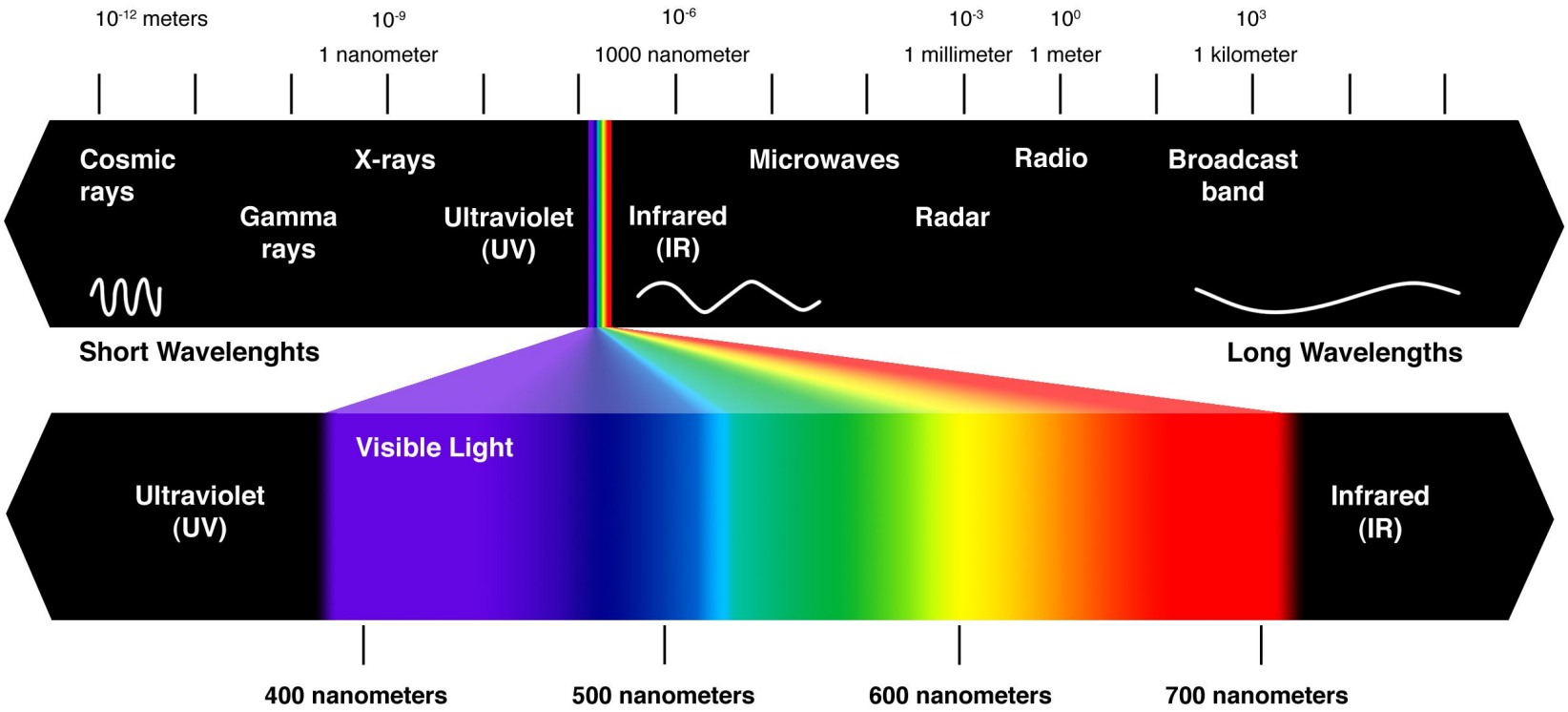
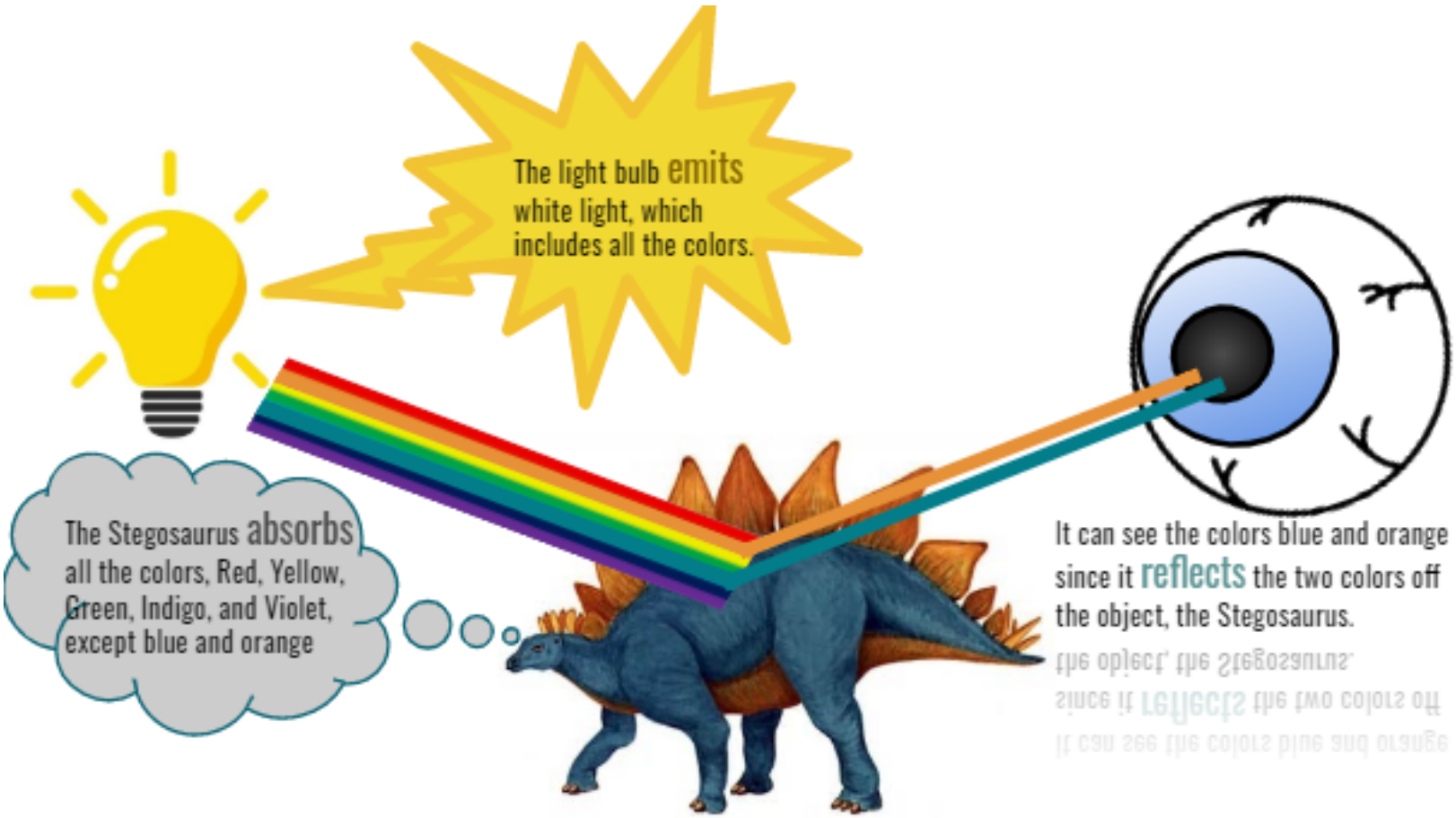
CS 461 - Computer Graphics

Colors

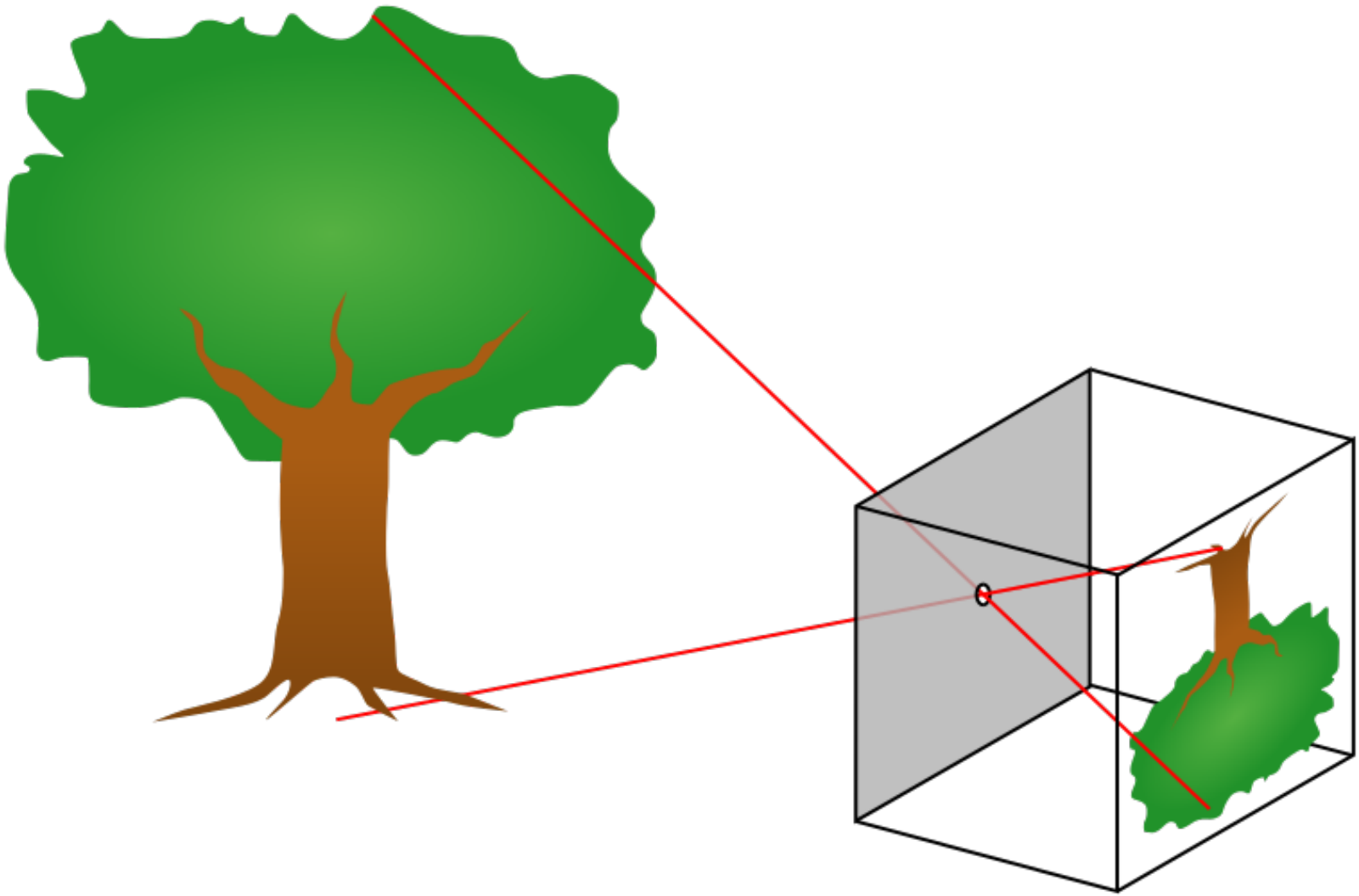
Visible Spectrum



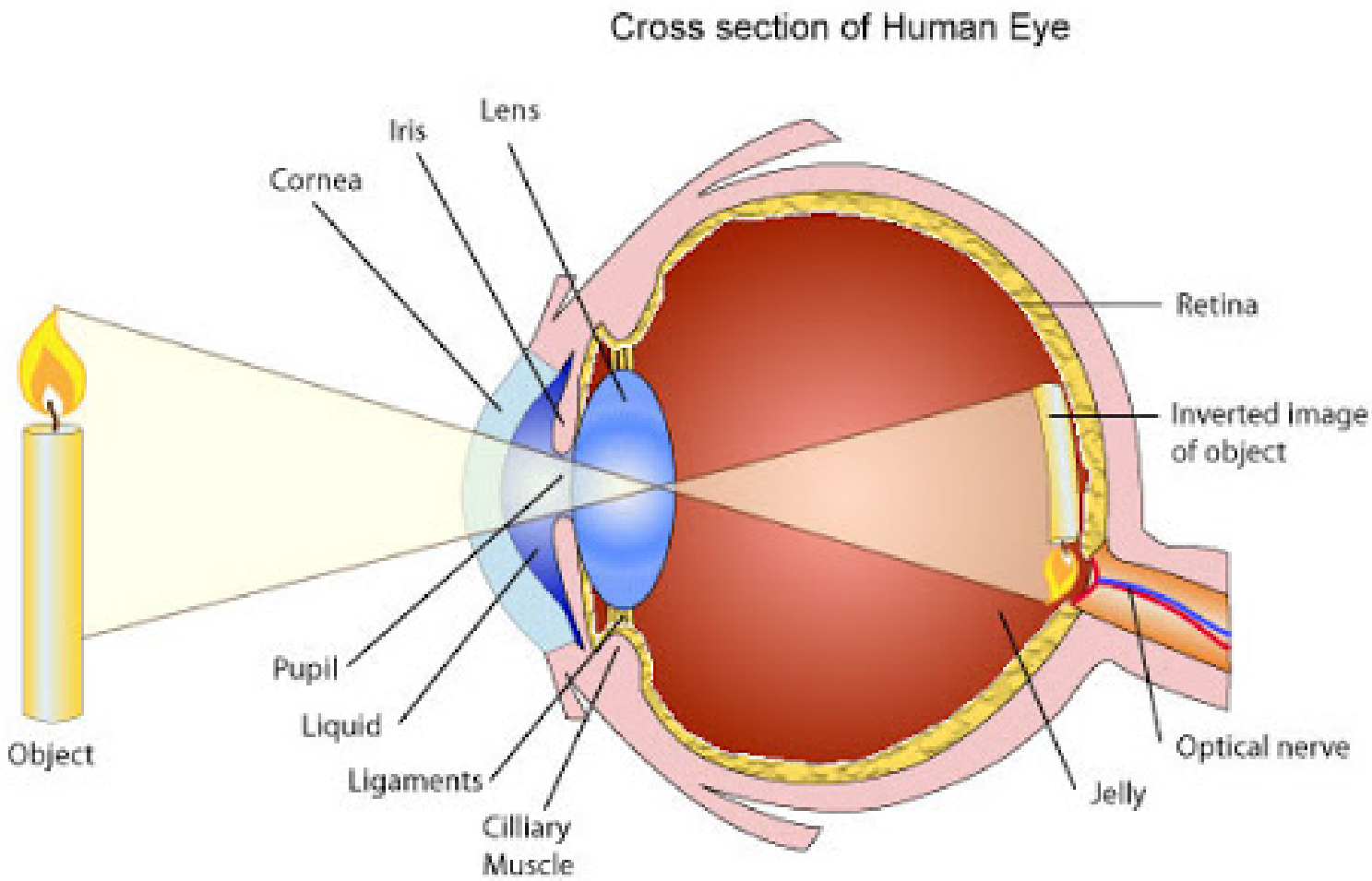
How it works


The light bulb emits white light, which includes all the colors.
The Stegosaurus absorbs all the colors, Red, Yellow, Green, Indigo, and Violet, except blue and orange
It can see the colors blue and orange since it reflects the two colors off the object, the Stegosaurus.

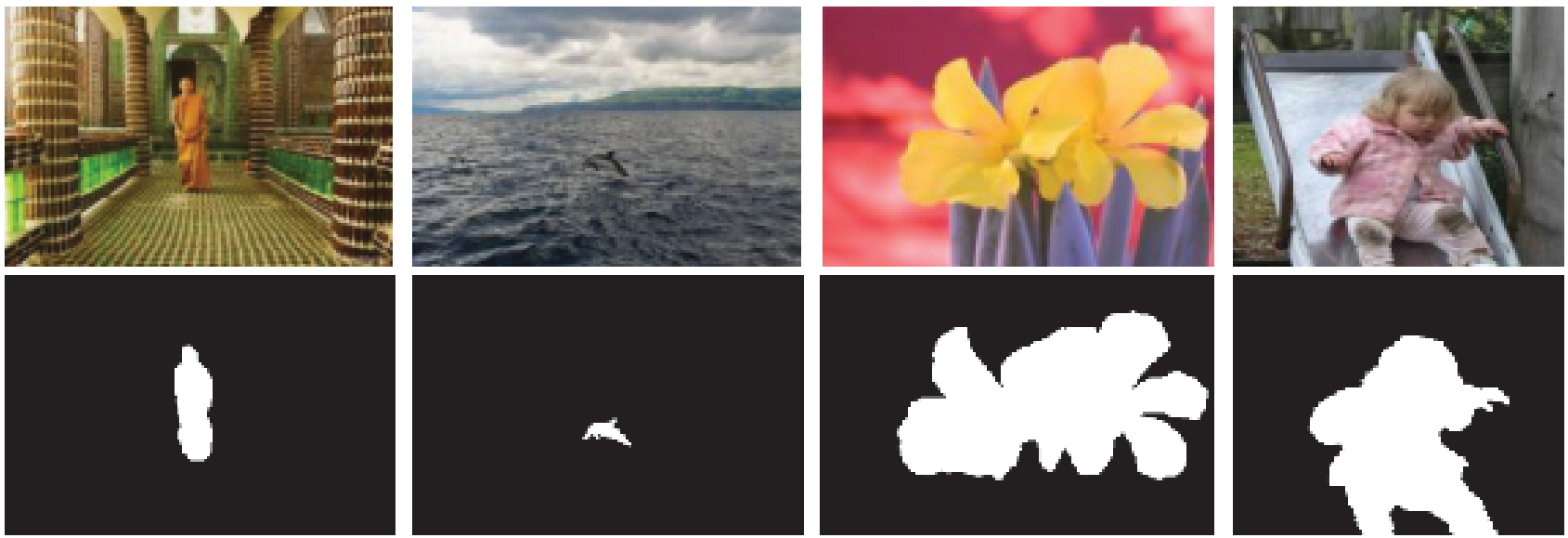
Pin hole camera



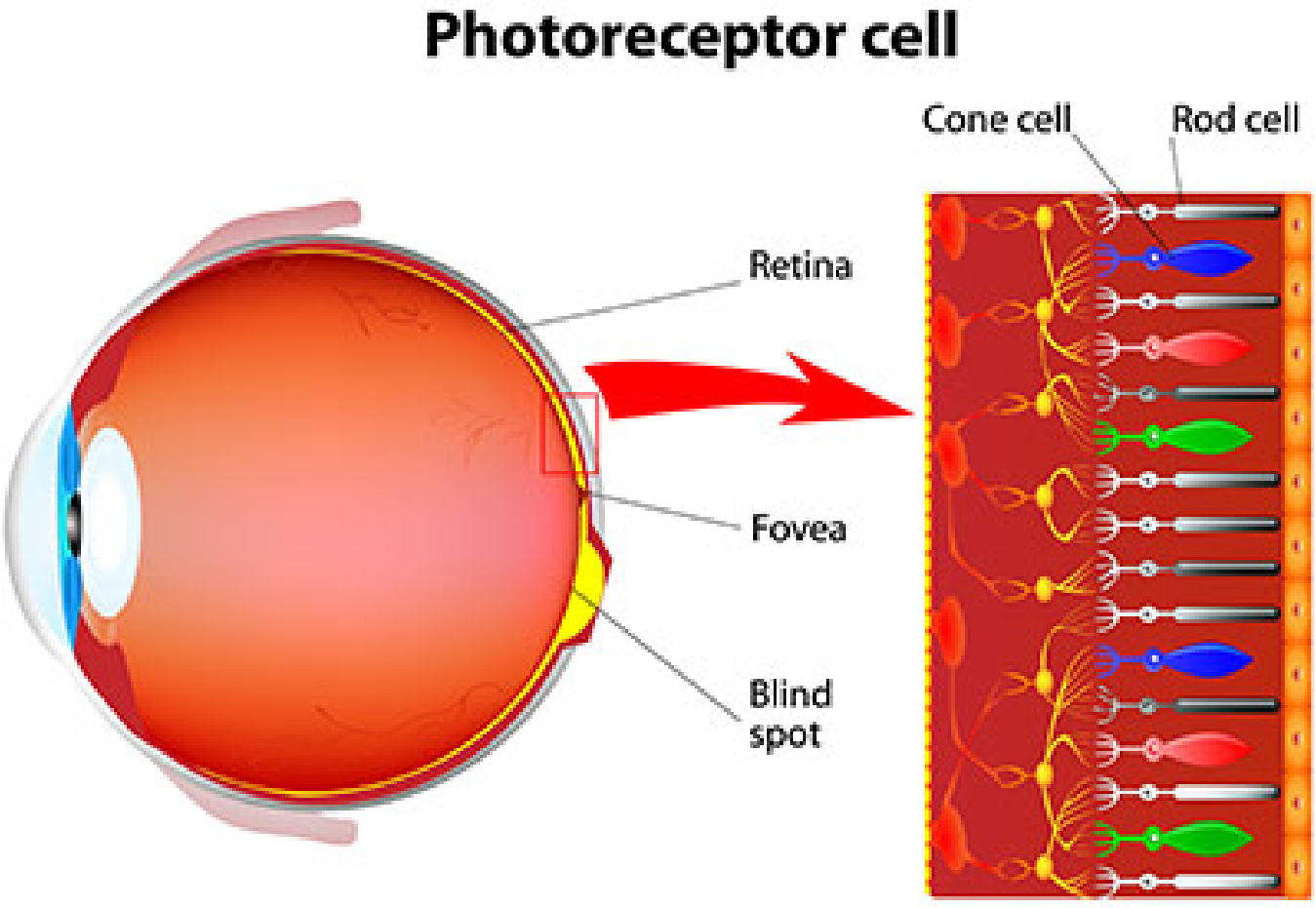
Human Eye


Cross section of Human Eye
Lens
Iris
Cornea
Retina
Inverted Image
of object
Pupil
Liquid
Ligaments
Cilliary
Muscle
Jelly
Optical nerve
Object

Visual Saliency



Cones & Rods

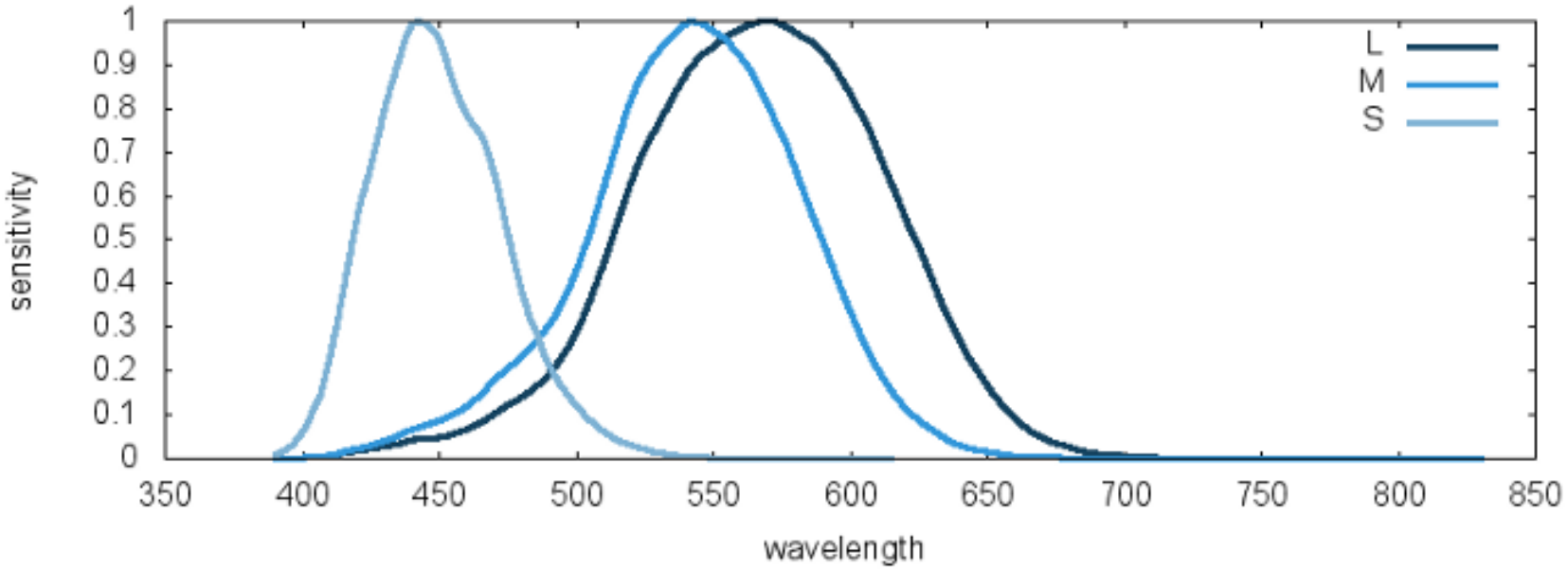

Photoreceptor cell
Cone cell
Rod cell
Retina
Fovea
Blind spot

Chromaticity

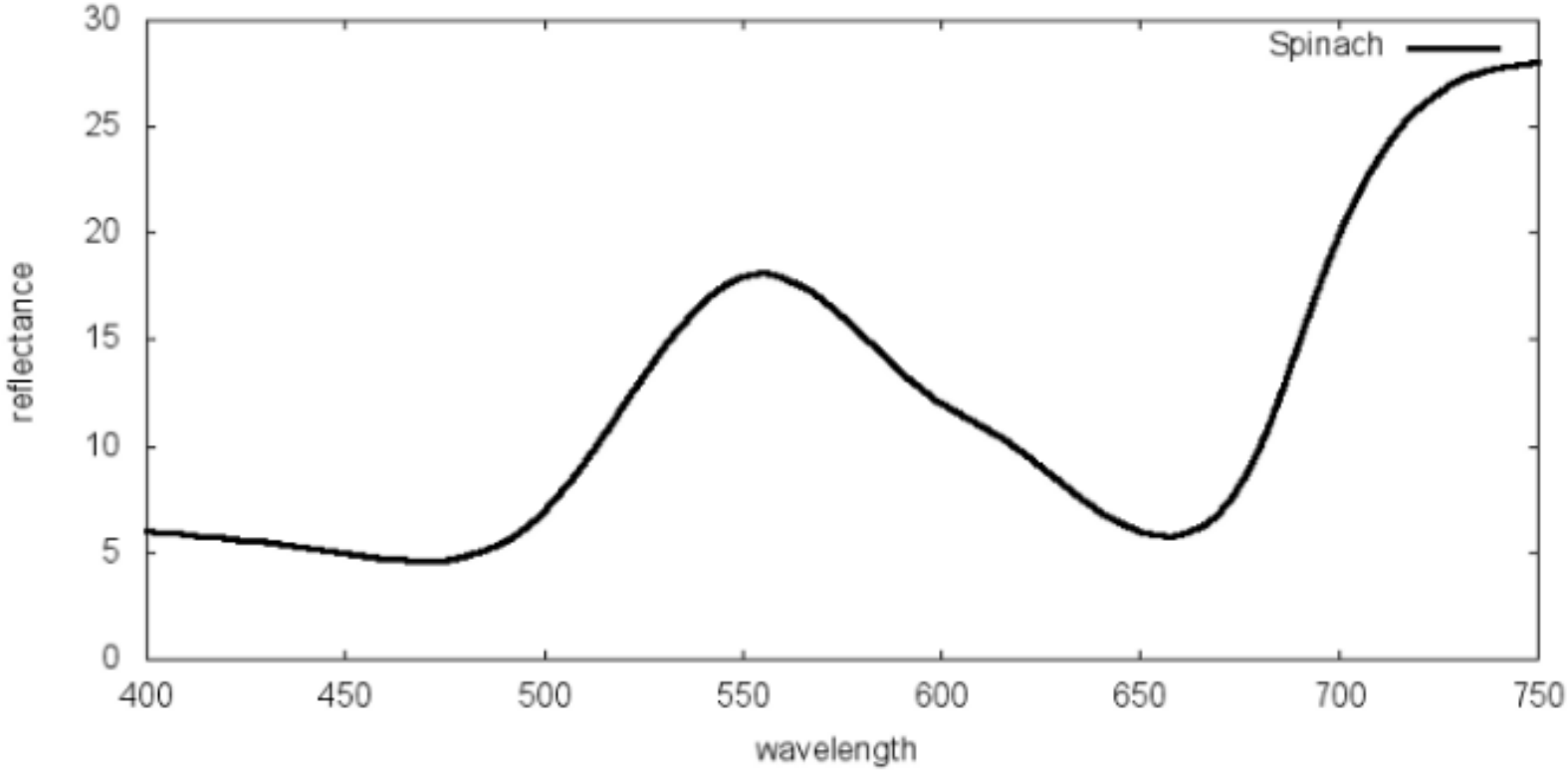
Color vision table

State	Types of cone cells	Approx. number of colors perceived	Carriers
Monochromacy	1	200	Marine mammals, owl monkey, Australian sea lion, achromat primates
Dichromacy	2	40,000	Most terrestrial non-primate mammals, color blind primates
Trichromacy	3	10 million[49]	Most primates, especially great apes (such as humans), marsupials, some insects (such as honeybees)
Tetrachromacy	4	100 million	Most reptiles, amphibians, birds and insects, rarely humans
Pentachromacy	5	10 billion	Some insects (specific species of butterflies), some birds (pigeons for instance)

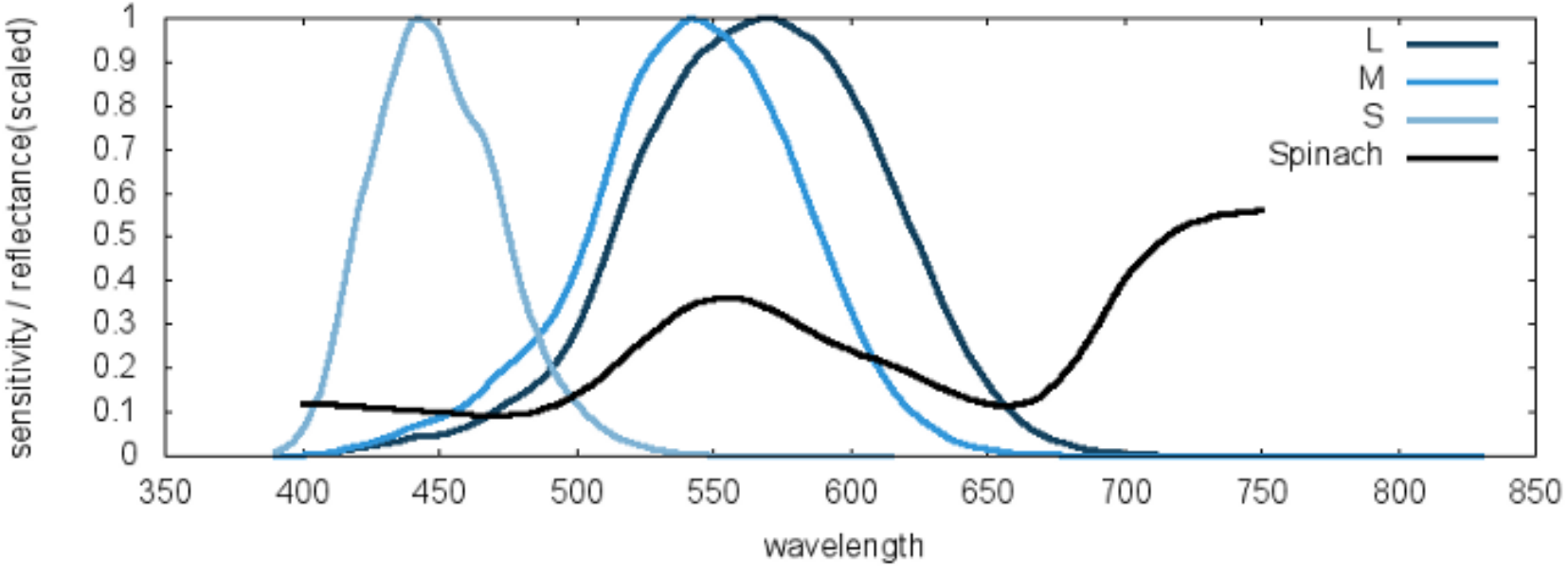
Photoreceptors



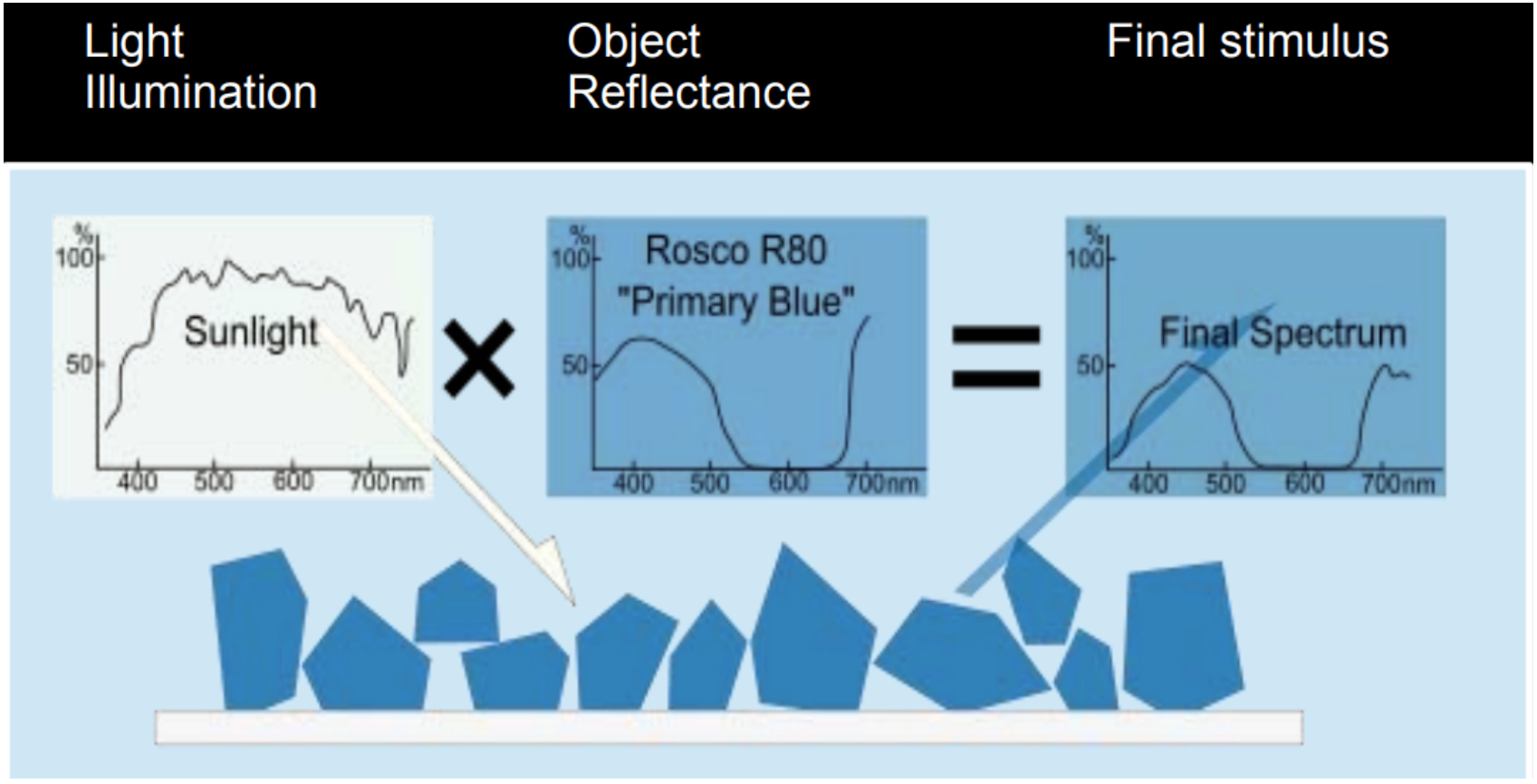
Reflecting the light



Overlapping the signals

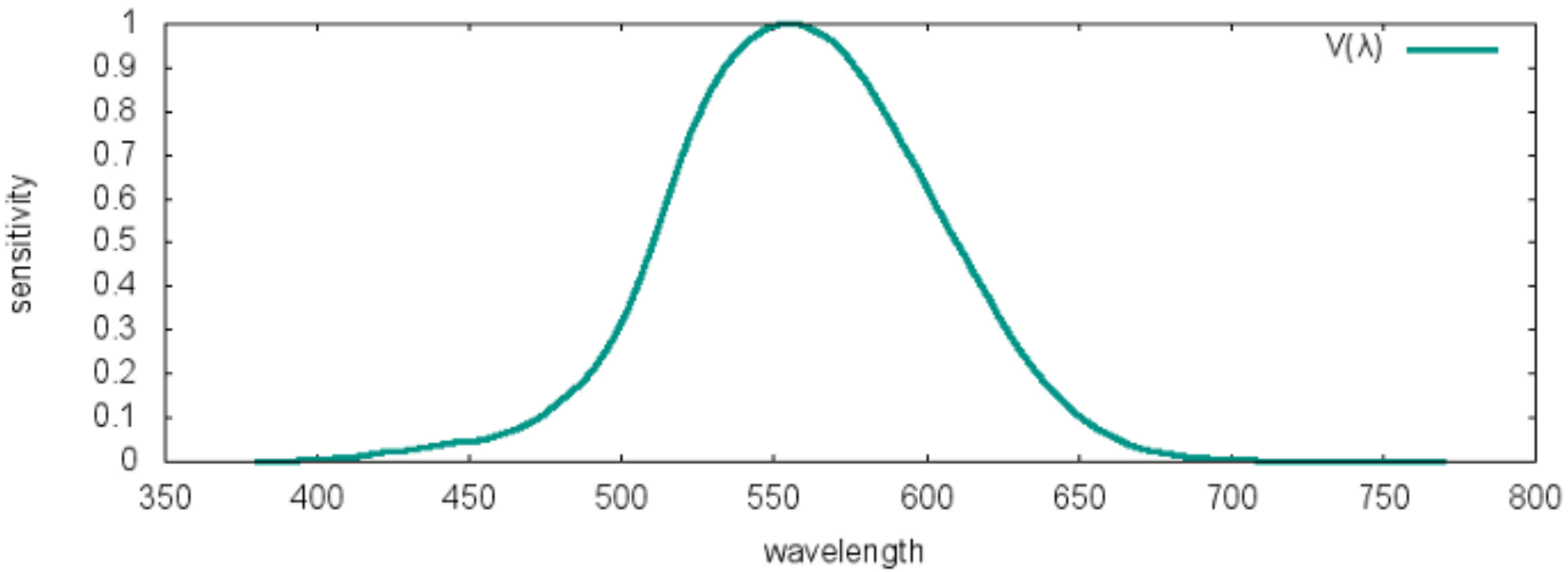


Stimulus

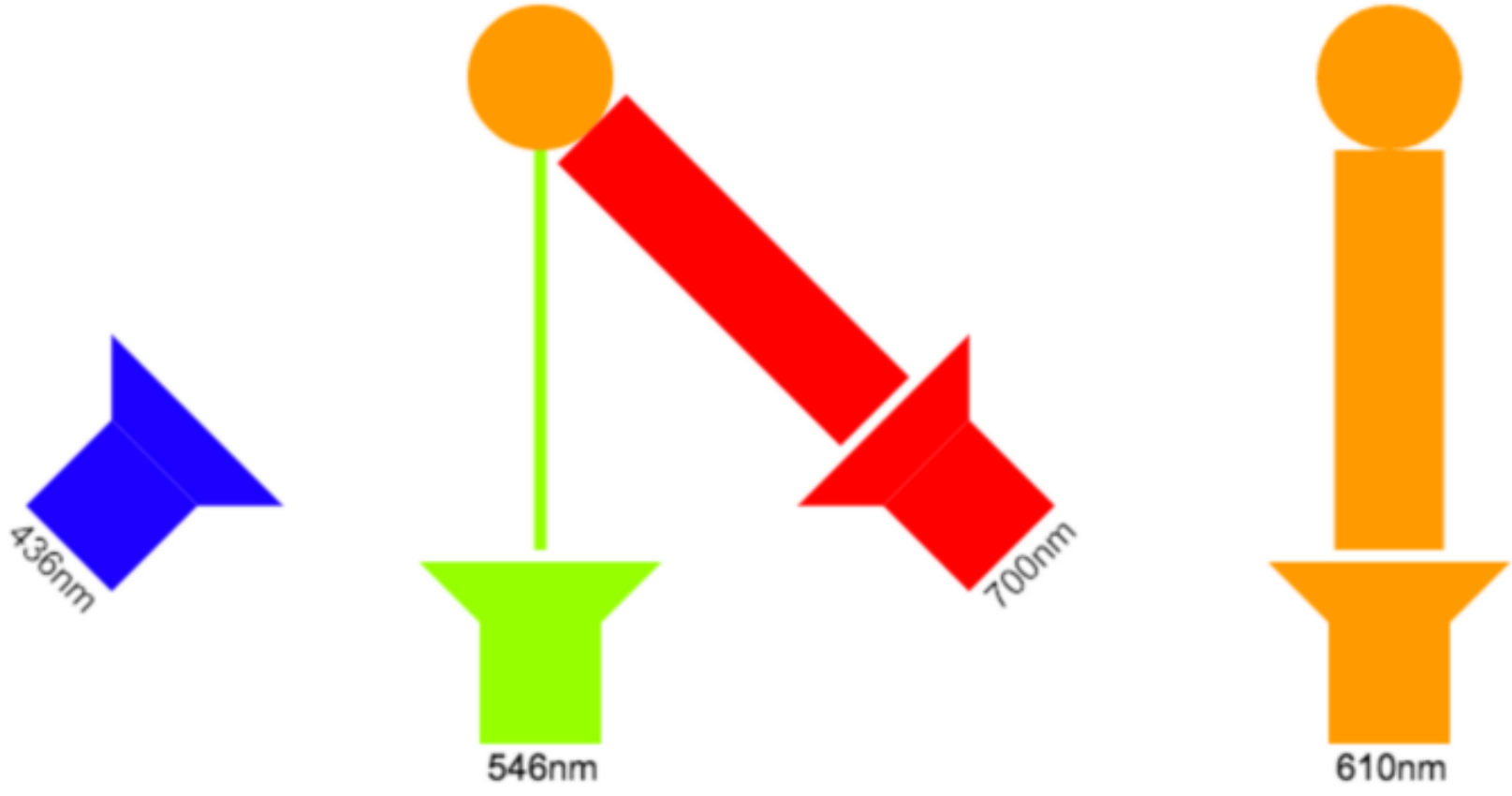

Light
Illumination
Object
Reflectance
Final stimulus
%
100
50
Sunlight
400
500
600
700nm
Rosco R80
"Primary Blue"
Final Spectrum

1924 Luminous Efficiency Function, V(λ)

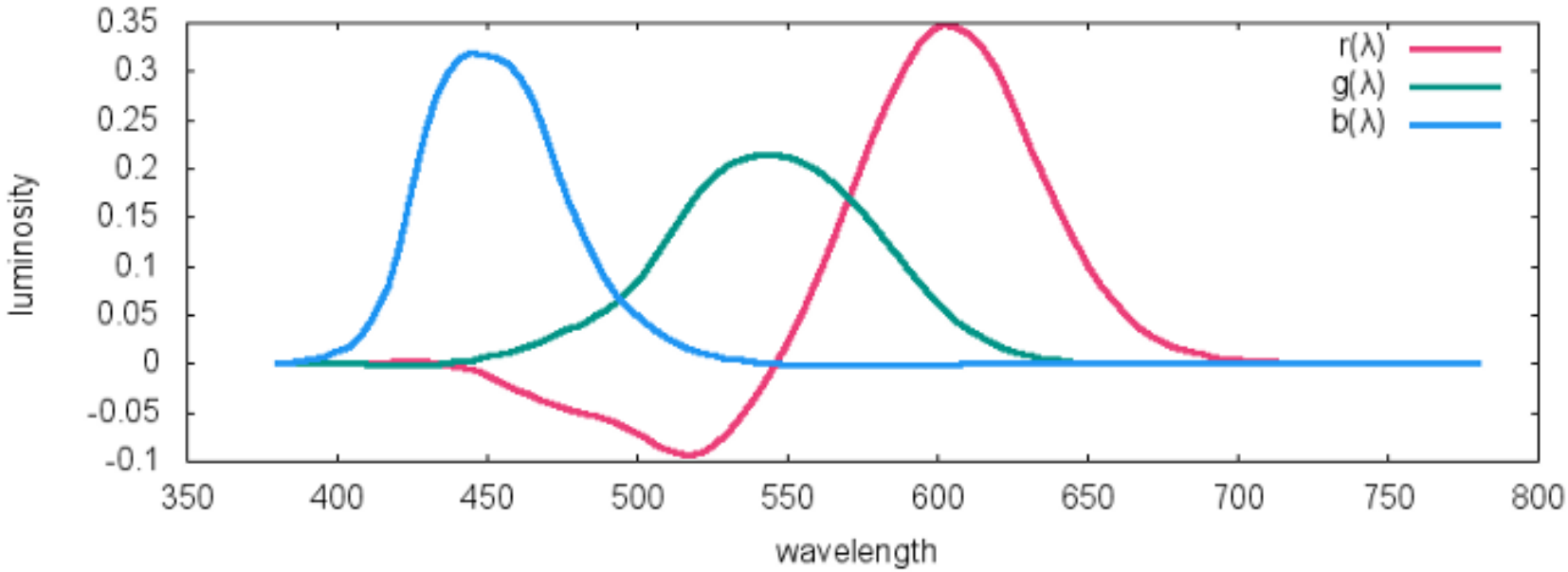
- Function that describes the human eye's sensitivity to light at different wavelengths in daylight
- If you have a green and blue light that appear to be equally bright, then you know that the blue light is more luminous



1931 RGB Color Matching Functions

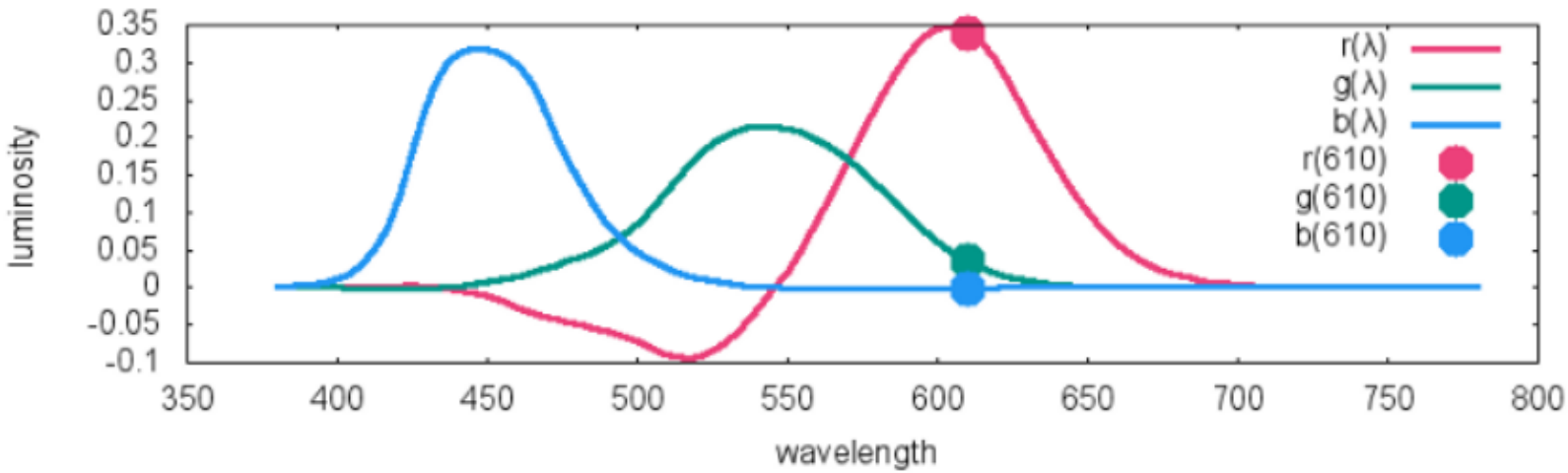


1931 RGB Color Matching Functions



1931 RGB Color Matching Functions

```
λ = 610nm r(λ) = 0.34756 g(λ) = 0.04776 b(λ) = -0.00038
```

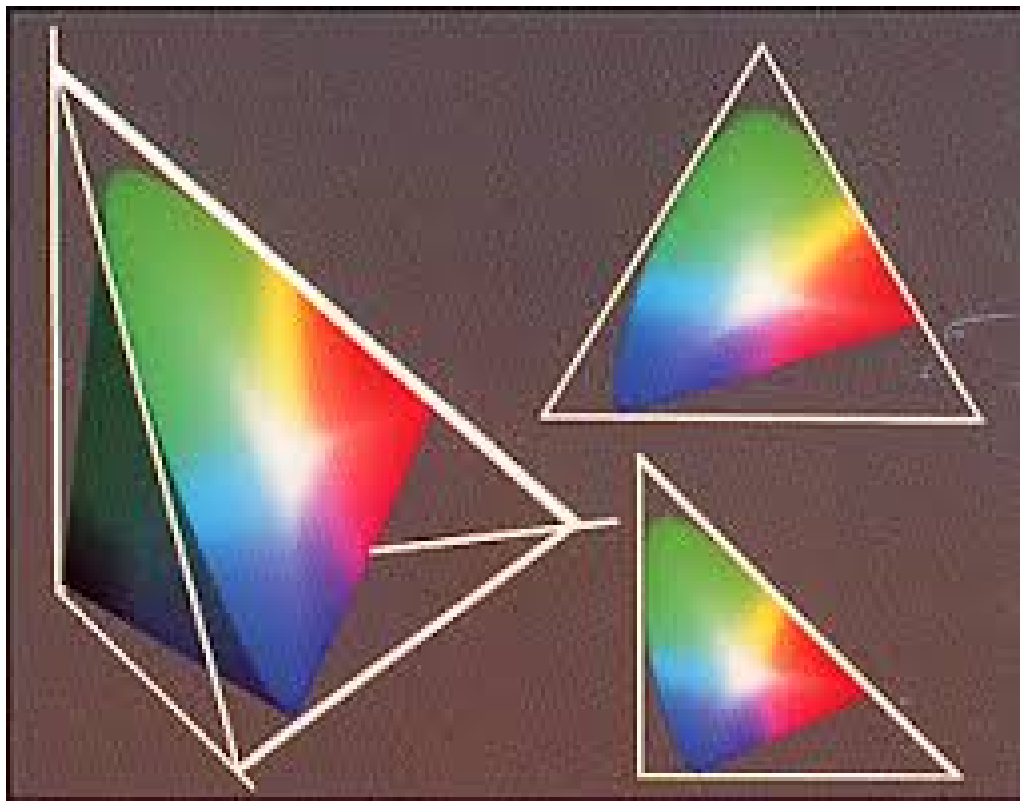


Tristimulus values

- Functions are scaled as if all the primary lights are equally bright
- Blue light must be more luminous than an equally bright green light
- Un-scaling to get absolute luminance

```
Lr = 1 # r luminance scale
Lg = 4.5907 # g luminance scale
Lb = 0.0601 # b luminance scale
λ = 610nm
R = r(λ)/Lr = 0.34756
G = g(λ)/Lg = 0.04776
B = b(λ)/Lb = -0.00038
```

Chromaticity

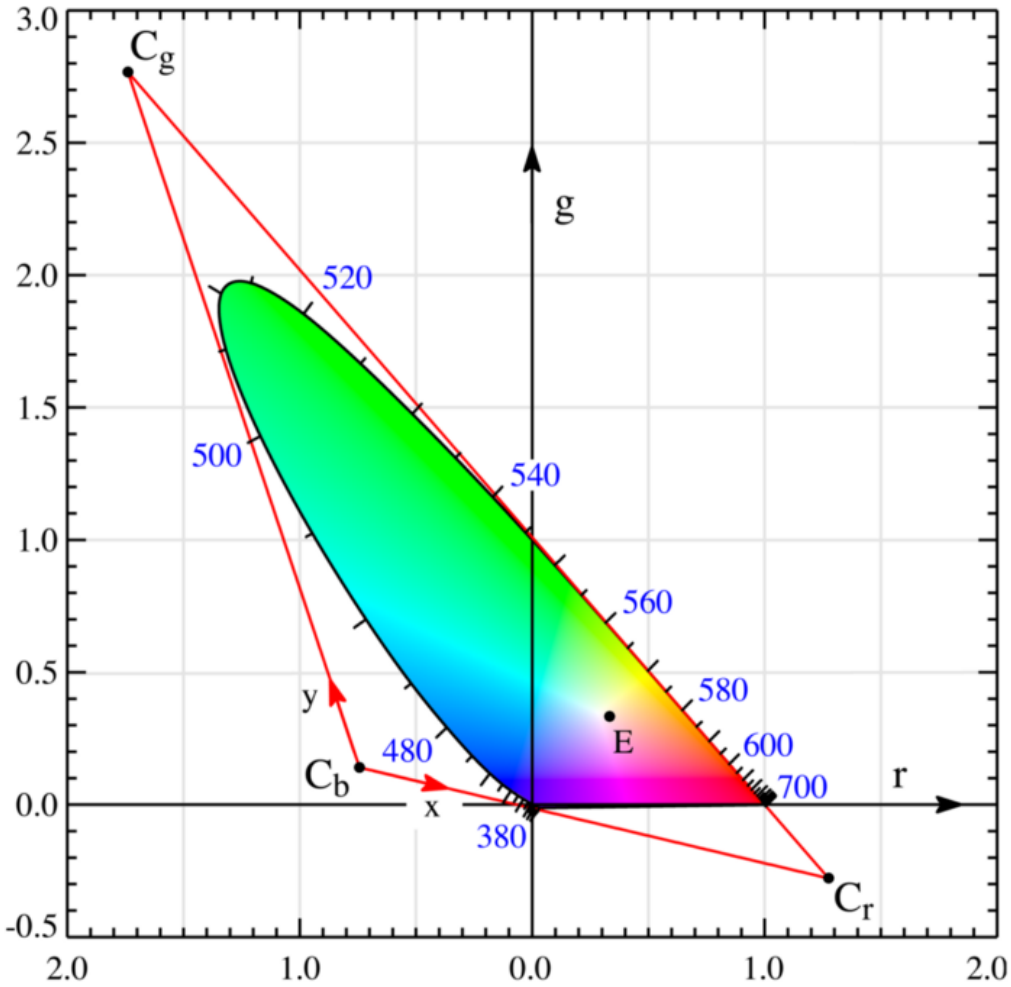


Chromaticity

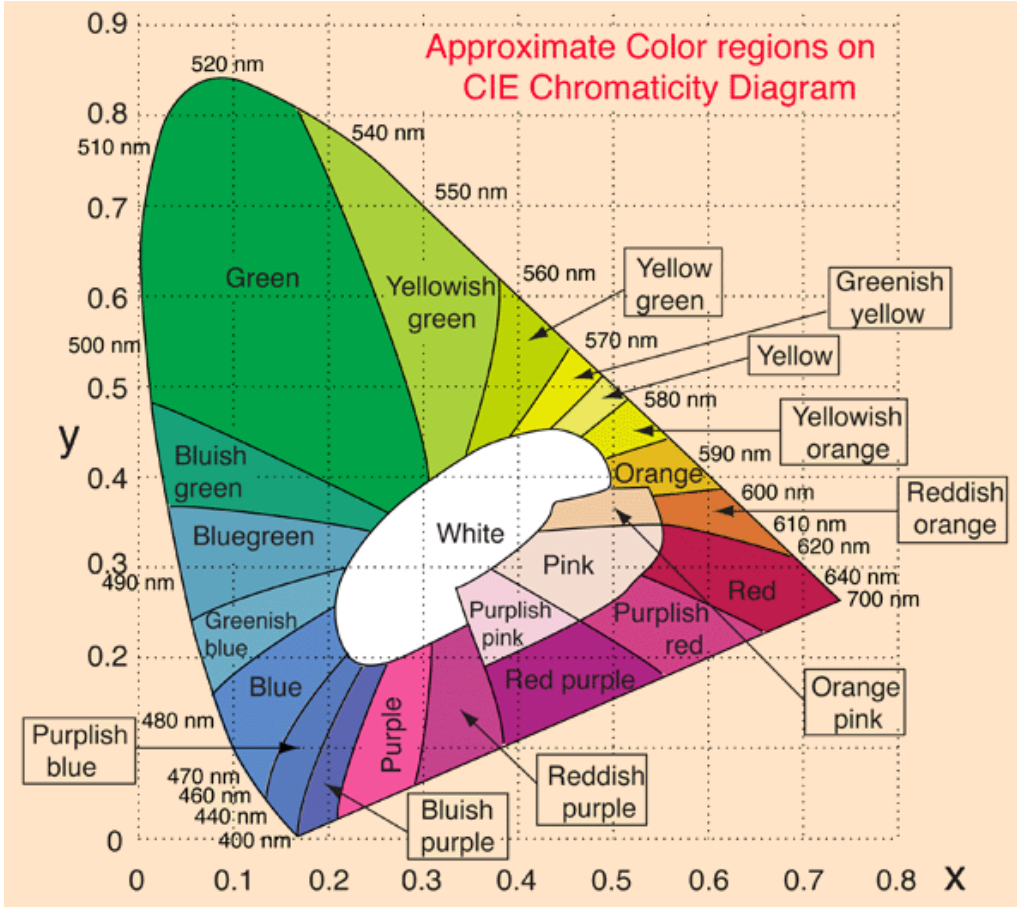
- Colors specified as three tristimulus values, like in the RGB, are difficult to visualize
- Remove the intensity dimension from the data, so that dark red and light red are the same value - Chromaticity

```
RGB are tristimulus values
r = R/(R+G+B)
g = G/(R+G+B)
b = B/(R+G+B)
rgb are chromaticity coordinates and r + g + b = 1
```

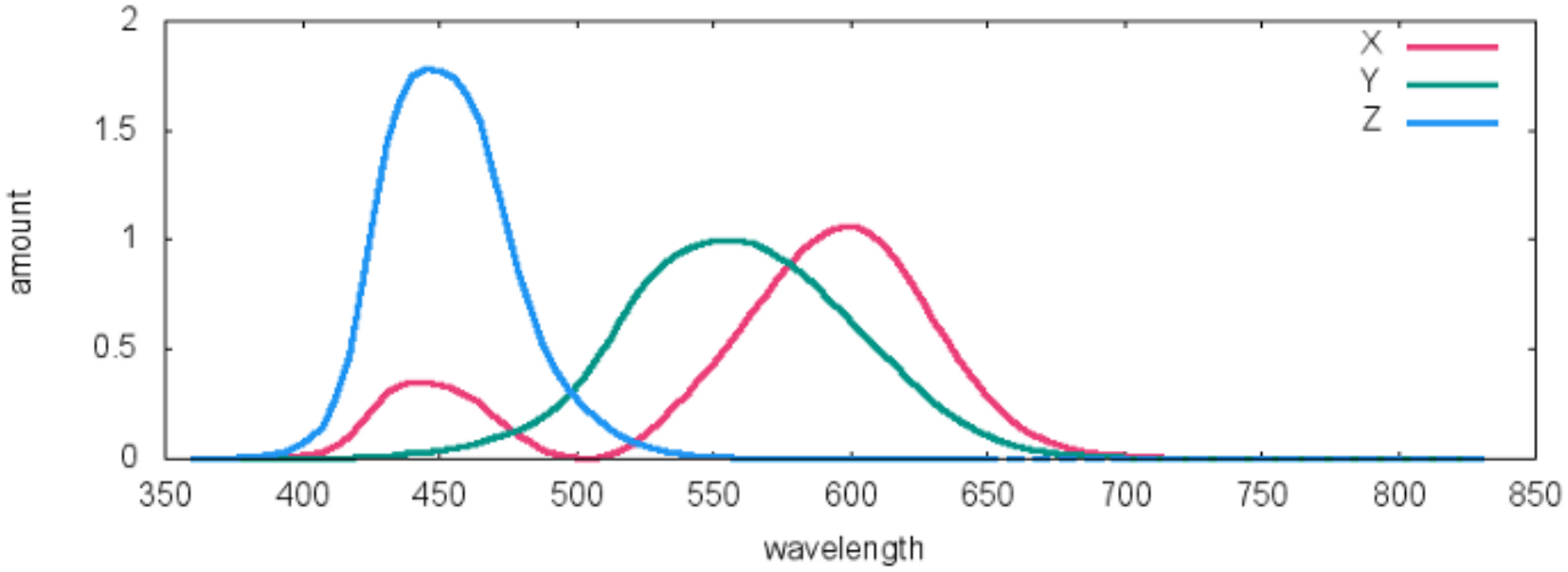
Chromaticity



CIE XYZ Color Space



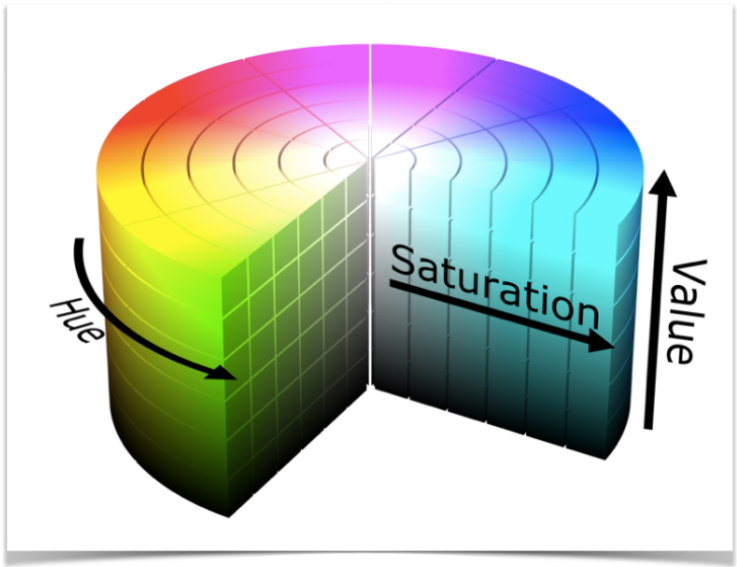
XYZ Color Matching Functions

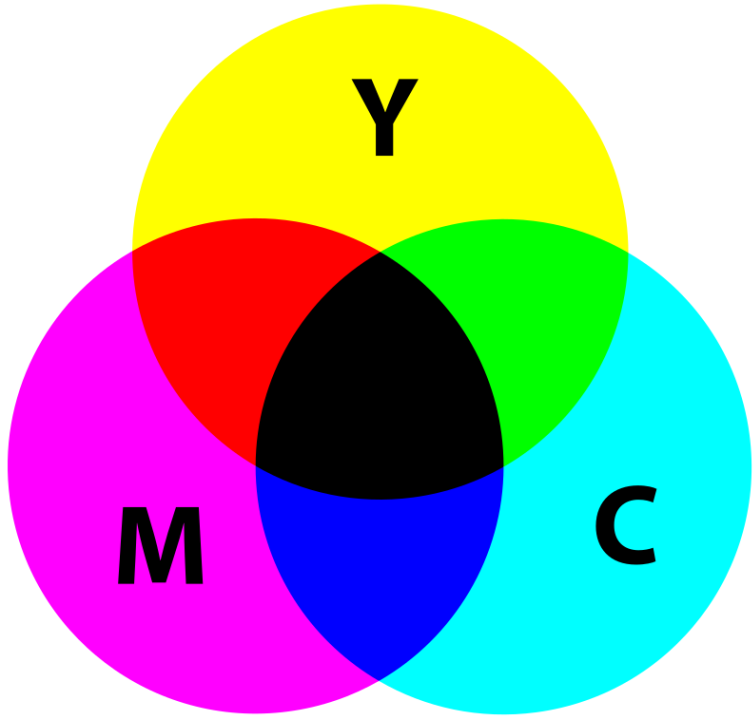


$$\begin{pmatrix} R \\ G \\ B \end{pmatrix} = \begin{pmatrix} 3.24 & -1.54 & -0.50 \\ -0.97 & 1.88 & 0.04 \\ 0.06 & -0.20 & 1.06 \end{pmatrix} \begin{pmatrix} X \\ Y \\ Z \end{pmatrix}$$

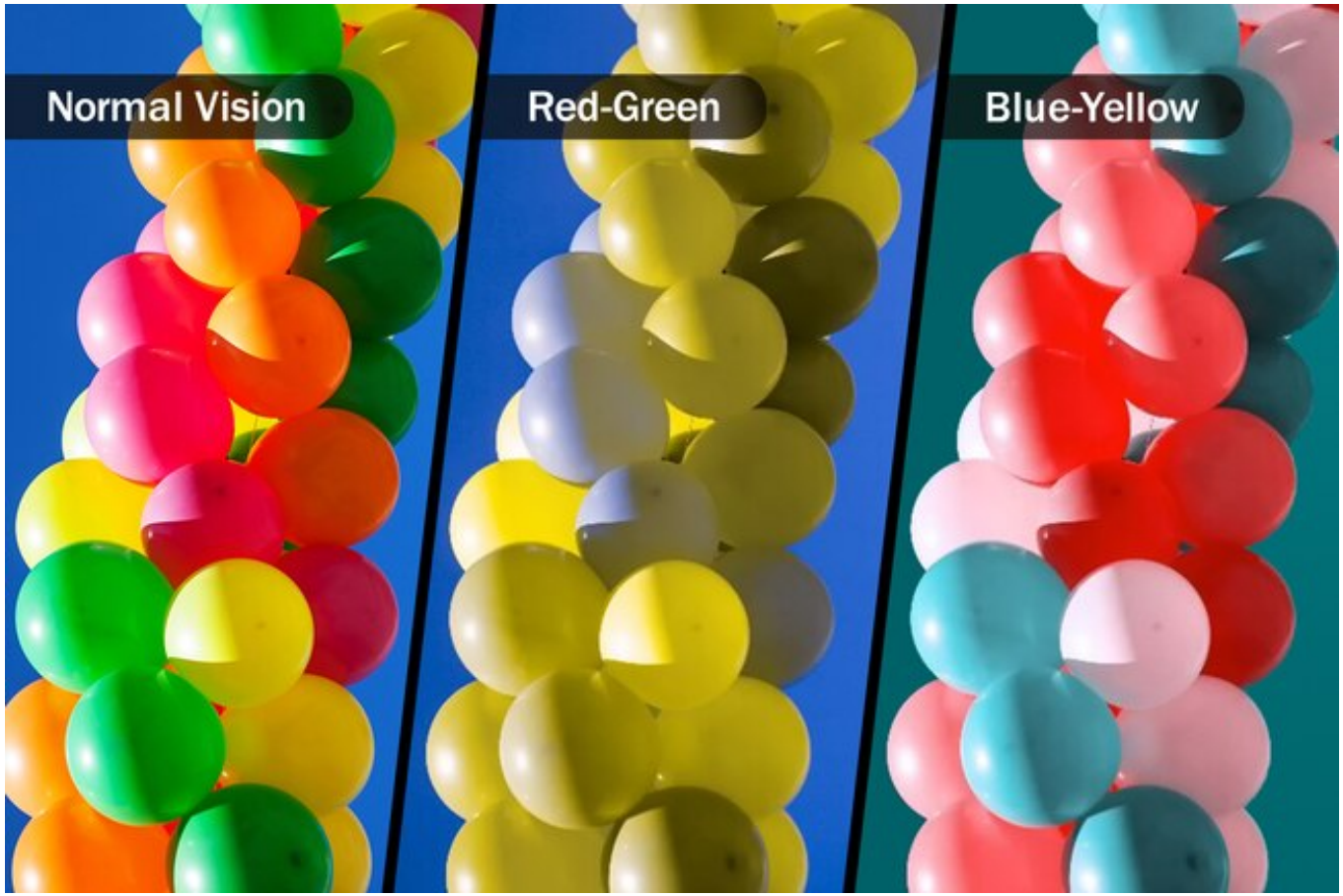
$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix} = \begin{pmatrix} 0.41 & 0.36 & 0.18 \\ 0.21 & 0.72 & 0.07 \\ 0.02 & 0.12 & 0.95 \end{pmatrix} \begin{pmatrix} R \\ G \\ B \end{pmatrix}$$

HSV & CMYK Color models





Color blindness



Ishihara Test

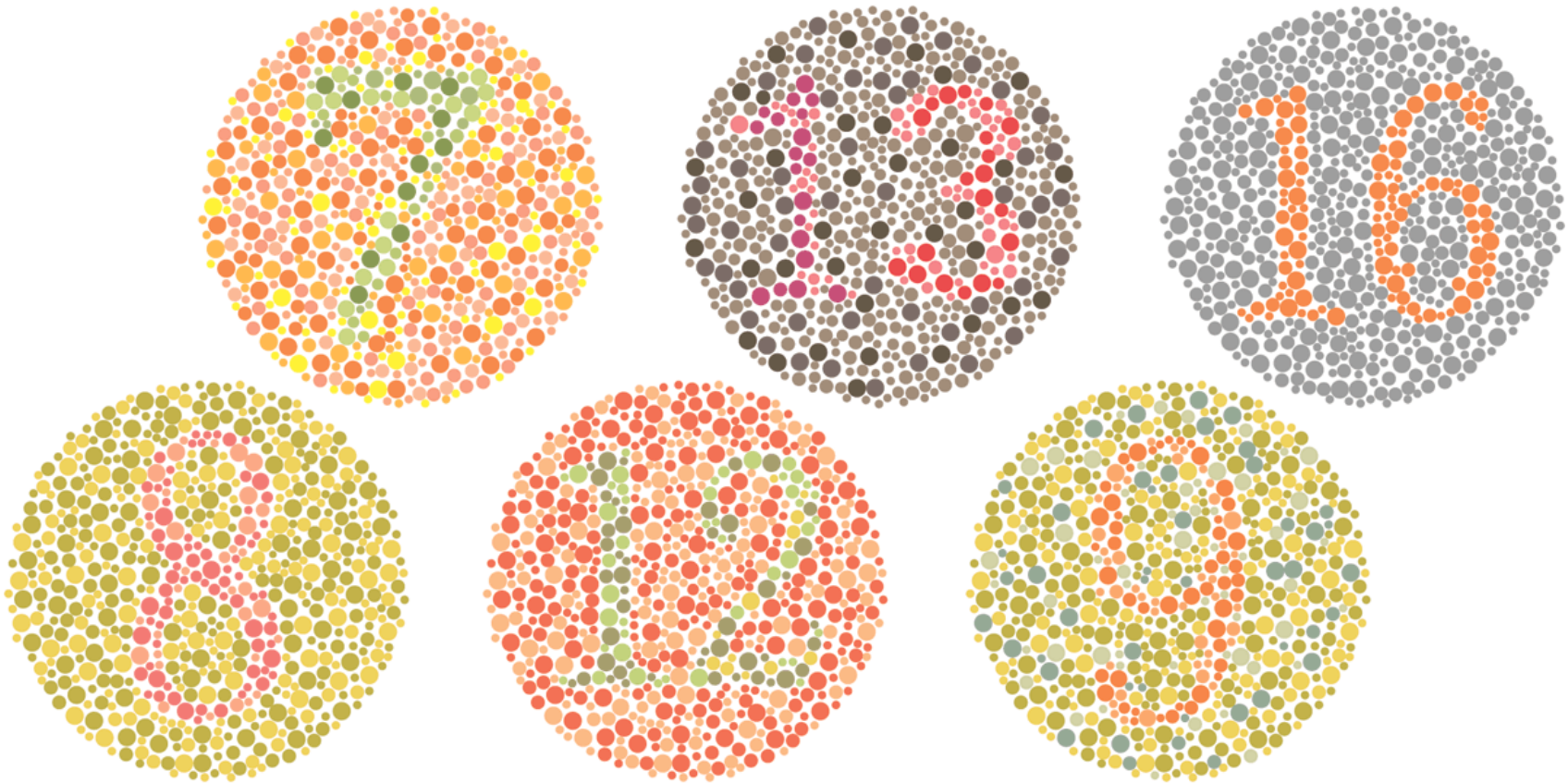


Image-Recoloring for Dichromats

Next class

- Only seminars on 10^{th}
- Next class: 12^{th} October - 9 to 10