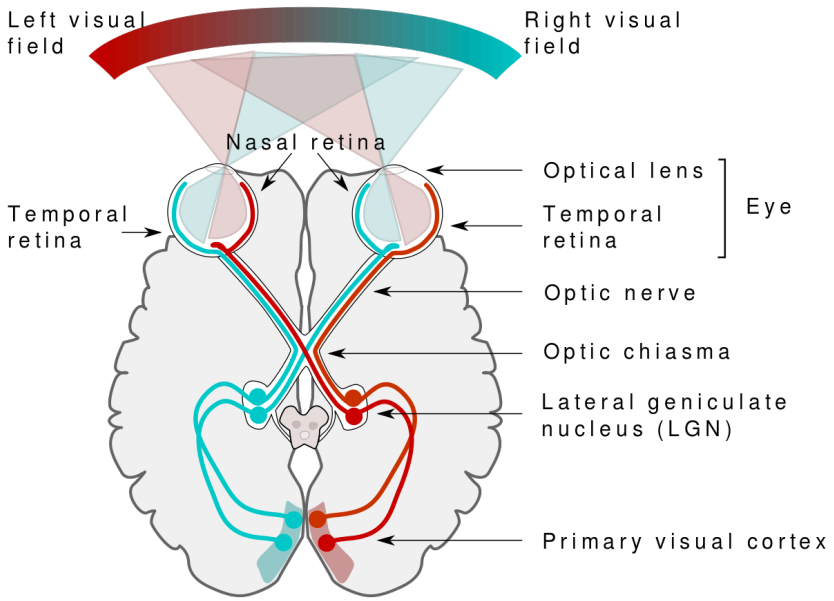
CENG 477
Introduction to Computer Graphics

Human Visual System

Human Visual System

- The HVS consists of the eyes, parts of the brain, and the connecting pathways between the two
- It is a complex system that even today not entirely understood
- We will briefly touch upon its basic working principles



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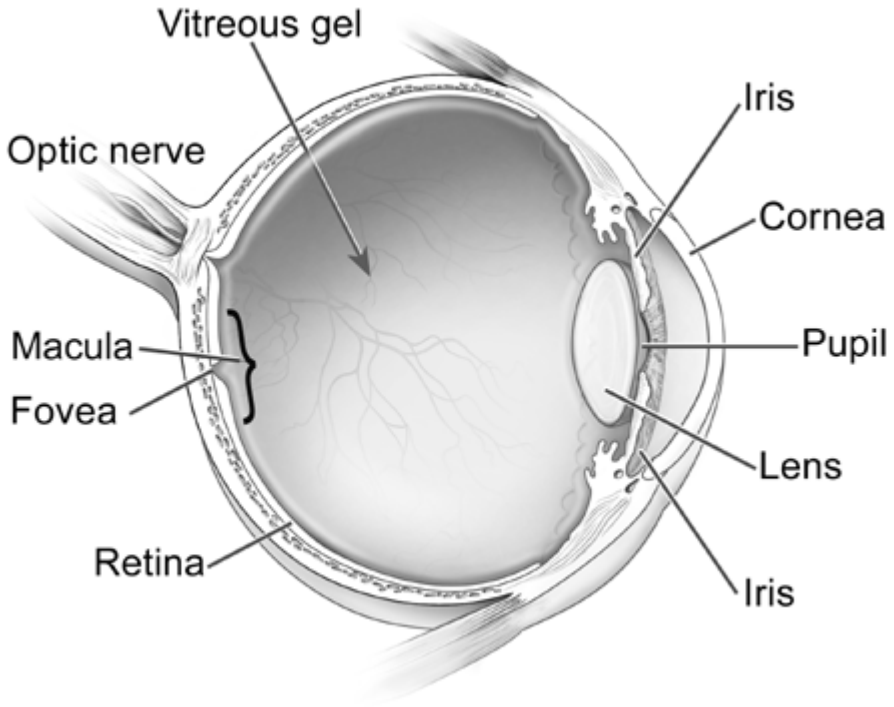
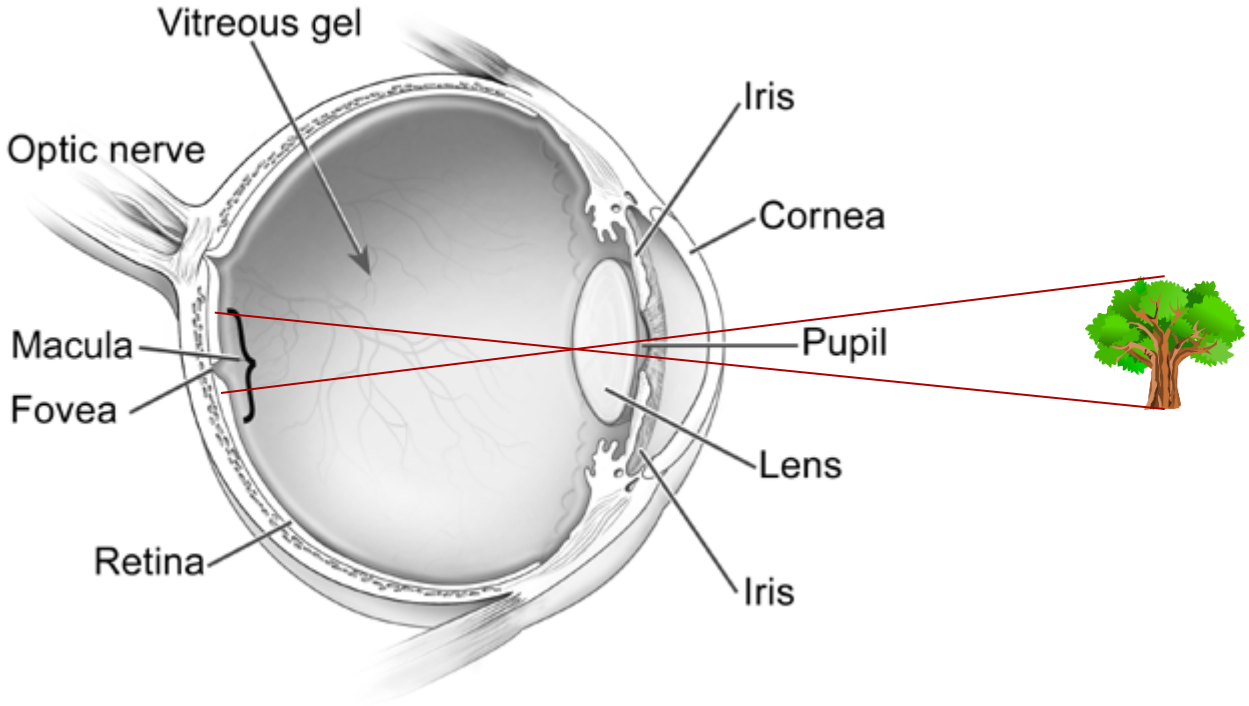
The Eye

- Vision starts at the eyes



The Eye

- Light entering the eye is focused on the fovea (inside retina) by the lens



Retina

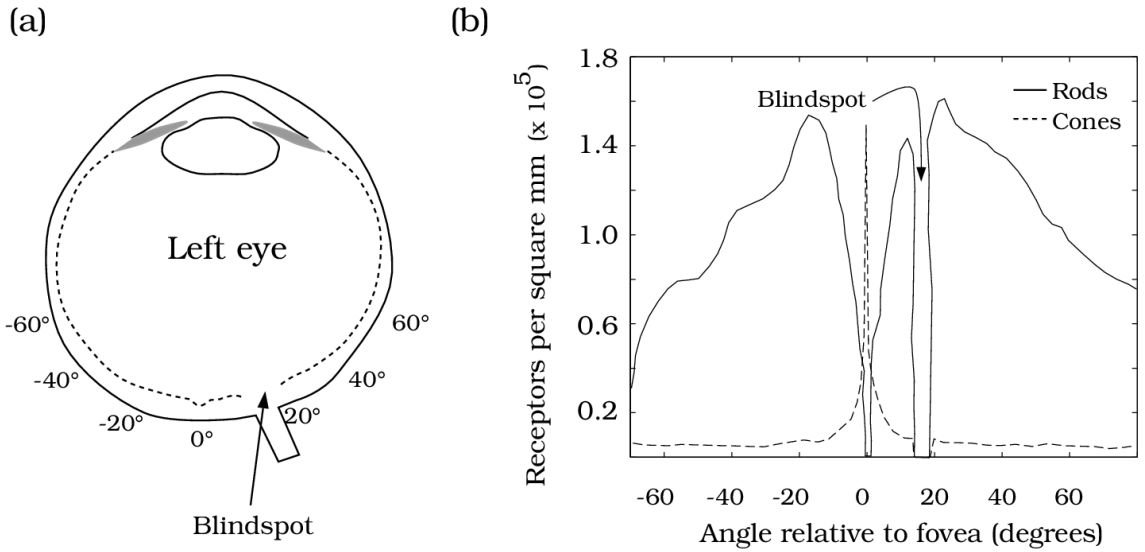
- This light is absorbed by two types of photosensitive cells on the retina
  - Rods
  - Cones

Rods and Cones

- While being more numerous than cones, rods do not exist in the fovea and there is only a single type of rods
  - That is why our night vision is not sharp and colorful
- Rods are active under low light conditions

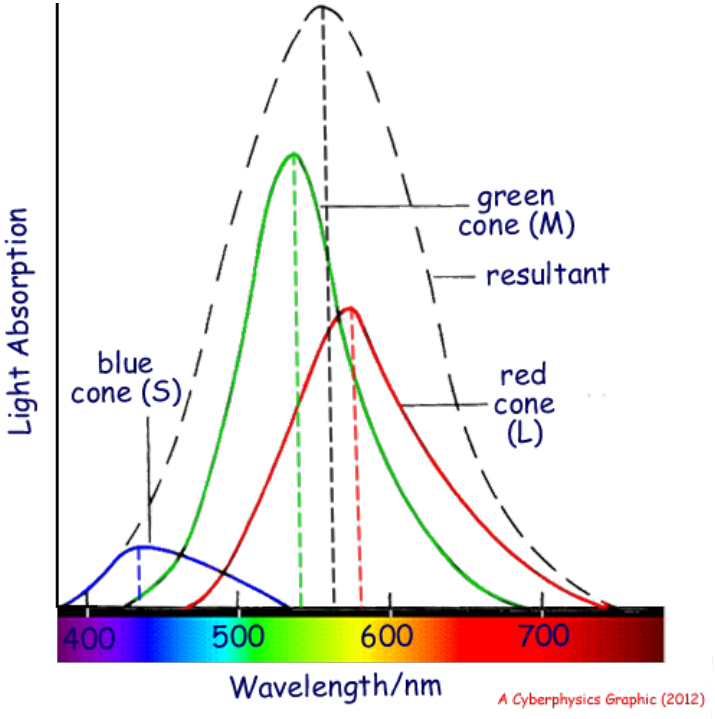
Cones

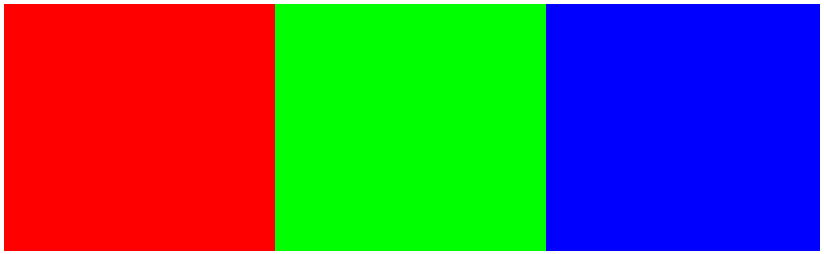
- Cones are very dense in the fovea
- There are three types of cones: long, medium, short
- Cones are active at normal light conditions



Cones

- Each cone type is responsive to a different color
- Their relative contribution determines the perceived color of an object
- Their combined contribution determines the perceived brightness of an object





(255, 0, 0) (0, 255, 0) (0, 0, 255)

Cones

- Each cone type is responsive to a different color
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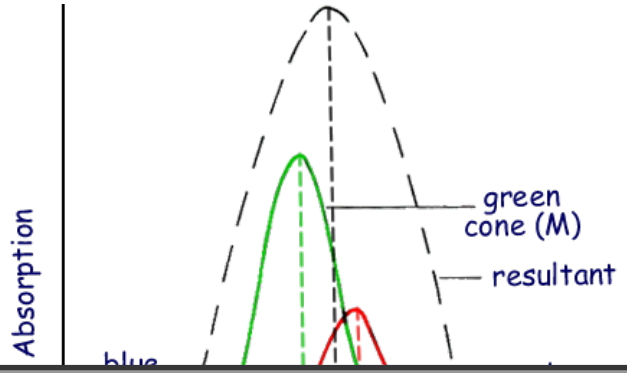
-

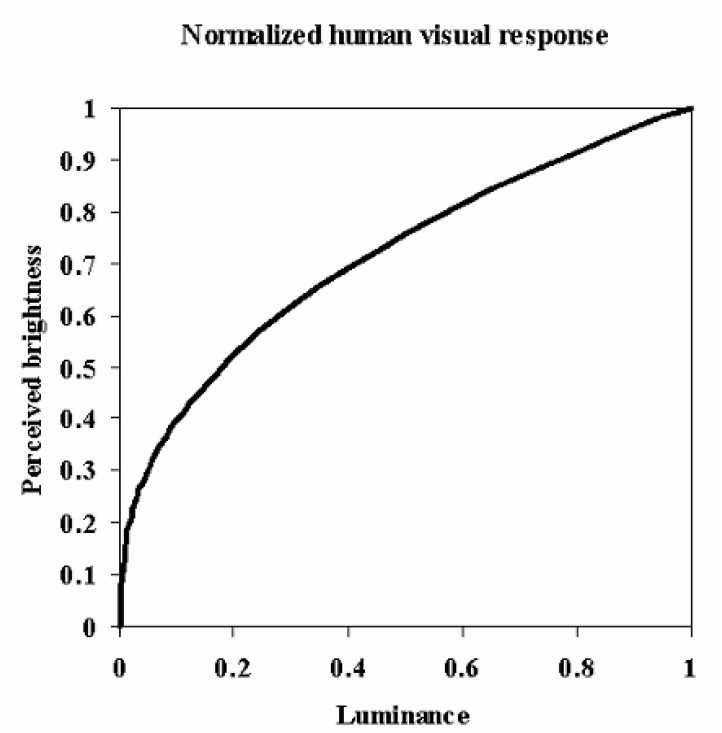


The primary reason that color is typically represented as an RGB triplet is because we also have three types of cones

(255, 0, 0) (0, 255, 0) (0, 0, 255)

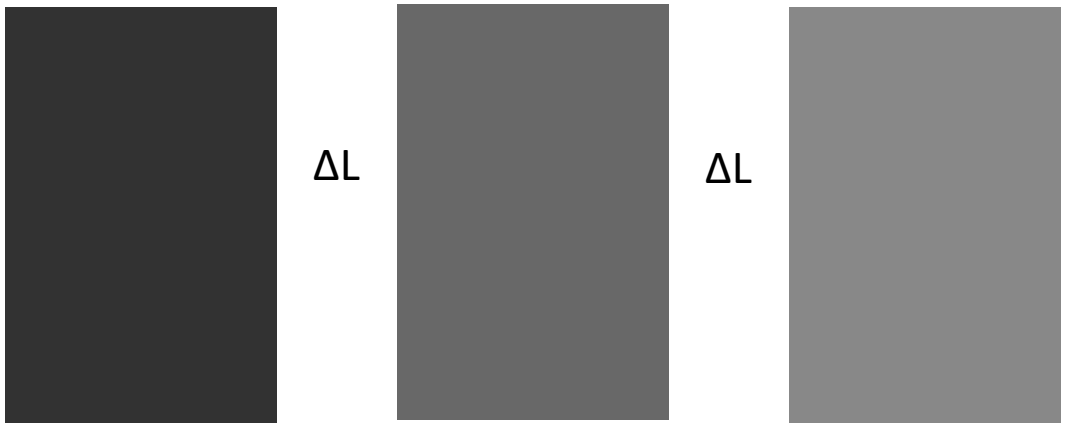
Non-linearity

- The human response to light is non-linear (logarithmic)
- In other words, cameras and the eye has a somewhat similar non-linearity



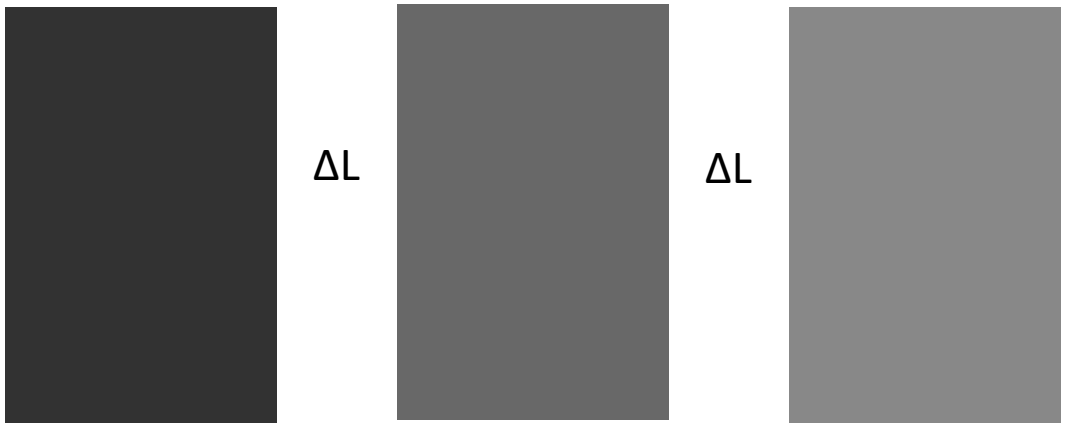
Non-linearity

- Therefore, equal change in luminance **does not map** to equal change in perceived brightness
- We can verify this experimentally
- The following three patches are separated by about the same amount of luminance difference



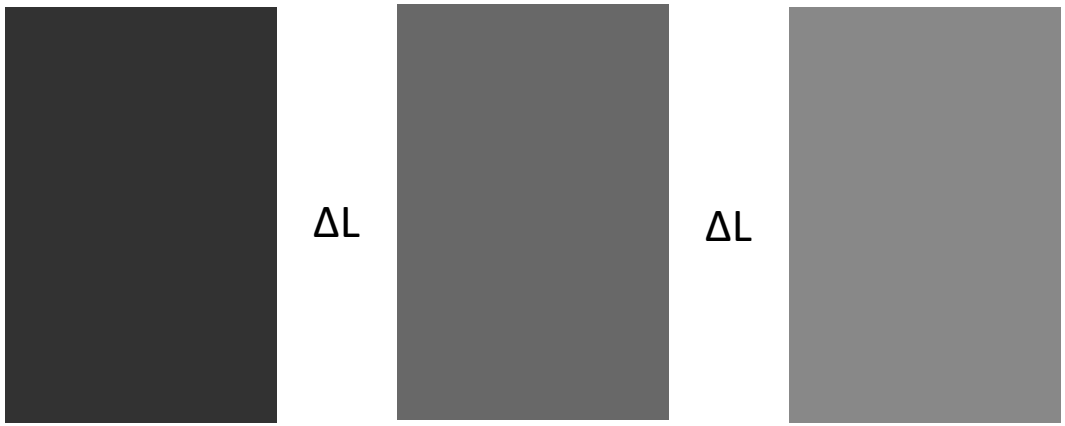
Non-linearity

- Therefore, equal change in luminance **does not map** to equal change in perceived brightness
- We can verify this experimentally
- But the perceived step size between them is different



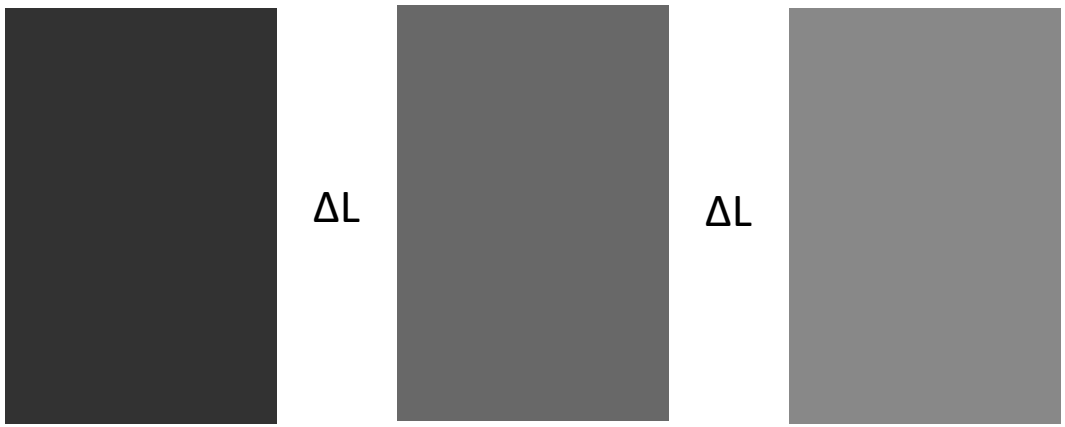
Non-linearity

- Note that to prepare these patches, we must take into account the gamma behavior of display devices:
  - **You cannot simply make the pixel value difference equal!**
- Imagine you want these patches to have luminance values L, 5L, and 9L (so ΔL = 4L)



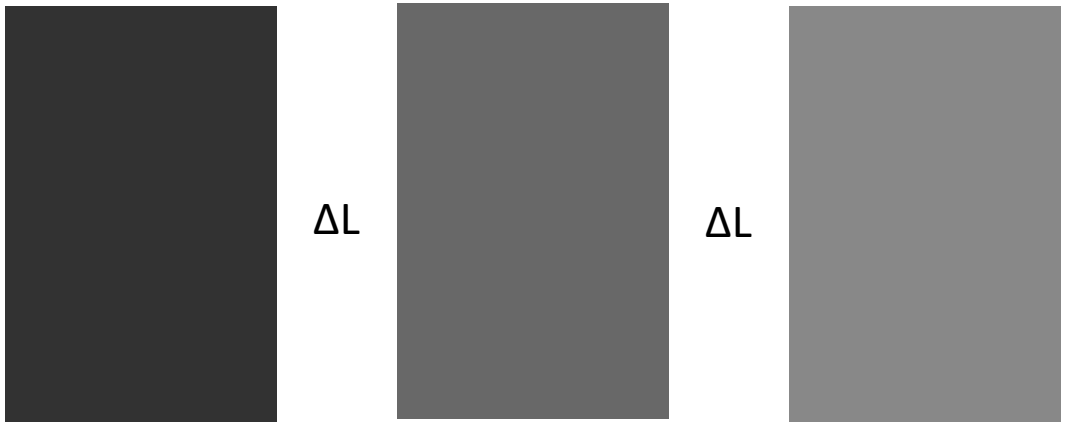
Non-linearity

- Note that to prepare these patches, we must take into account the gamma behavior of display devices:
  - **You cannot simply make the pixel value difference equal!**
- Assume that pixel value of 50 results in a luminance of L
- Also assume that the gamma (ɣ) of your display device is 2.2



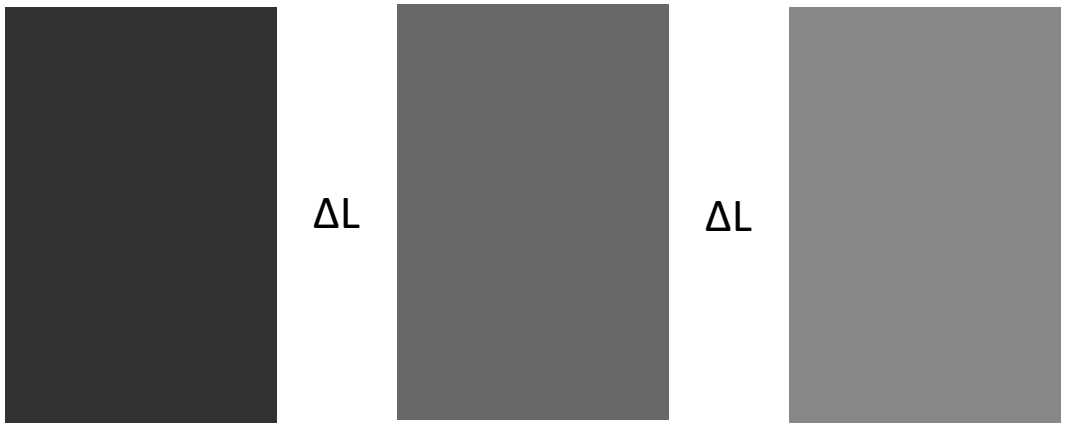
Non-linearity

- What should be the pixel value of the second patch in order to have a luminance of 5L?
- Remember our display model: $L_{out} = cV^{\gamma} + b$
- Assuming c = 1 and b = 0, we can say: $L = \left(\frac{50}{255}\right)^{2.2}$



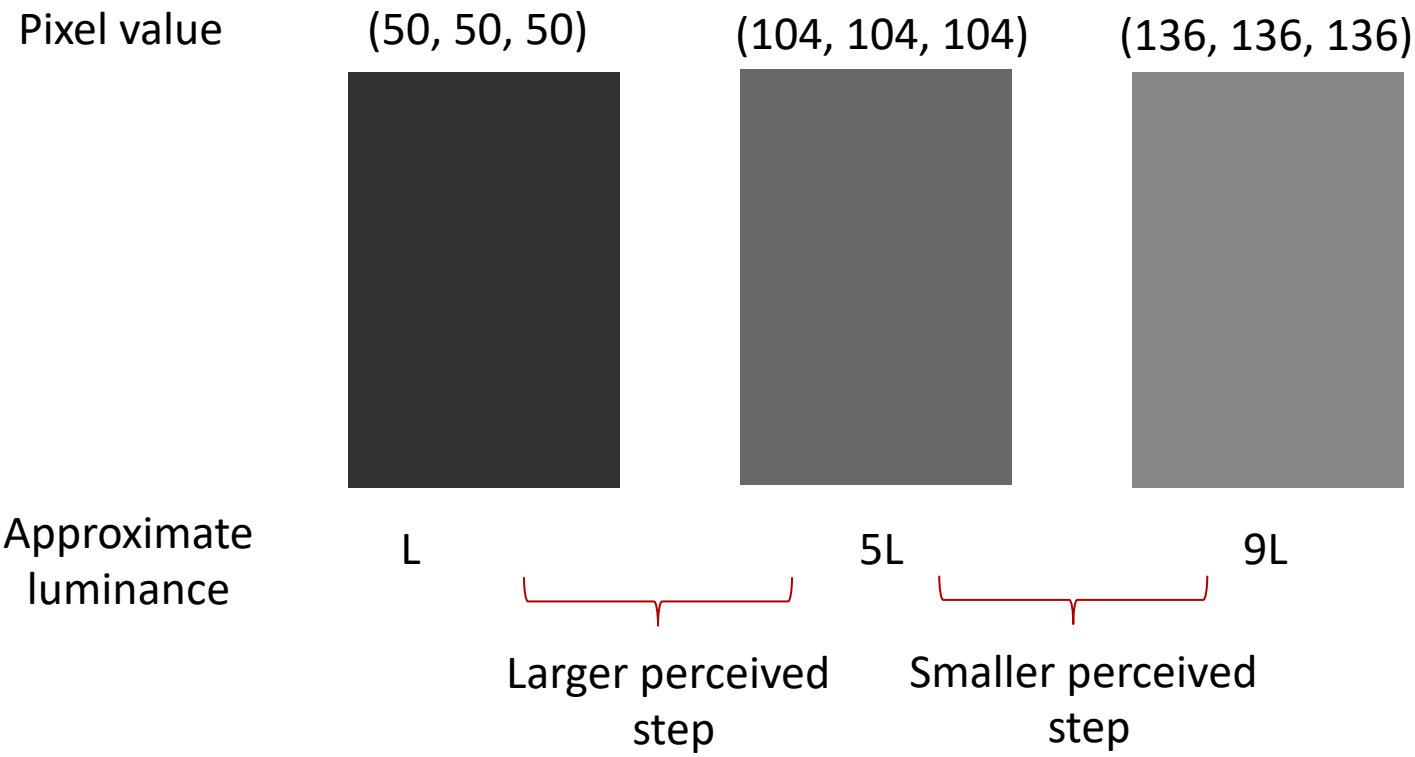
Non-linearity

- If $L = \left(\frac{50}{255}\right)^{2.2}$ then what is x such that $5L = \left(\frac{x}{255}\right)^{2.2}$
- $5 = \left(\frac{x}{50}\right)^{2.2}$ therefore $x \cong 104$
- For the brightest patch (9L), $9 = \left(\frac{y}{50}\right)^{2.2}$ therefore $y \cong 136$



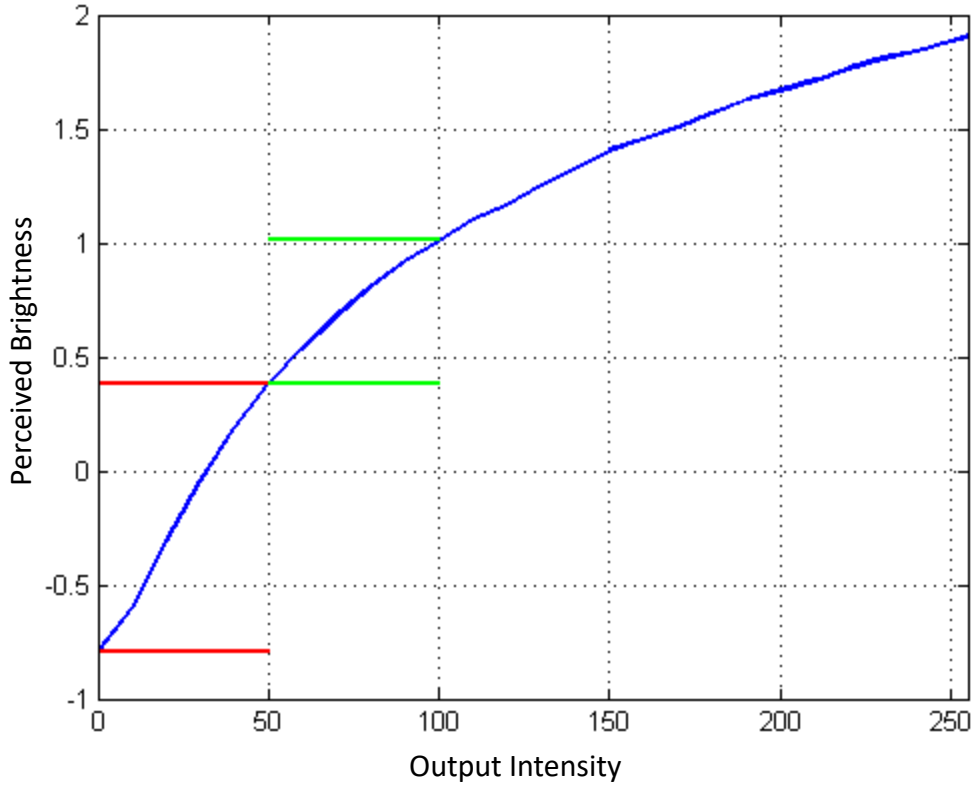
Non-linearity

- Equal change in luminance **does not map** to equal change in perceived brightness



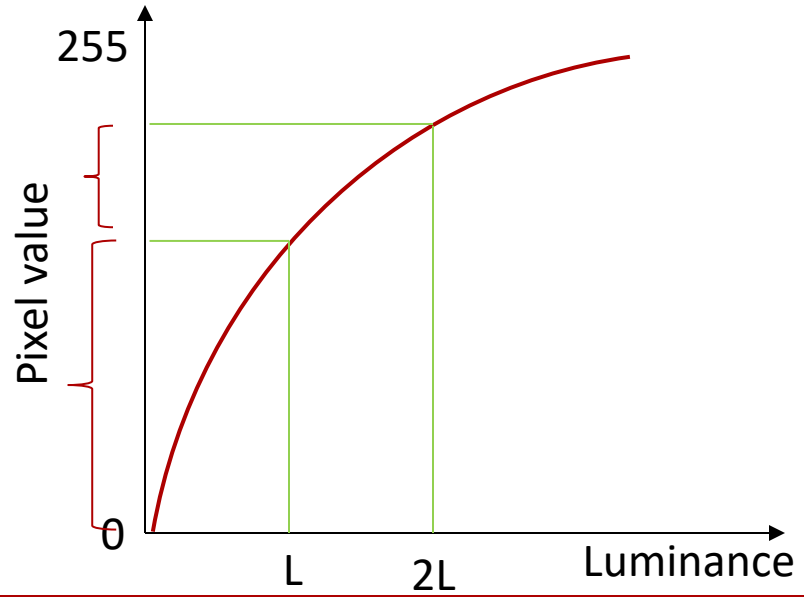
Non-linearity

- This can be explained by the perceived brightness curve:



Back to Gamma Correction

- When apply gamma correction to an image, we are somewhat mimicking the human non-linear response
- We are using more bits to represent luminances to which we are more sensitive



This creates the appearance of more smooth transition between intensity values

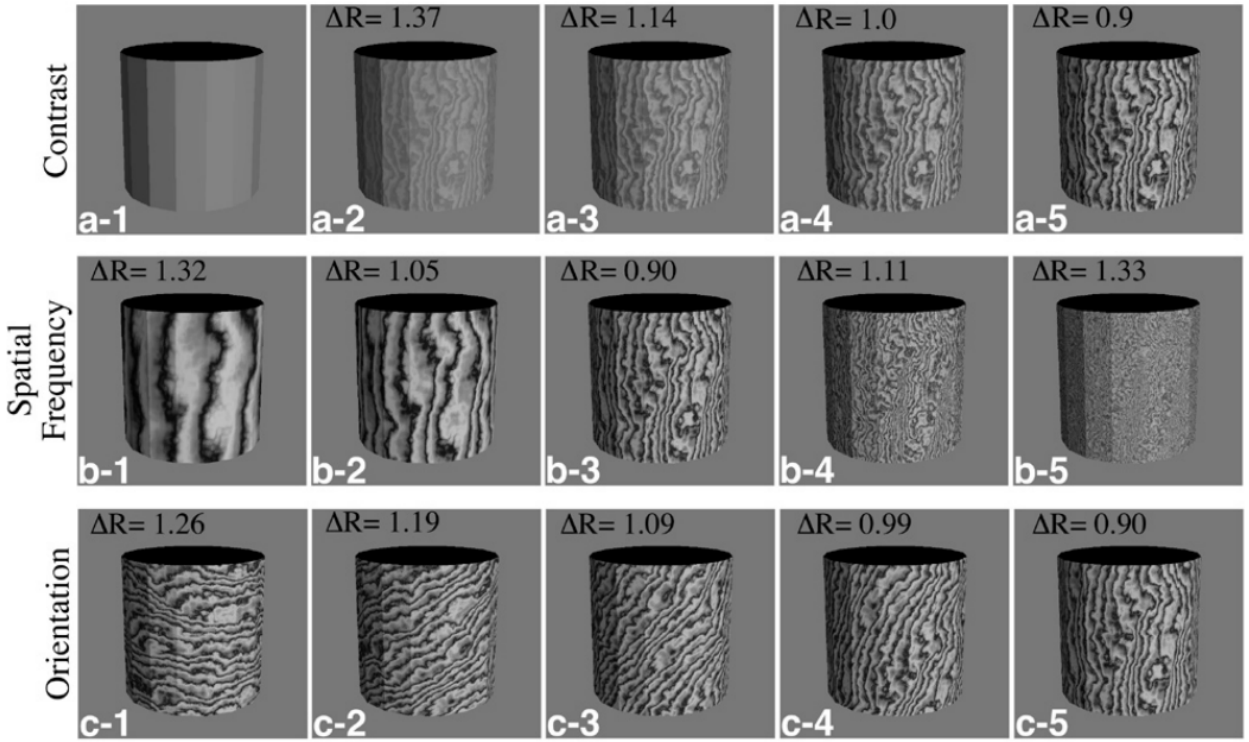
Perception and Graphics

- Understanding visual perception allows for various optimizations in computer graphics
- For example, we can use lower polygon count if the visual system cannot understand it due to presence of a texture

Ferwerda et al. 1997: A Model of Visual Masking for Computer Graphics

Perception and Graphics

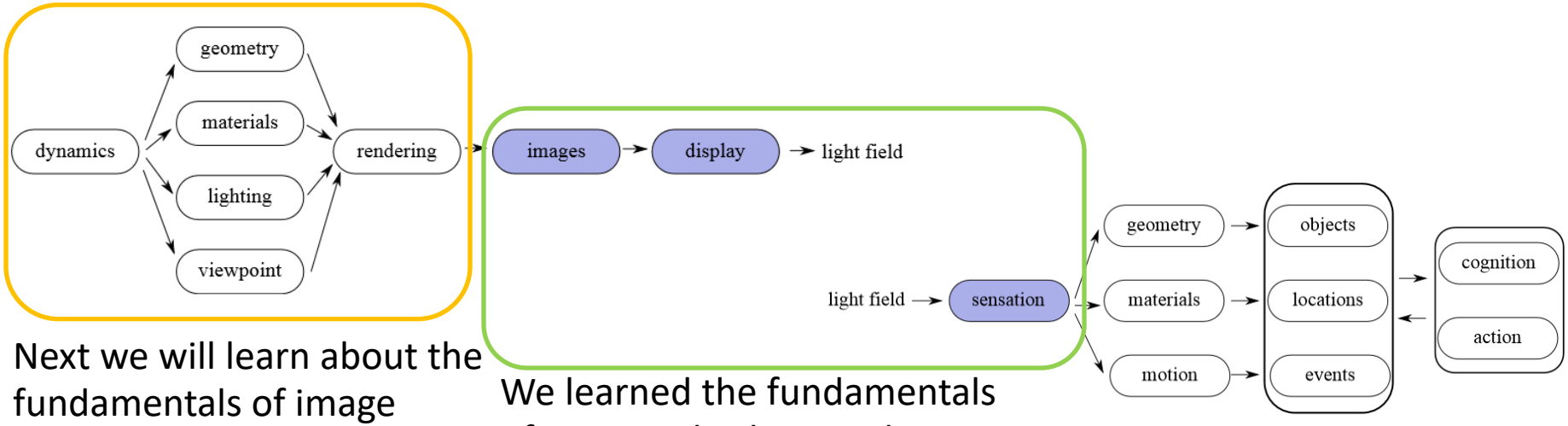
- All cylinders have the same number of polygons but this is masked under textures with different properties



Ferwerda et al. 1997: A Model of Visual Masking for Computer Graphics

Summary

- In CG, images (frames) are rendered and then are either written to a file or directly sent to a display device to be perceived by an observer

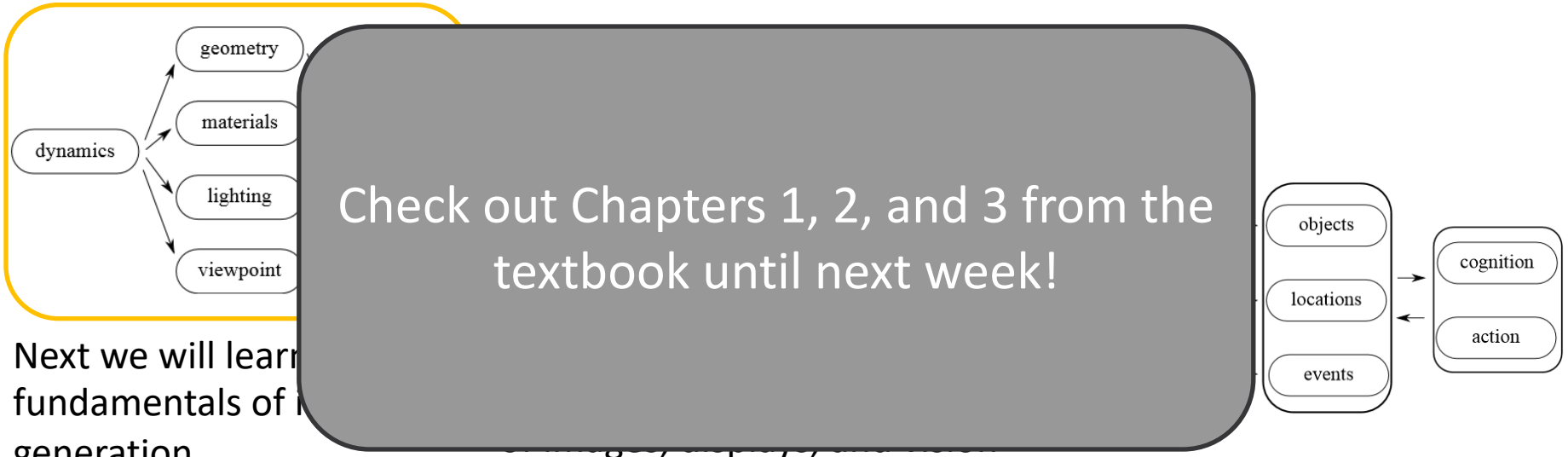


Next we will learn about the fundamentals of image generation

We learned the fundamentals of images, displays, and vision

Summary

- In CG, images (frames) are rendered and then are either written to a file or directly sent to a display device to be perceived by an observer



Check out Chapters 1, 2, and 3 from the textbook until next week!

Next we will learn
fundamentals of
generation