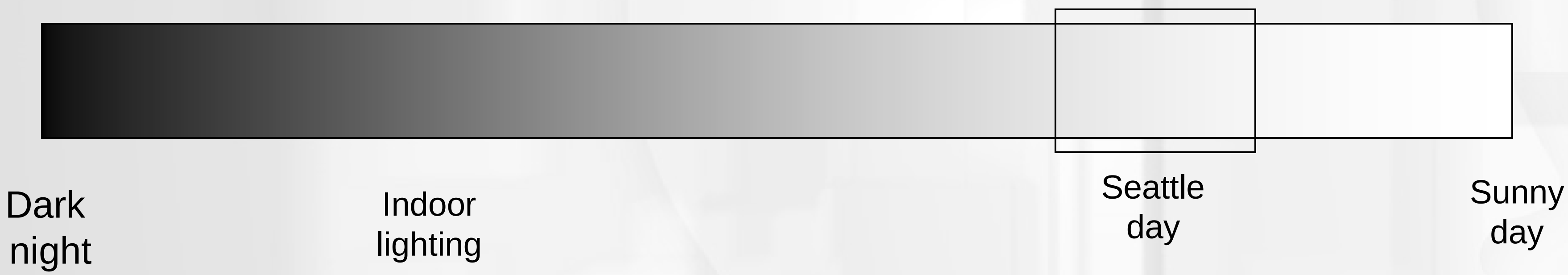
Light intensities range across 9 orders of magnitude.

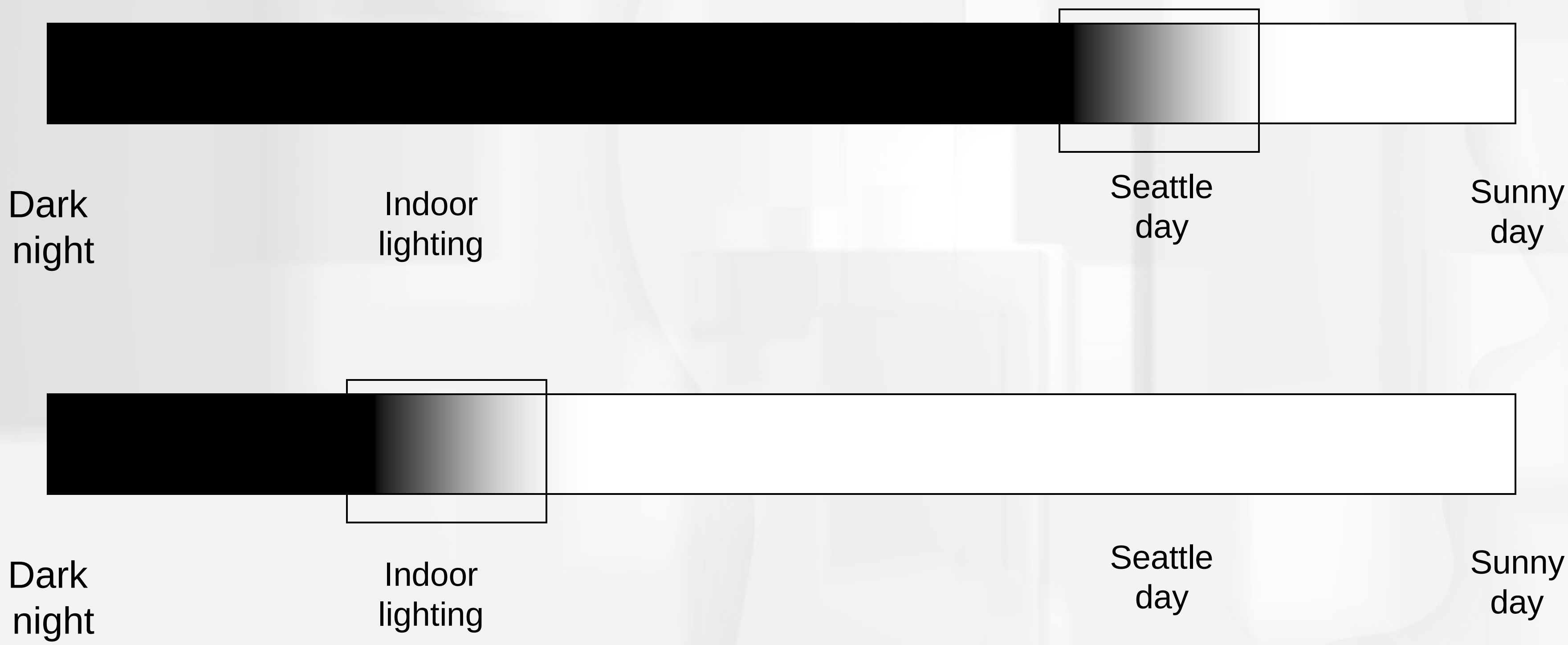
A piece of white paper can be 1,000,000,000 times brighter in outdoor sunlight than in a moonless night.

But in a given lighting condition, light ranges over only about two orders of magnitude.



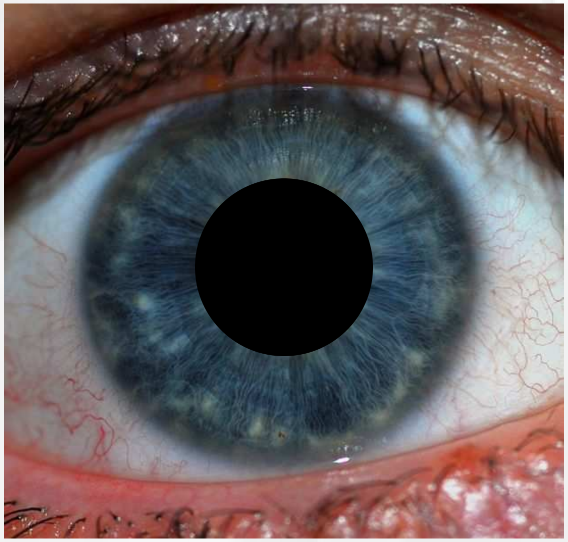
If we were sensitive to this whole range all the time, there wouldn't be able to discriminate lightness levels in a typical scene.

The visual system solves this problem by restricting the ‘dynamic range’ of its response to match the current overall or ‘ambient’ light level.



Three Mechanisms for Light/Dark adaptation

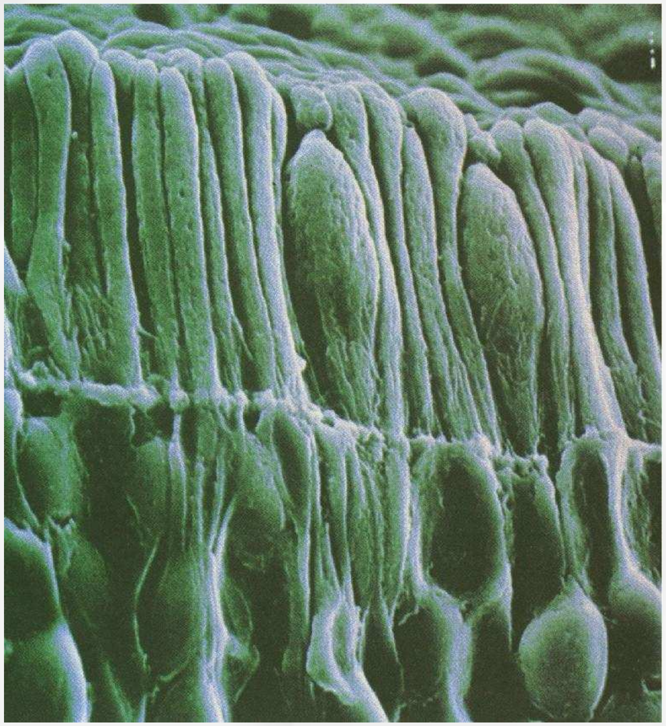
1. The **pupil** ranges in diameter from about 2mm to 8mm. This factor of 4 means that the amount of eye ranges over a factor of 16, or just about one order of magnitude.



We still have 8 orders of magnitude to go!

Mechanisms of Light/Dark adaptation

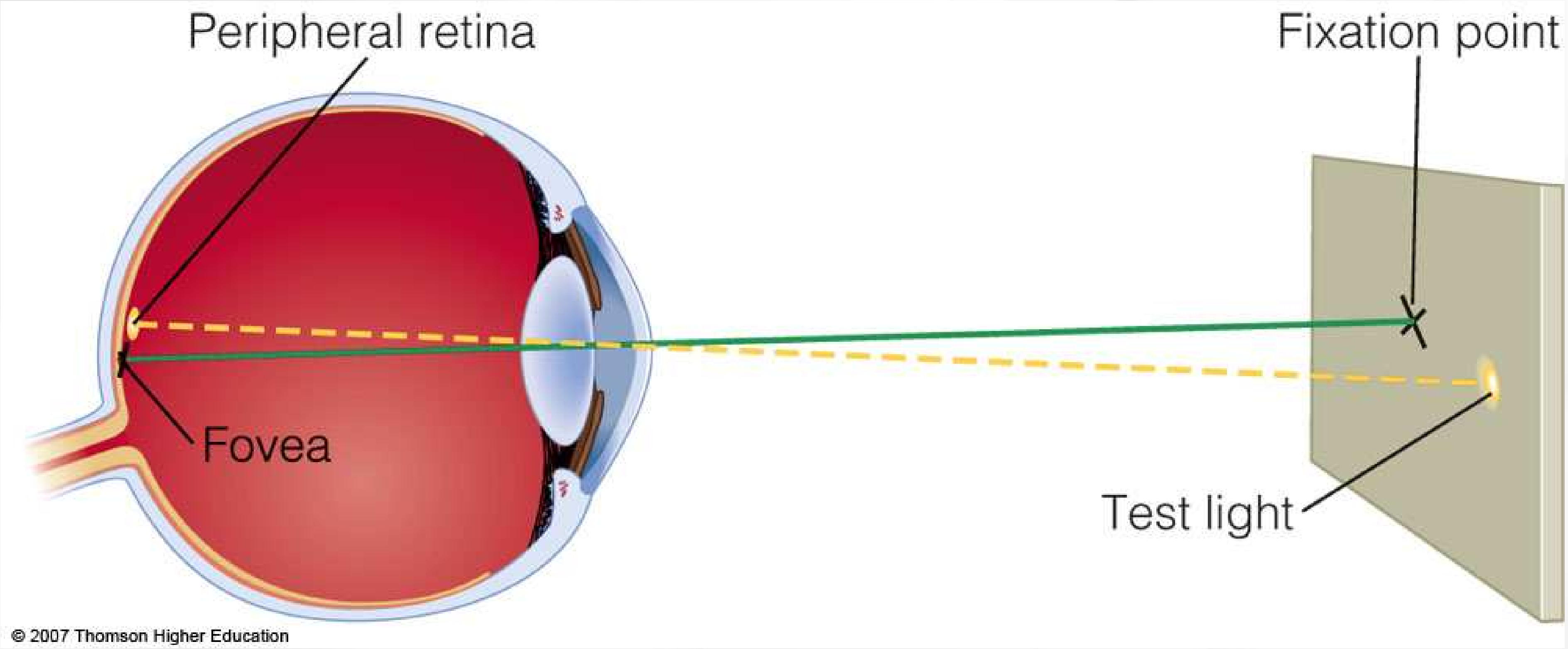
2. Rods vs Cones. We essentially have two visual systems in the eye.



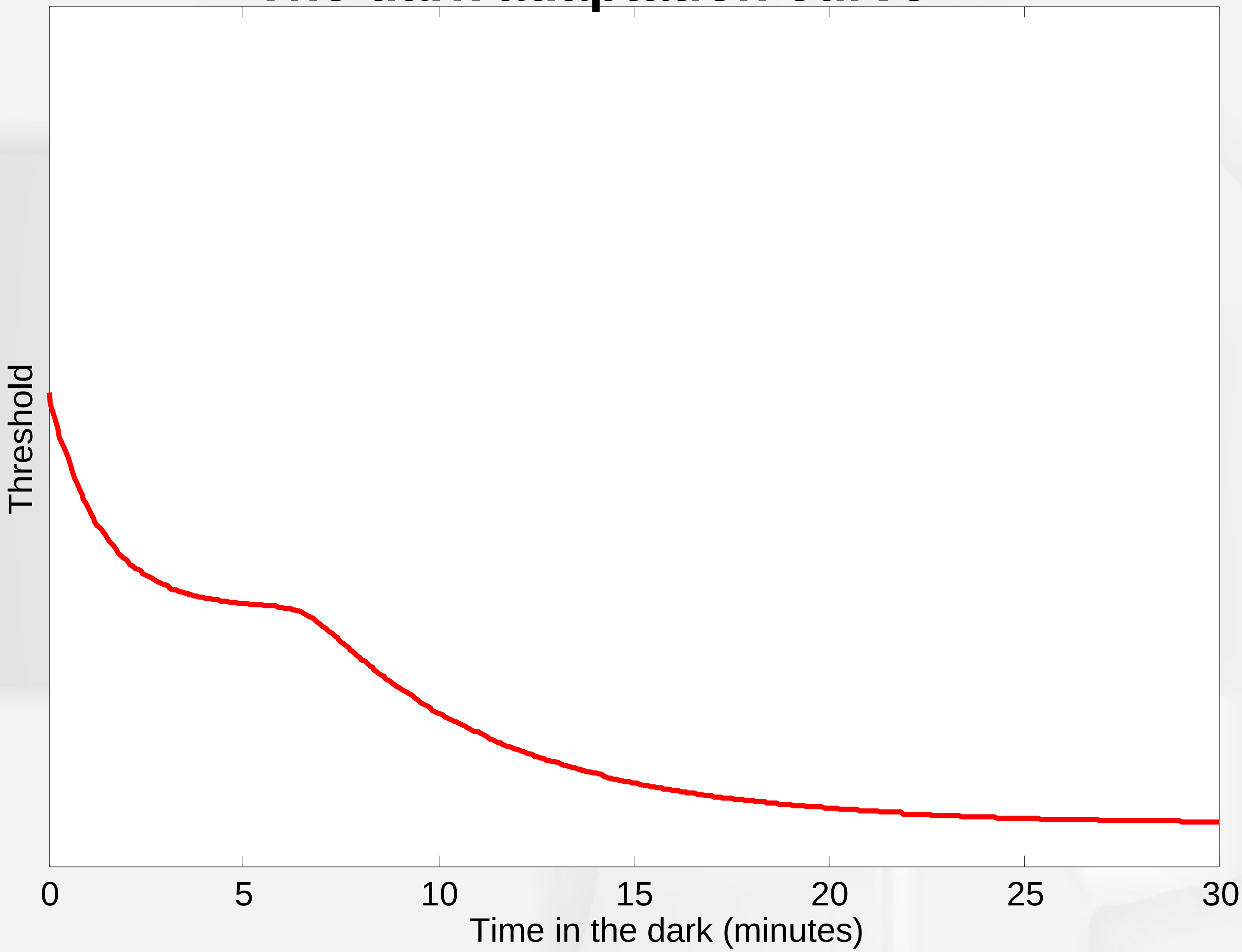
3. Rods and Cones adapt. Both rods and cones become less sensitive as light levels increase.

Psychophysical Measurement of Dark Adaptation

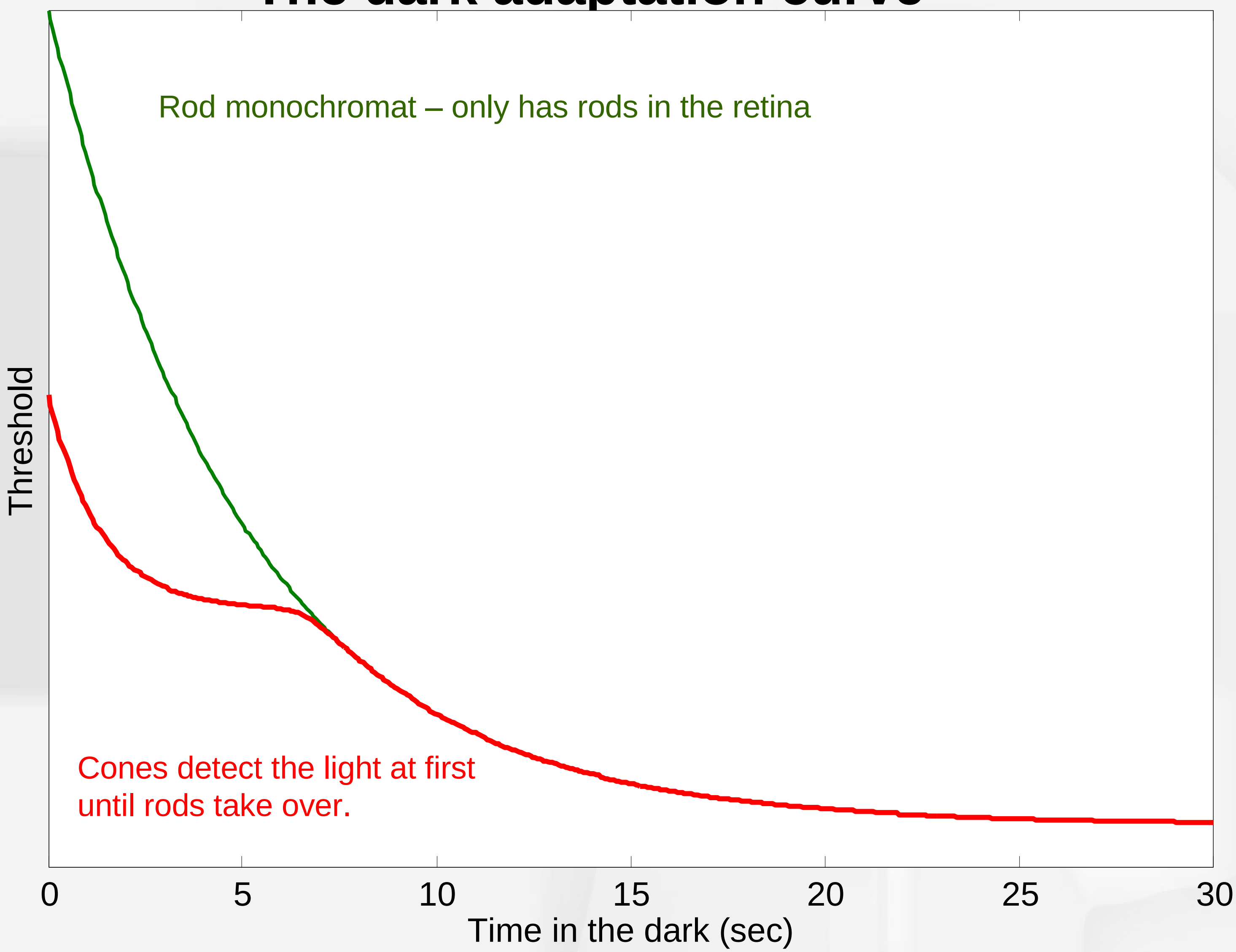
- Measure detection thresholds as function of time in the dark.
- Experiment for rods and cones
  - Observer looks at fixation point but pays attention to a test light to the side



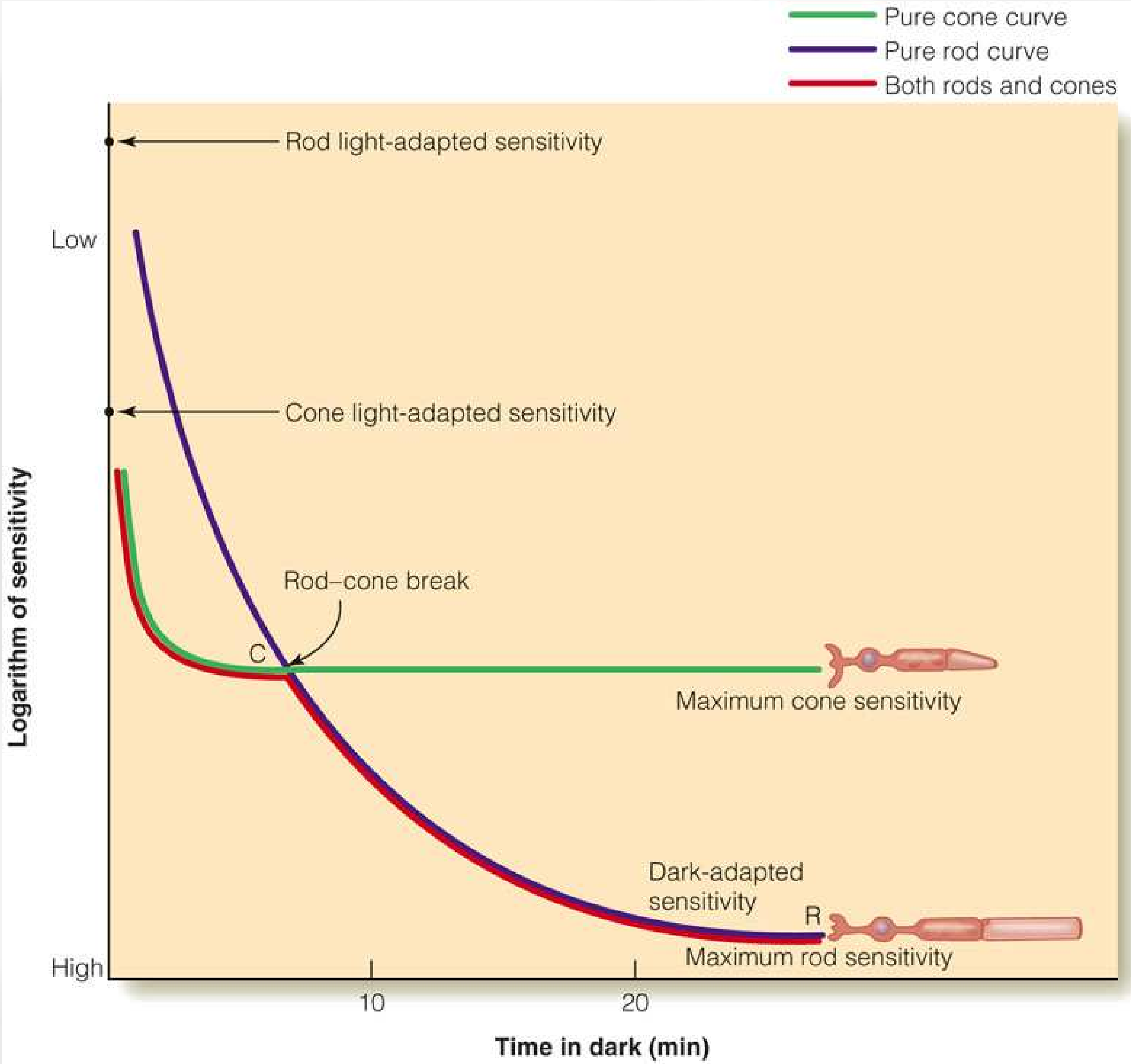
The dark adaptation curve



The dark adaptation curve

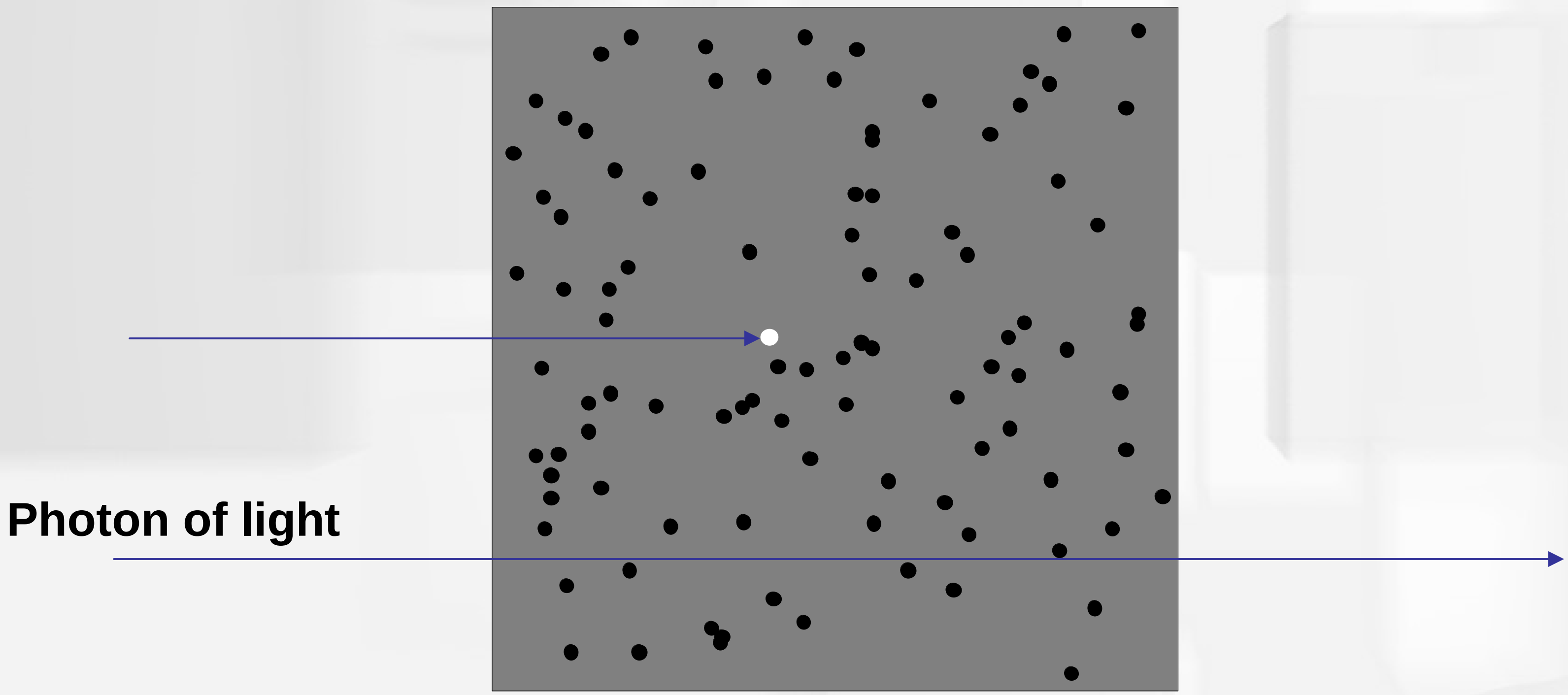


The dark adaptation curve



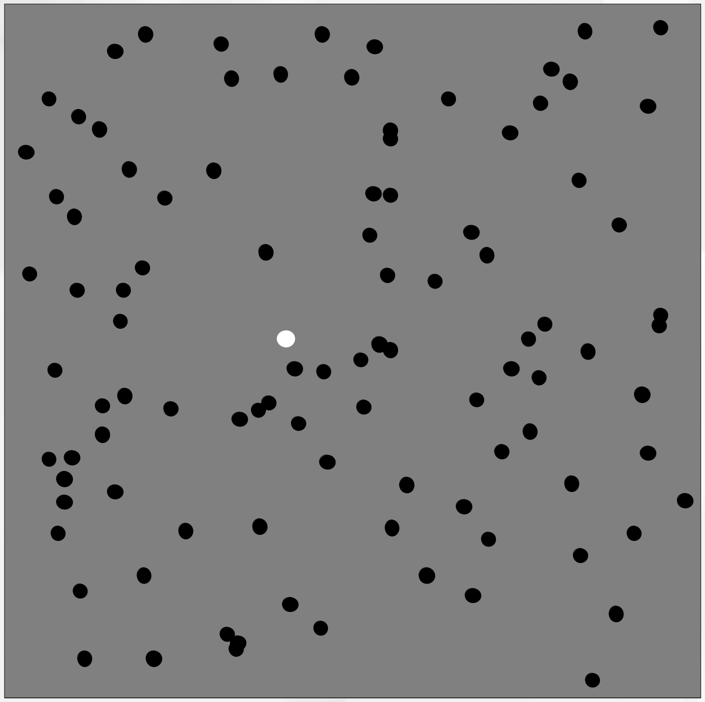
Demonstration of dark adaptation:

Dark spots – unisomerized molecules in a cone (ready for a photon)



Demonstration of dark adaptation:

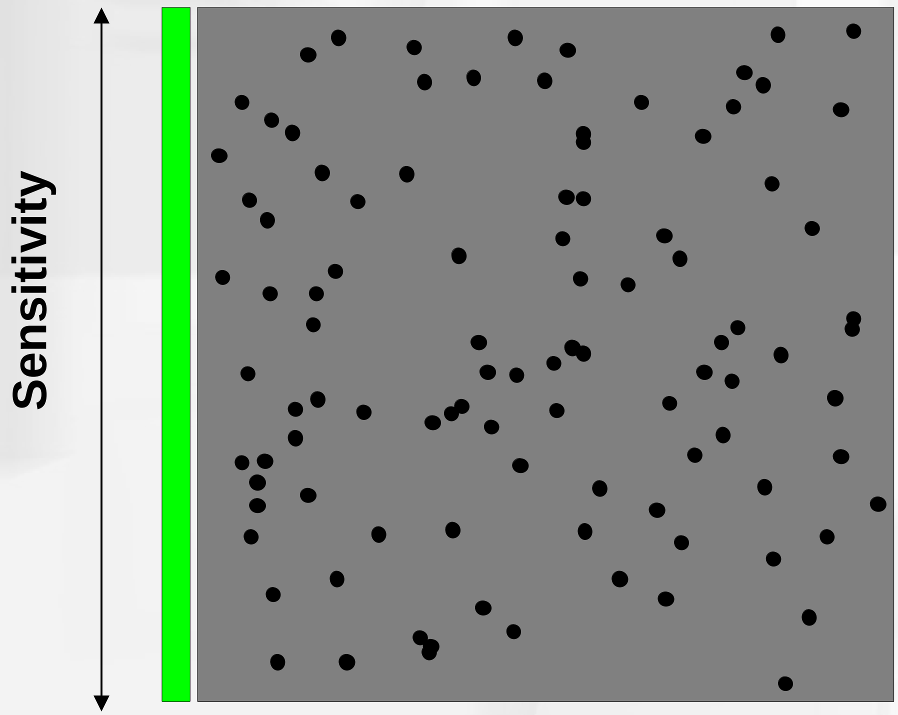
Dark spots – unisomerized molecules in a cone (ready for a photon)



Demonstration of dark adaptation:

Dark spots – unisomerized molecules in a cone (ready for a photon)

In the dark, all retinal molecules are ready for a photon
The photoreceptor is very sensitive to light

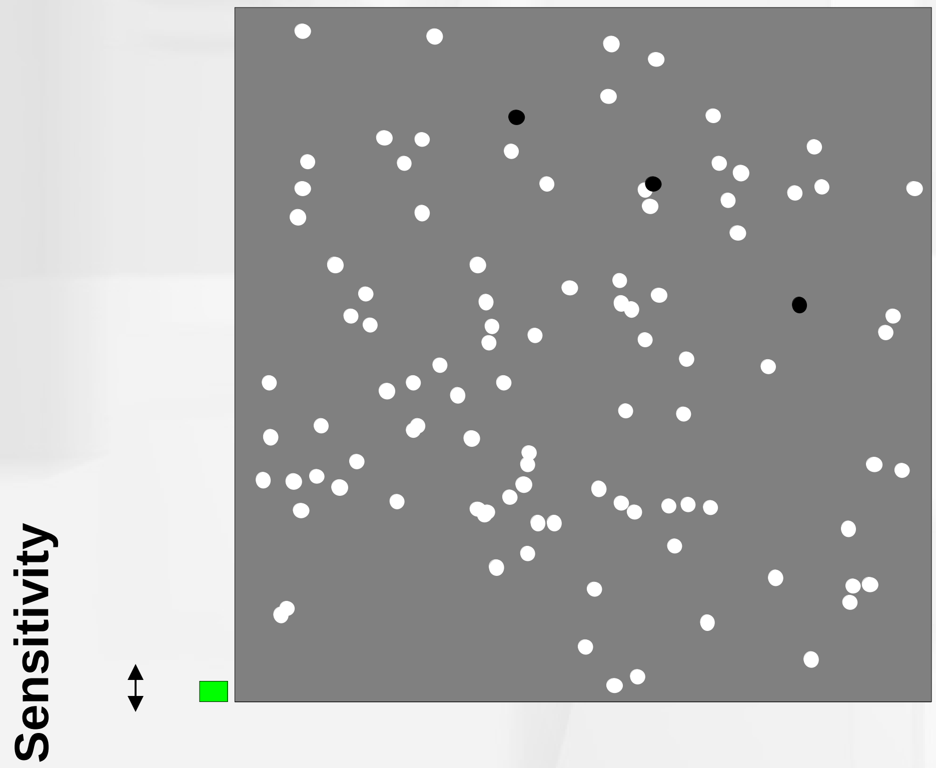


This is a good state to be in for walking around in the dark. But not if you walk outside.

Demonstration of dark adaptation:

Dark spots – unisomerized molecules in a cone (ready for a photon)
Bright spots: isomerized molecules

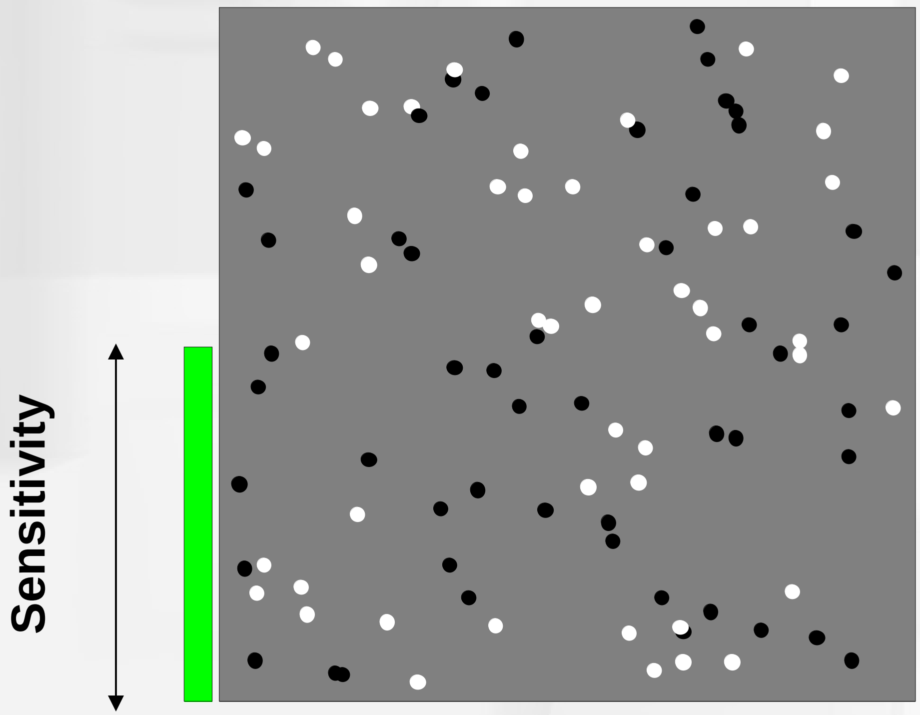
In bright light, nearly all molecules are isomerized.
The photoreceptor is not sensitive to light



Now you're not overexposed outside, but you can't see in the dark.

Demonstration of dark adaptation:

Back in the dark, the molecules slowly recover and are ready to receive photons again. The cone recovers its sensitivity over time.



Light adaptation in the frog retina

Time in the light

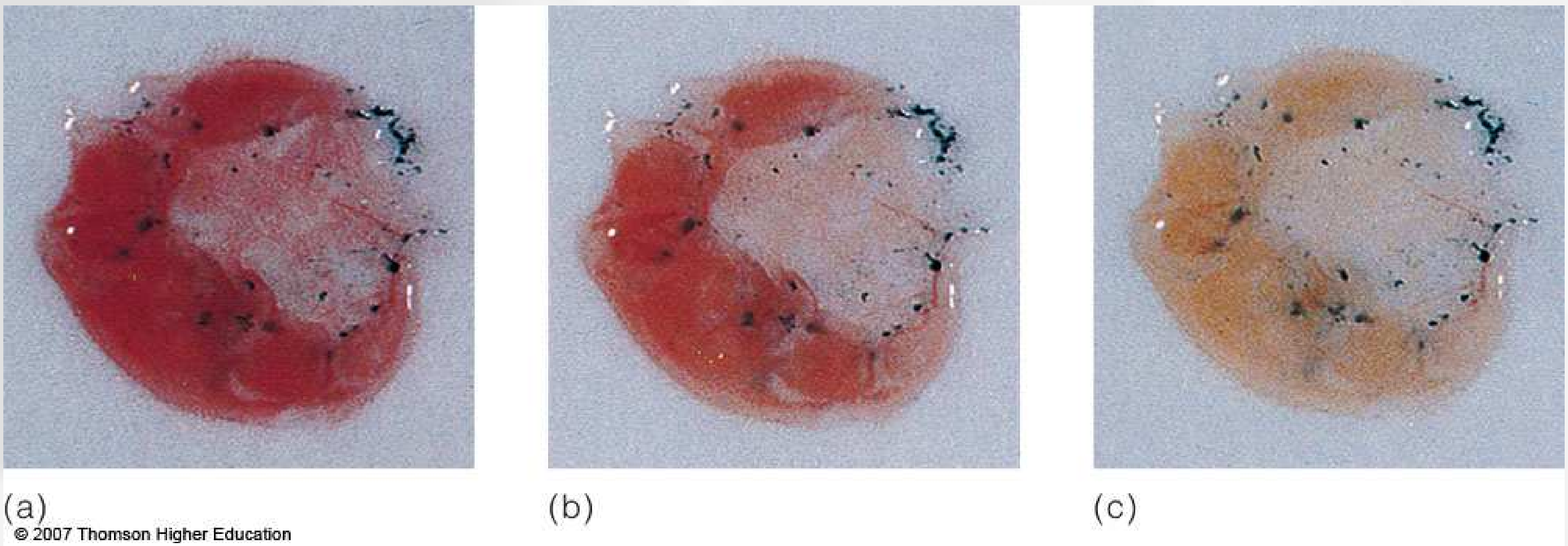


Figure 2.25 A frog retina was dissected from the eye in the dark and then exposed to light. (a) This picture was taken just after the light was turned on. The dark red color is caused by the high concentration of visual pigment in the receptors. As the pigment bleaches, the retina becomes lighter, as shown in (b) and (c).

With digital cameras and software, you can combine pictures with different exposures to expand the 'dynamic range'. You get detail at all light levels.

Underexposed

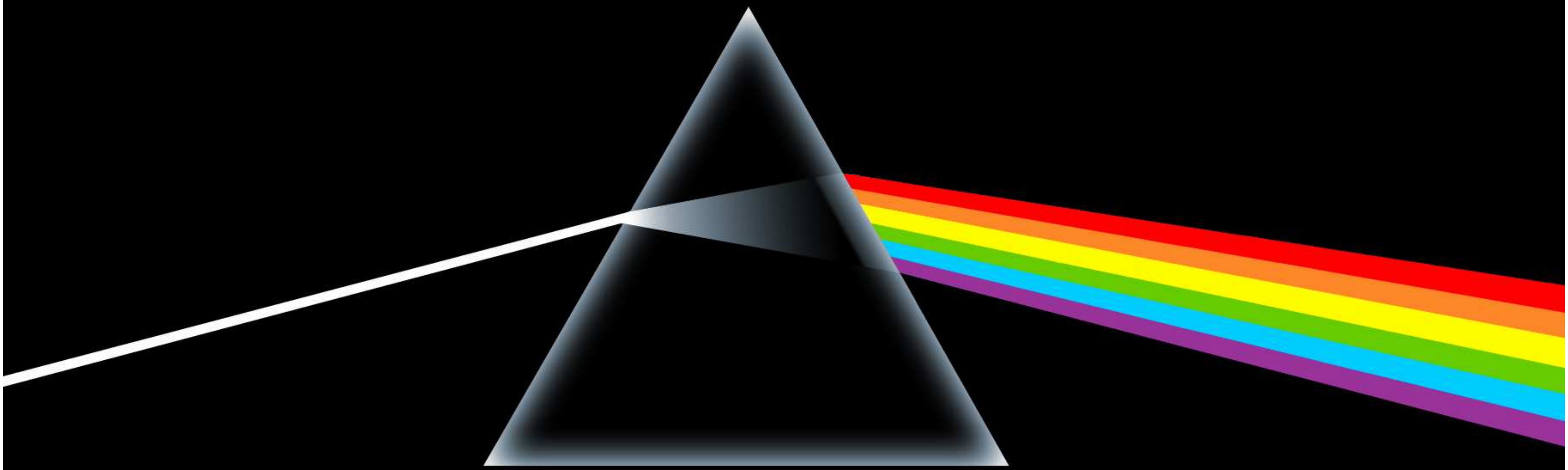
Overexposed

Combined

With digital cameras and software, you can combine pictures with different exposures to expand the 'dynamic range'. You get detail at all light levels.

Spectral Sensitivity of Rods and Cones

- 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

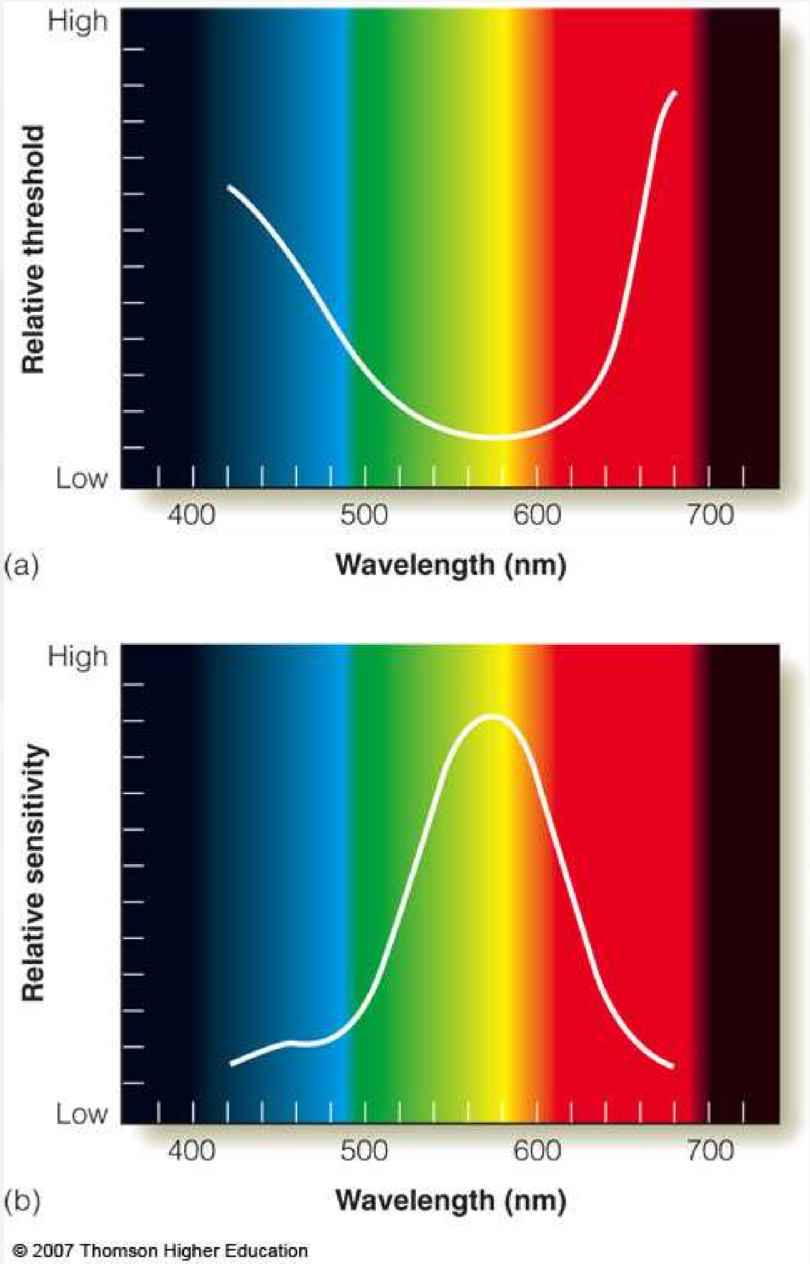


Figure 2.26 (a) The threshold for seeing a light versus wavelength. (b) Relative sensitivity versus wavelength -- the *spectral sensitivity curve.*

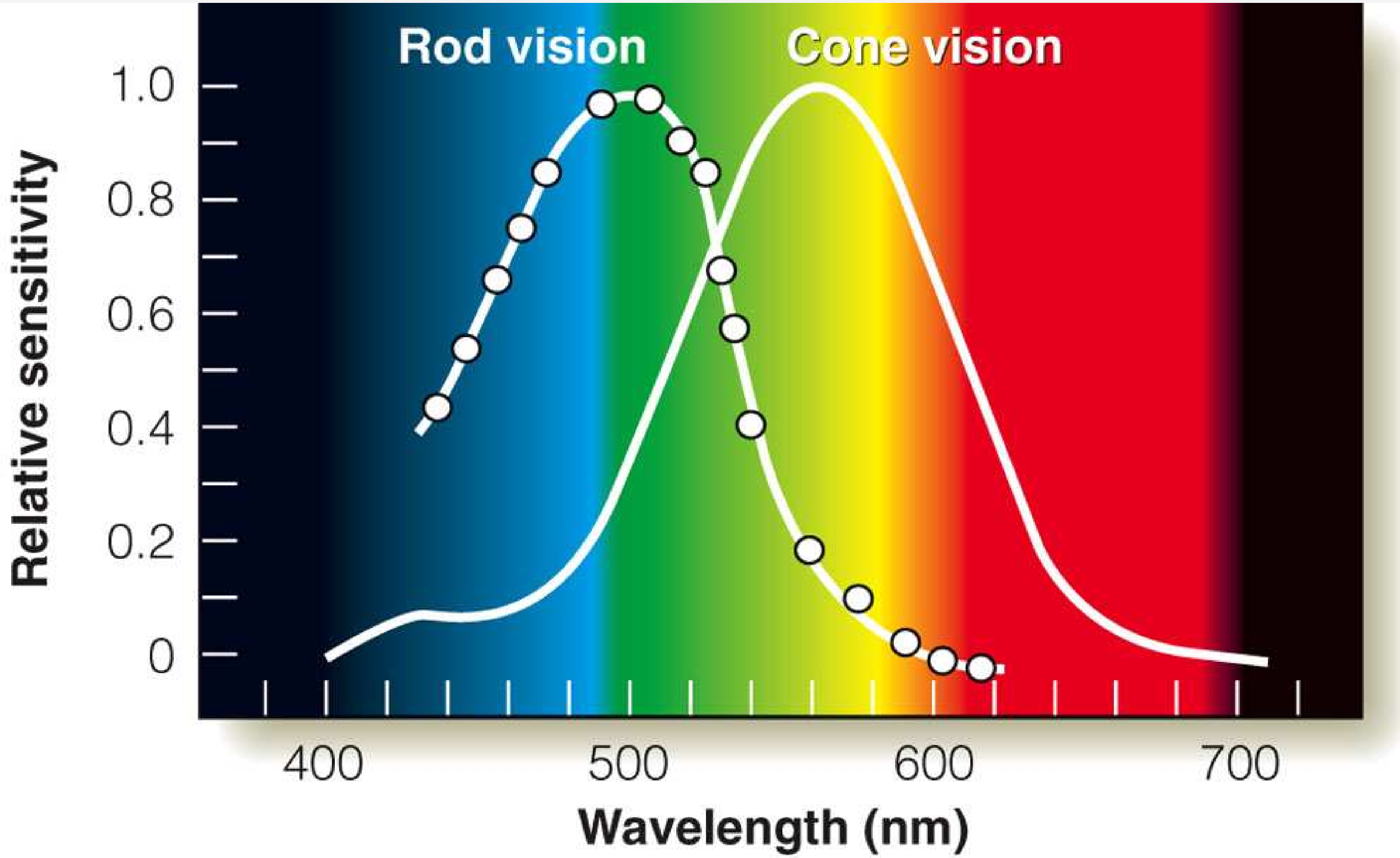
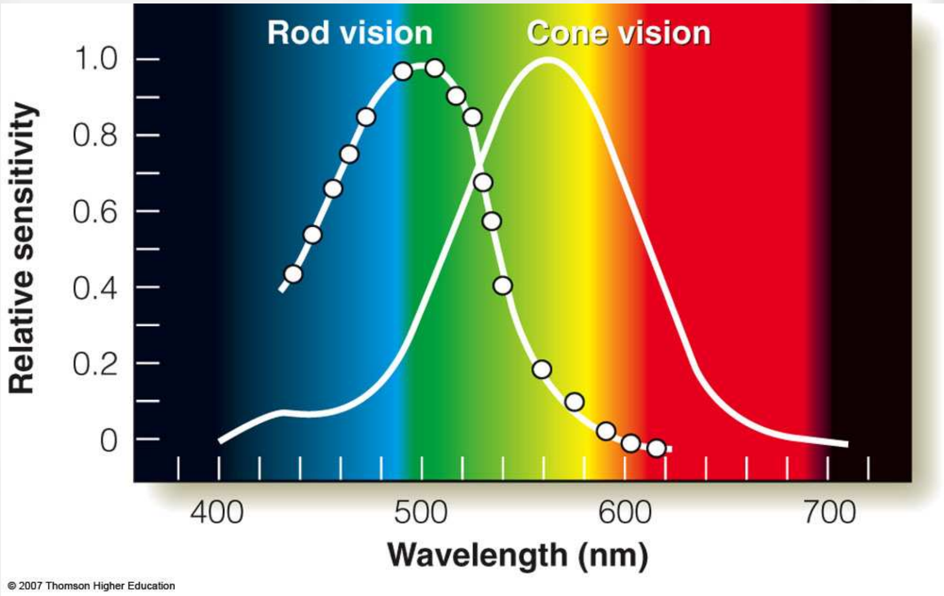


Figure 2.27 Spectral sensitivity curves for rod vision (left) and cone vision (right).

Spectral Sensitivity of Rods and Cones - continued

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



Demonstration of Purkinje Shift

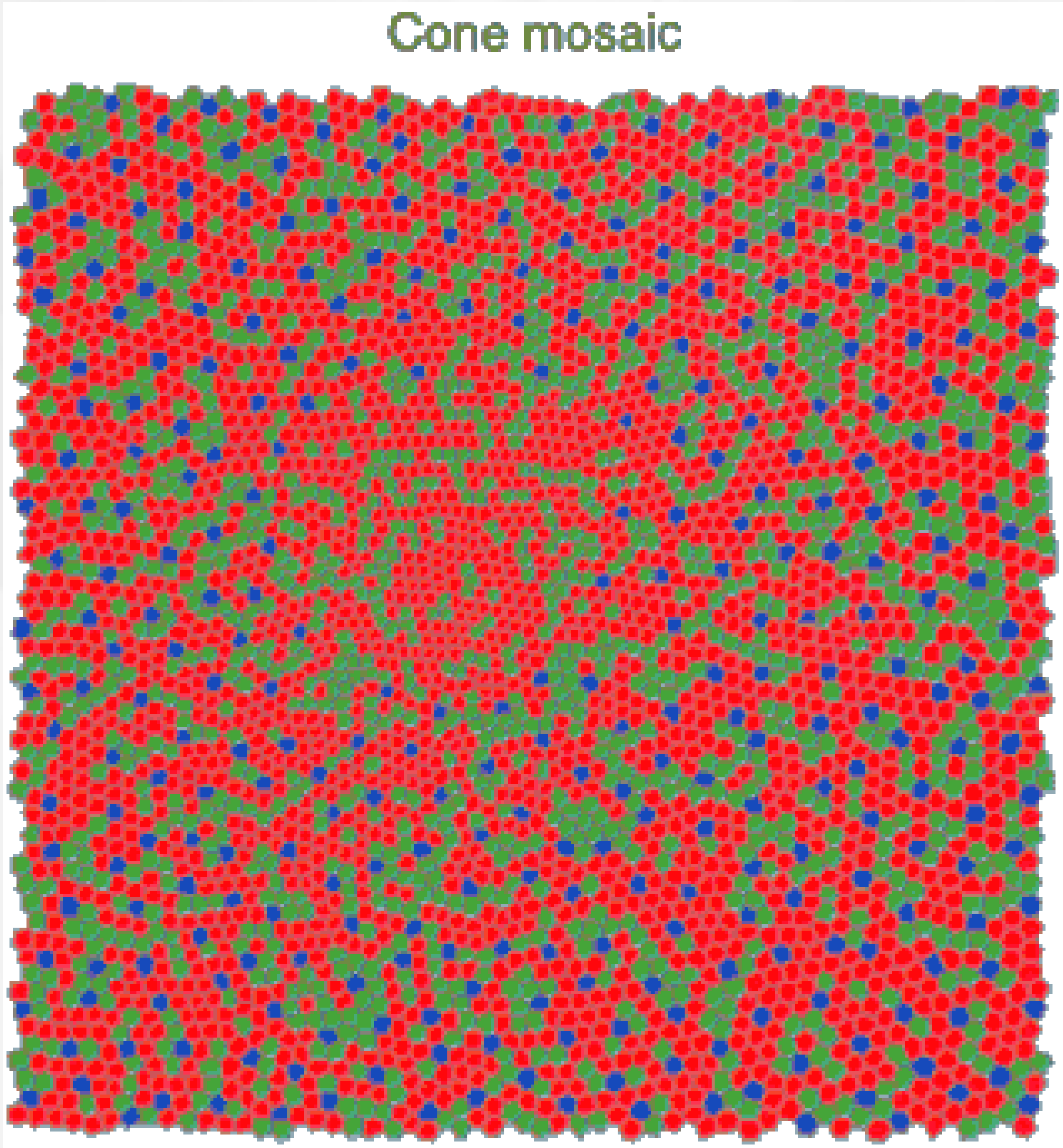
Cone vision (day)

Rod vision (night)

Demonstration of Purkinje Shift

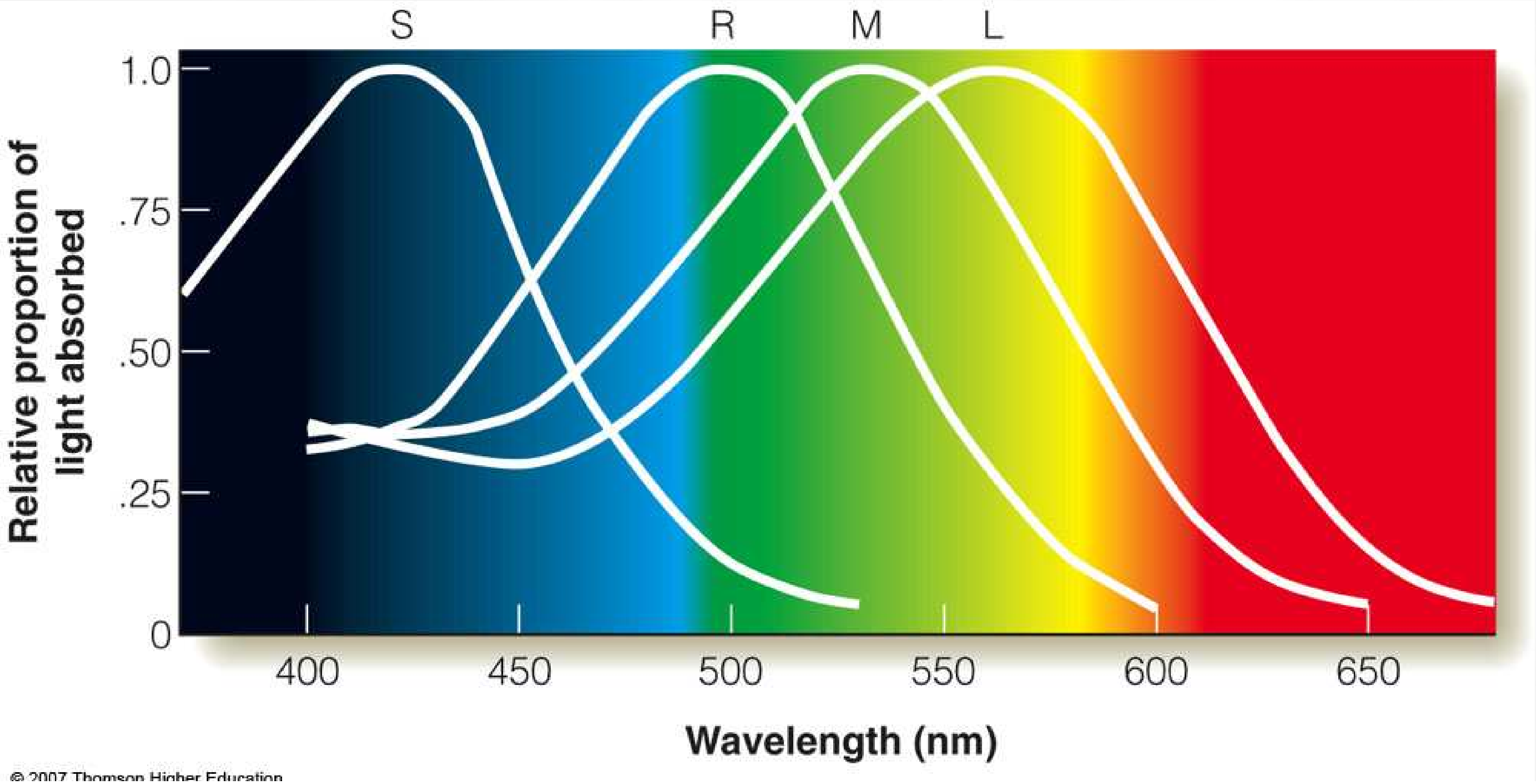
Cone vision (day)

Rod vision (night)


Cone mosaic

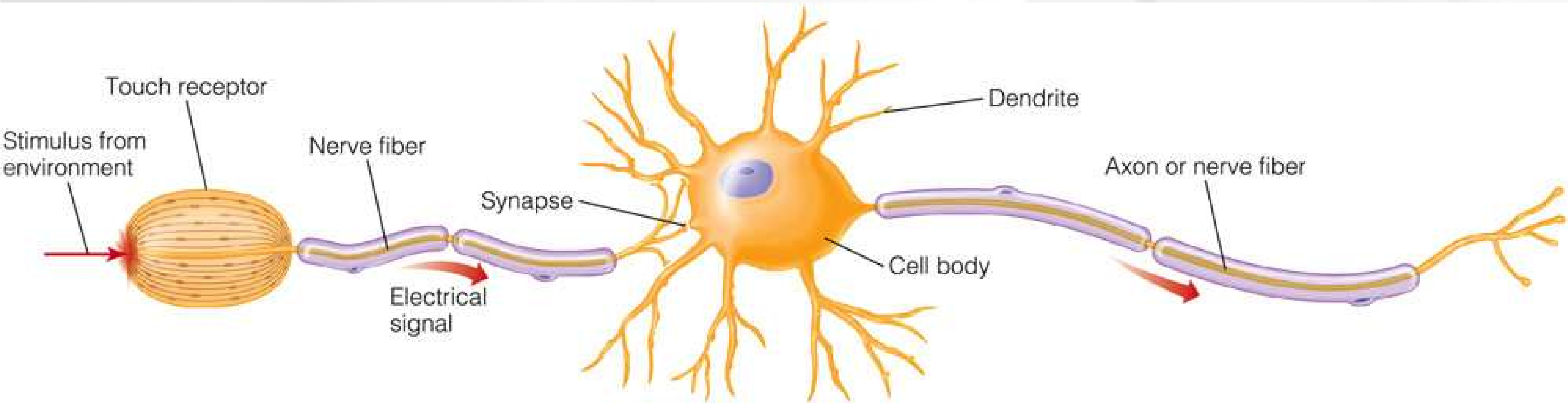
Normally, we have three cone types, with pigments that absorb best at 419nm, 532nm, & 558nm.

More on that later when we get to color vision (Chapter 7)

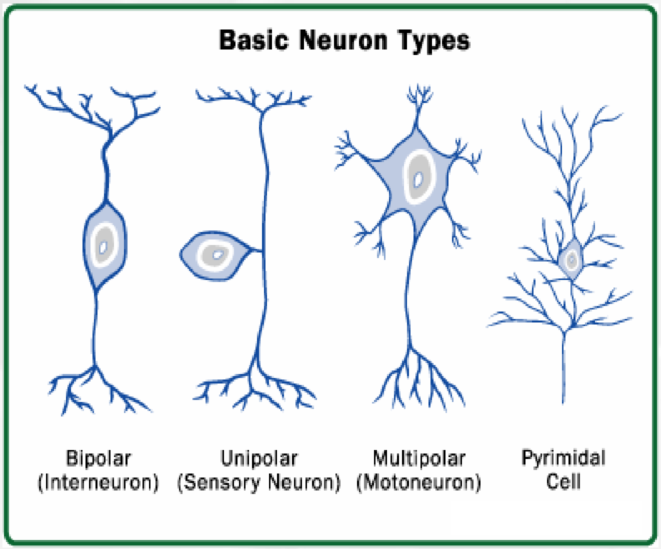


Crash course on basic neurophysiology

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

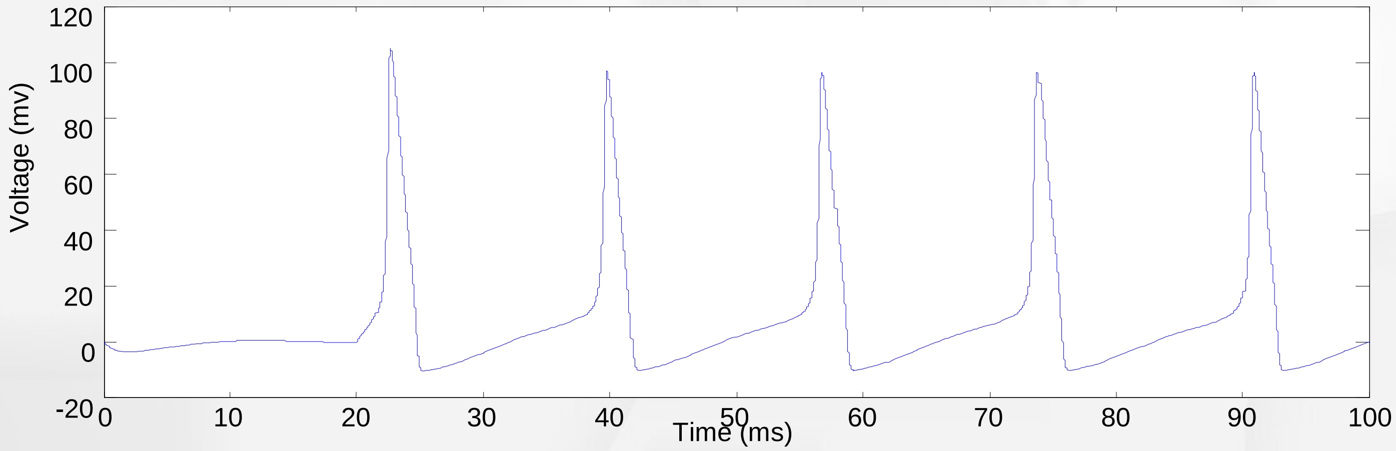


There are many kinds of neurons

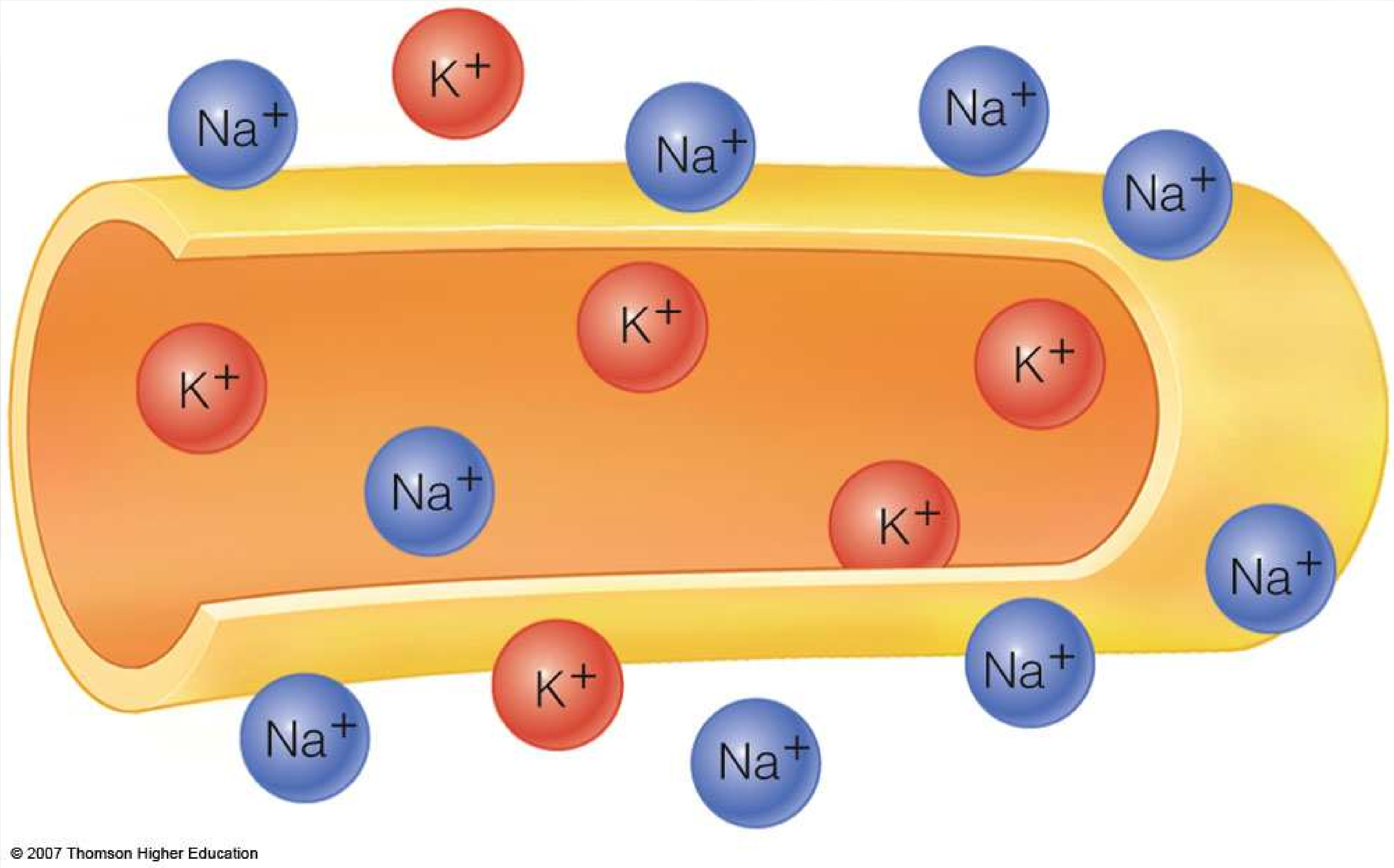


Sequence of Events for Neuronal Communication

1. Membrane permeability changes.
2. Sodium rushes in.
3. Voltage inside gets more positive.
4. Critical Value reached and action potential occurs.
5. Potassium flows out.
6. Action potential travels down the **axon** and stimulates **synaptic vesicles**.
7. Synaptic vesicles release **neurotransmitters** into the synapse that influence the permeability of the next neuron.

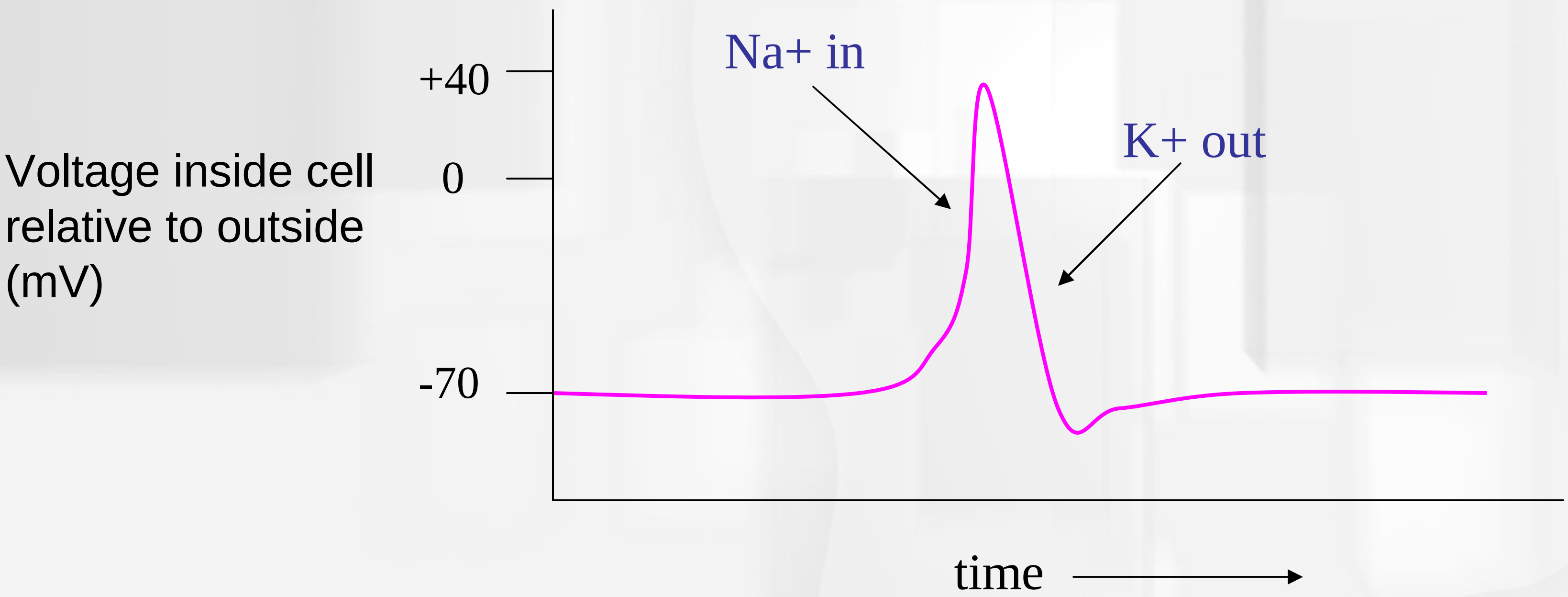


At rest, there are is a higher concentration of Na+ (Sodium) molecules outside, and K+ (Potassium) molecules inside the cell.

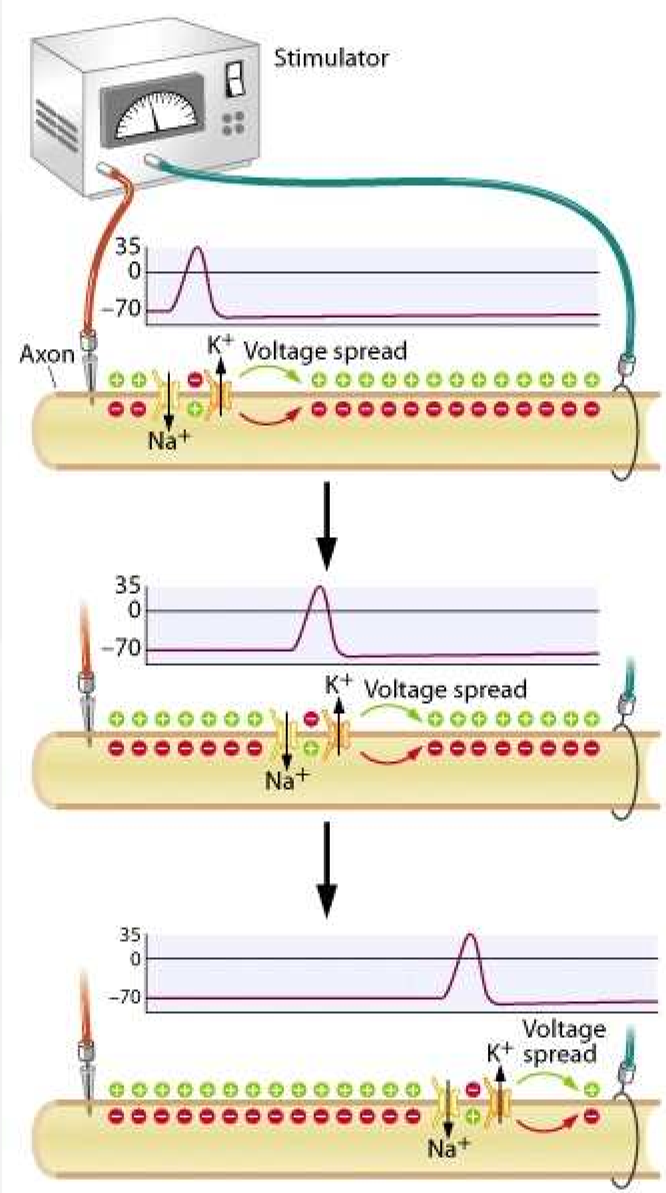


When a neuron receives input from another neuron, the permeability of the cell membrane changes, allowing **sodium (Na+) to rush in and potassium (K+) to rush out.**

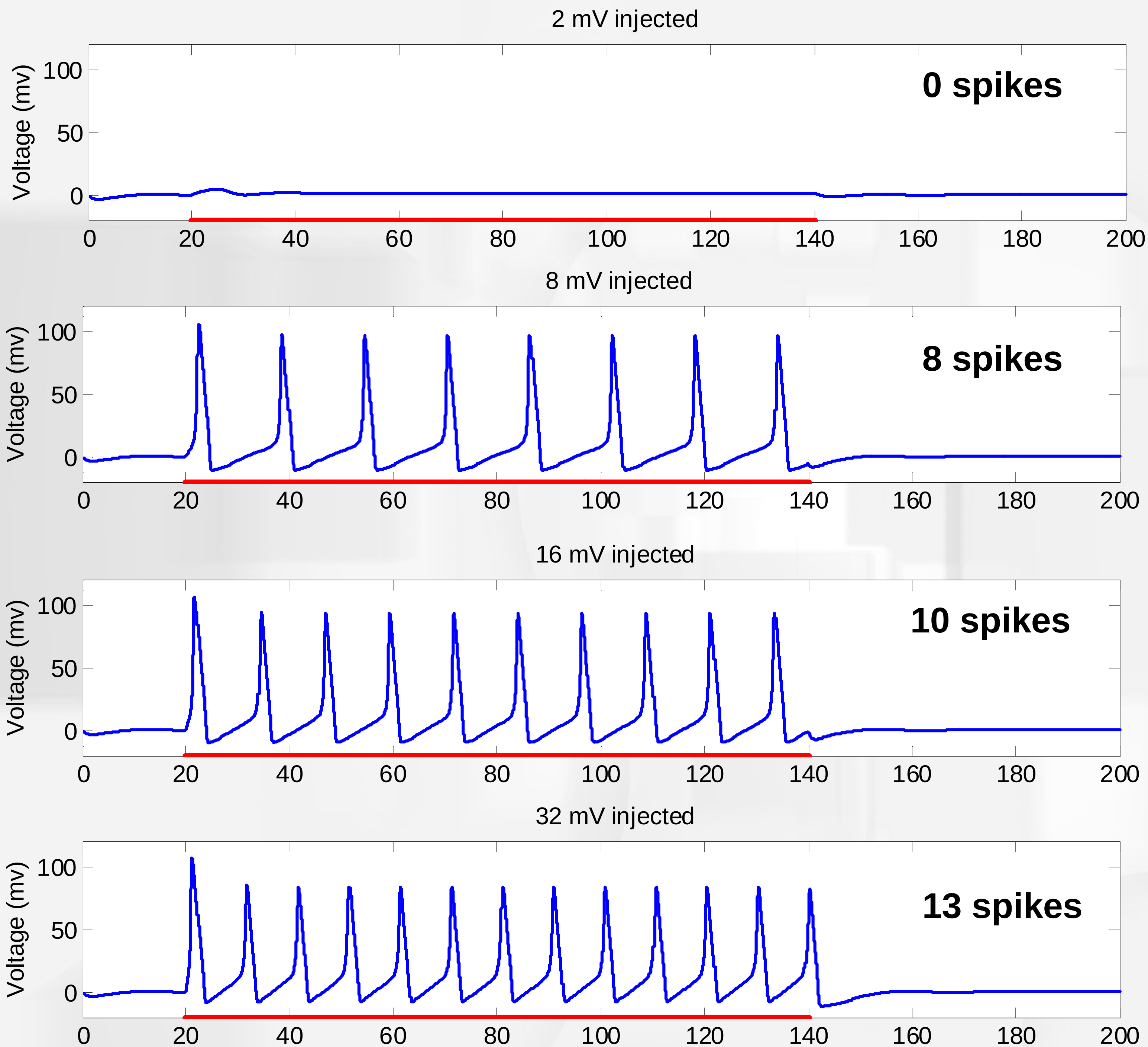
The influx of positively charged Na+ increases the potential (voltage) inside the cell, and then the outflow of the K+ decreases the voltage back to resting level.



When the potential gets positive enough to reach a critical value (about -55 mV), it FIRES and produces what is called an ACTION POTENTIAL.



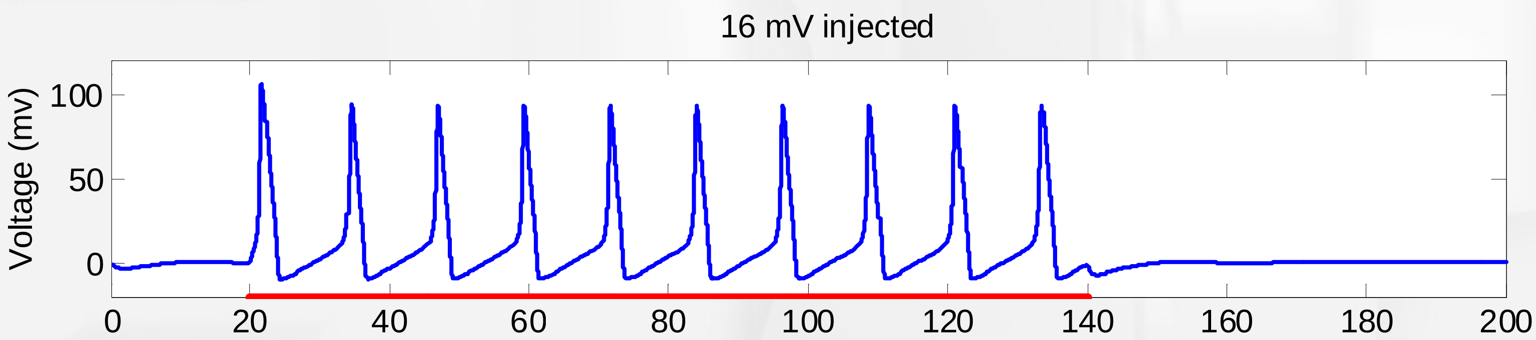
Stimulator
35
0
−70
Axon
K+
Voltage spread
Na+
35
0
−70
K+
Voltage spread
Na+
35
0
−70
Voltage
spread
K+
Na+



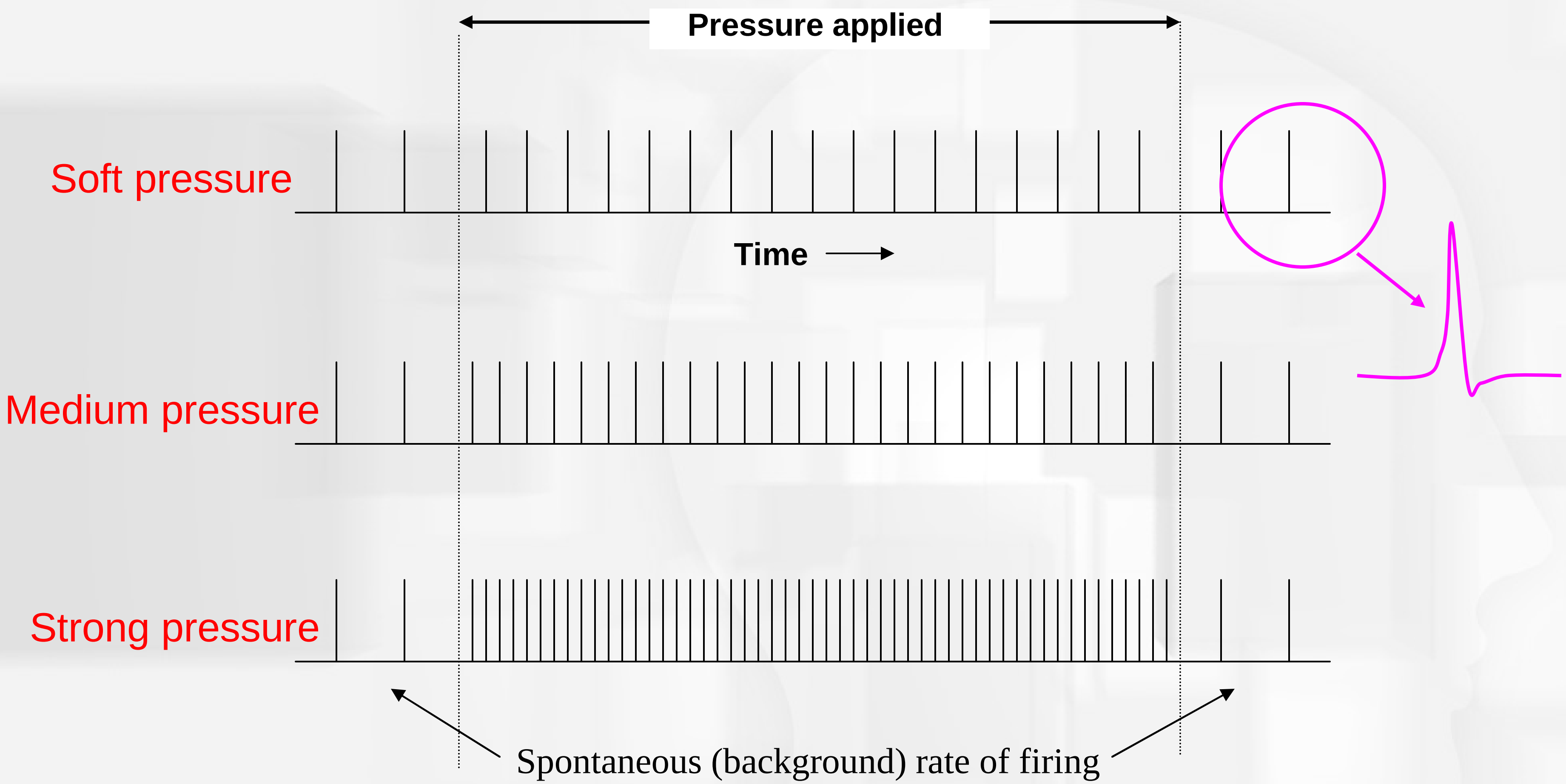
2 mV injected
0 spikes
8 mV injected
8 spikes
16 mV injected
10 spikes
32 mV injected
13 spikes
Voltage (mv)
100
50
0
0
20
40
60
80
100
120
140
160
180
200

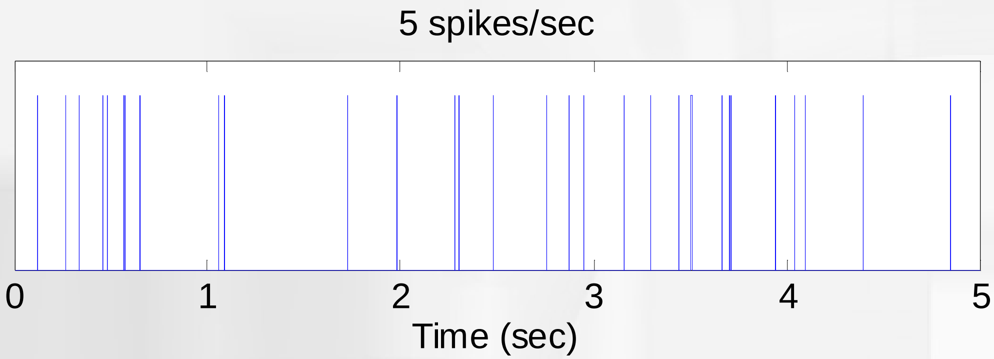
Three important facts about these processes:

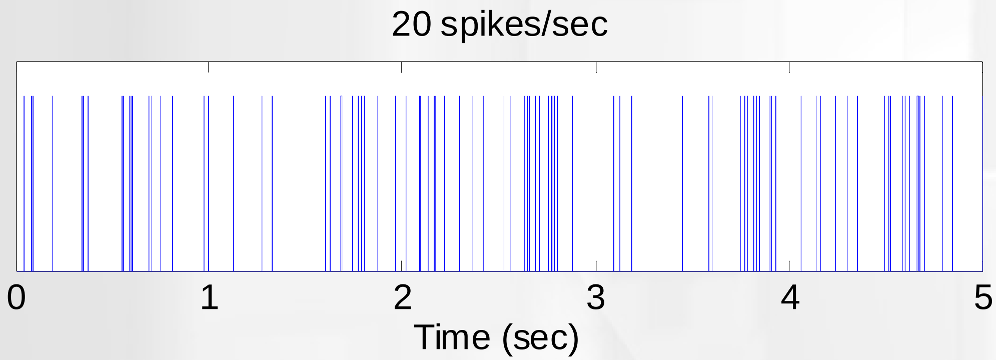
1. Action potentials are ALL-OR-NONE.
2. There's a REFRACTORY PERIOD after an action potential during which another action potential cannot occur.
3. There is a SPONTANEOUS, background level of firing even in the absence of stimulation.

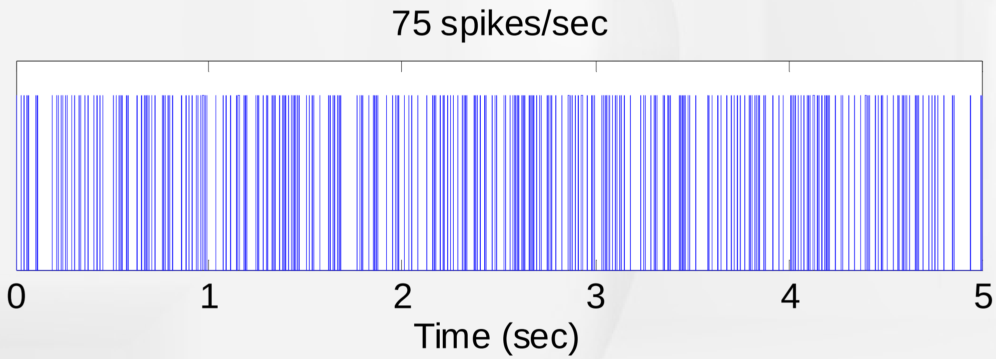


Action potentials and intensity of stimulation




5 spikes/sec
0
1
2
3
4
5
Time (sec)


20 spikes/sec
0
1
2
3
4
5
Time (sec)


75 spikes/sec
0
1
2
3
4
5
Time (sec)