



Chapter 3

The Eye and Retina

Icebreaker: Visual Perception Comparison

1. The class will be broken up into pairs of students or small groups
2. Each group of students will select an object in the classroom to focus on.
3. One student in each group will move the selected objects to different areas of the room such as a window sill, under a lamp, or a dark corner.
4. Students will discuss how the placement of the object shapes their perception of the object—its depth, color, and/or shape.

Chapter Objectives (1 of 2)

03.01 Identify the key structures of the eye and describe how they work together to focus light on the retina.

03.02 Explain how light is transduced into an electrical signal.

03.03 Distinguish between the influence of rods and cones on perception in both dark and light environments.

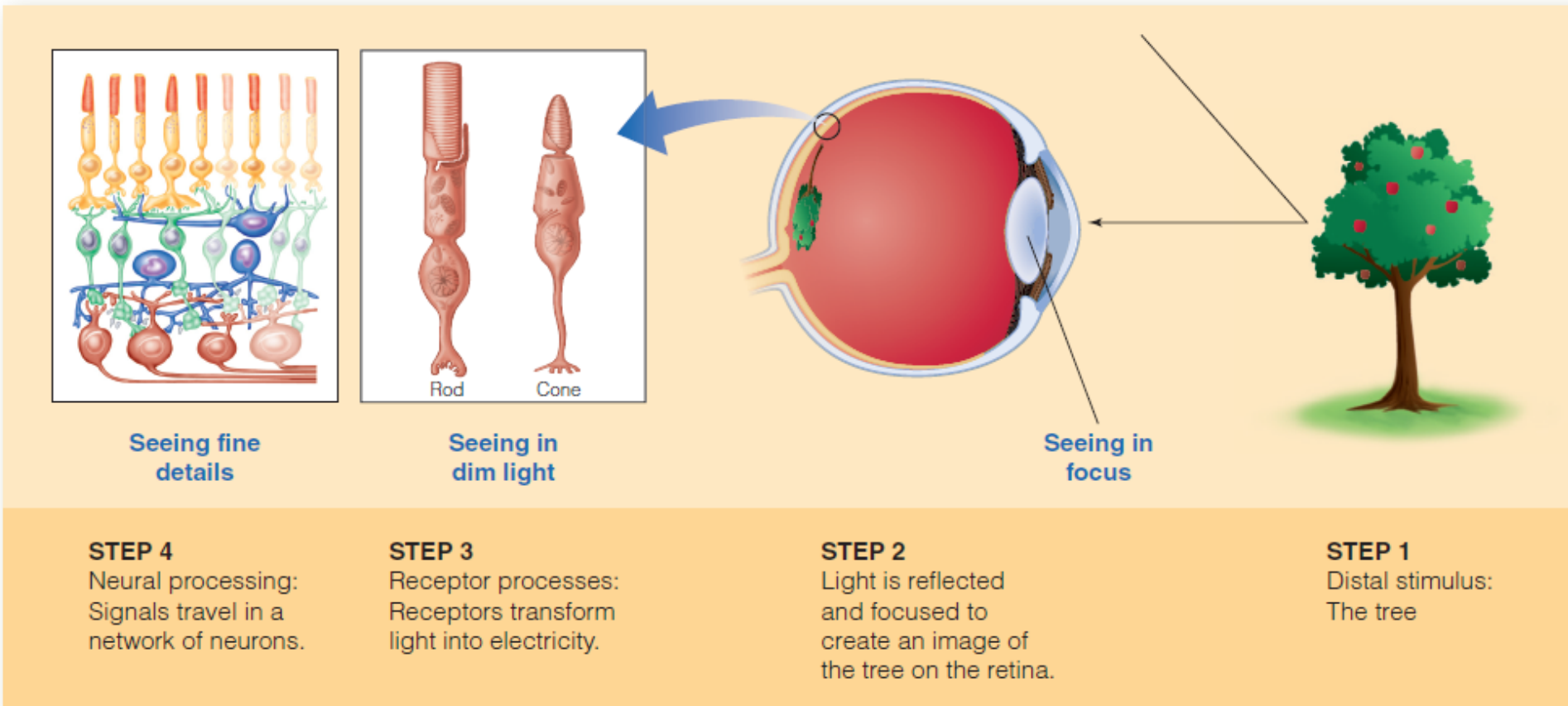
03.04 Use your knowledge of neural processing to explain how signals travel through the retina.

Chapter Objectives (2 of 2)

03.05 Describe how lateral inhibition and convergence underlie center-surround antagonism in ganglion cell receptive fields.

03.06 Understand the development of visual acuity over the first year of life.

Starting at the Beginning

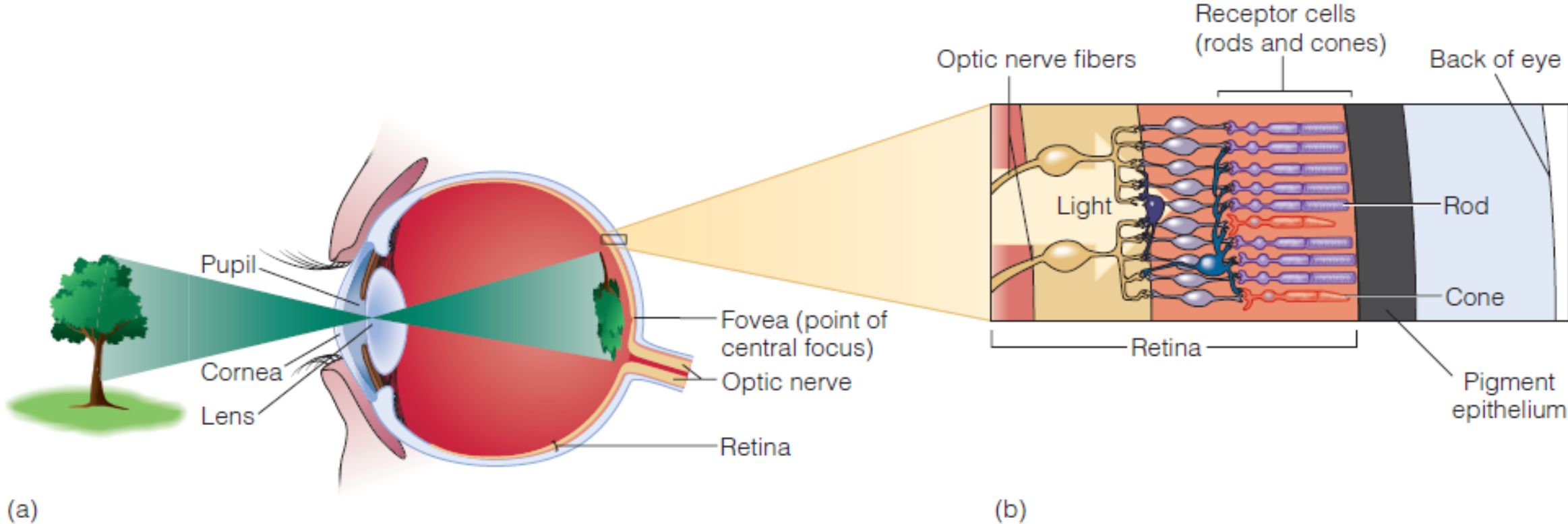


Light: The Stimulus for Vision

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.

The Eye (1 of 5)



The Eye (2 of 5)

- 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 (3 of 5)

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 (4 of 5)

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 (5 of 5)



(a)



(b)

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Focusing Light Onto the Receptors (1 of 4)

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 the retina.

Focusing Light Onto the Receptors (2 of 4)

The near point occurs when the lens can no longer adjust for close objects.

Presbyopia: “old eye”

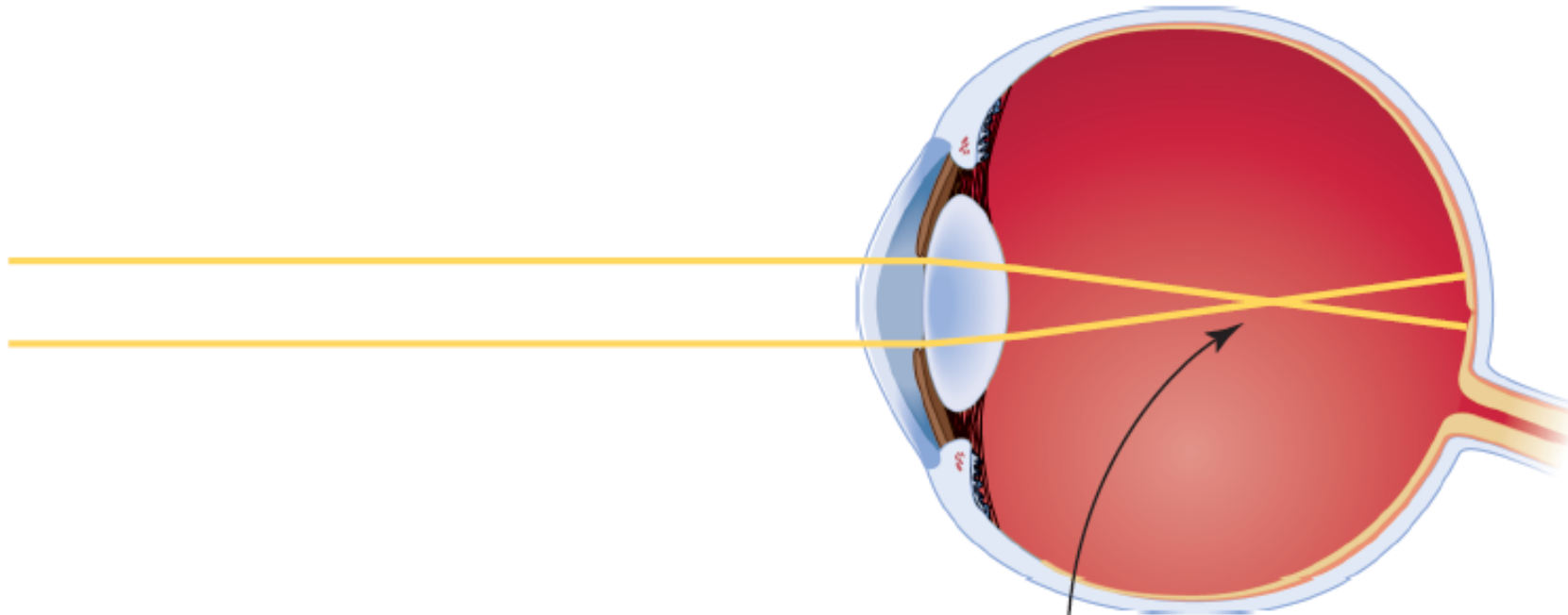
- Distance of near point increases.
- Due to hardening of lens and weakening of ciliary muscles.
- Corrective lenses are needed for close activities, such as reading.

Focusing Light Onto the Receptors (3 of 4)

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.

Myopia



(d) Myopia—
eye relaxed

Focus in front of retina

Focusing Light Onto the Receptors (4 of 4)

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.

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

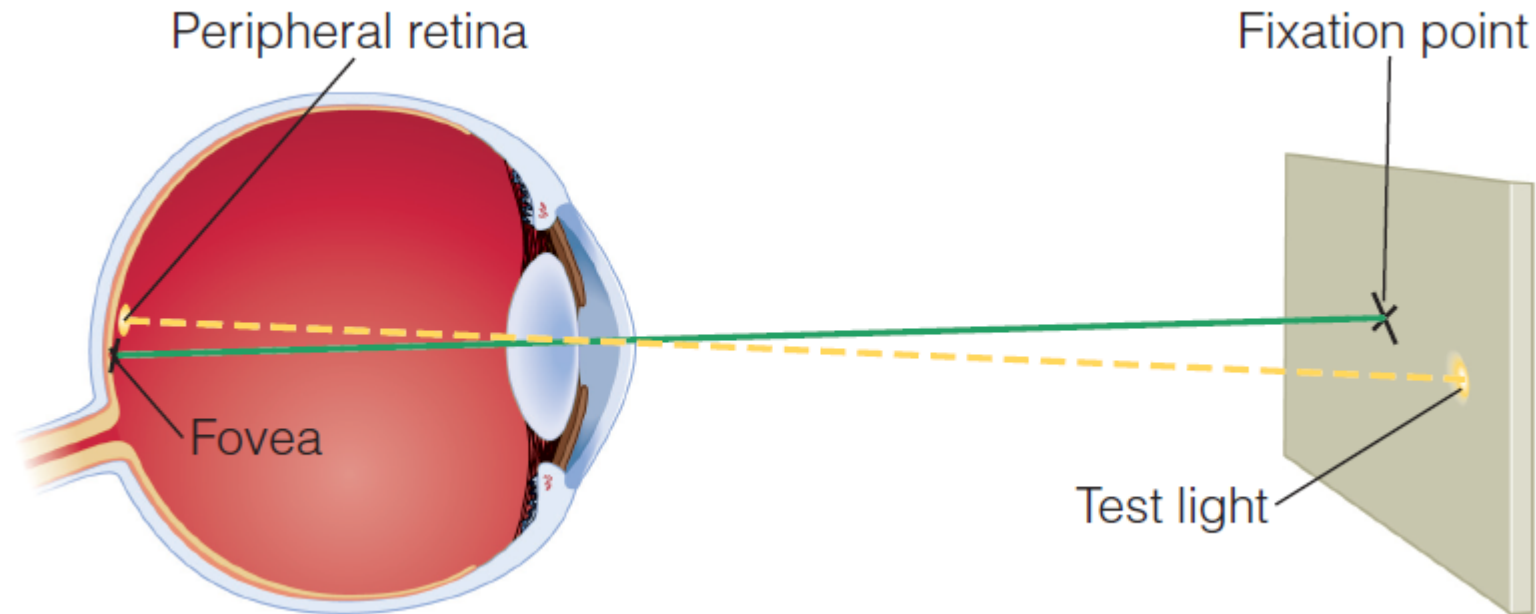
Visual transduction occurs when the retinal absorbs one photon.

- Retinal changes its shape, which is known as isomerization.

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 (1 of 3)

Three separate experiments are used.

Method used in all three experiments:

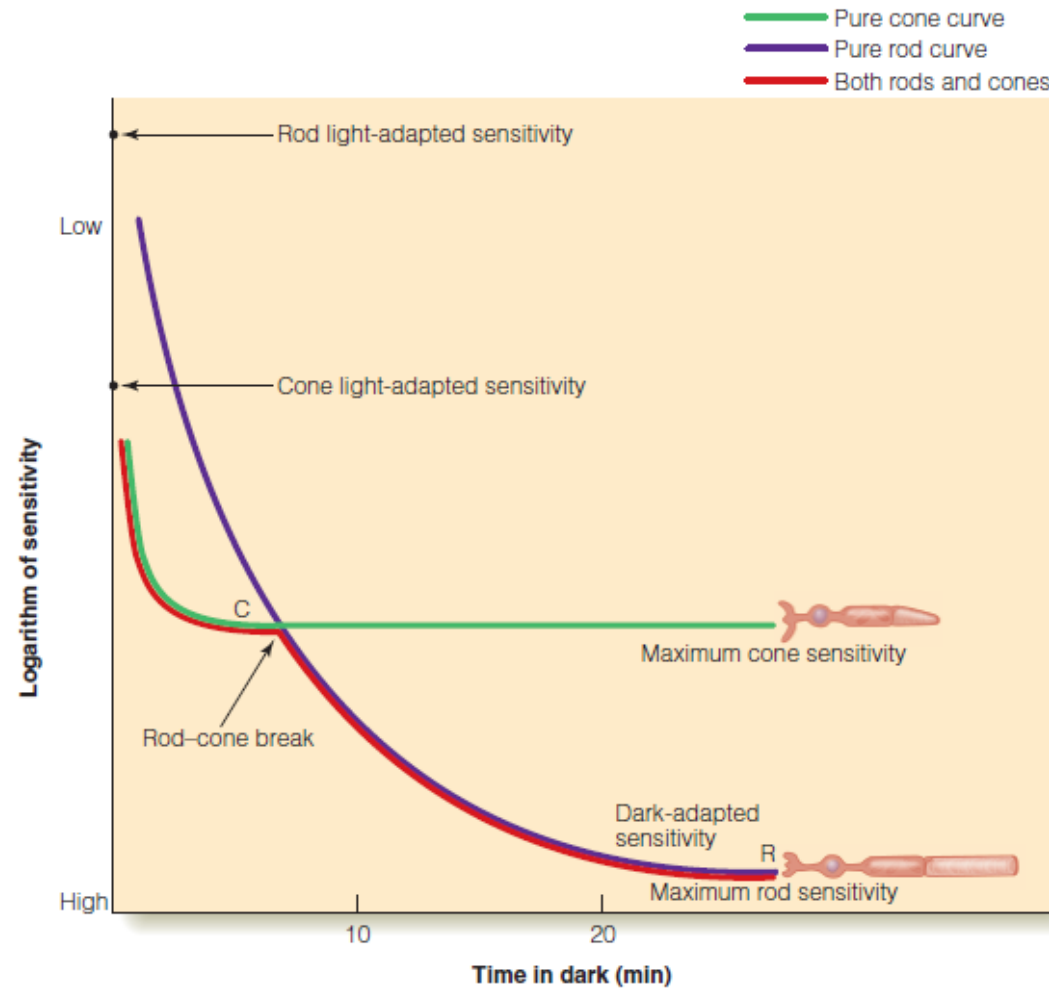
- Observer is light adapted.
- Light is turned off.
- Once the observer is dark adapted, they adjust the intensity of a test light until they can just see it.

Measuring the Dark Adaptation Curve (2 of 3)

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 (3 of 3)



Measuring Cone and Rod Adaptation

Experiment for cone adaptation

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

Experiment for rod adaptation

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

Discussion Questions

1. In the demonstration “Becoming Aware of What Is in Focus” on page 44, you saw that we see things clearly only when we are looking directly at them, so that their image falls on the cone-rich fovea. However, consider the common observation that the things we aren’t looking at do not appear fuzzy, that the entire scene appears sharp or in focus. How can this be, considering the results of the demonstration?

Spectral Sensitivity (1 of 5)

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.
- $1/\text{threshold} = \text{sensitivity}$, which produces the spectral sensitivity curve.

Spectral Sensitivity (2 of 5)

Rod spectral sensitivity

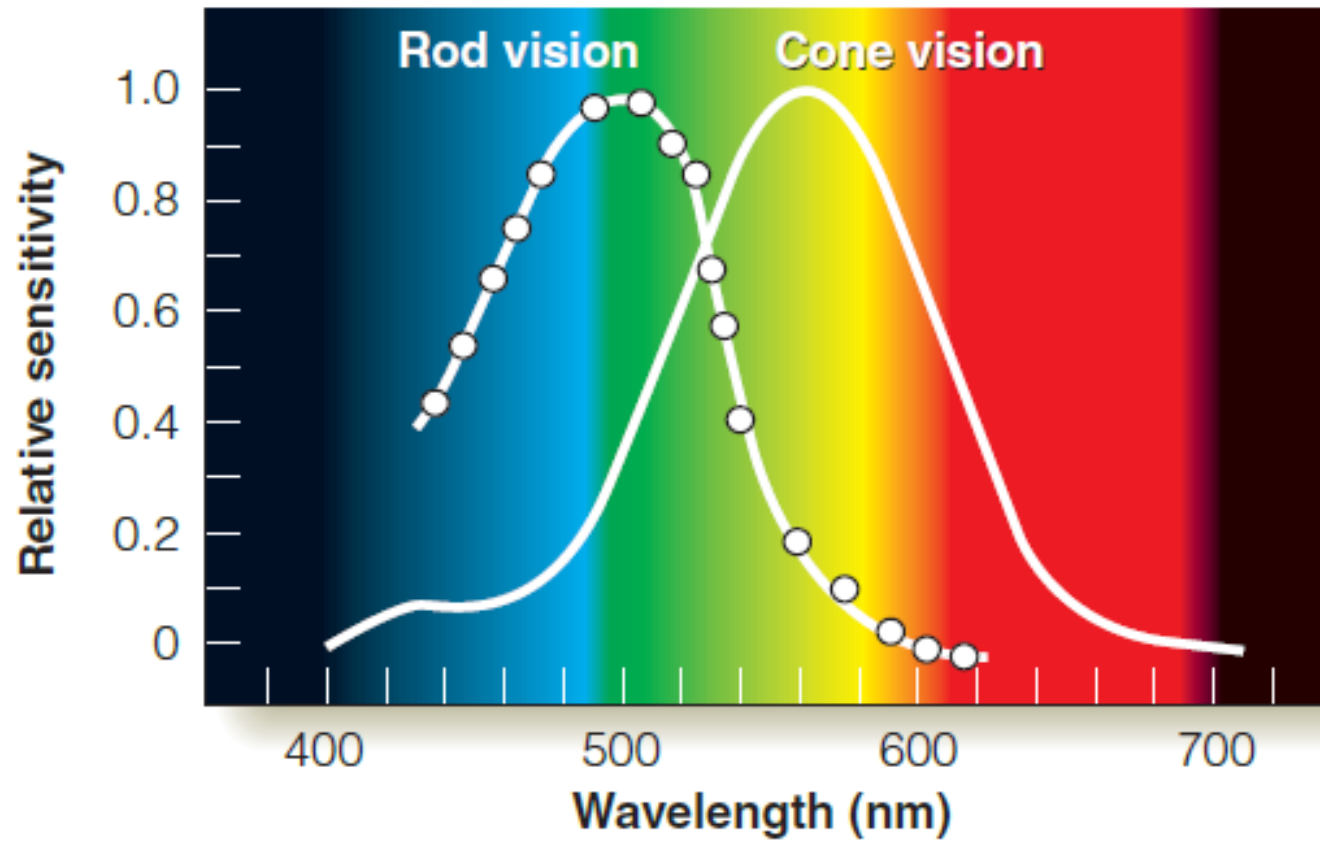
- More sensitive to short-wavelength light
- Most sensitivity at 500 nm

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 (3 of 5)



Spectral Sensitivity (4 of 5)

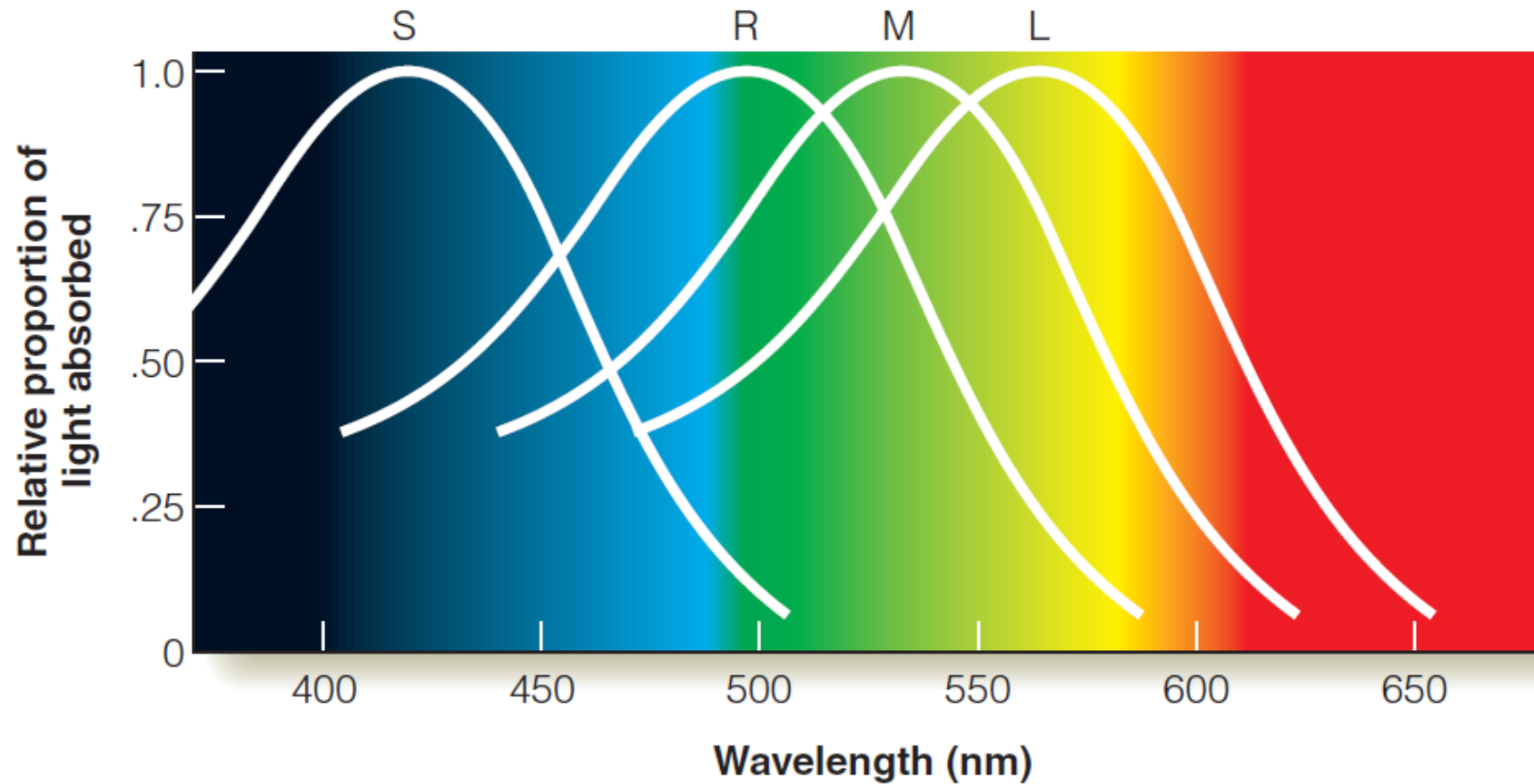
Difference in spectral sensitivity is due to absorption spectra of visual pigments.

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 (5 of 5)



Neural Convergence and Perception (1 of 2)

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 (2 of 2)

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

Convergence Causes Rods to Be More Sensitive Than 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.

Less Convergence Causes 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.

Chapter Summary (1 of 2)

Now that the lesson has ended, you should have learned to:

- Identify the key structures of the eye and describe how they work together to focus light on the retina.
- Explain how light is transduced into an electrical signal.
- Distinguish between the influence of rods and cones on perception in both dark and light environments.
- Use your knowledge of neural processing to explain how signals travel through the retina.

Chapter Summary (2 of 2)

Now that the lesson has ended, you should have learned to:

- Describe how lateral inhibition and convergence underlie center-surround antagonism in ganglion cell receptive fields.
- Understand the development of visual acuity over the first year of life.