Module # 2—Seeing Lightness, Darkness, and Color

Visual Perception and the Brain

DUKE INSTITUTE *for* BRAIN SCIENCES

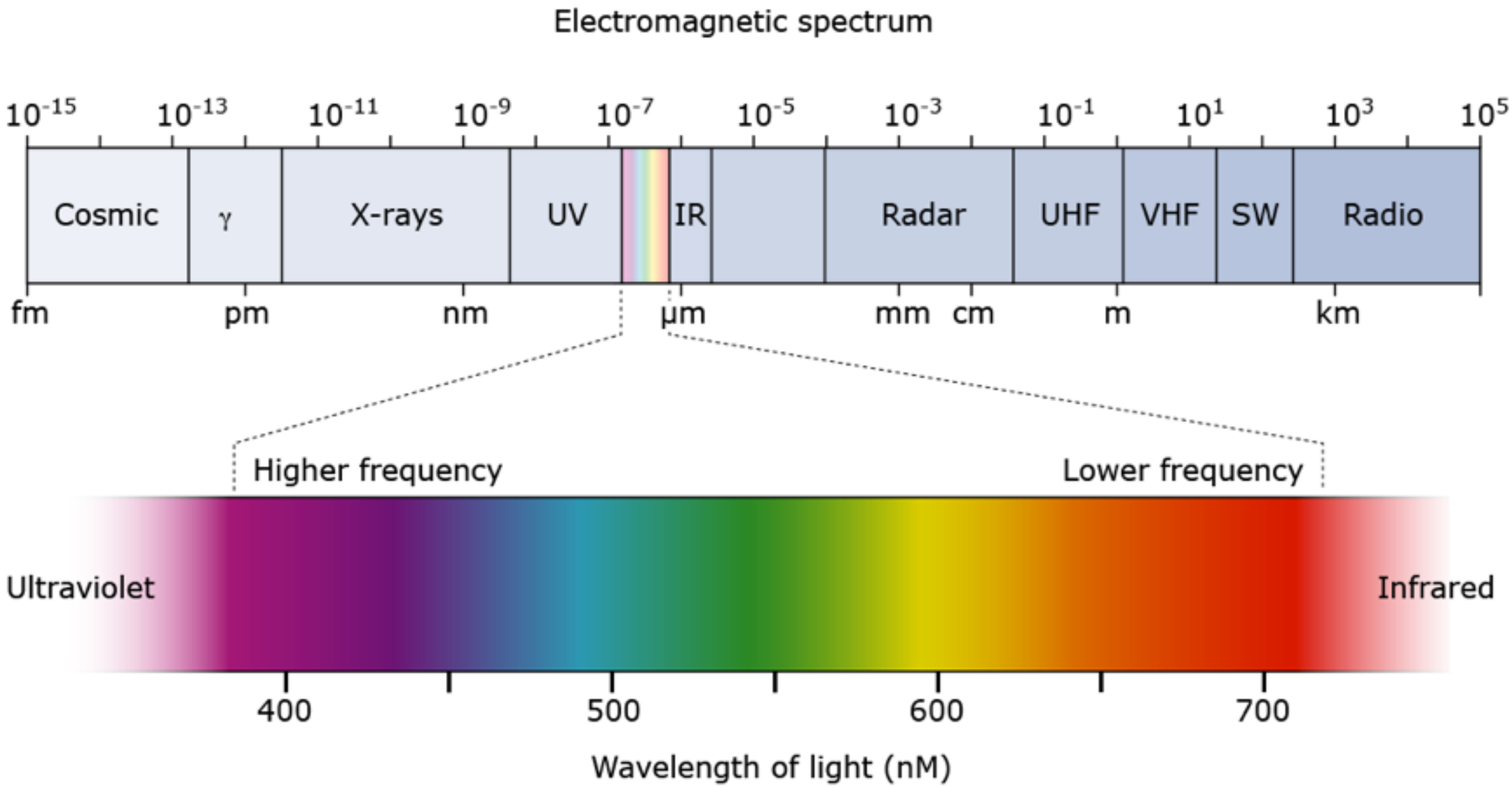
Lesson 1. Definitions

Some Definitions

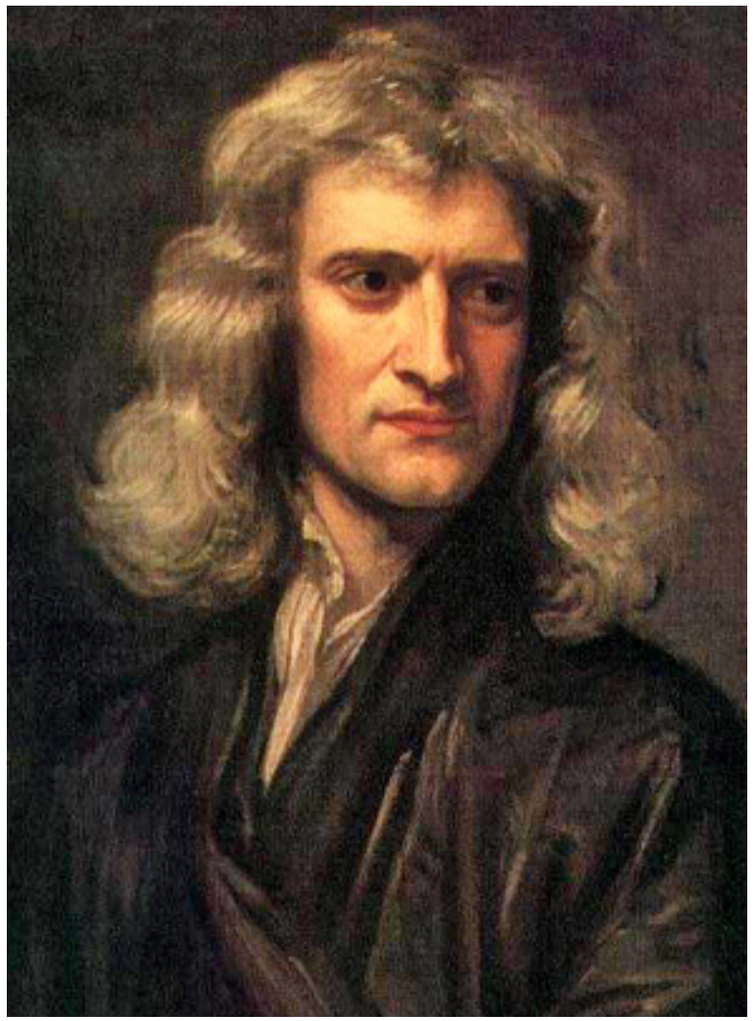
- **Color:** the set of perceptions elicited by the spectral distribution of light
- **Physical measurement:** the relative intensities of wavelengths in light measured with a spectrophotometer
- **Psychophysical measurement:** report of the color seen by a normal subject, typically made by comparison

Lesson 2. Light and Color

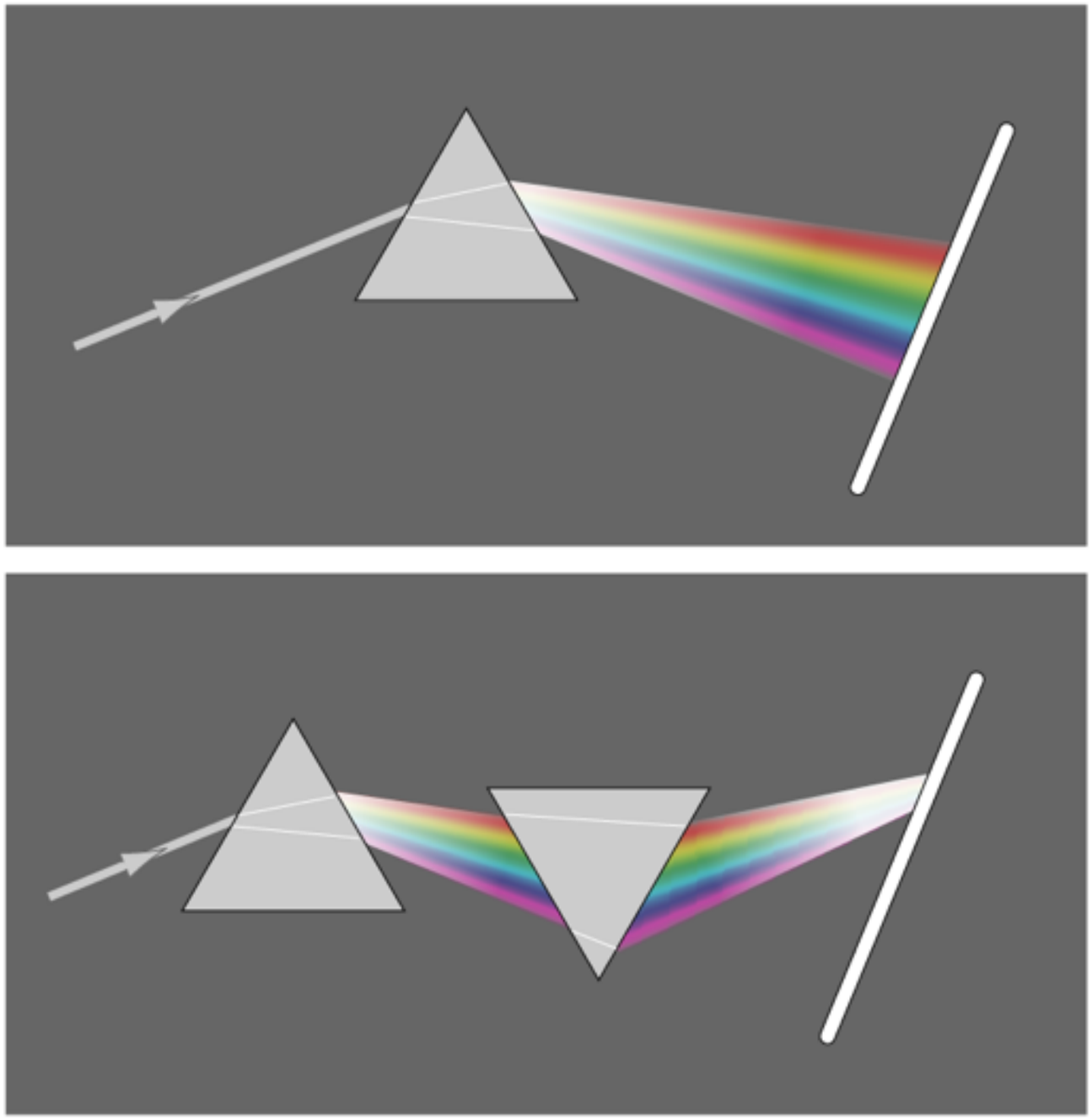
More about the Nature of Light



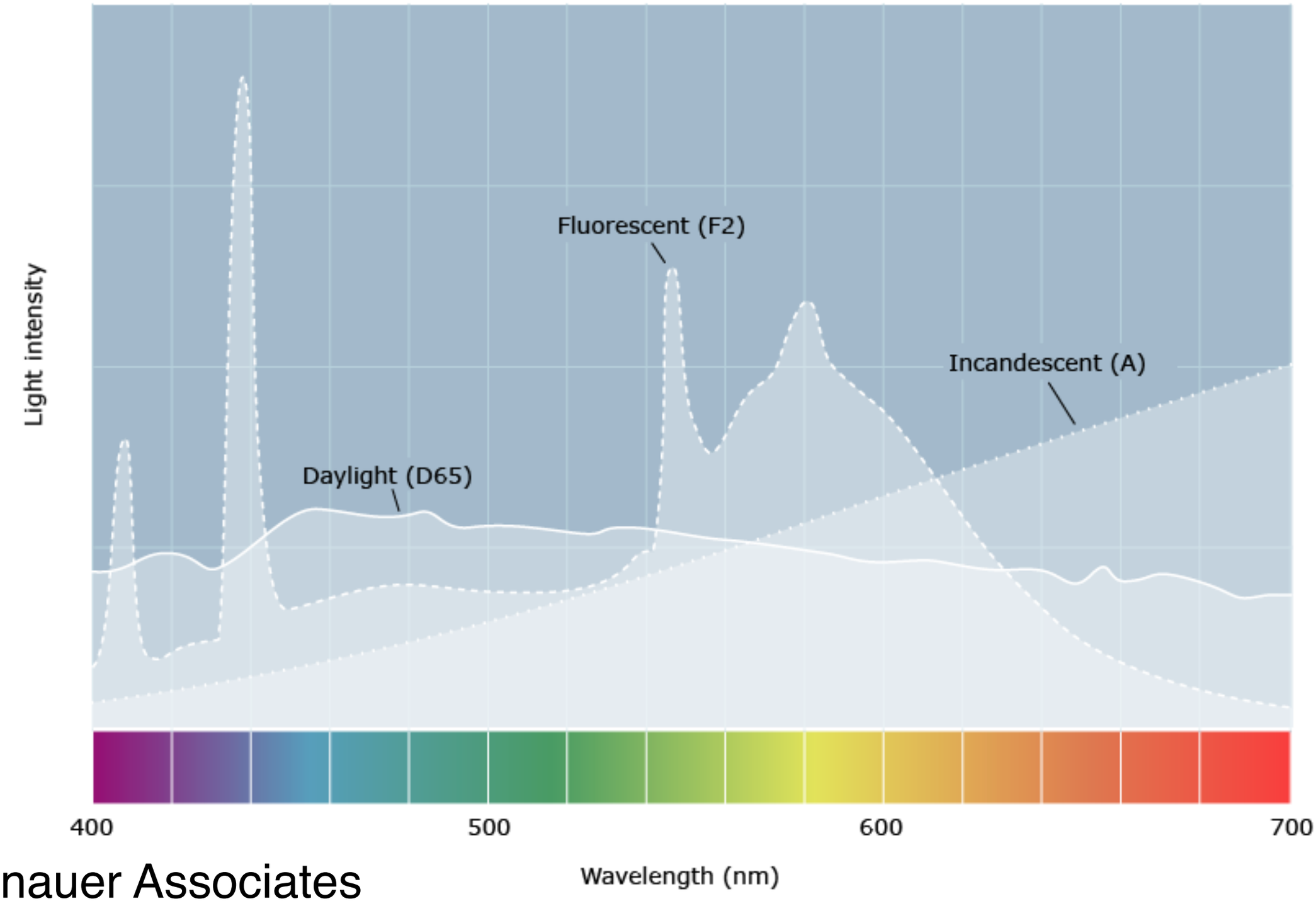
Isaac Newton's Demonstration of Light Spectra (1670)



Isaac Newton
(1642-1727)



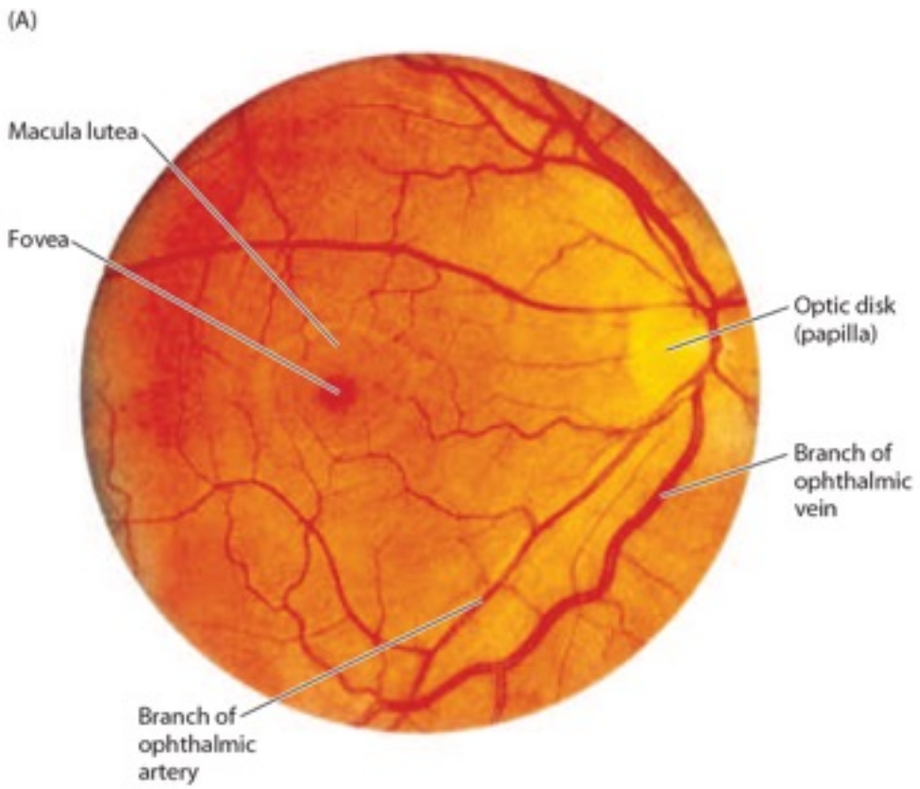
Some Examples of White Light Spectra

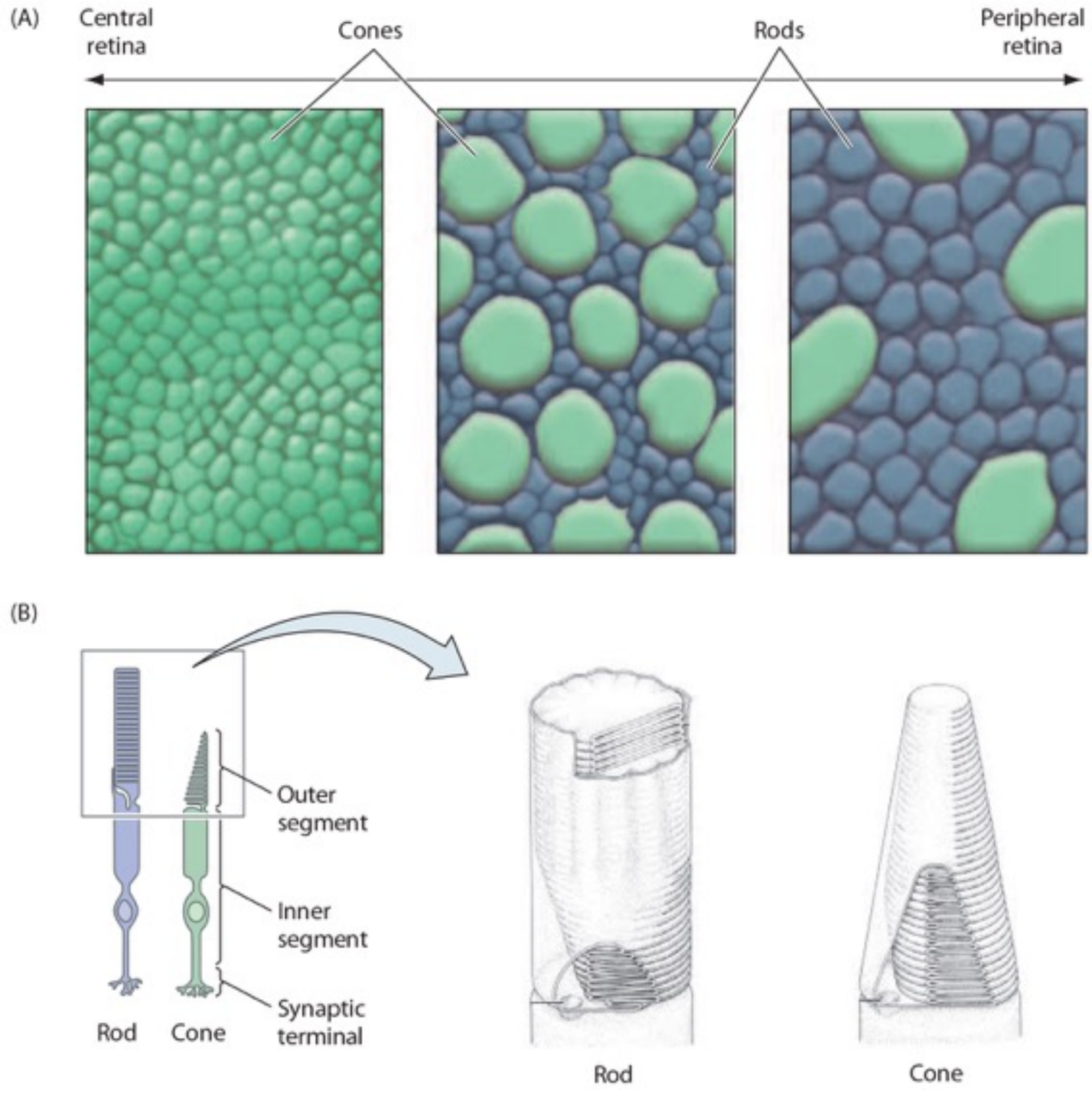


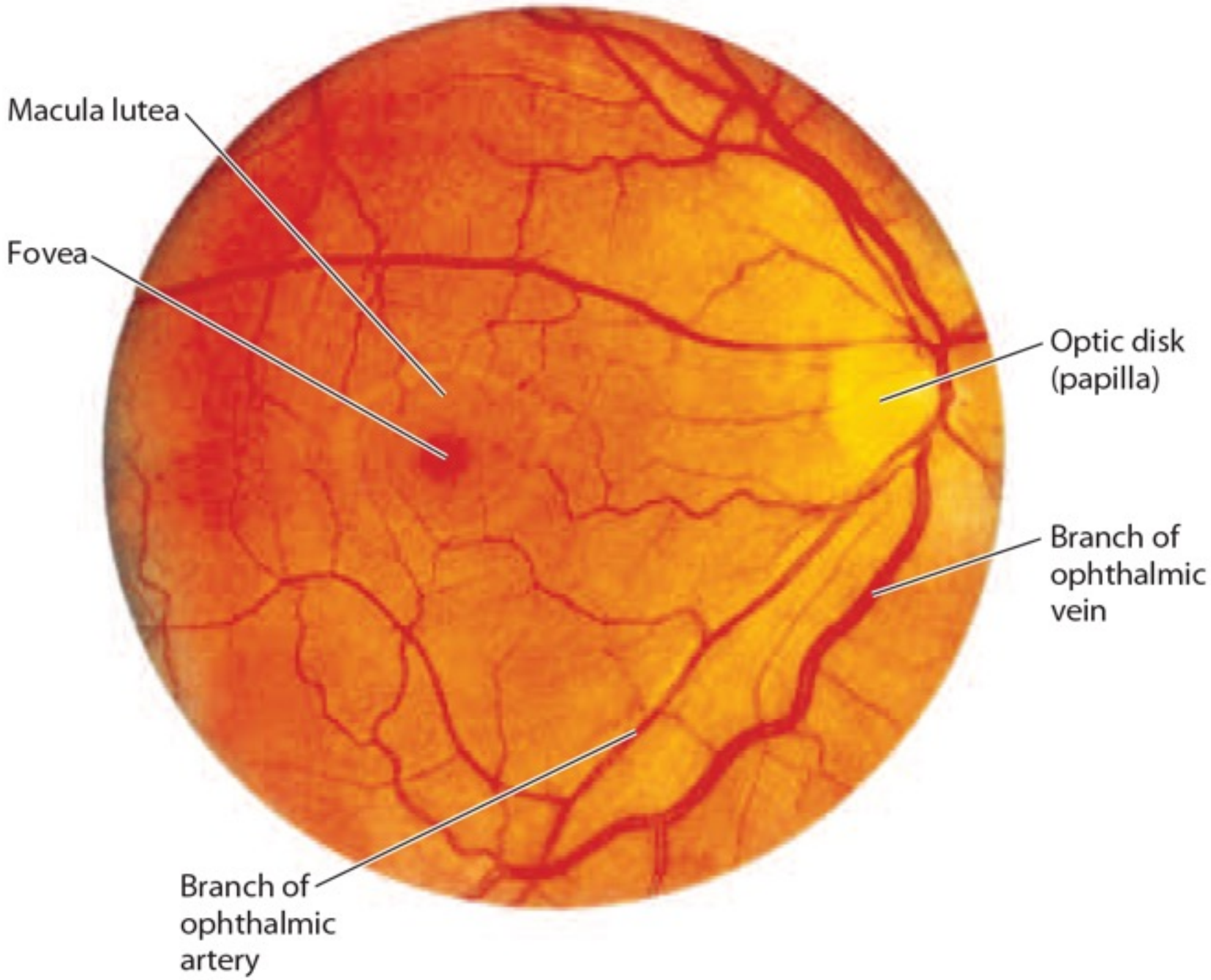
Colors are Not Properties of Objects

- The qualities we call colors are generated by the visual brain
- Moreover there is no one to one relationship between the colors seen and wavelengths

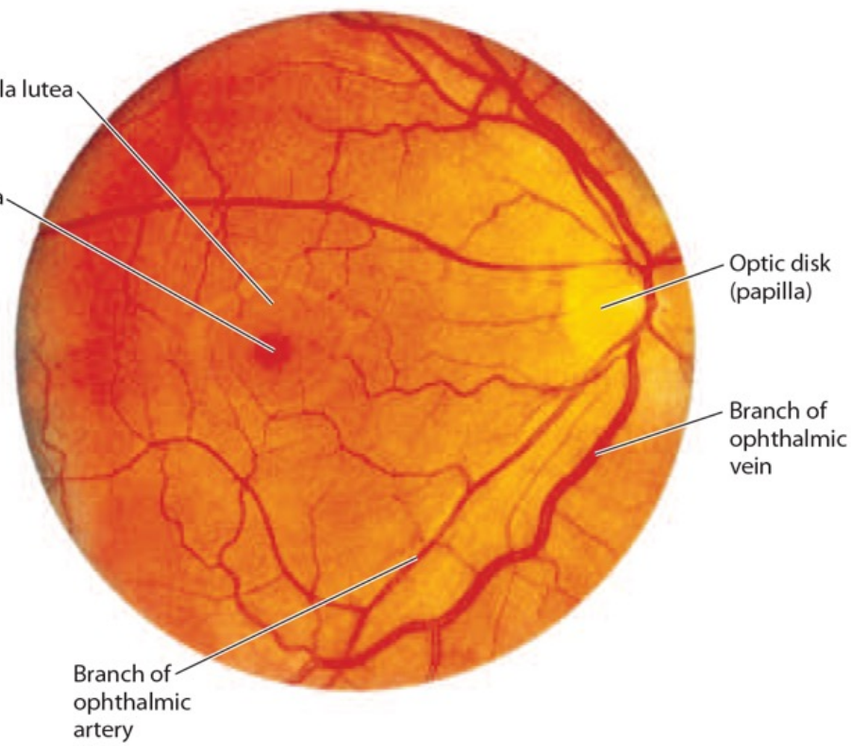
Lesson 3. How the Retina Initiates Color Vision

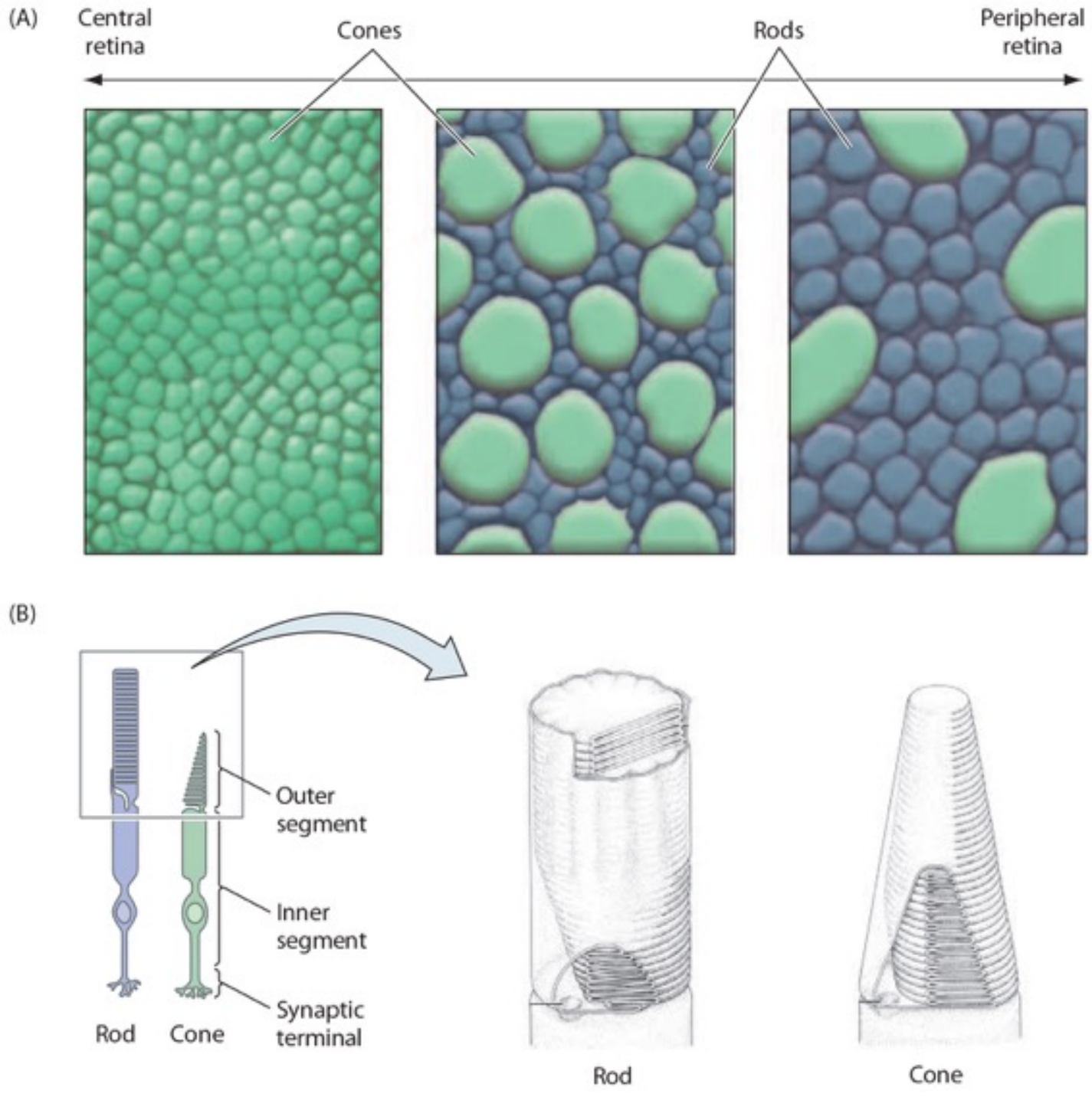






(A)





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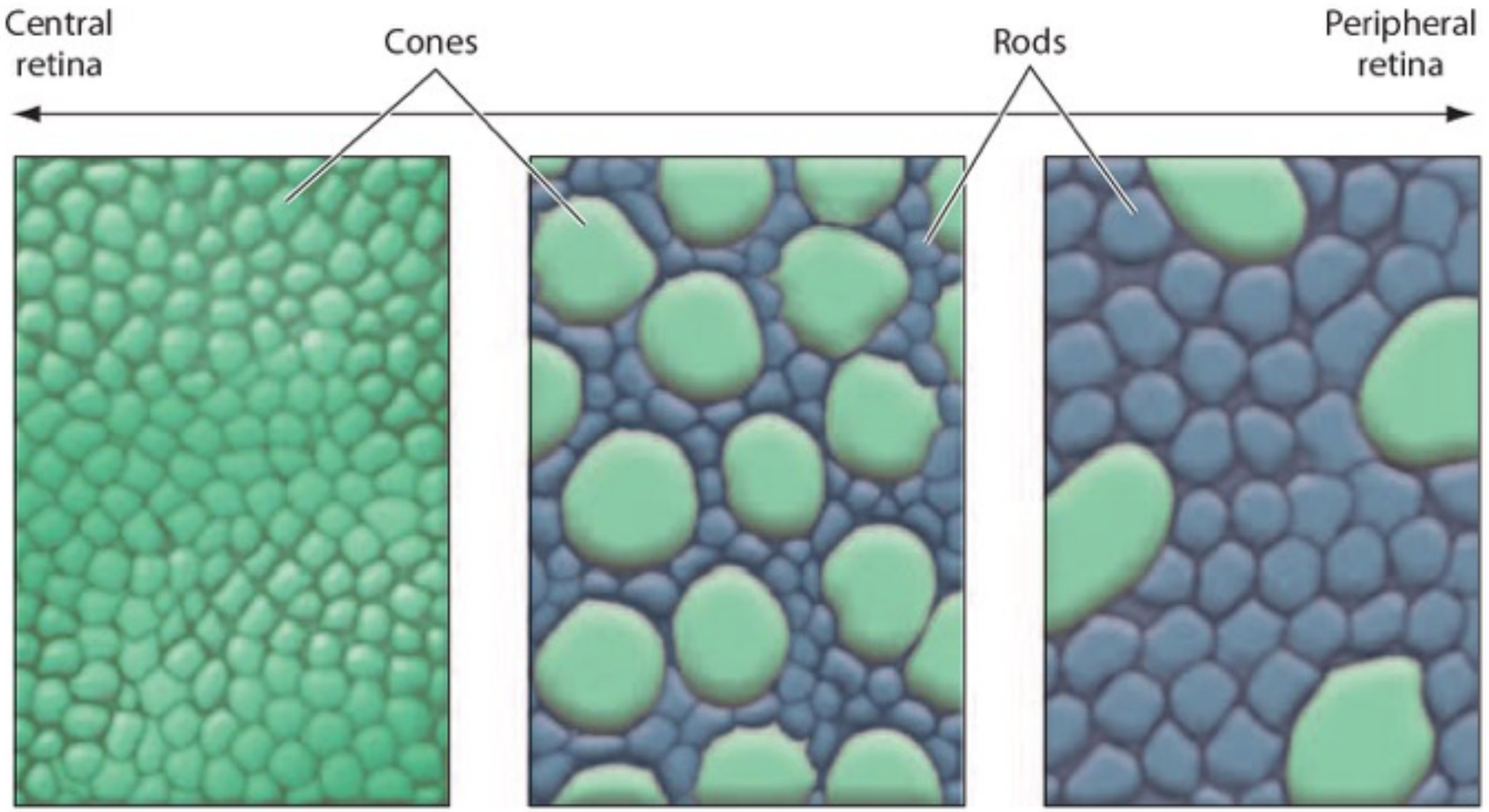

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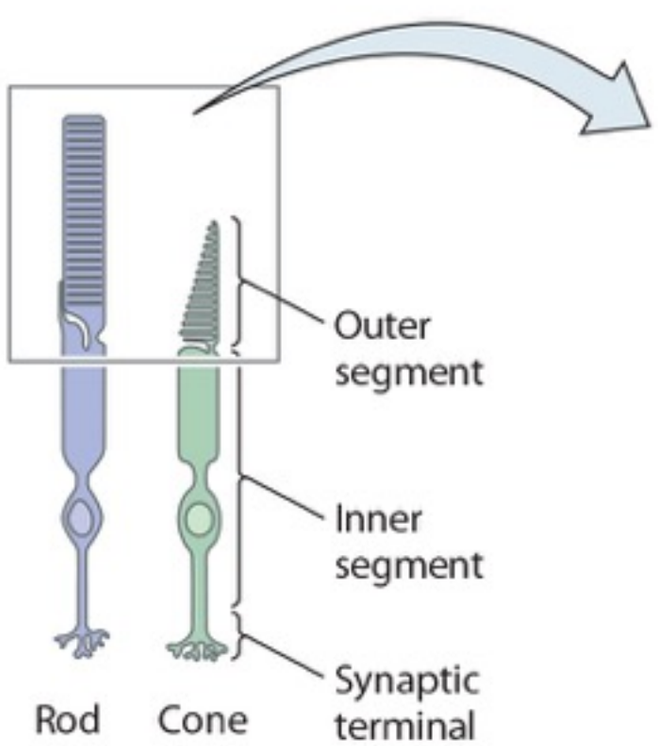
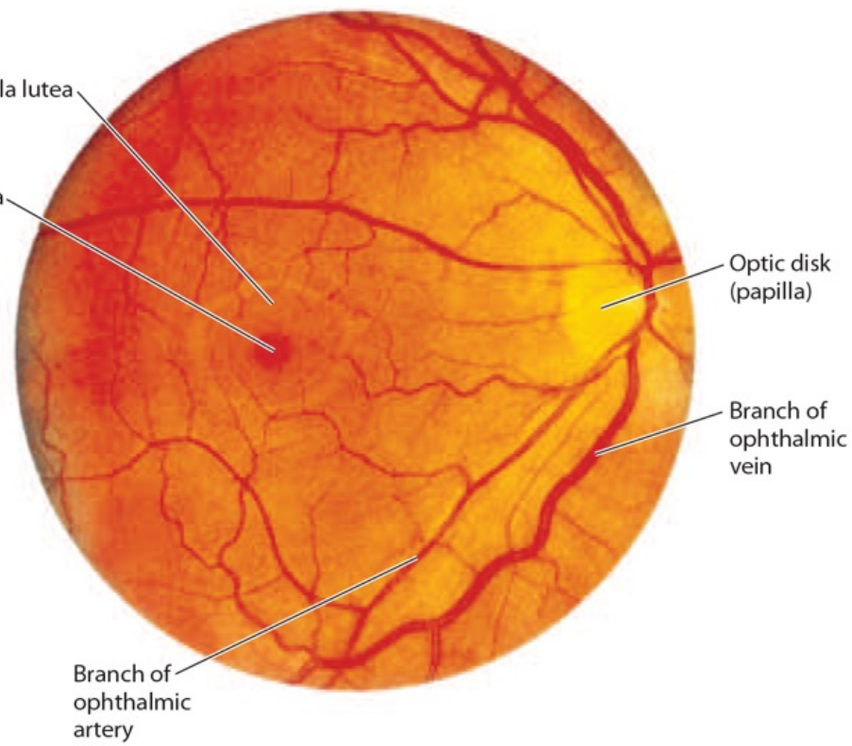


Rod

Cone

(A)



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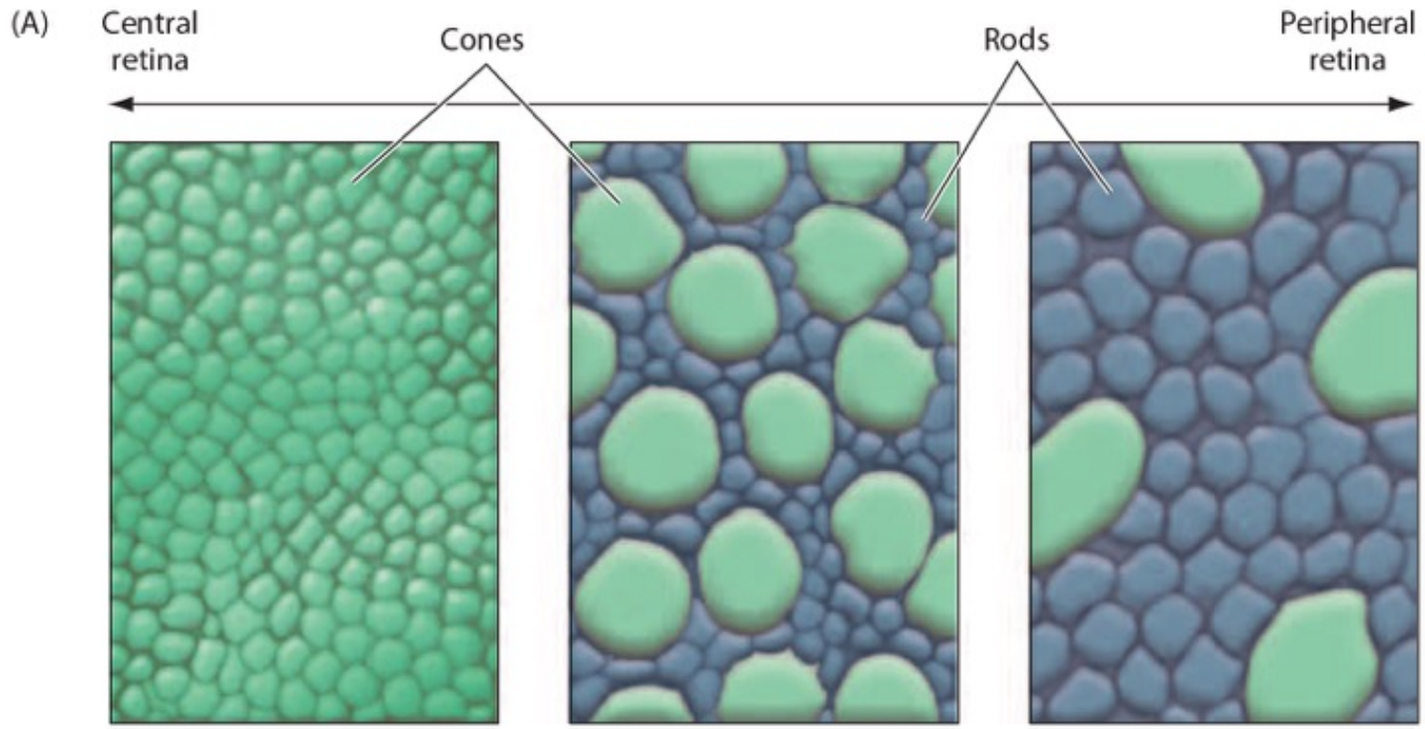

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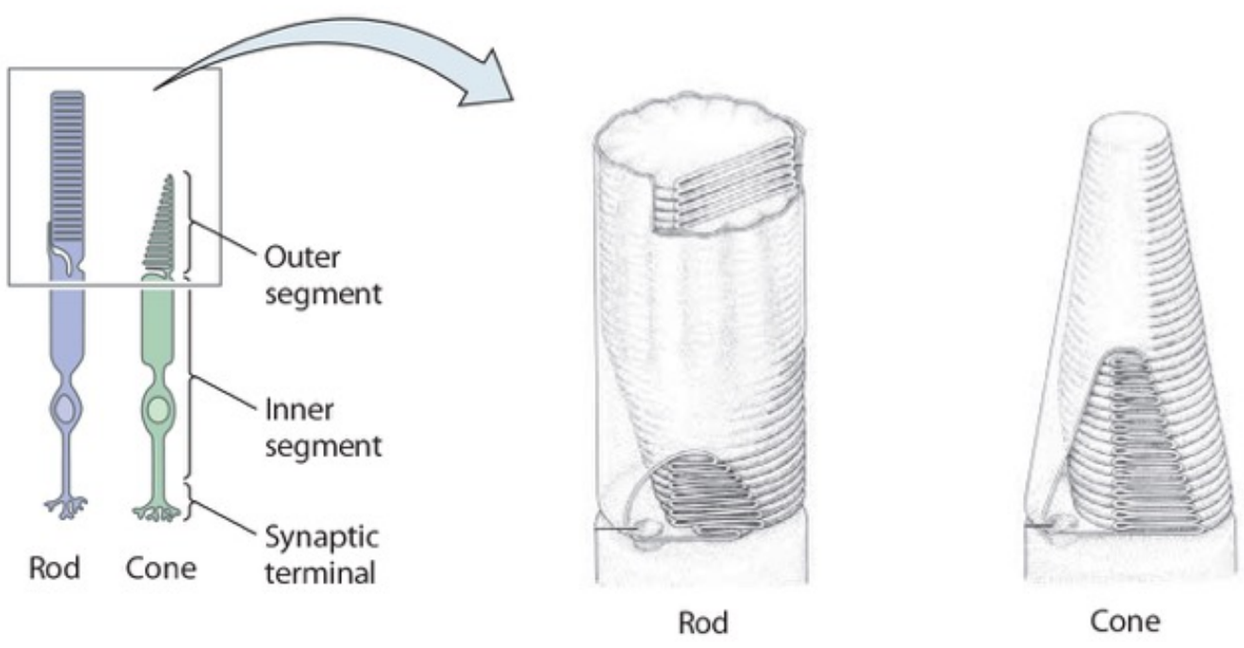
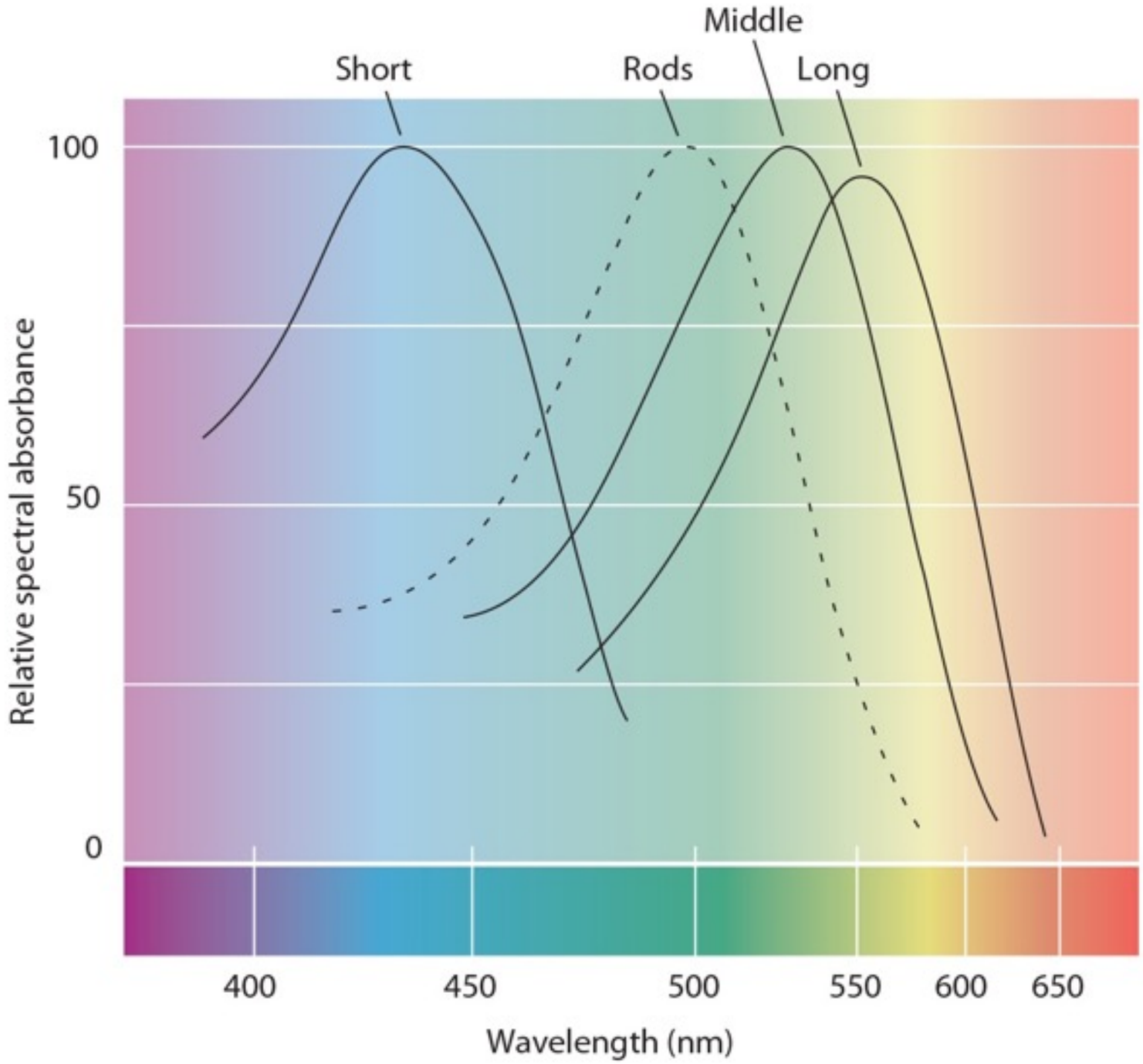
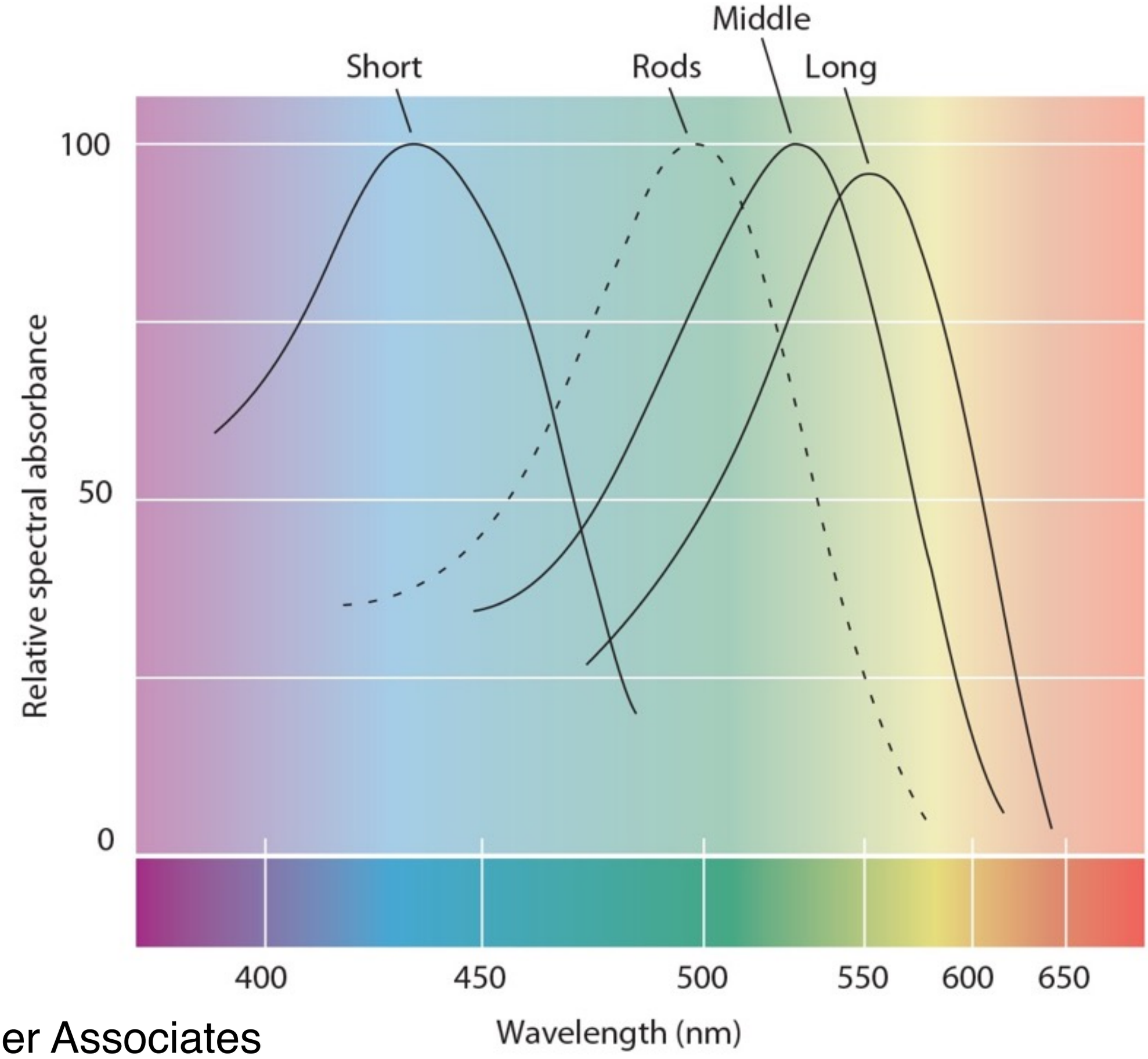


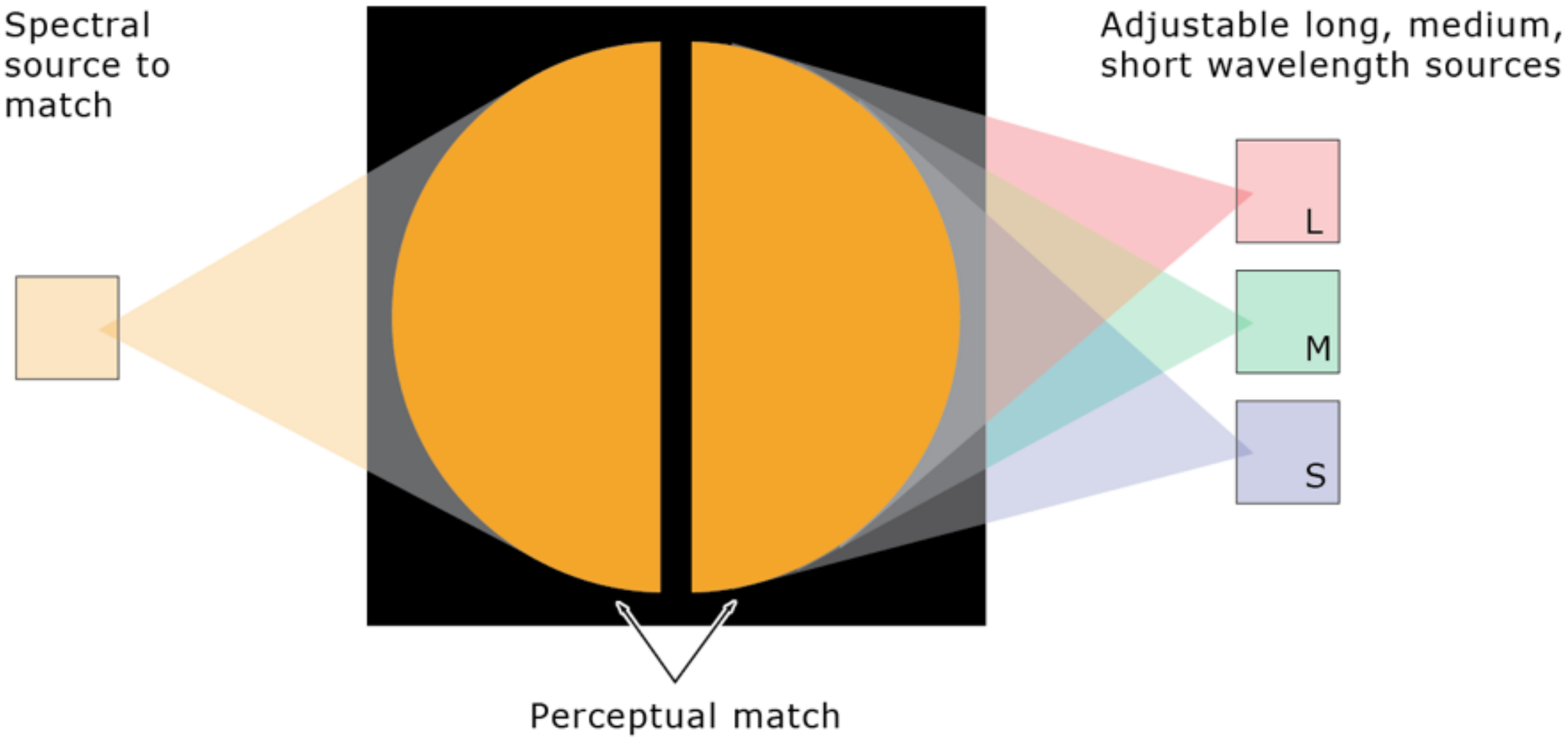
The Absorption Spectra of the Three Human Cone Types ("Trichromacy")

Thomas Young, (1773-1829)



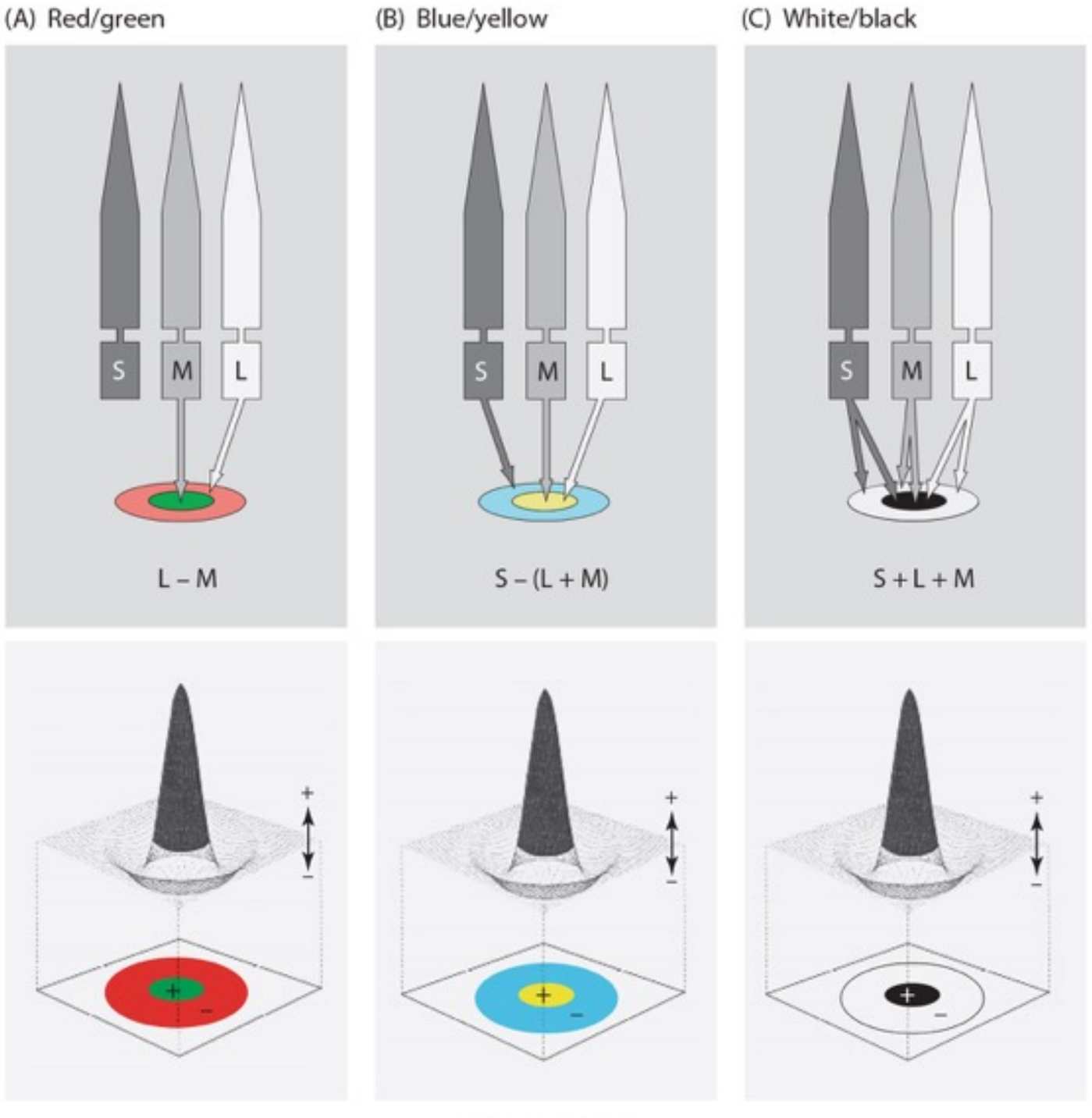


Mixing Short, Medium and Long Wavelength Light Can Match (nearly) Any Color



Responses of the Three Different Cone Types: Color “Opponency”

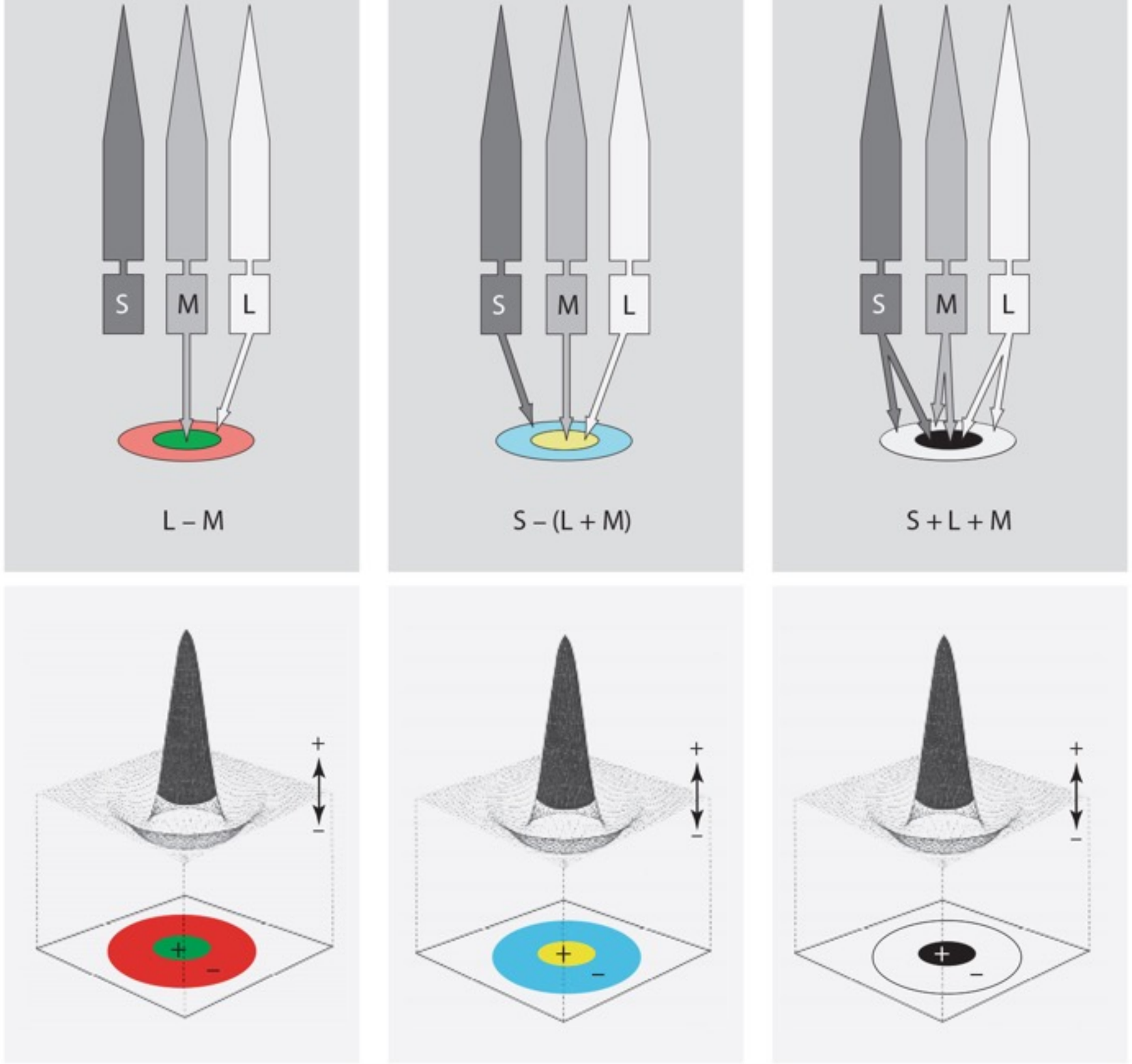
Ewald Hering, (1834–1918)



(A) Red/green

(B) Blue/yellow

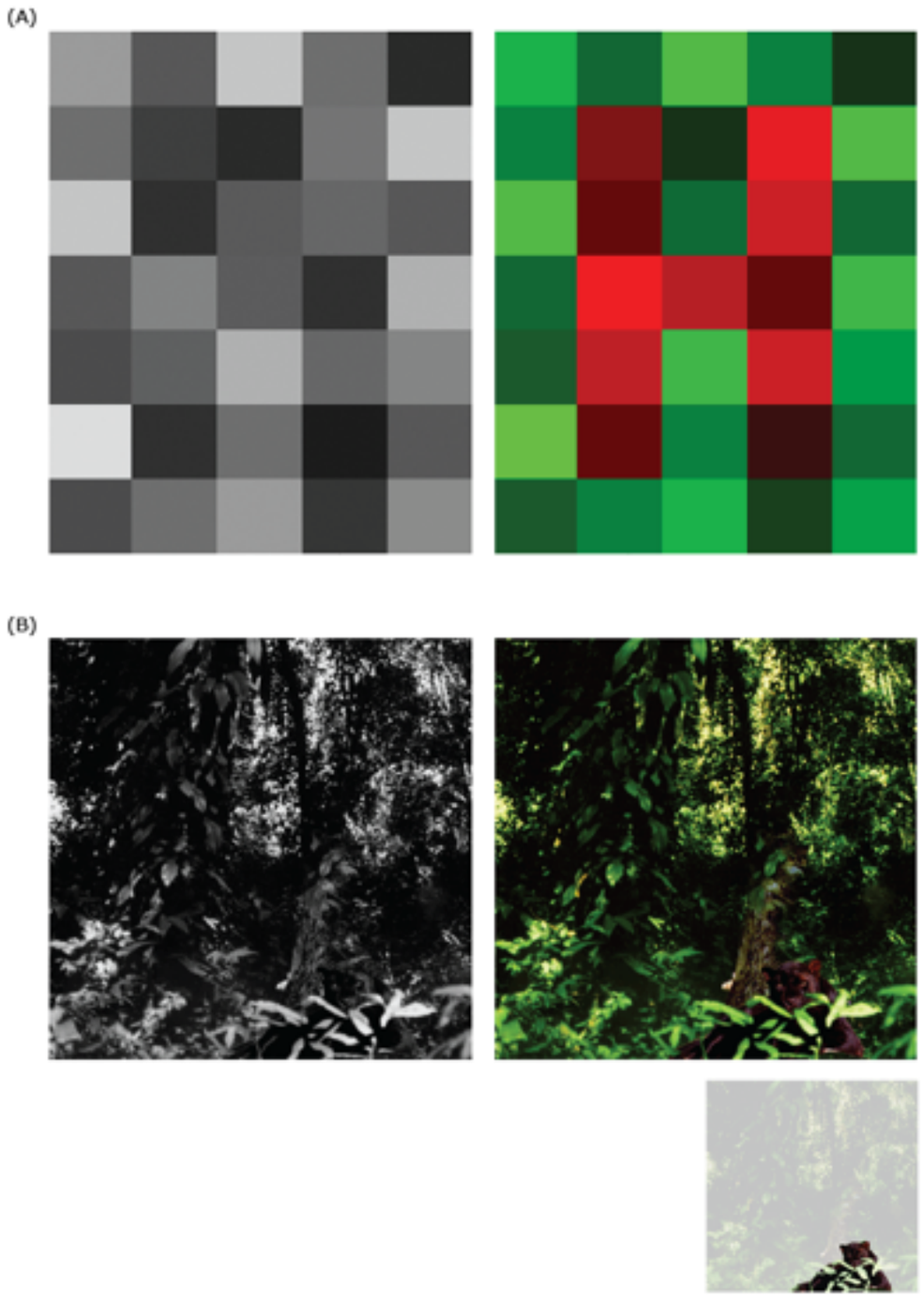
(C) White/black



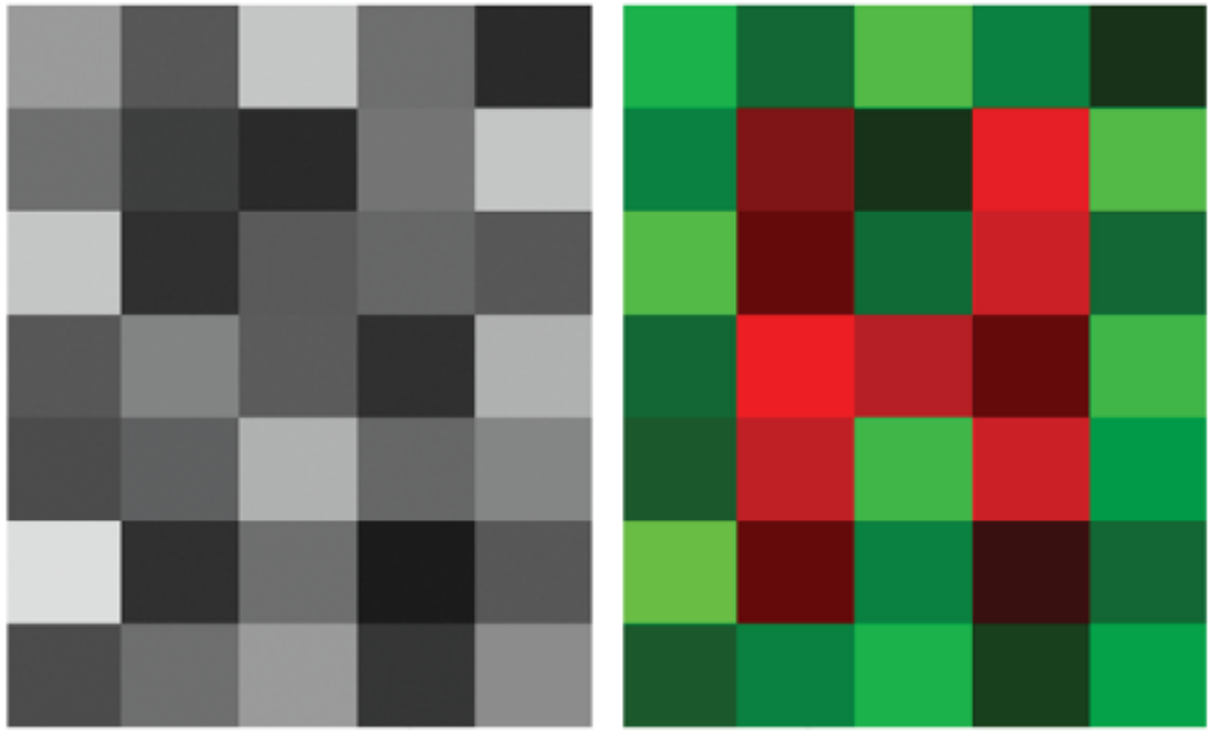
Receptive fields

Lesson 4. Why Do We Have Color Vision?

Biological Rationale for the Evolution of Color Vision



(A)



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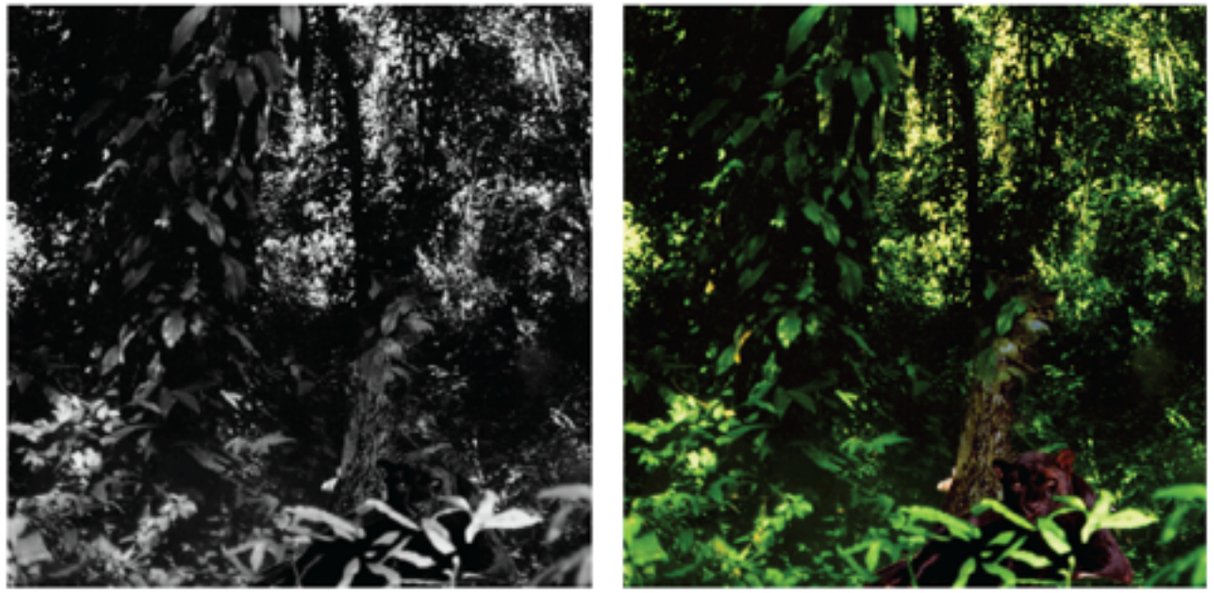
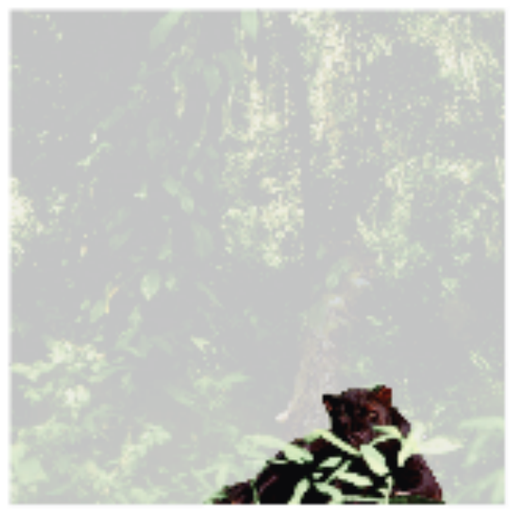


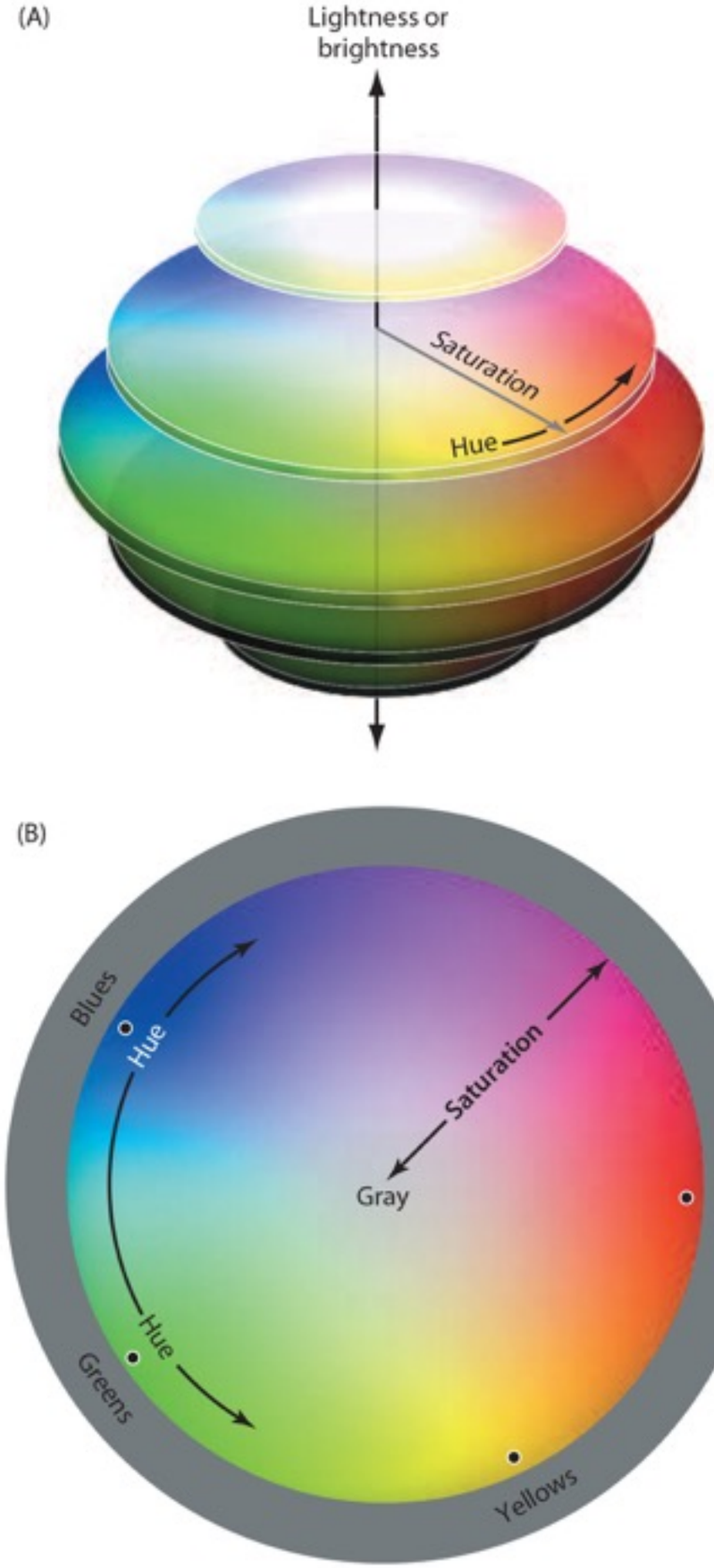


Lesson 5. Describing Color Perception

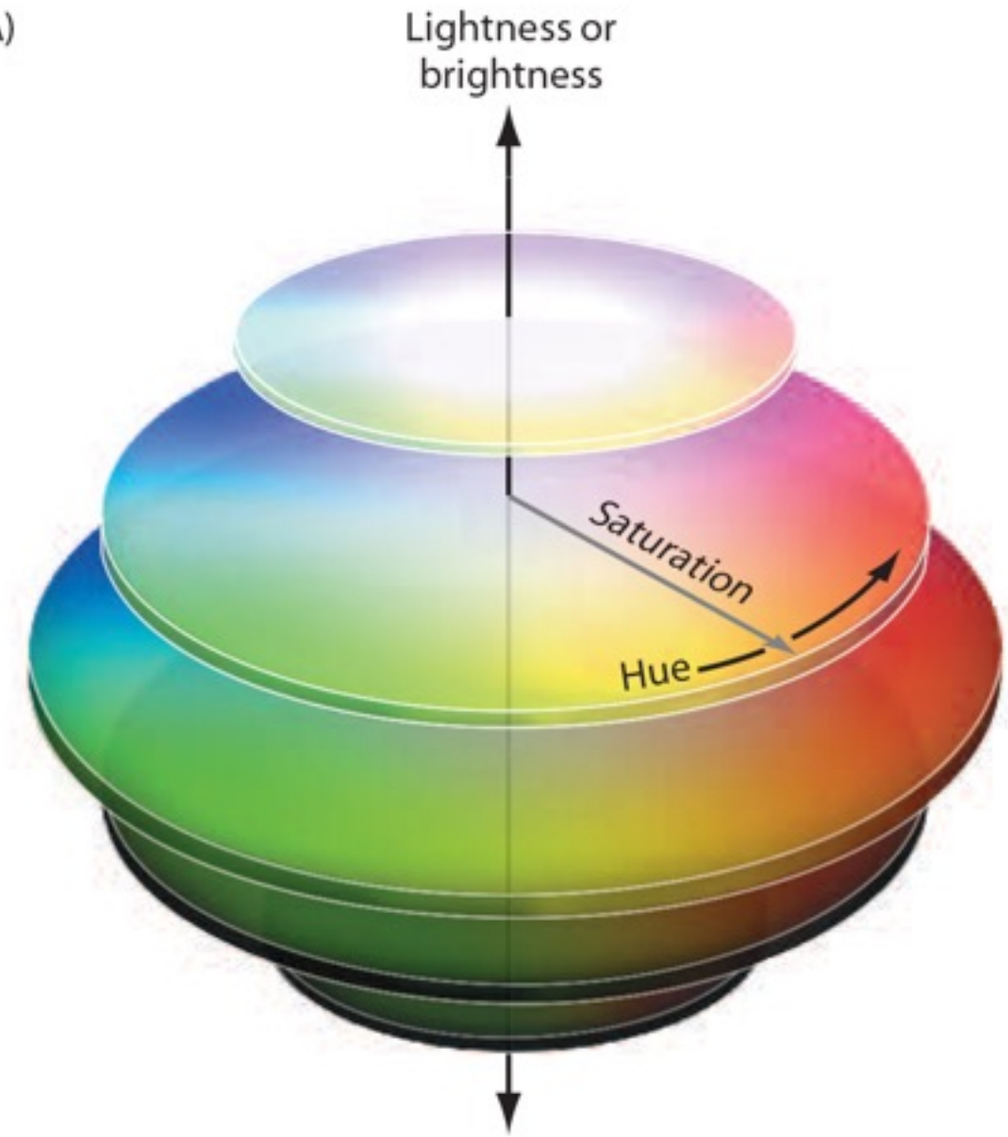
Describing Color Perception

- Hue: color we see
- Saturation: degree to which hue differs from neutral gray
- Lightness/Brightness: the intensity of a colored surface or source

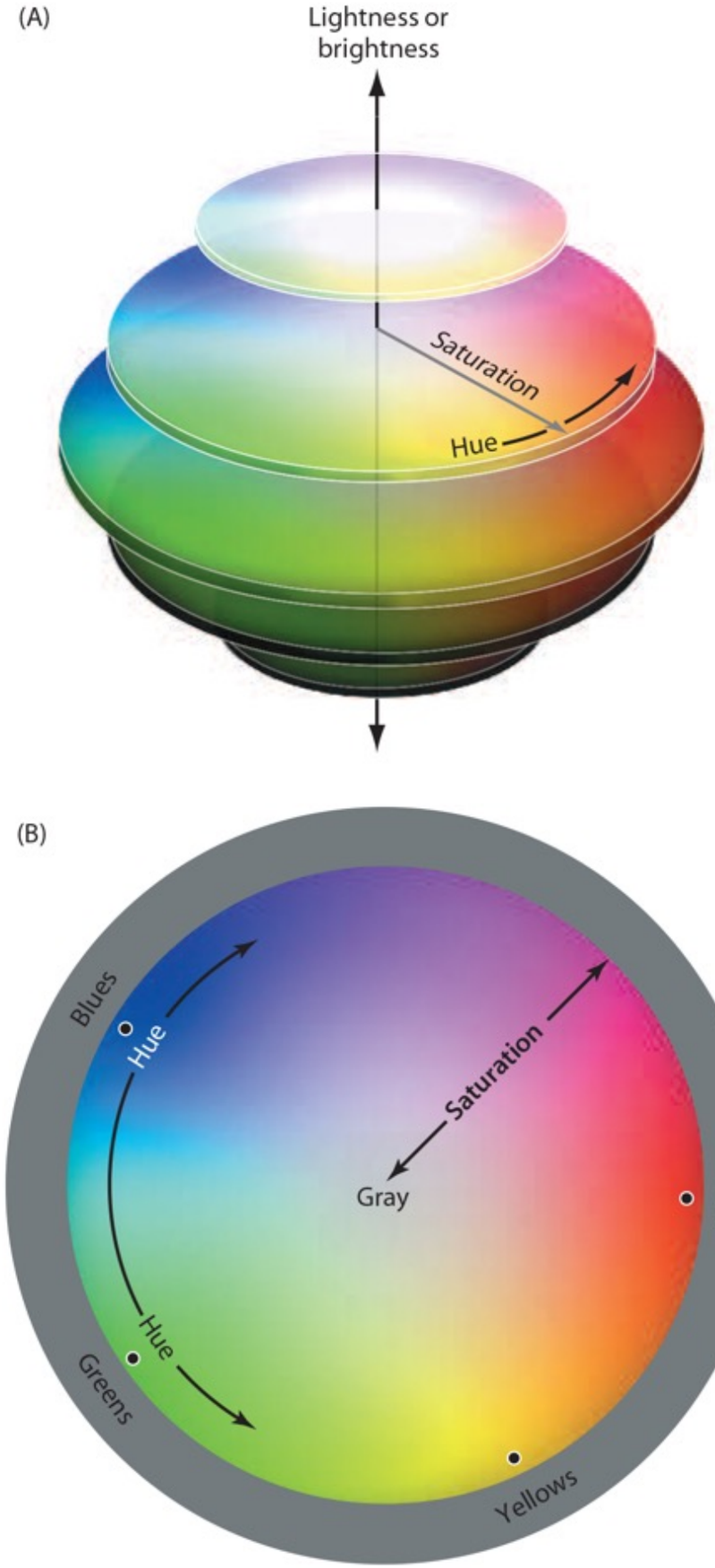
Perceptual “color space”



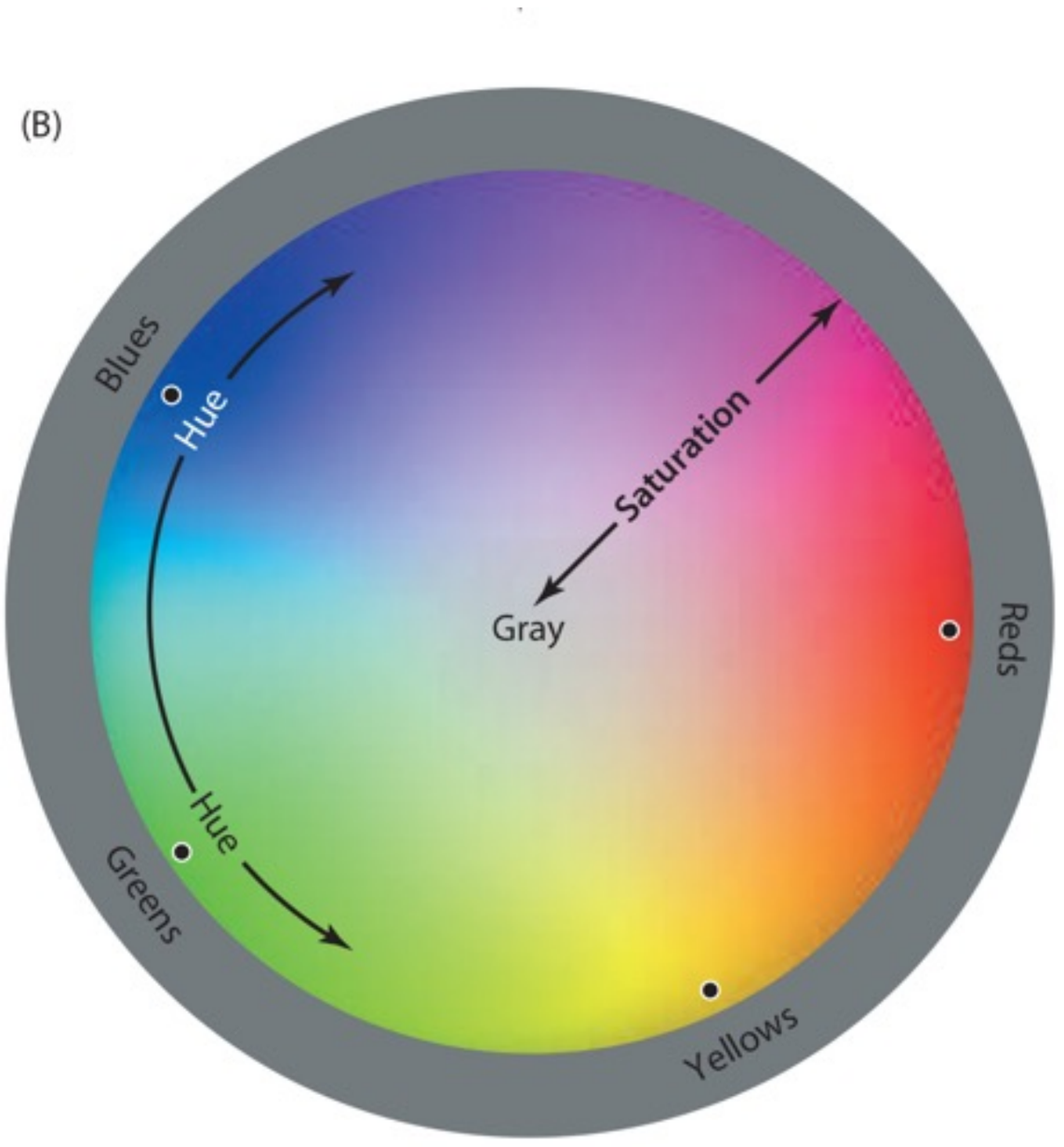
Perceptual “color space”



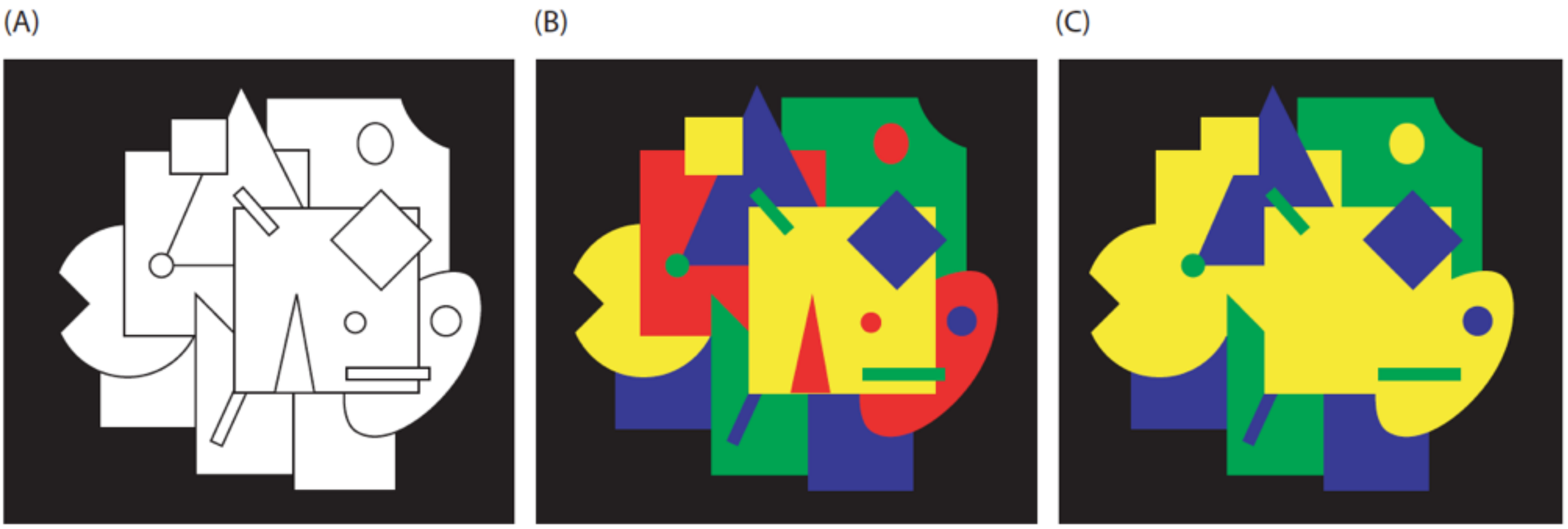
Perceptual “color space”



Perceptual “color space”



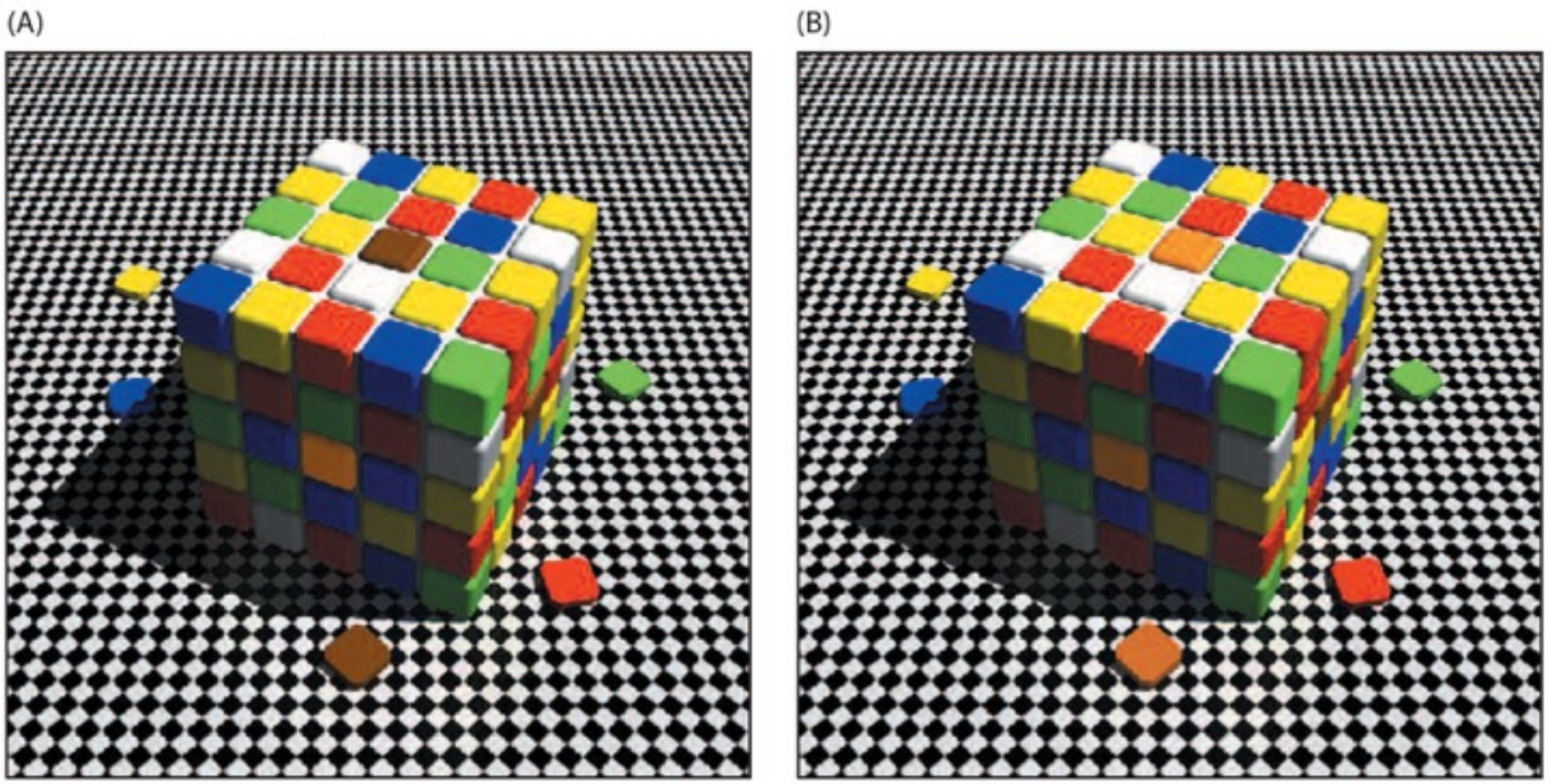
Why do we see four primary color categories (red, green, blue, and yellow)?



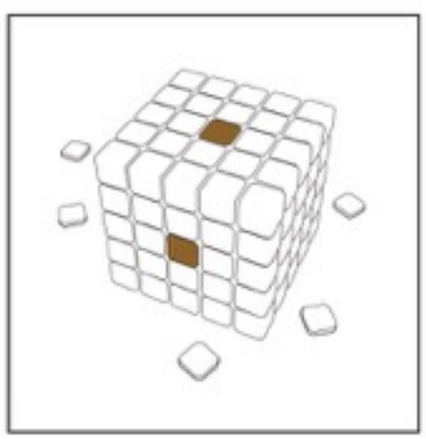
The “four color map problem”

Lesson 6.The Strange Way We See Color

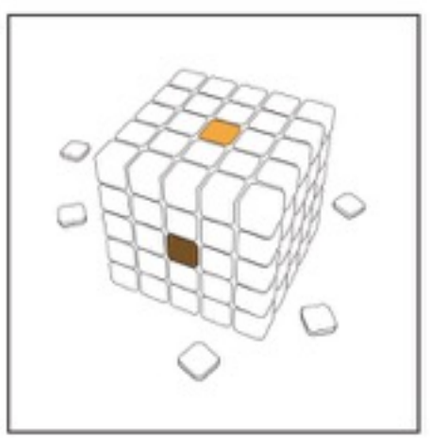
Color contrast and color constancy



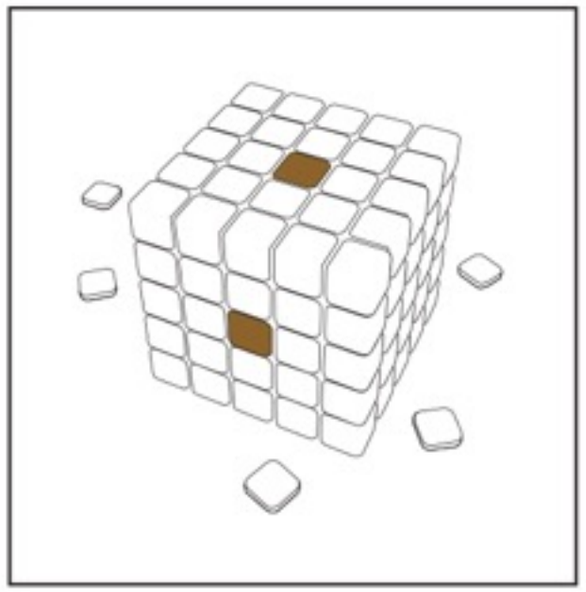
Contrast



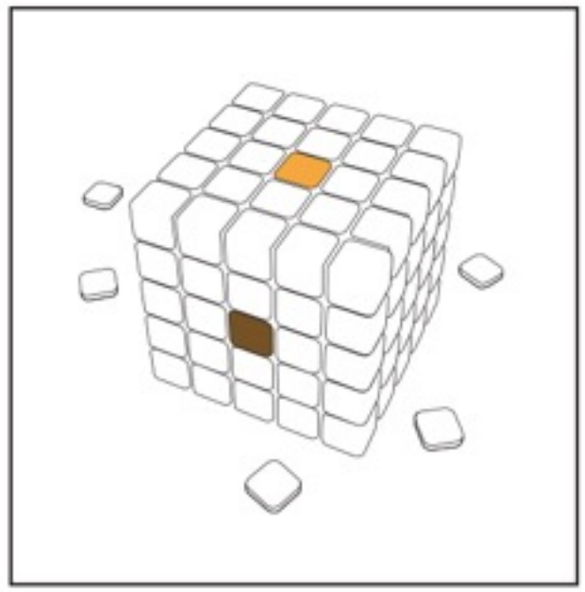
Constancy



Color contrast and color constancy

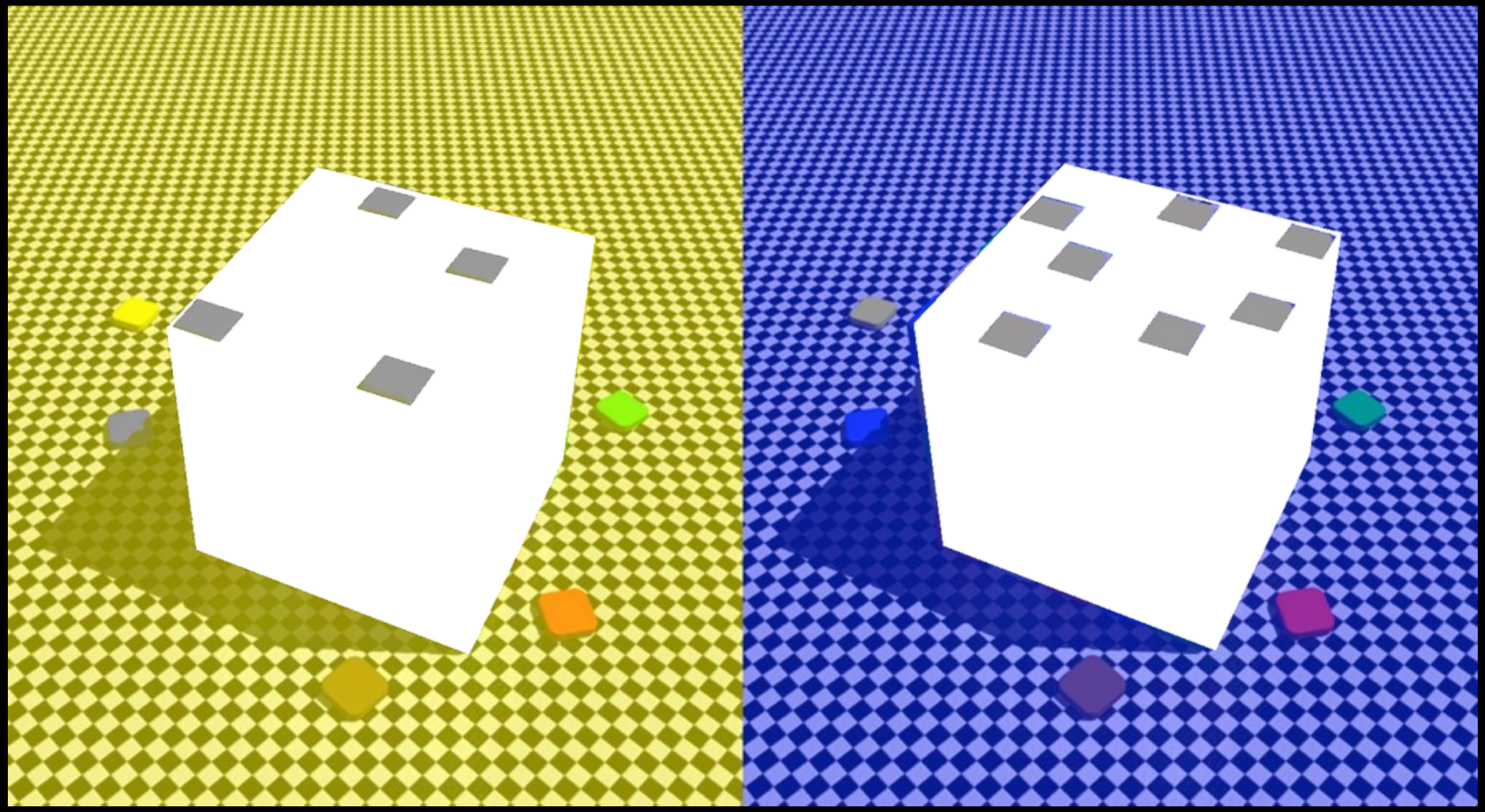


Contrast



Constancy

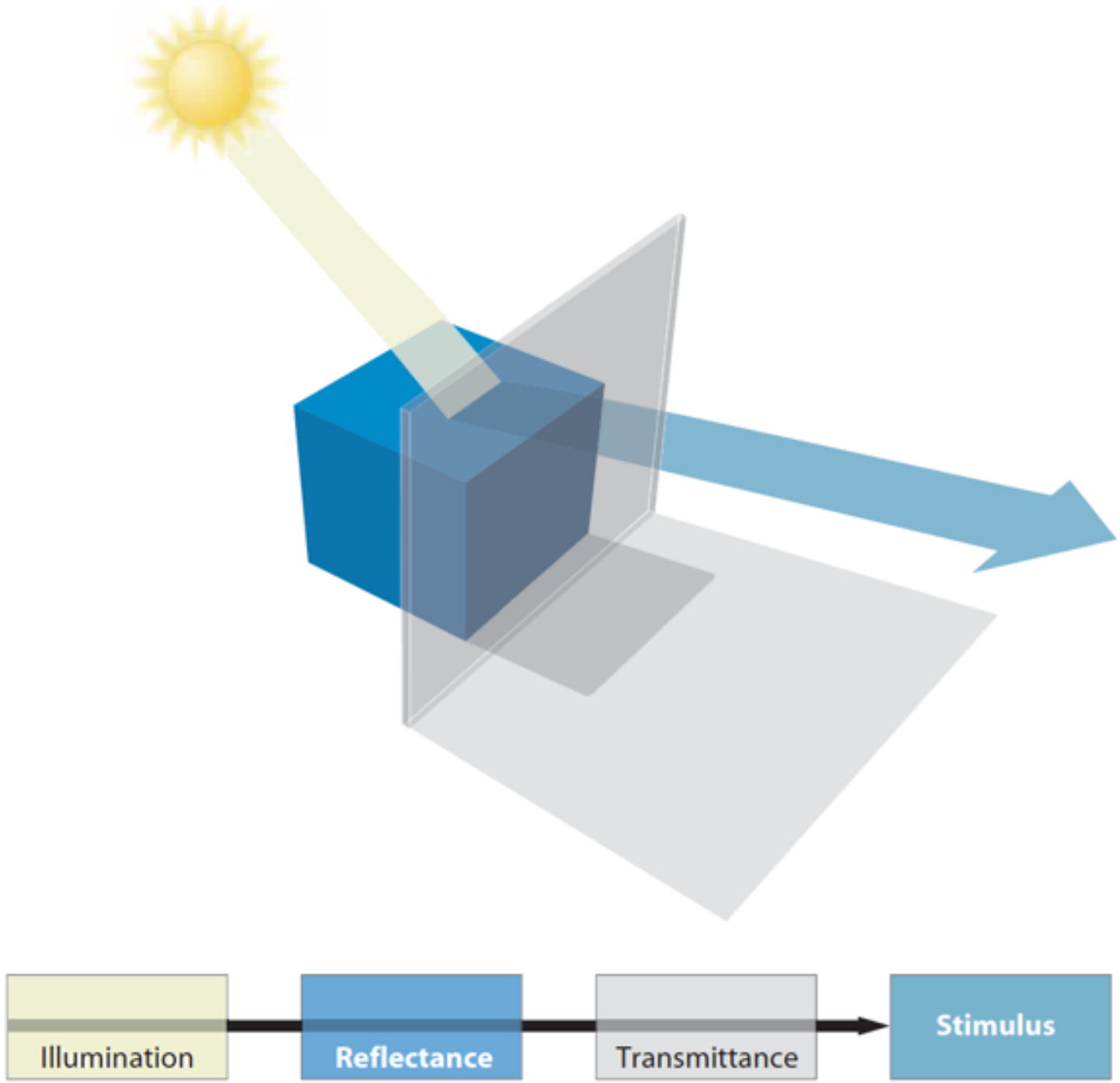
The context of any surface patch has an enormous effect on the color we see



So again, what's going on here?

Lesson 7. An Empirical Answer

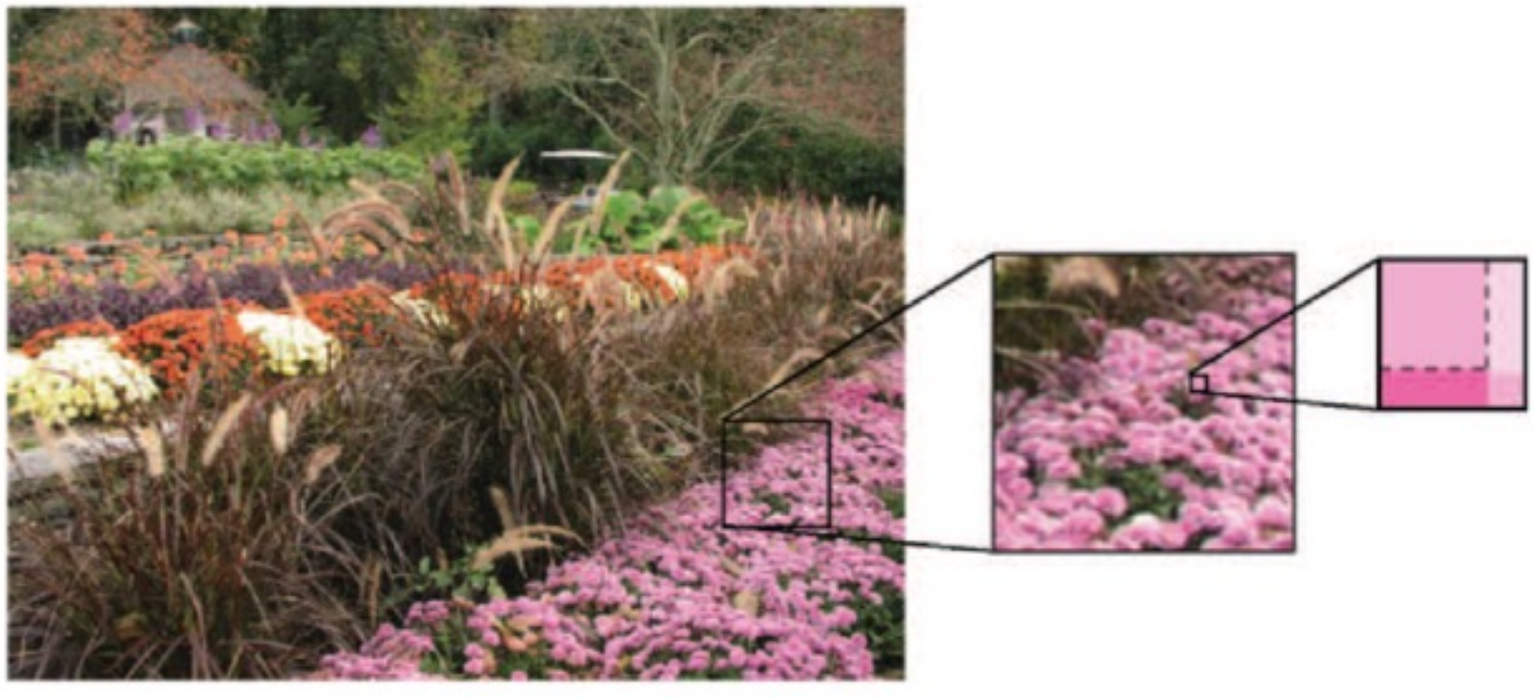
The inverse optics problem for color



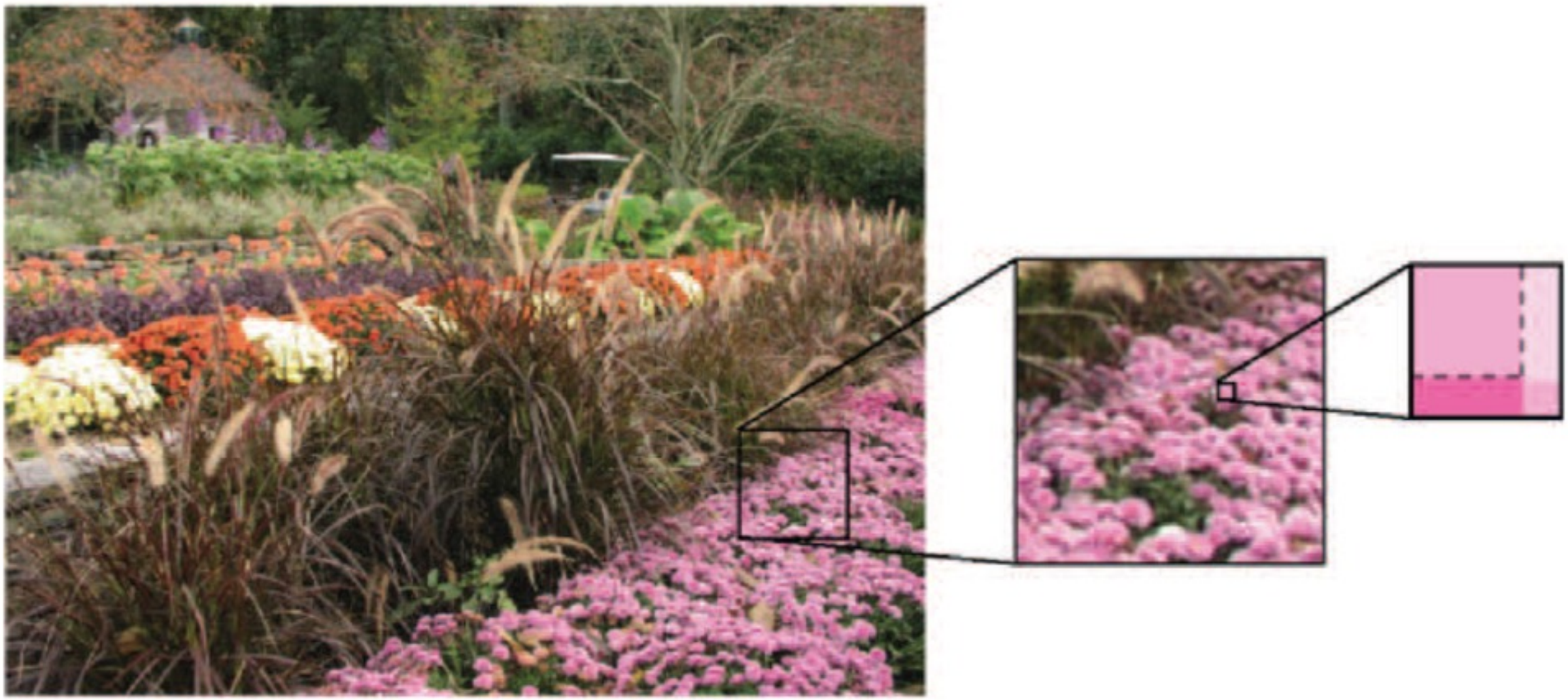
Sampling Color Experience

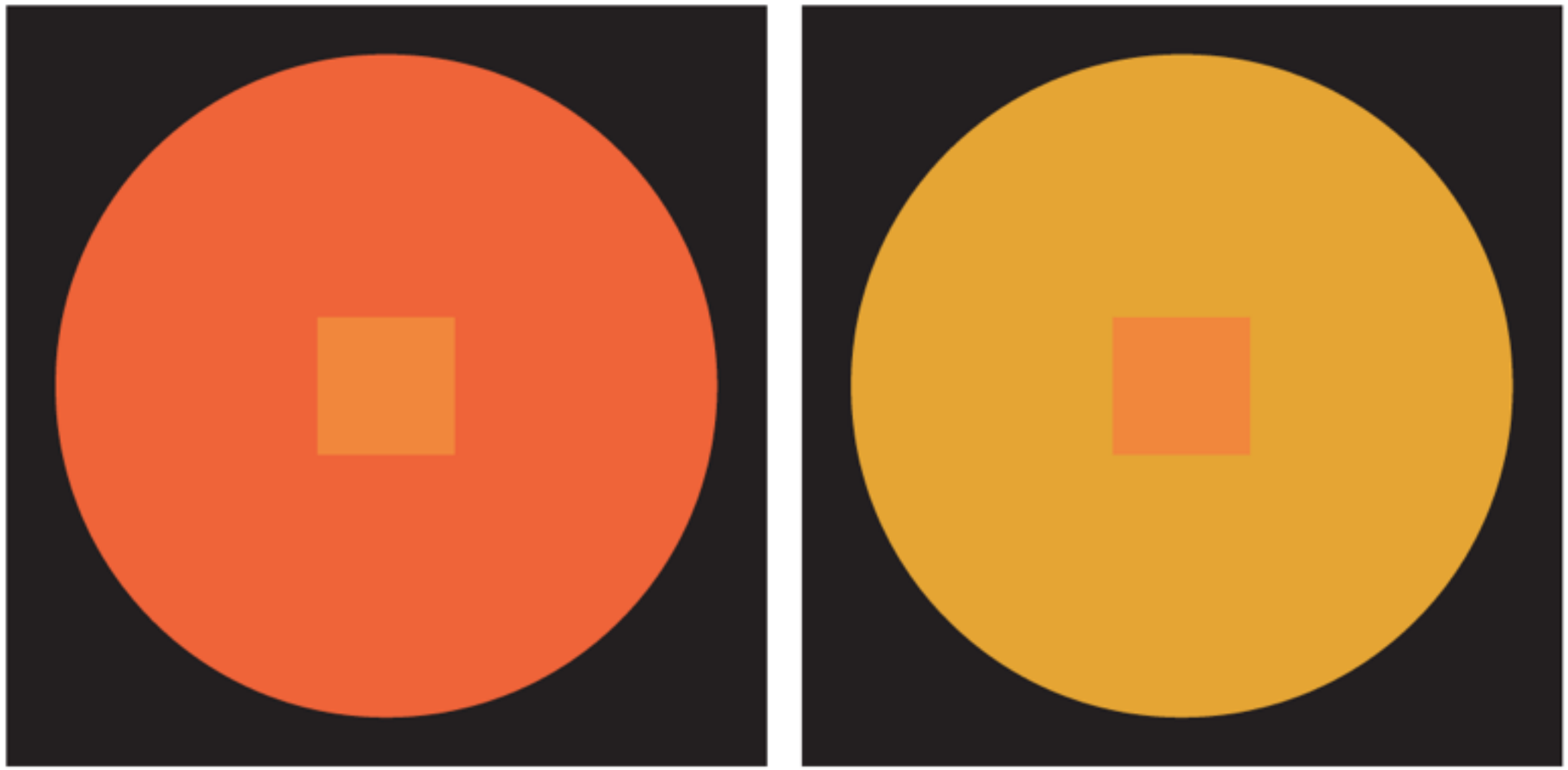
(A)

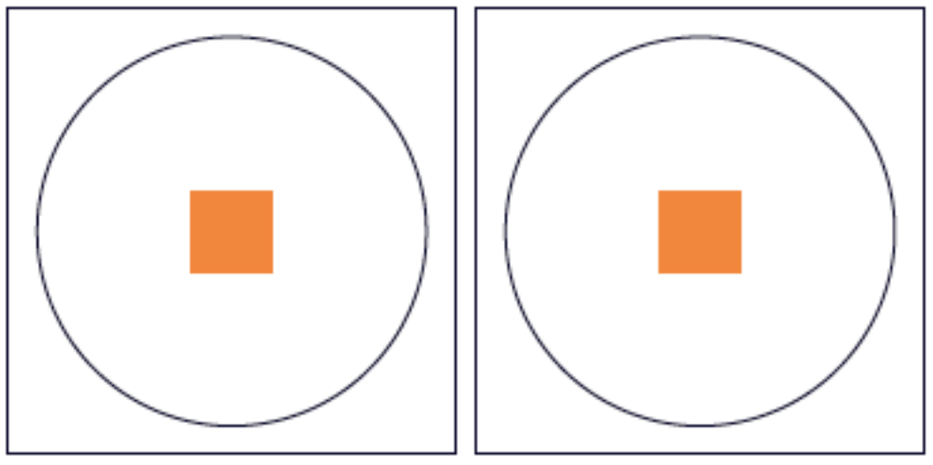
(B)



Sampling Color Experience







The two identical central targets look different because these perceived lightness values track reproductive success, not physical properties in the world.

Summary of the Main Points

- Color is the name we give to perceptions elicited by different distributions of light energy
- It is fascinating aspect of vision, but not all that important biologically
- The main challenge is to explain the peculiar way we see color, which not correspond to physical measurements
- The answer again seems to be a way of coping with the inverse problem

Credits

Dale Purves, R. Beau Lotto. *Why We See What We Do Redux*, Sinauer Associates Inc. 2011

- Electromagnetic spectrum, pg. 16
- Light and prisms, pg. 52
- White light spectra, pg. 152
- Human retina, rods and cones, pg. 204-205
- Spectral sensitivity, pg. 55
- Color matching, pg. 56
- Cone type responses, pg. 58

Biological advantages, Dale Purves, R. Beau Lotto, *Why We See What We Do*, Sinauer Associates Inc., 2003, pg. 103

Credits, Cont.

Dale Purves, R. Beau Lotto. *Why We See What We Do Redux*, Sinauer Associates Inc. 2011

- Perceptual color space, pg. 61
- Four color map problem, pg. 63
- Color contrast and constancy, pg. 79
- Inverse optics problem for color, pg. 71
- Sampling color experience, pg. 86
- Squares in circles, pg. 64