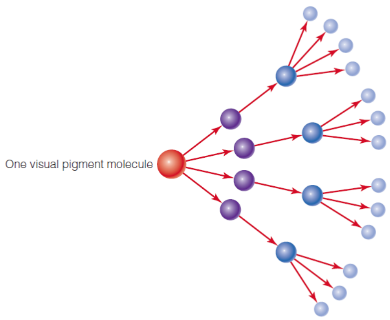
- Receptors have outer segments, which contain:
- Visual pigment molecules, which have two components:
  - **Opsin**, a large protein
  - **Retinal**, a light sensitive molecule
- Visual transduction occurs when the retinal absorbs one photon.
  - Retinal changes its shape, which is known as isomerization.



## Transforming of Light Energy Into Electrical Energy



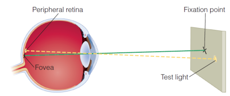
## Transforming of Light Energy Into Electrical Energy






## Adapting to the Dark

- Dark adaption is the process of increasing sensitivity in the dark.
  - Measured by determining a dark adaptation curve






## Measuring the Dark Adaptation Curve

- Three separate experiments are used.
- Method used in all three experiments:
  - Observer is light adapted.
  - Light is turned off.
  - Once the observer is dark adapted, she adjusts the intensity of a test light until she can just see it.

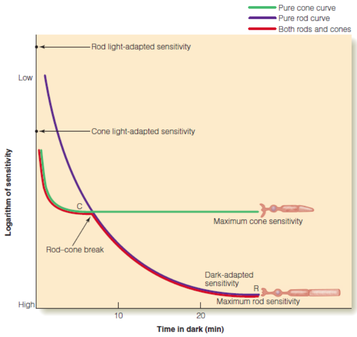


## Measuring the Dark Adaptation Curve (cont'd.)

Experiment for rods and cones:

- Observer looks at fixation point but pays attention to a test light to the side.
- Results show a dark adaptation curve:
  - Sensitivity increases in two stages.
  - Stage one takes place for three to four minutes.
  - Then sensitivity levels off for seven to ten minutes – the rod-cone break.
  - Stage two shows increased sensitivity for another 20 to 30 minutes.

## Measuring the Dark Adaptation Curve






## Measuring Cone Adaptation

- Experiment for cone adaptation
  - Test light only stimulates cones.
  - Results show that sensitivity increases for three to four minutes and then levels off.



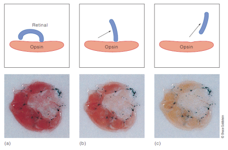
## Measuring Rod Adaptation

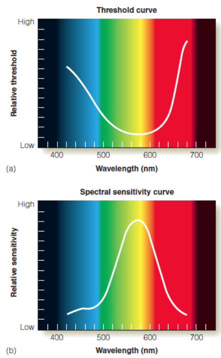
- Experiment for rod adaptation
  - Must use a rod monochromat.
  - Results show that sensitivity increases for about 25 minutes and then levels off.



## Visual Pigment Regeneration

- Process needed for transduction:
  - Retinal molecule changes shape.
  - Opsin molecule separates.
  - The retina shows visual pigment bleaching.
  - Retinal and opsin must recombine to respond to light.
  - Visual pigment regenerates.



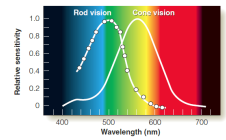



- Sensitivity of rods and cones to different parts of the visual spectrum
  - Use monochromatic light to determine threshold at different wavelengths.
  - Threshold for light is lowest in the middle of the spectrum.
  - 1/threshold = sensitivity, which produces the spectral sensitivity curve.



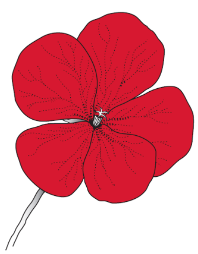
# Spectral Sensitivity

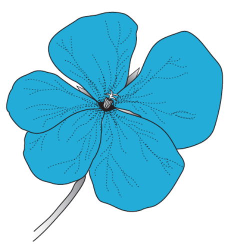
- Rod spectral sensitivity
  - More sensitive to short-wavelength light
  - Most sensitivity at 500 nm
- Cone spectral sensitivity
  - Most sensitivity at 560 nm
- Purkinje shift: enhanced sensitivity to short wavelengths during dark adaptation when the shift from cone to rod vision occurs






# Spectral Sensitivity



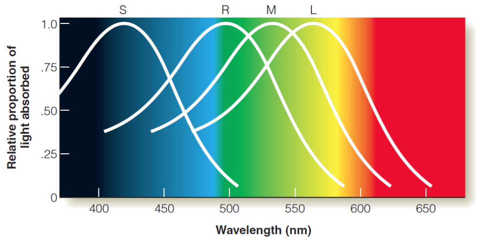




# Spectral Sensitivity (cont'd.)

- Difference in spectral sensitivity is due to absorption spectra of visual pigments.
- Rod pigment absorbs best at 500 nm.
- Cone pigments absorb best at 419nm, 531nm, and 558nm.
  - Absorption of all cones equals the peak of 560nm in the spectral sensitivity curve.

## Spectral Sensitivity






## Electrical Signals in Neurons

Identify the key components of neurons.

Define propagated response, and discuss
how this is related to measuring activity in a single neuron.

Describe depolarization, hyperpolarization, and inhibition.

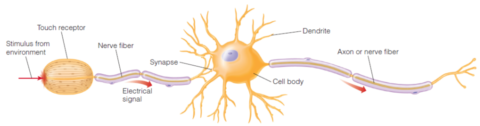


## Electrical Signals in Neurons

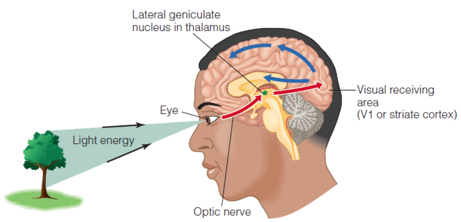
- Key components of neurons:
  - Cell body
  - Dendrites
  - Axon or nerve fiber
- Sensory receptors: specialized neurons that respond to specific kinds of energy



## Electrical Signals in Neurons



## Electrical Signals in Neurons



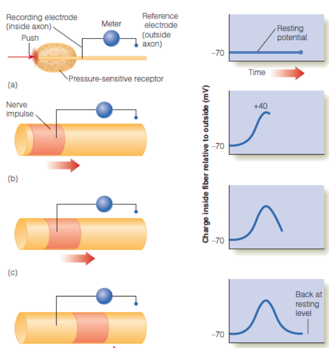



## Recording Electrical Signals in Neurons

- Small electrodes are used to record from single neurons.
  - Recording electrode is inside the nerve fiber.
  - Reference electrode is outside the fiber.
  - Difference in charge between them is -70 mV
  - This negative charge of the neuron relative to its surroundings is the resting potential.

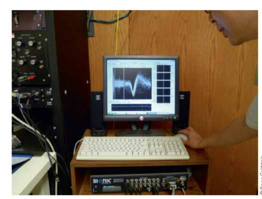


## Recording Electrical Signals in Neurons






## Recording Electrical Signals in Neurons

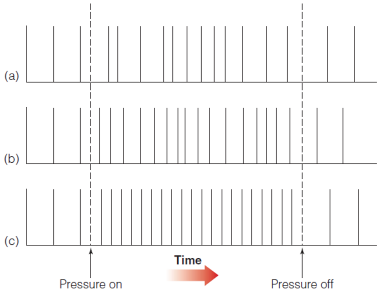


## Basic Properties of Action Potentials

- Action potentials:
  - Show propagated response.
  - Remain the same size regardless of stimulus intensity.
  - Increase in rate to increase in stimulus intensity.
  - Have a refractory period of 1 ms – upper firing rate is 500 to 800 impulses per second.
  - Show spontaneous activity that occurs without stimulation.



## Basic Properties of Action Potentials



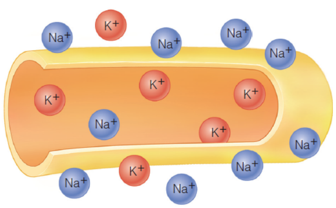



## Chemical Basis of Action Potentials

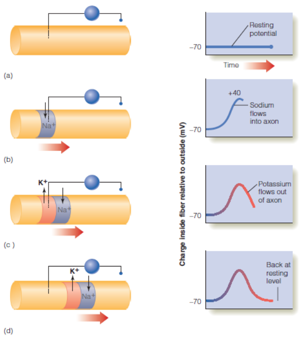
- Neurons are surrounded by a solution containing ions.
  - Ions carry an electrical charge.
  - Sodium ions (Na+): positive charge
  - Chlorine ions (Cl-): negative charge
  - Potassium ions (K+): positive charge
  - Electrical signals are generated when such ions cross the membranes of neurons.
- Membranes have selective permeability.



## Chemical Basis of Action Potentials



## Chemical Basis of Action Potentials



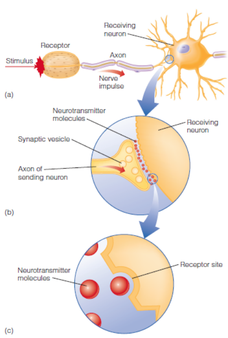



## Transmitting Information Across a Gap

- Synapse is the small space between neurons.
- Neurotransmitters are:
  - Released by the presynaptic neuron from vesicles
  - Received by the postsynaptic neuron on receptor sites
  - Matched like a key to a lock into specific receptor sites
  - Used as triggers for voltage change in the postsynaptic neuron



## Transmitting Information Across a Gap

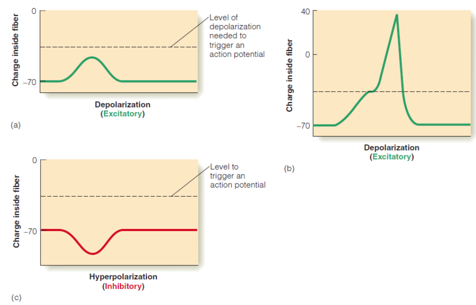





## Transmitting Information Across a Gap

- Excitatory transmitters cause depolarization.
  - Neuron becomes more positive.
  - Increases the likelihood of an action potential
- Inhibitory transmitters cause hyperpolarization.
  - Neuron becomes more negative.
  - Decreases the likelihood of an action potential

## Transmitting Information Across a Gap






## Neural Convergence and Perception

Describe what convergence is, and how it related to acuity in rods and cones.



## Neural Convergence and Perception

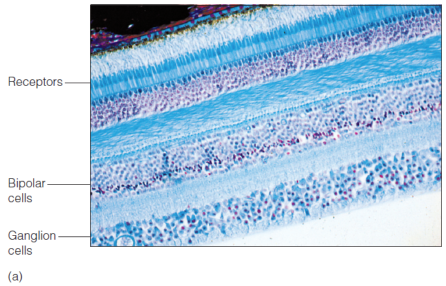
- Rods and cones send signals vertically through:
  - Bipolar cells
  - Ganglion cells
  - Ganglion axons
- Signals are sent horizontally:
  - Between receptors by horizontal cells
  - Between bipolar and between ganglion cells by amacrine cells



## Neural Convergence and Perception

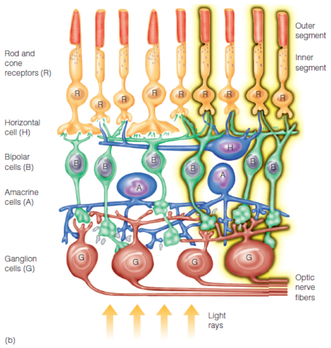
- 126 million rods and cones converge to 1 million ganglion cells.
- Higher convergence of rods than cones
  - Average of 120 rods to one ganglion cell
  - Average of six cones to one ganglion cell
  - Cones in fovea have one to one relation to ganglion cells

## Neural Convergence and Perception






## Neural Convergence and Perception



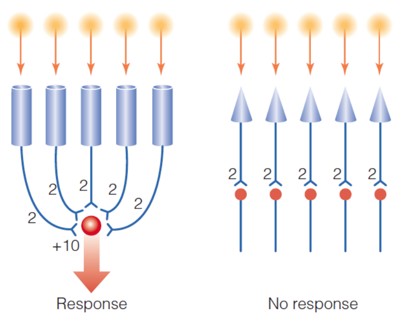



## Convergence Causes the Rods to Be More Sensitive Than the Cones

- Rods are more sensitive to light than cones.
    - Rods take less light to respond.
    - Rods have greater convergence, which results in summation of the inputs of many rods into ganglion cells increasing the likelihood of response.
    - The trade-off is that rods cannot distinguish detail.



## Convergence Causes the Rods to Be More Sensitive



## Lack of Convergence Causes the Cones to Have Better Acuity

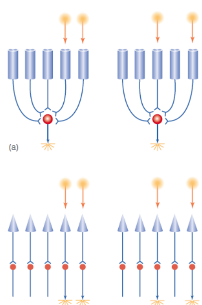
- All-cone foveal vision results in high visual acuity.
  - One-to-one wiring leads to ability to discriminate details.
  - The trade-off is that cones need more light to respond than rods.



## Lack of Convergence Causes the Cones to Have Better Acuity

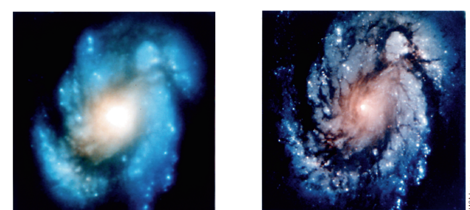


## Lack of Convergence Causes the Cones to Have Better Acuity






## Early Events Are Powerful




(a) Wide field planetary camera 1 **Before**

(b) Wide field planetary camera 2 **After correction**

- Hubble space telescope

## Early Events Are Powerful

(a)

(b)



## Infant Visual Acuity

Preferential looking (PL) technique Visual evoked potential (VEP)