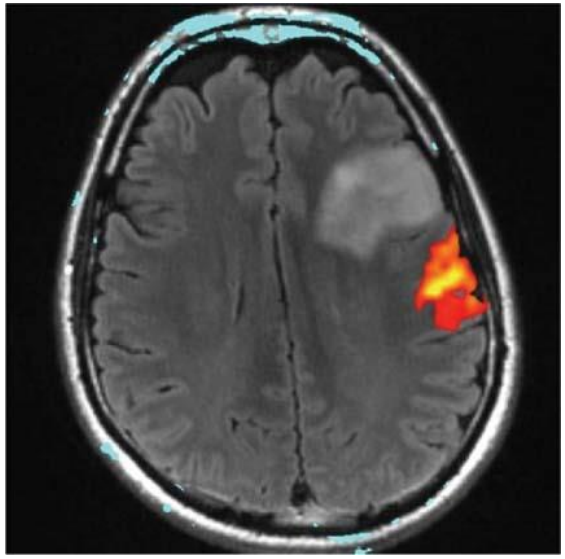
ECE 4973: Lecture 8
Color and representation

Samuel Cheng

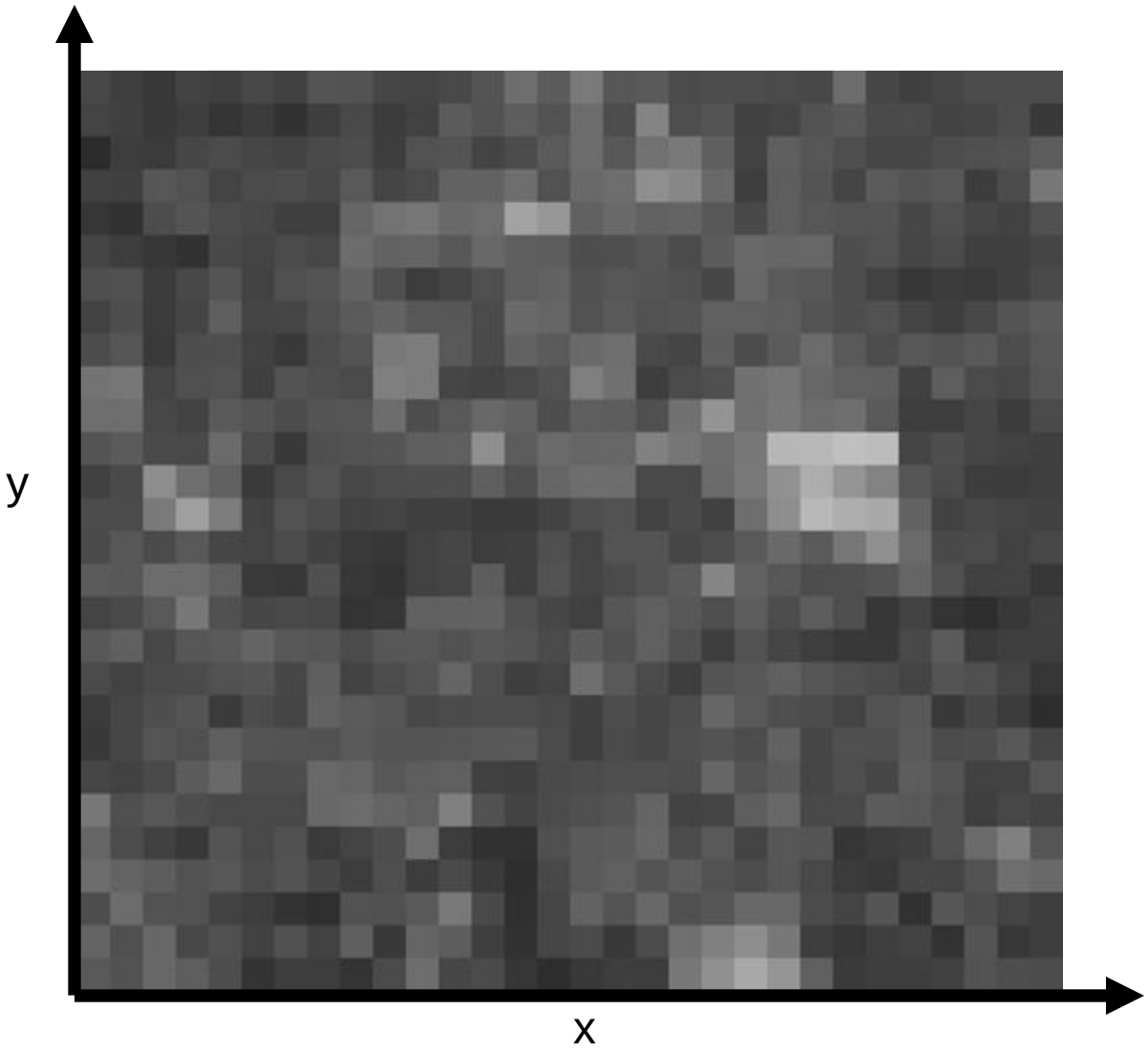
Slide credits: James Thompkin, Juan Carlos Niebles and Ranjay Krishna

WHAT IS AN IMAGE?



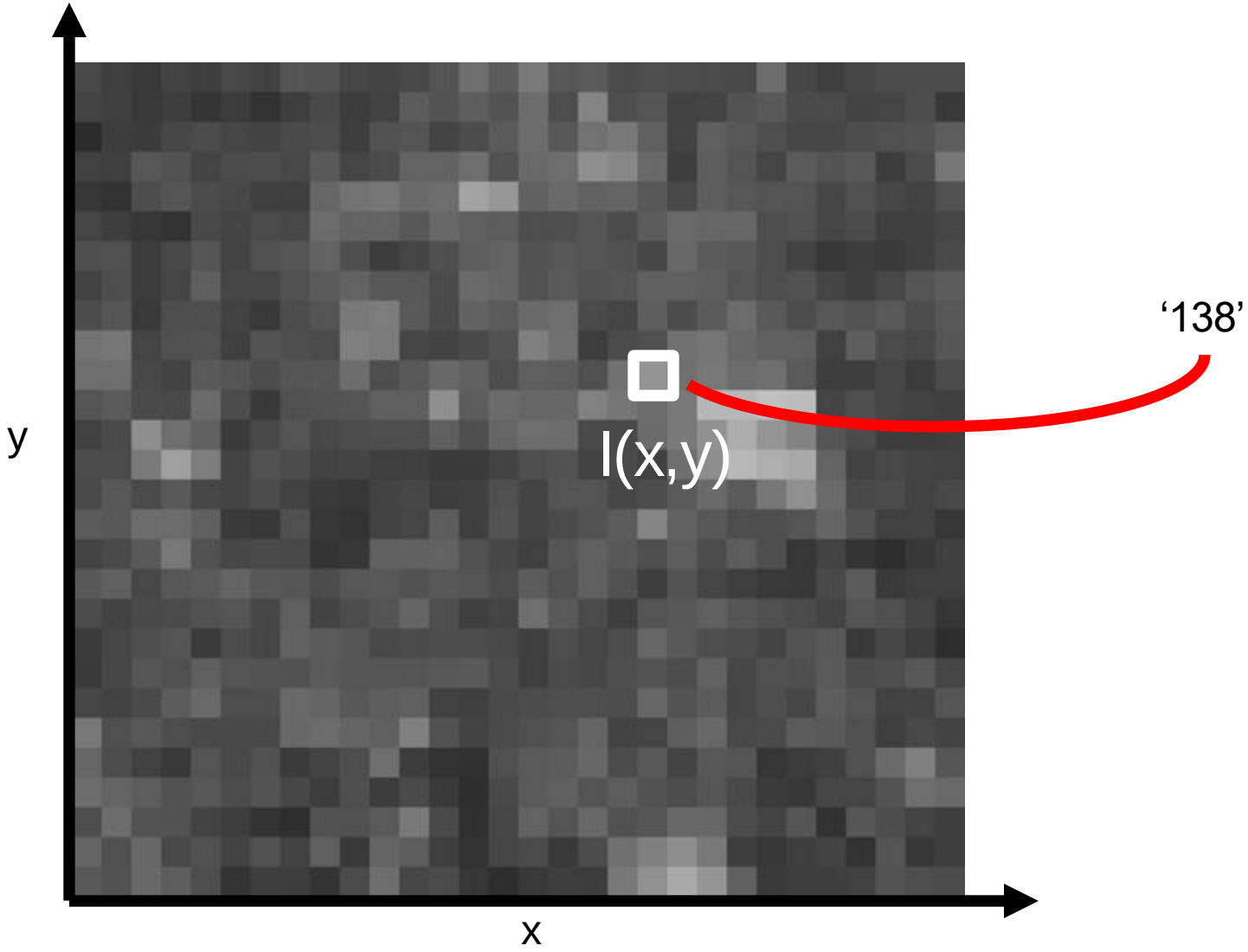
Danny Alexander

What is each part of a greyscale image?

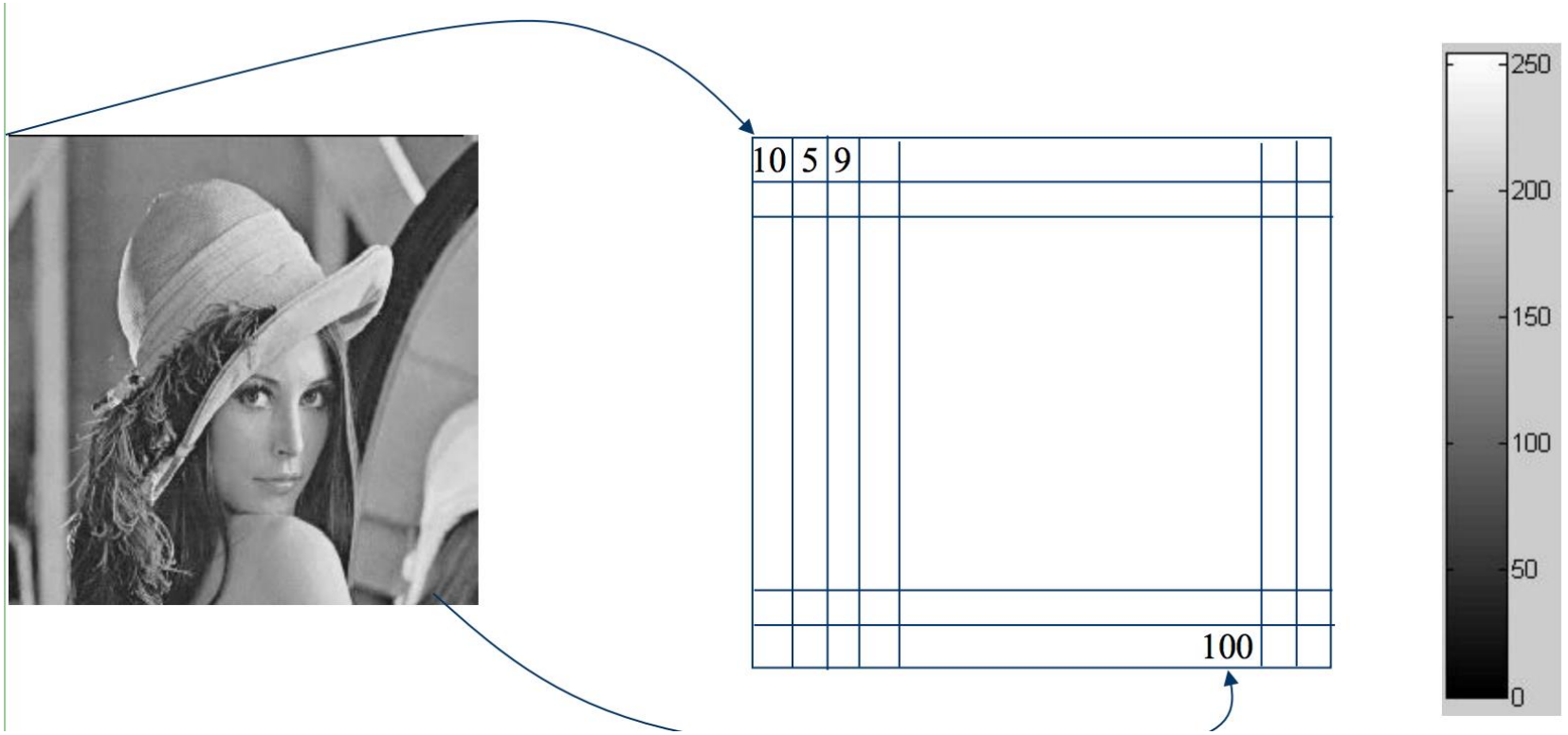


What is each part of a greyscale image?

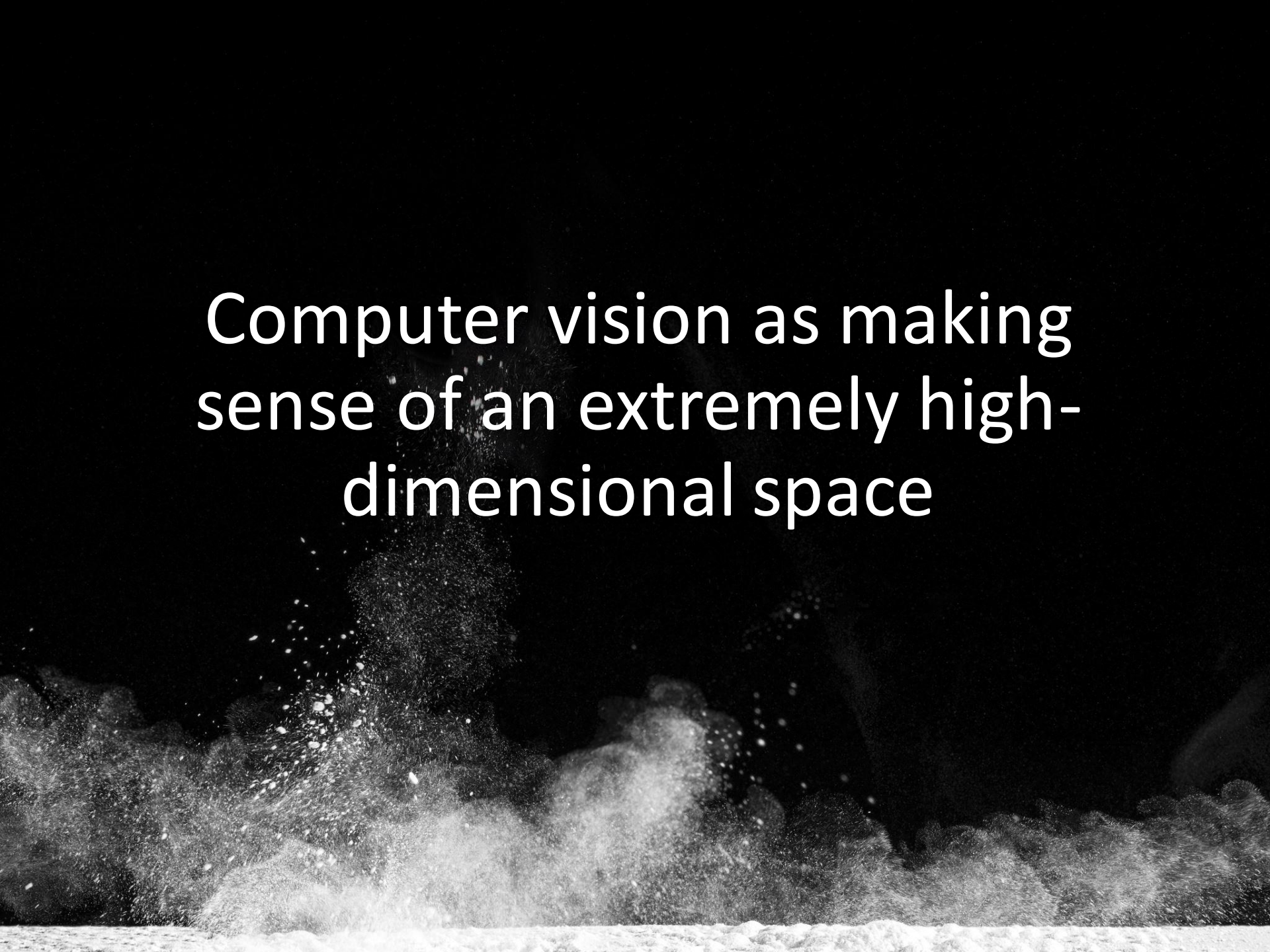
- Pixel -> picture element



Another example: Lena



Slide credit: Ulas Bagci


Computer vision as making sense of an extremely high-dimensional space

Color image representation

Slide credit: Ulas Bagci

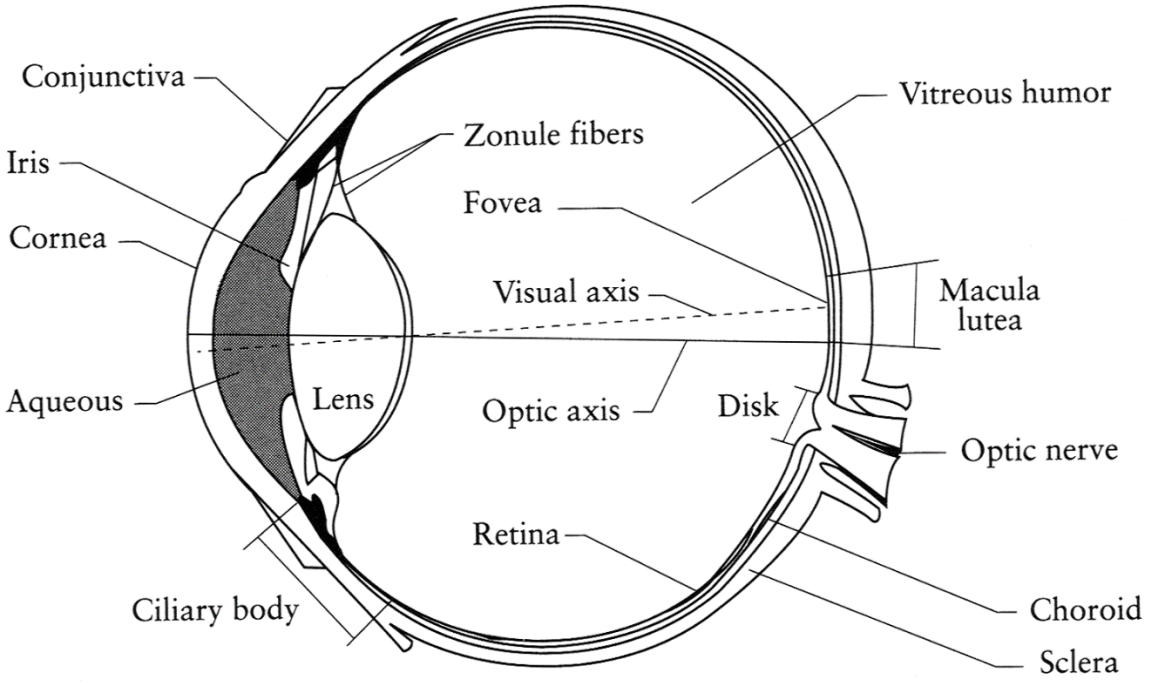
Color in human vision

ANATOMY


Cuisinart
WÓDKA
VODKA
SNOW CRYSTALS
FOTOGRAFIE UND DAS UNSICHTBARE
DER KLEINE STOWASSER
MATHEMATICS
MAN AND SPACE
DRUGS
STACK-ON


Cuisinart
WÓDKA
VODKA
SNOW CRYSTALS
MATHEMATICS
MAN AND SPACE
DRUGS
STACK-ON

The Eye



- The human eye is a camera
  - photoreceptor cells (rods and cones) in the **retina**

Slide by Steve Seitz

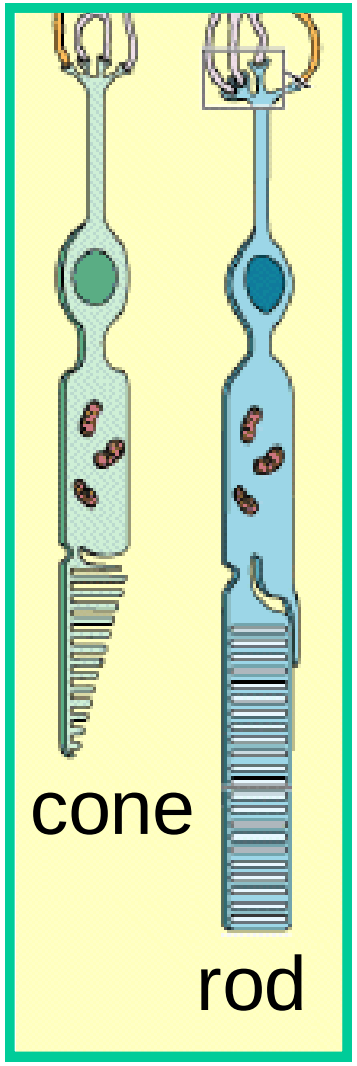
Two types of light-sensitive receptors

Cones

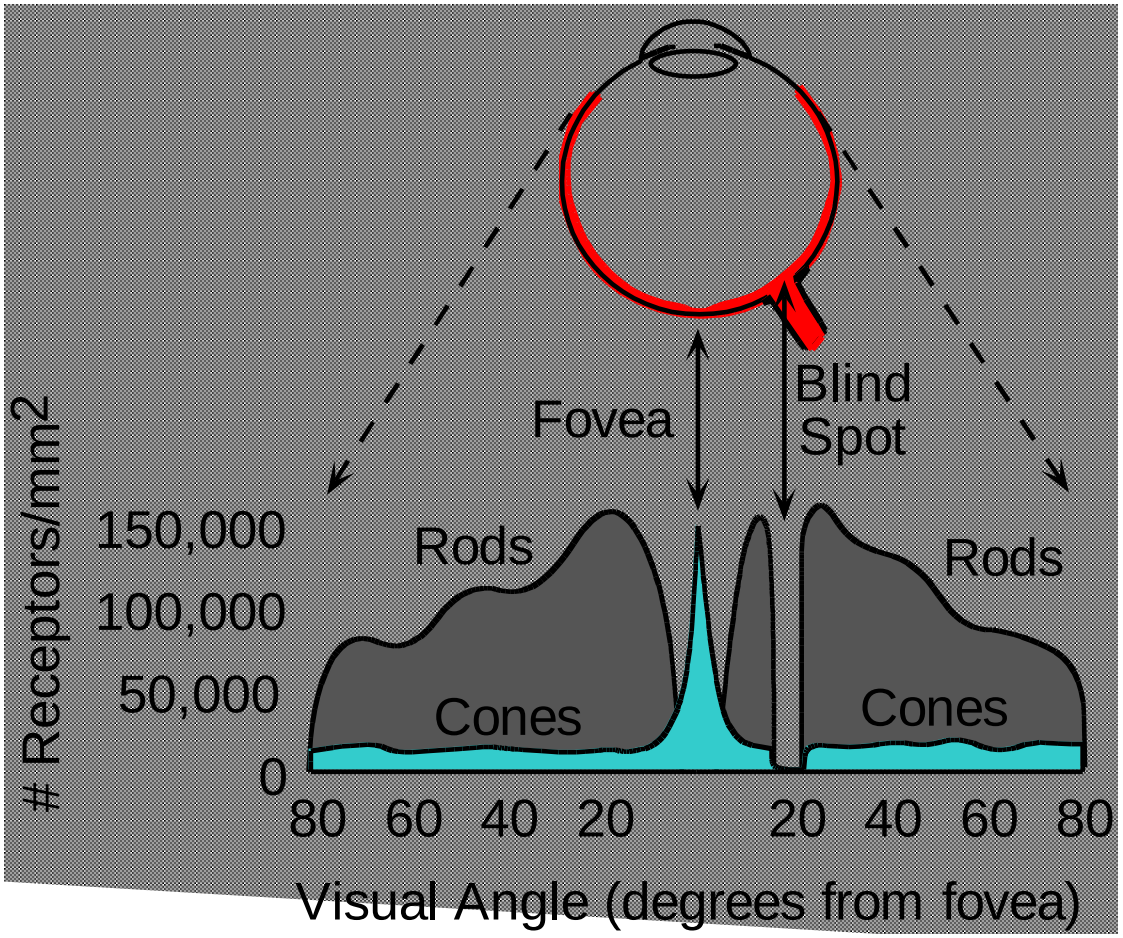
cone-shaped
less sensitive
operate in high light
color vision

Rods

rod-shaped
highly sensitive
operate at night
gray-scale vision



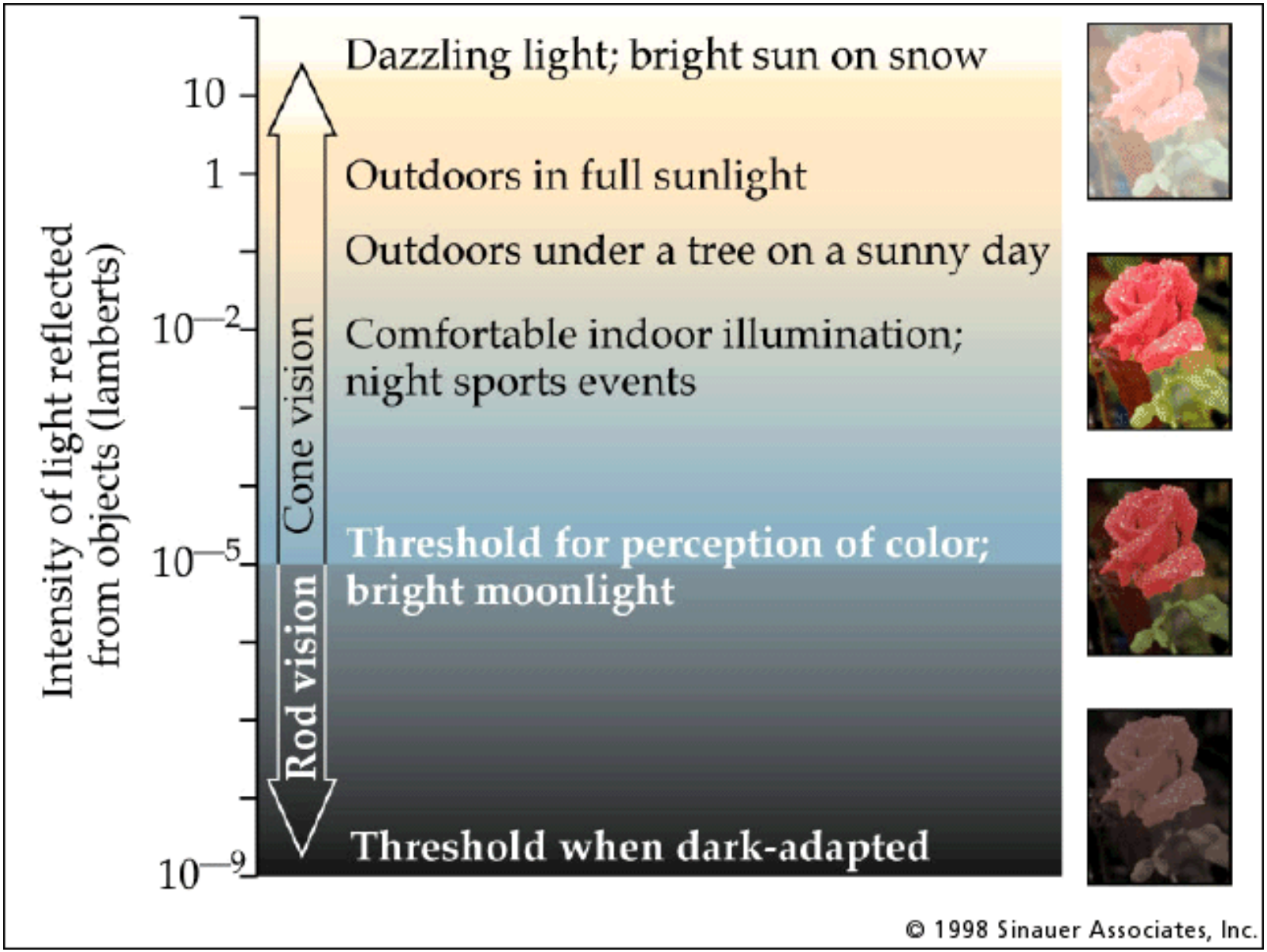
Distribution of Rods and Cones



Night Sky: why are there more stars off-center?

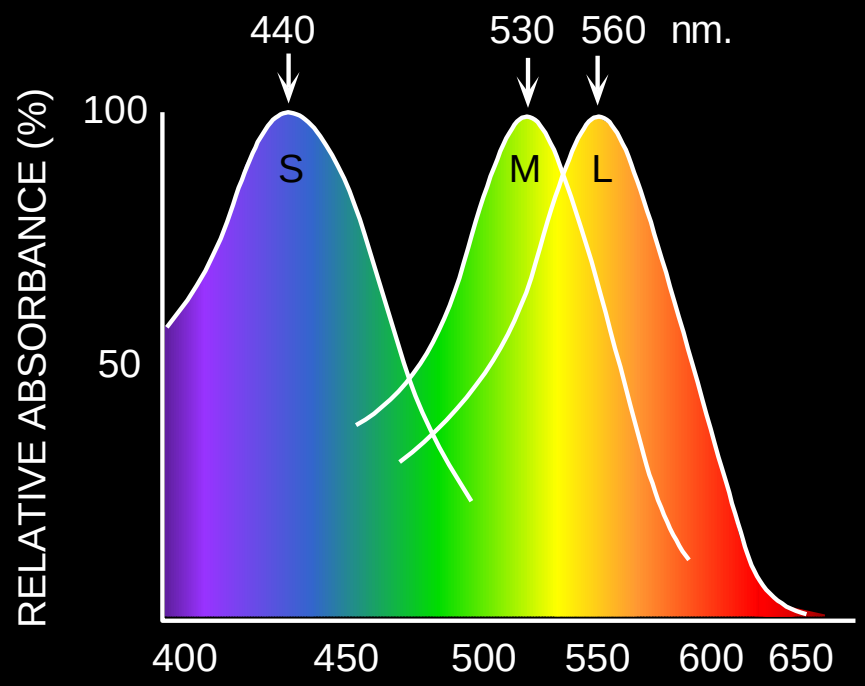
Averted vision: http://en.wikipedia.org/wiki/Averted_vision

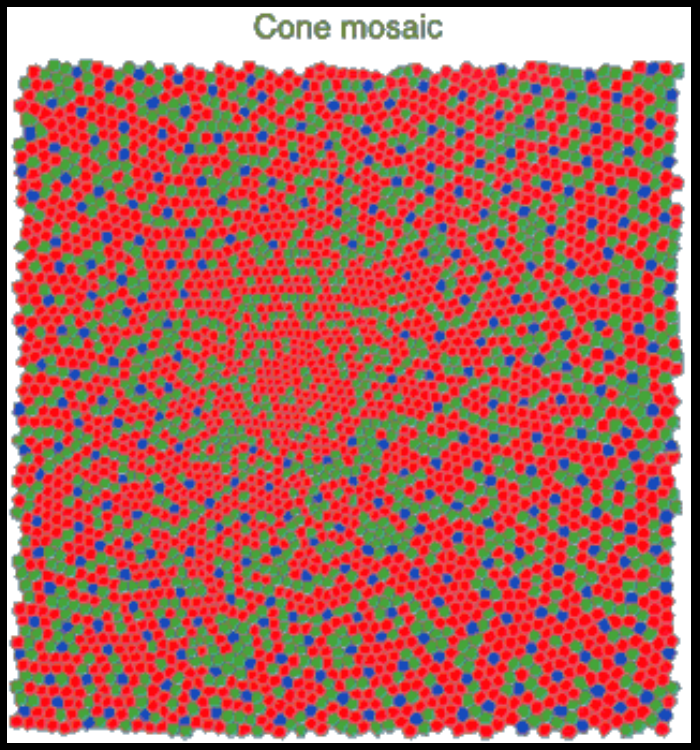
Rod / Cone sensitivity

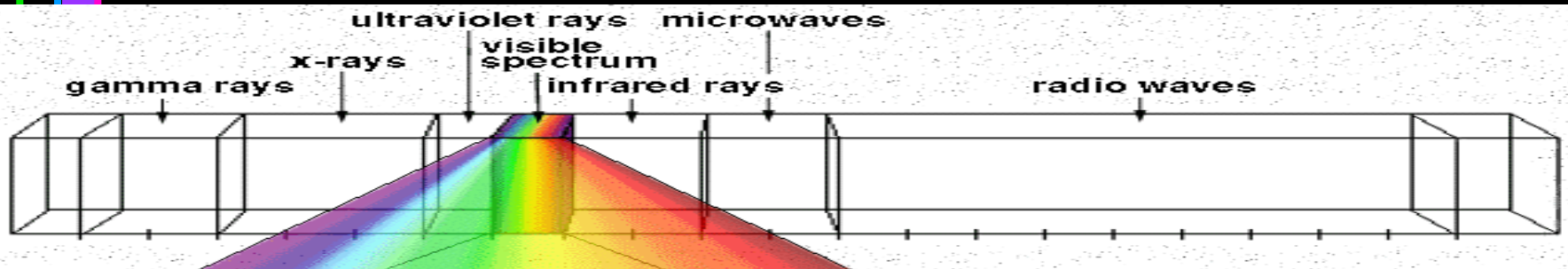


Physiology of Color Vision

Three kinds of cones:



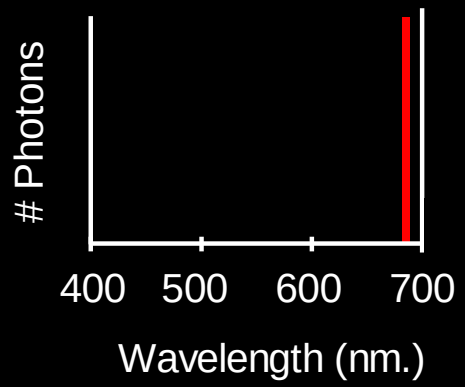




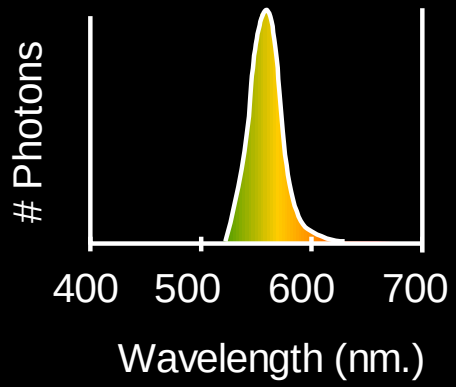
The Physics of Light

Some examples of the spectra of light sources

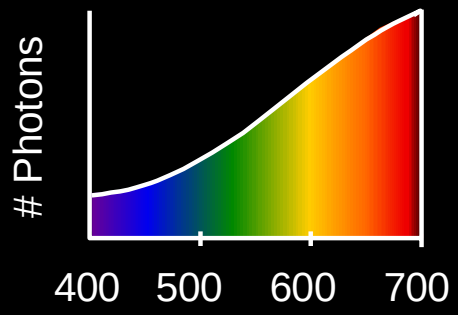
A. Ruby Laser



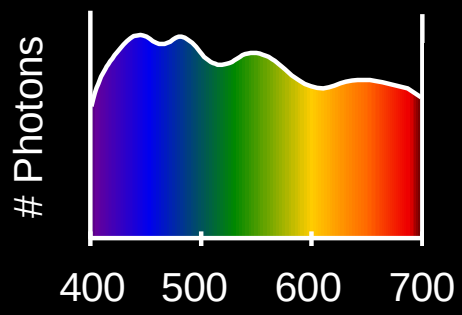
B. Gallium Phosphide Crystal



C. Tungsten Lightbulb



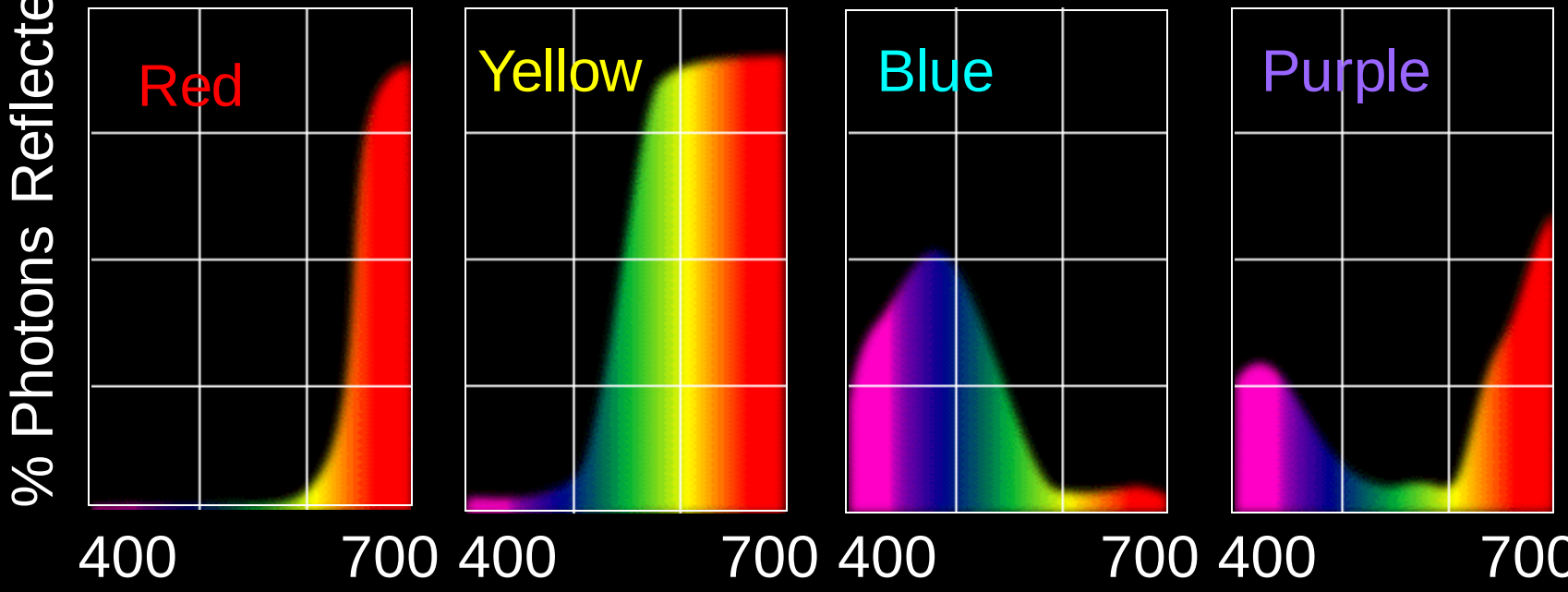
D. Normal Daylight



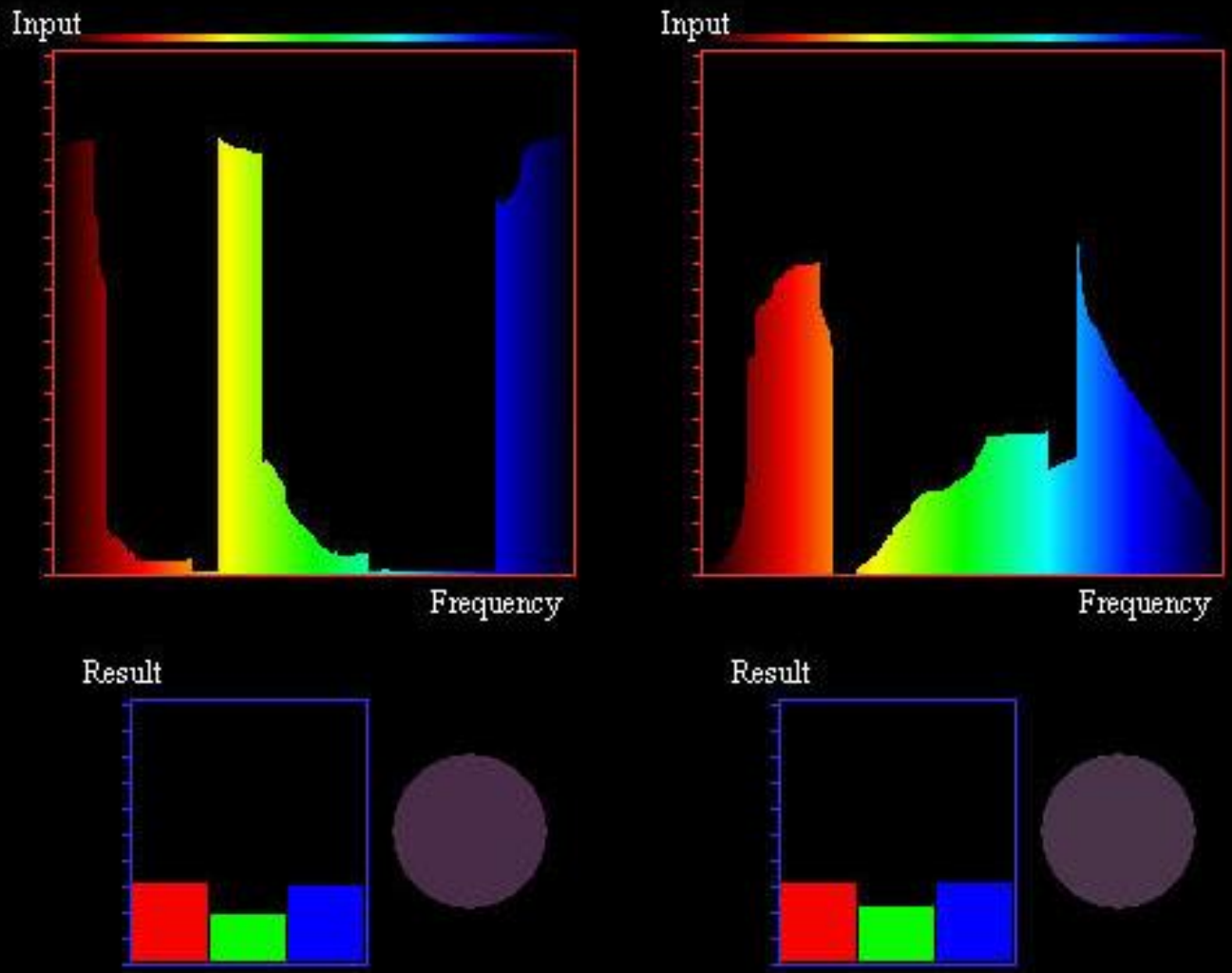
The Physics of Light

Some examples of the reflectance spectra of surfaces



Metamers



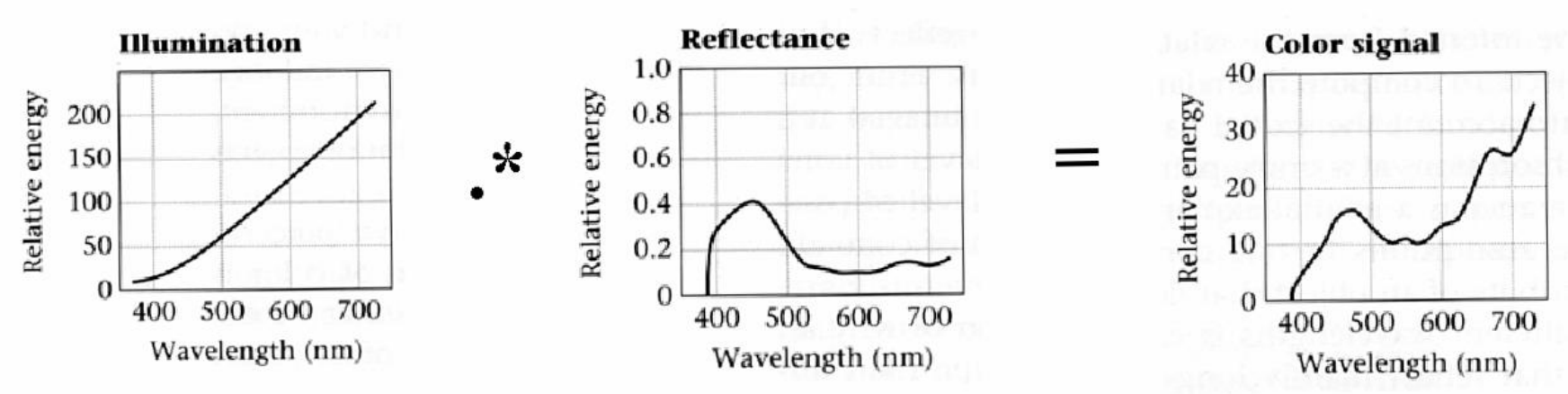
by Jeff Beall, Adam Doppelt and John F. Hughes

Magenta is a ``fake" color

- You won't see Magenta in a rainbow

- Color Mixing: The Mystery of Magenta

Interaction of light and surfaces



From Foundation of Vision by Brian Wandell, Sinauer Associates, 1995

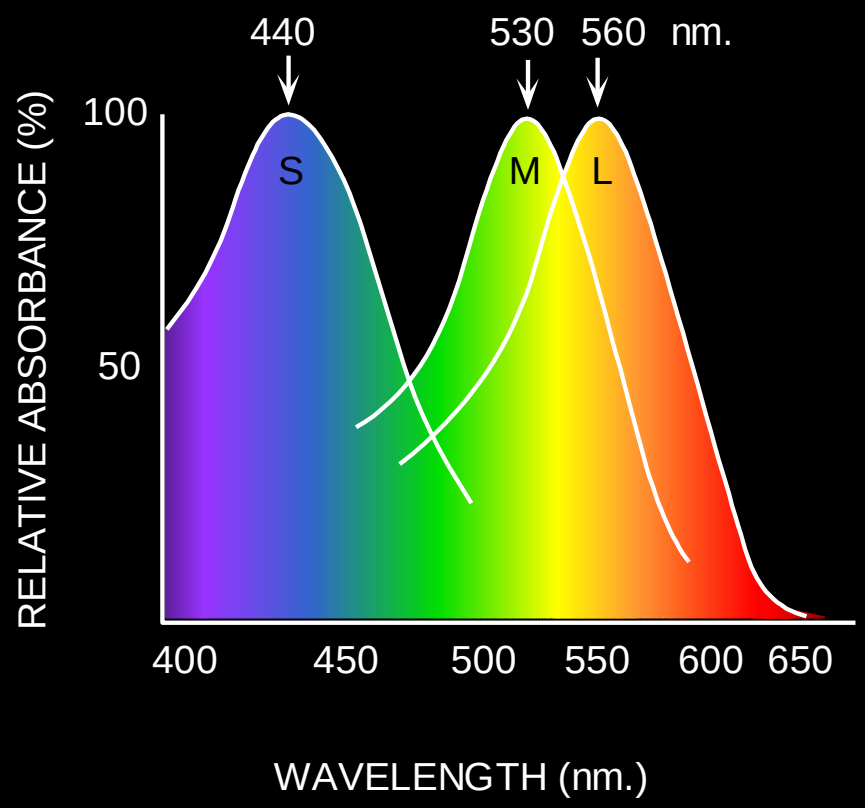
Under monochromatic light

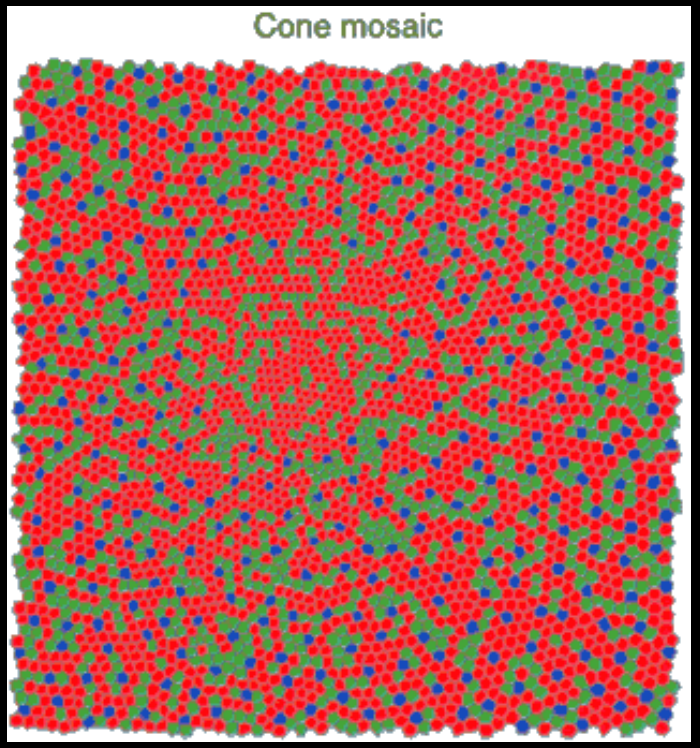
Olafur Eliasson, *Room for one color*

Slide by S. Lazebni

Physiology of Color Vision

Three kinds of cones:





- Why are M and L cones so close?
- Why are there 3?

S are more different from the M and L

- S cones (peak at 420 nm, bluish-violet)
- M cones (peak at 534 nm, bluish-green)
- L cones (peak at 564 nm, yellowish-green)

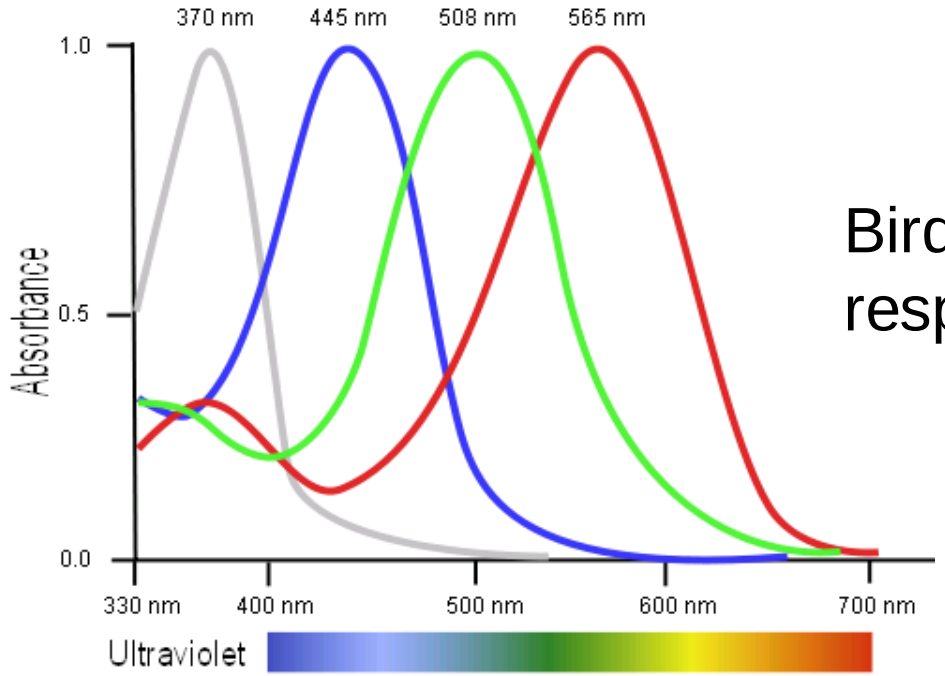
- S cones and rods are totally absent in the foveal area
- Note that both M and L are sensitive to green

S are more different from the M and L

The genes of the photoreceptors lie on different chromosomes

- rod lies on chromosome 8,
- S cone lies on chromosome 7
- Both L and M cones lie on the X chromosome

Tetrachromatism



Bird cone responses

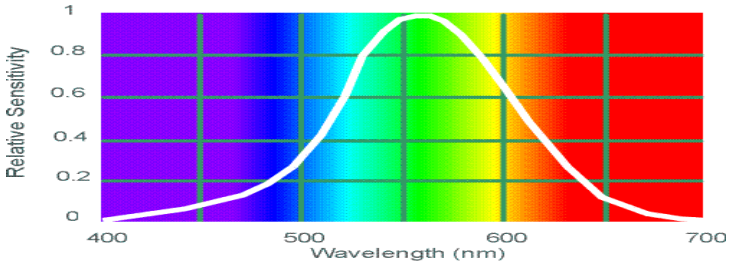
- Most birds, and many other animals, have cones for ultraviolet light.
- Some humans seem to have four cones (12% of females).
- True tetrachromatism is *rare*; requires learning.

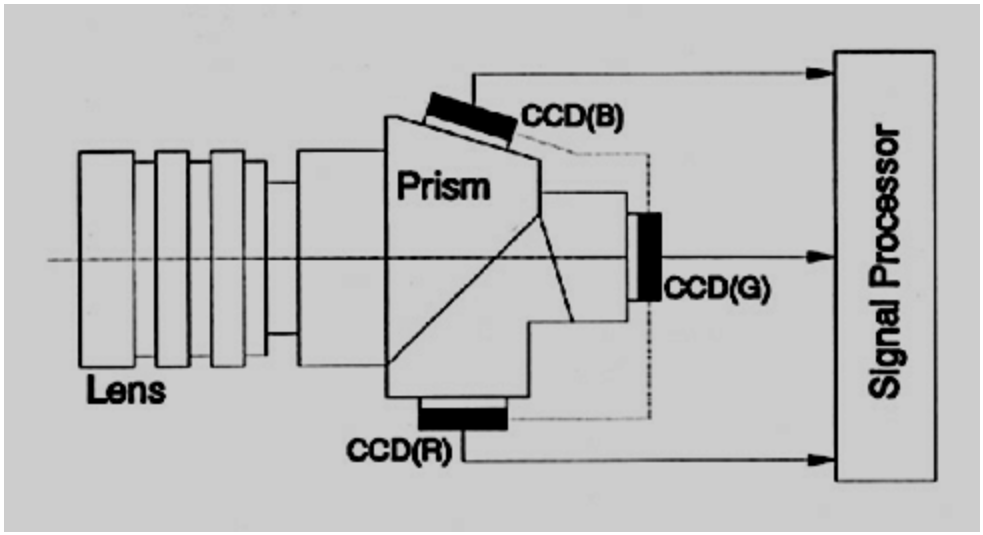
Bee vision

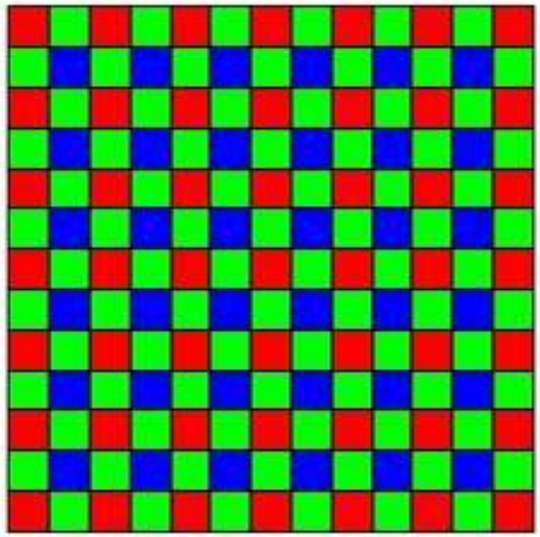
COLOR SENSING IN CAMERA

Color Sensing in Camera (RGB)

- 3-chip vs. 1-chip: quality vs. cost
- Why more green?







Bayer filter

Why 3 colors?

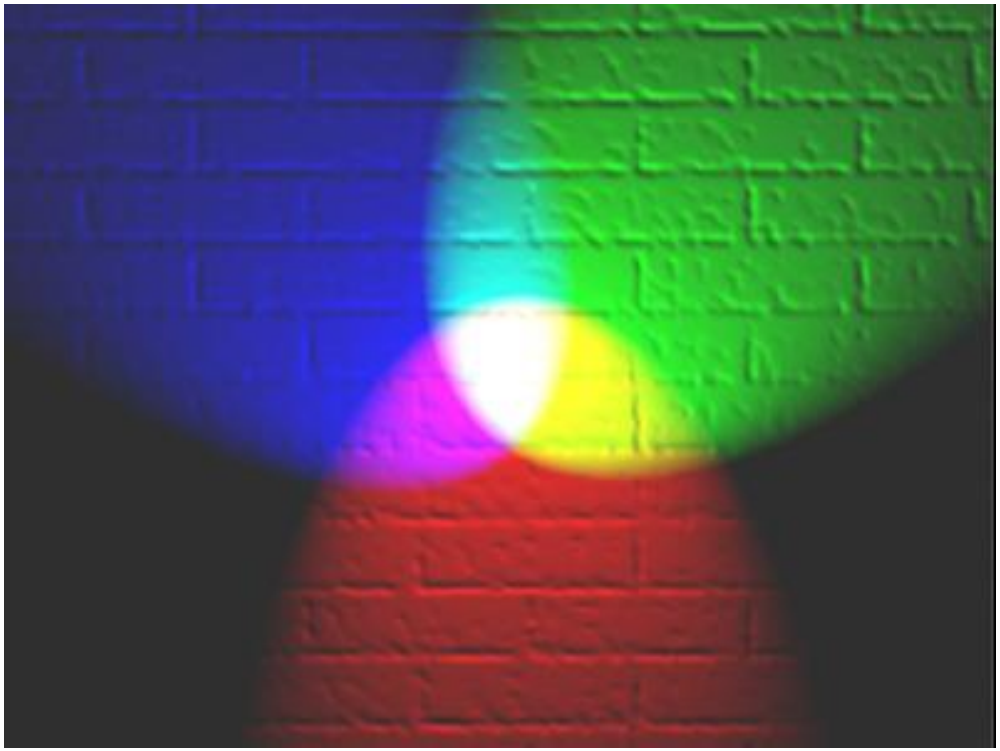
http://www.cooldictionary.com/words/Bayer-filter.wikipedia

Slide by Steve Seitz

COLOR SPACES

Color spaces

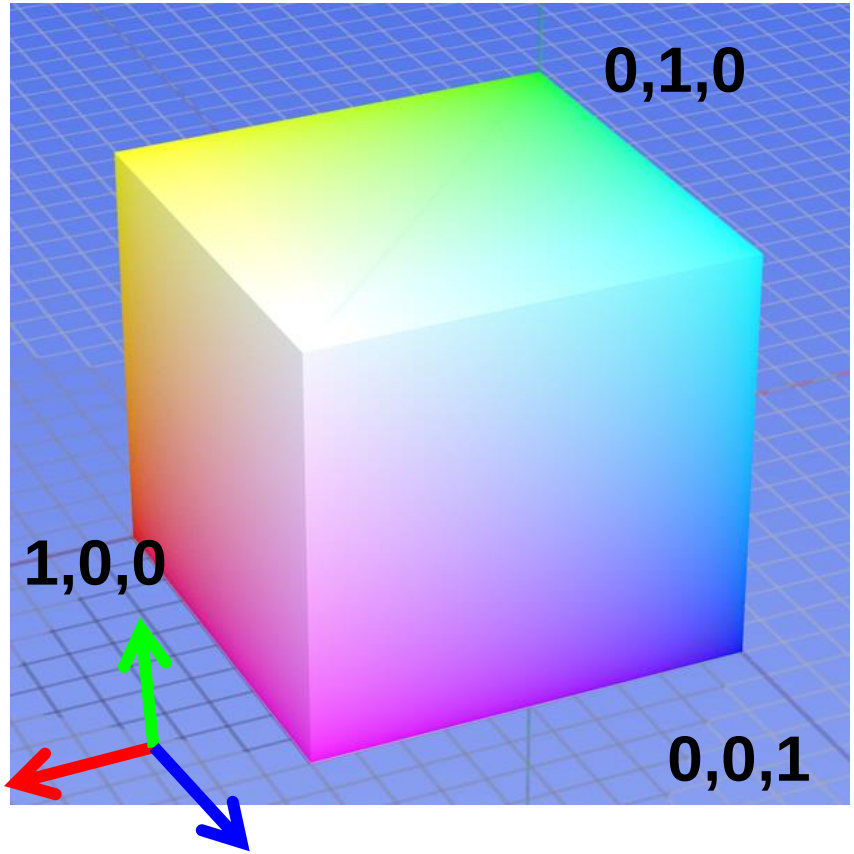
- How can we represent color?



http://en.wikipedia.org/wiki/File:RGB_illumination.jpg

Color spaces: RGB

Default color space



R = 1
(G=0,B=0)

G = 1
(R=0,B=0)

B = 1
(R=0,G=0)

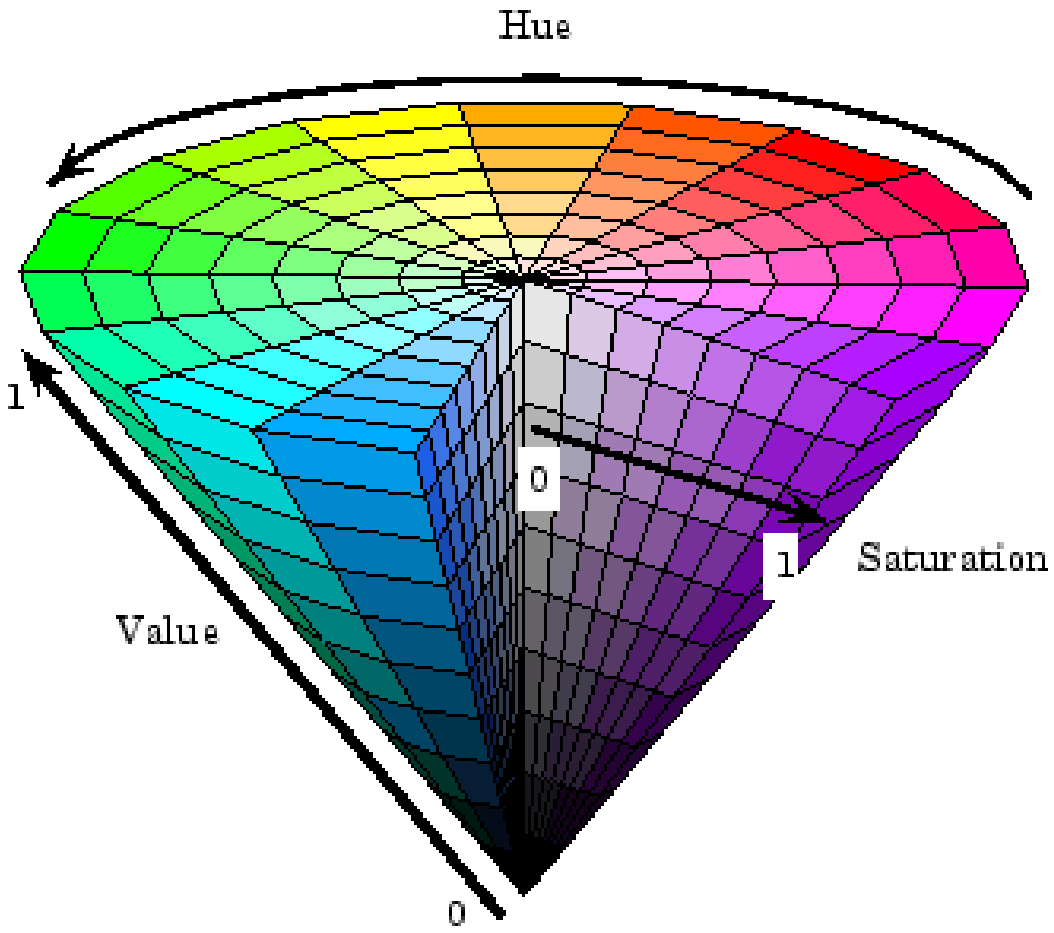
Any color = r*R + g*G + b*B

- Strongly correlated channels
- Non-perceptual

Image from: http://en.wikipedia.org/wiki/File:RGB_color_solid_cube.png

Color spaces: HSV

Intuitive color space

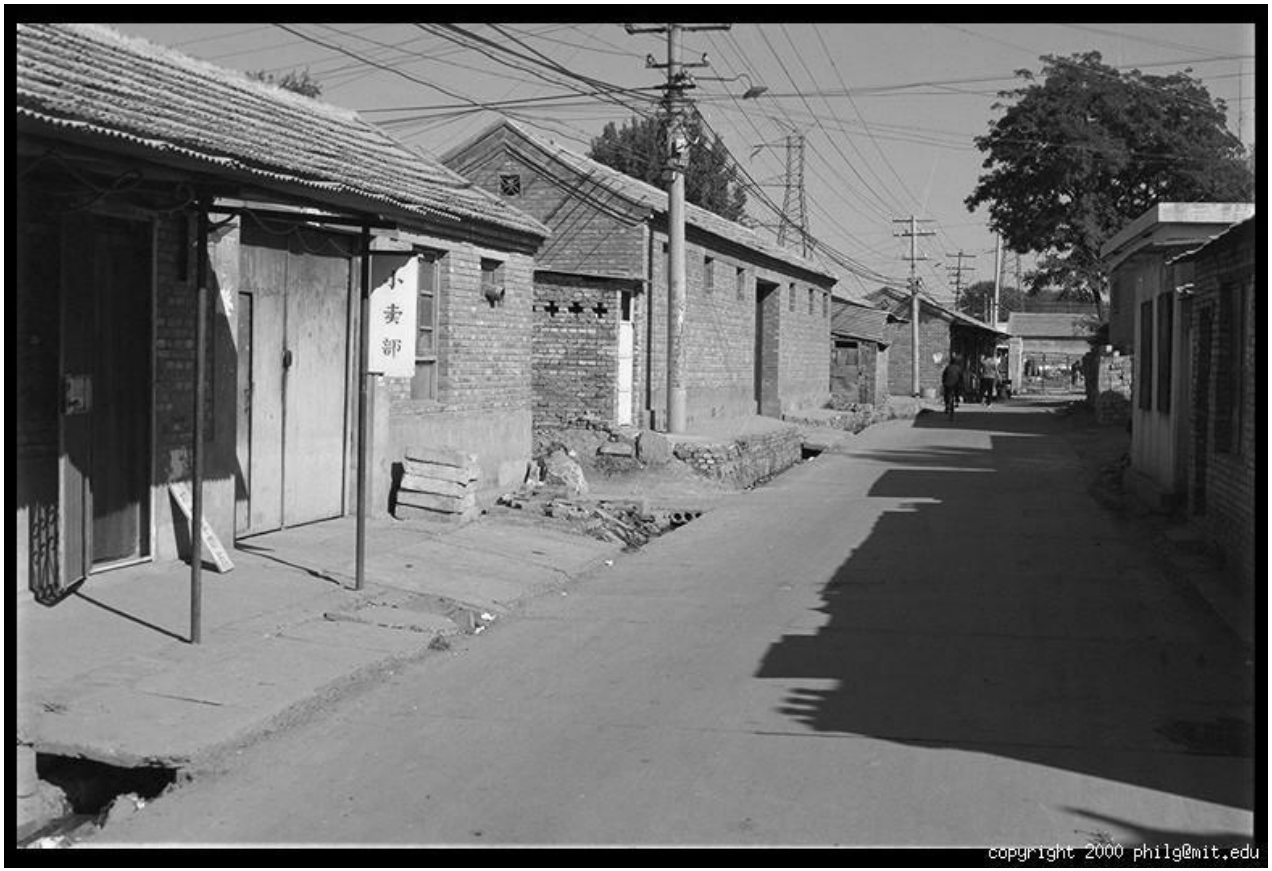


If you had to choose, would you rather go without luminance or chrominance?

Most information in intensity

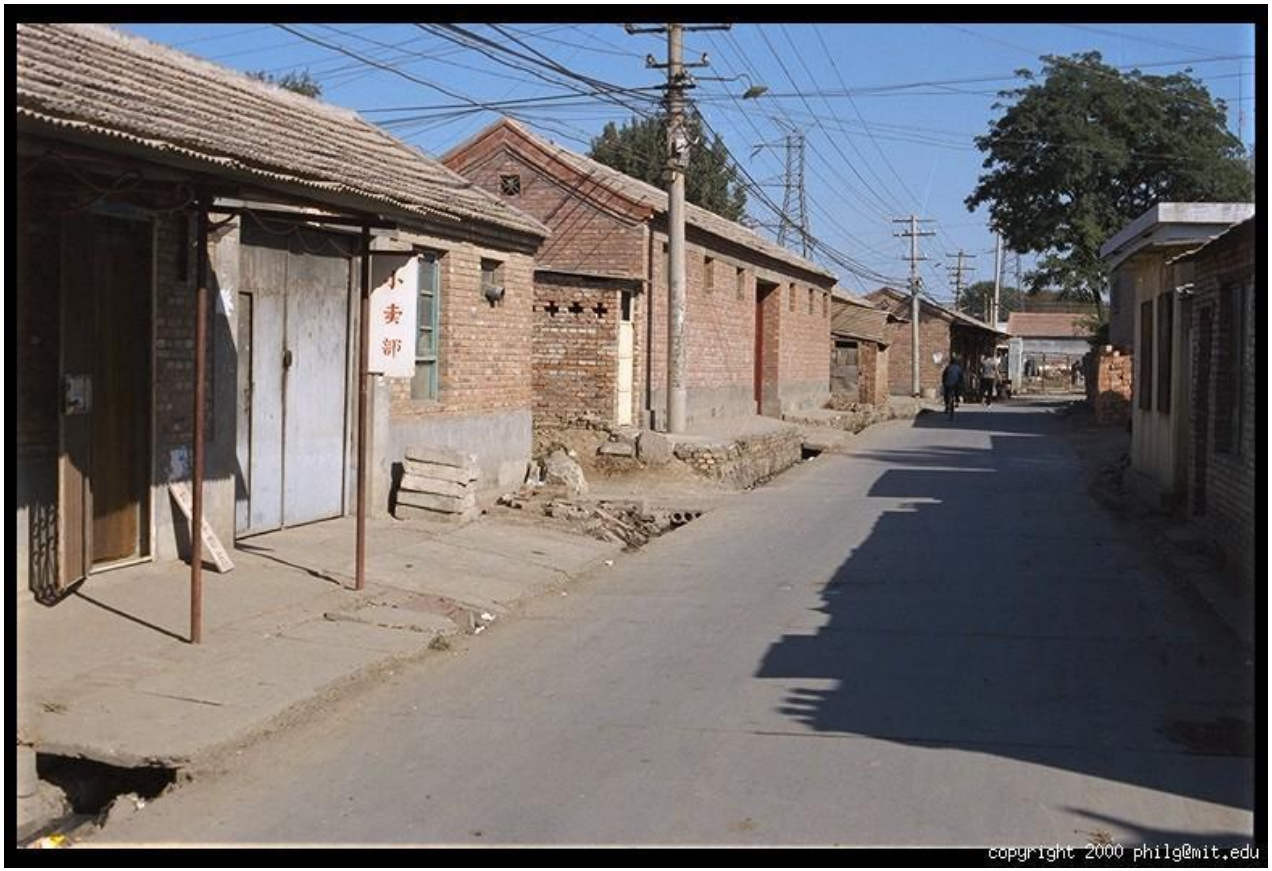
Only color shown – constant intensity

Most information in intensity



Only intensity shown – constant color

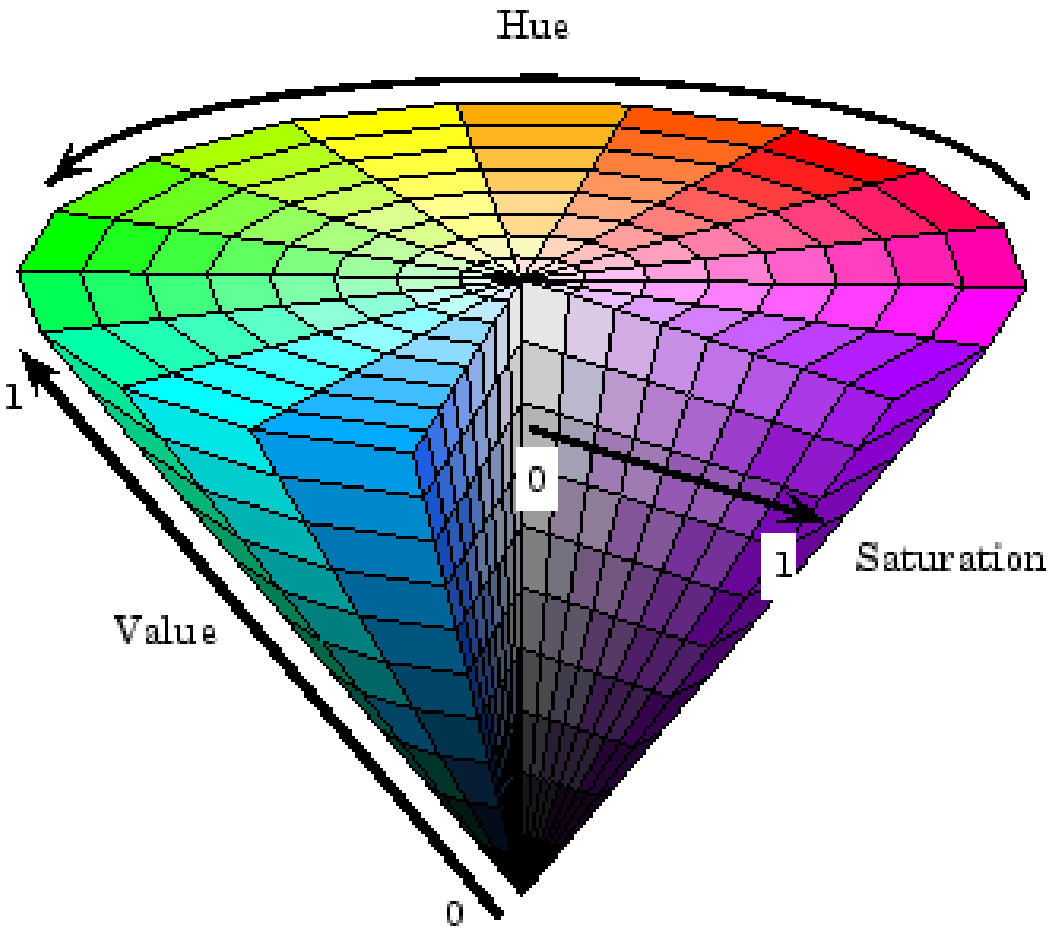
Most information in intensity

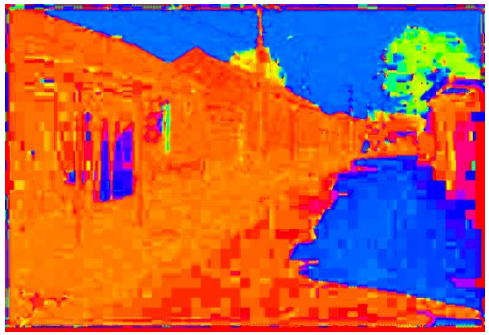


Original image

Color spaces: HSV

Intuitive color space





H

(S=1,V=1)

S

(H=1,V=1)

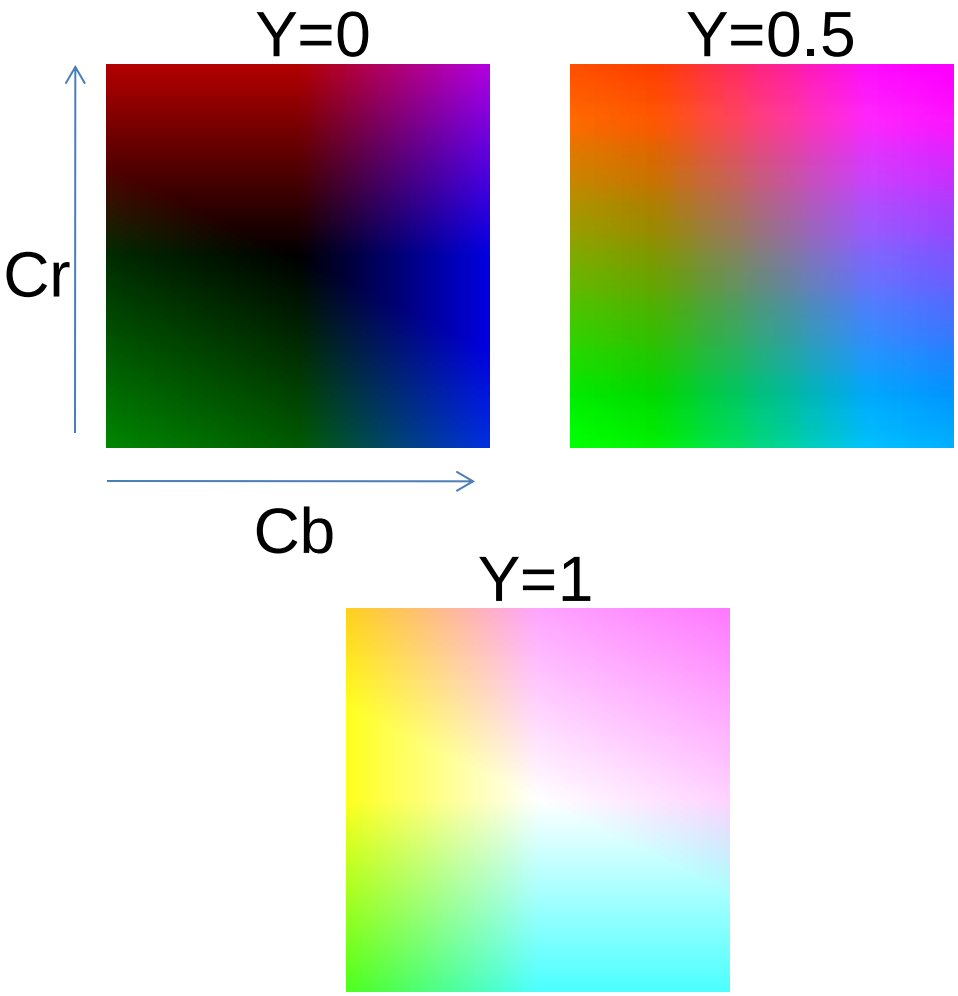
V

(H=1,S=0)

James Hays

Color spaces: YCbCr

Fast to compute, good for compression, used by TV



Y
(Cb=0.5,Cr=0.5)

Cb
(Y=0.5,Cr=0.5)

Cr
(Y=0.5,Cb=05)

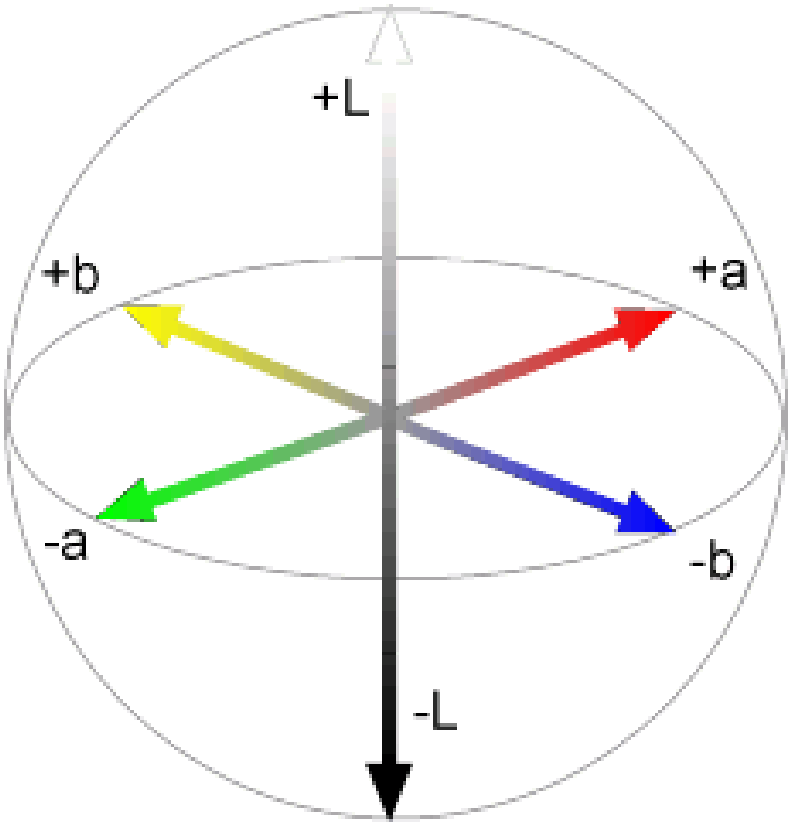
Most JPEG images & videos subsample chroma

PSP Comp 3
2x2 Chroma subsampling
285K

Original
1,261K lossless
968K PNG

Color spaces: L*a*b*

"Perceptually uniform"* color space



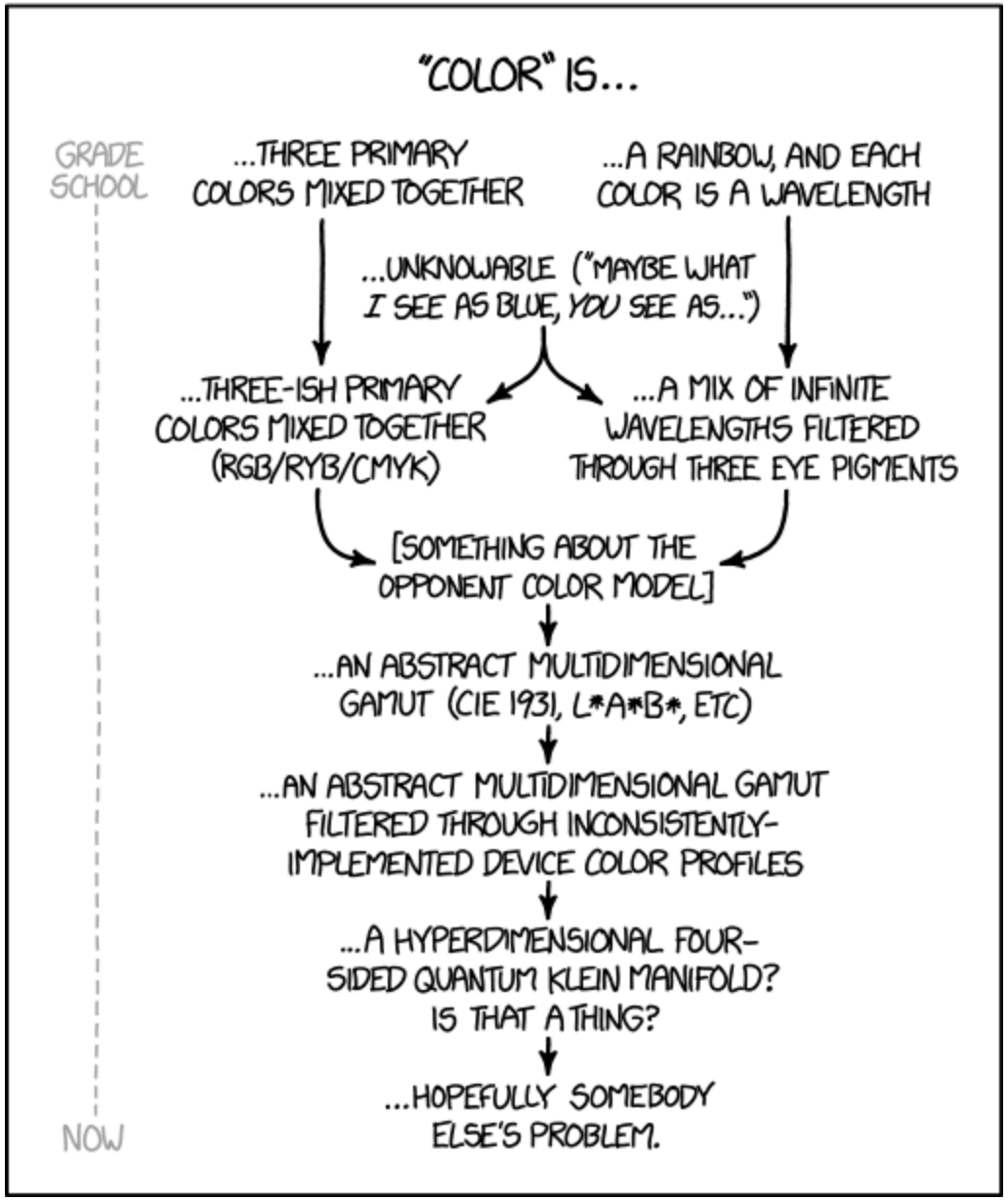
L
(a=0,b=0)

a
(L=65,b=0)

b
(L=65,a=0)

James Hays

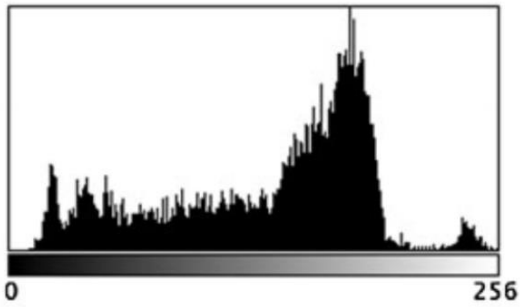
EVOLUTION OF MY UNDERSTANDING OF COLOR OVER TIME:

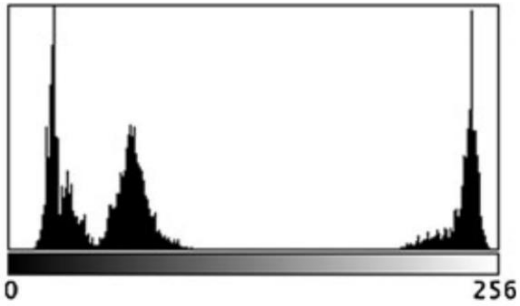


XKCD

Image histograms

Histogram





Slide credit: Dr. Mubarak Shah

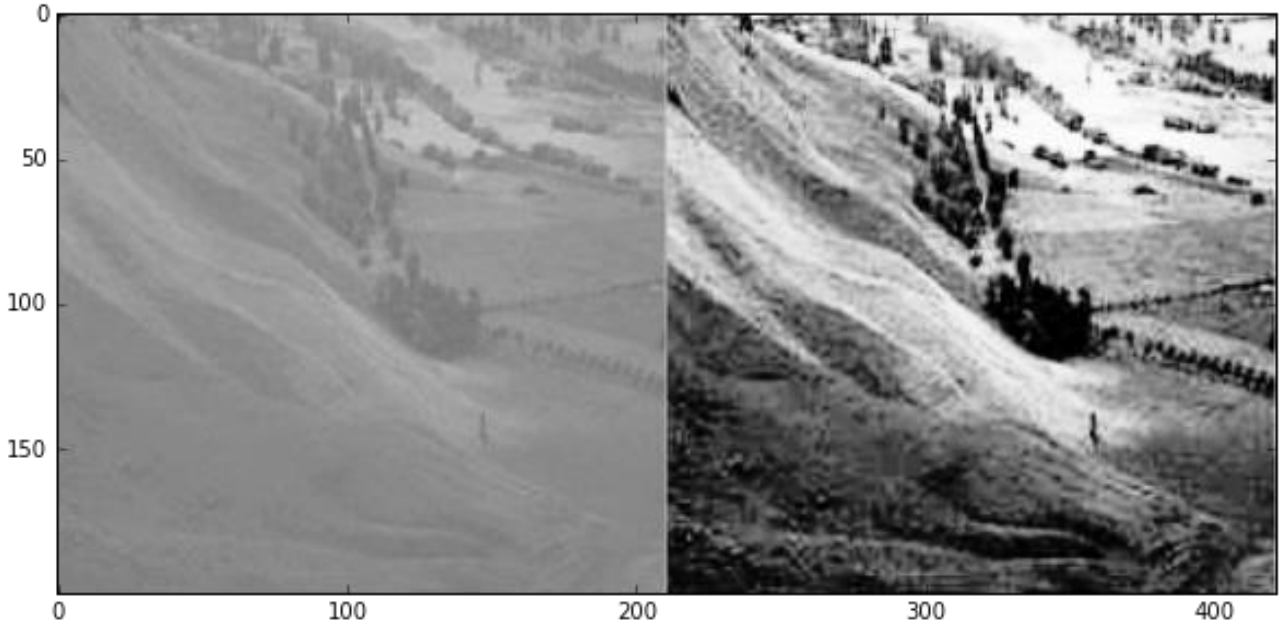
Histogram

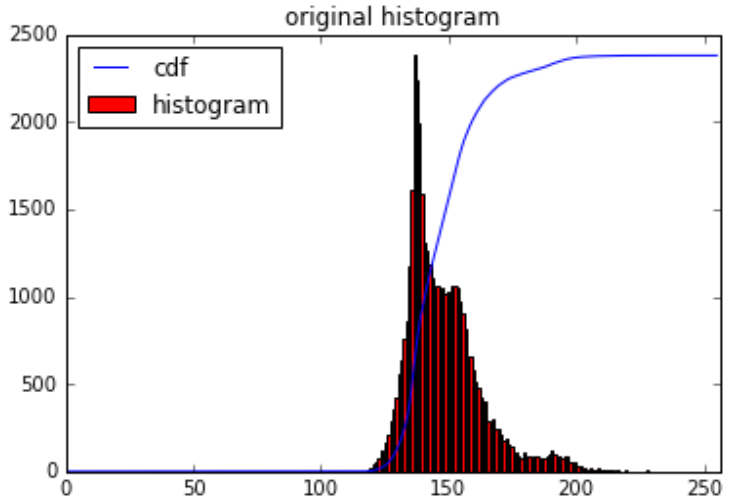
- Histogram of an image provides the frequency of the brightness (intensity) value in the image.

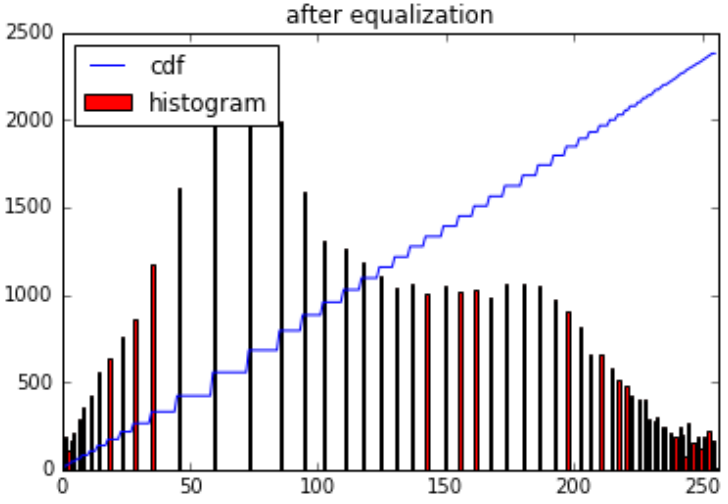
```
function h=histogram(im)
    h=zeros(1,255);
    for row=1:size(im,1)
        for col=1:size(im,2)
            val = im(row,col)+1;
            h(val)=h(val)+1;
        end
    end
end
```

```
def histogram(im):
    h = np.zeros(255)
    for row in im.shape[0]:
        for col in im.shape[1]:
            val = im[row, col]
            h[val] += 1
```

A use case: histogram equalization







White balance

- When looking at a picture on screen or print, we adapt to the illuminant of the room, not to that of the scene in the picture
- When the white balance is not correct, the picture will have an unnatural color “cast”

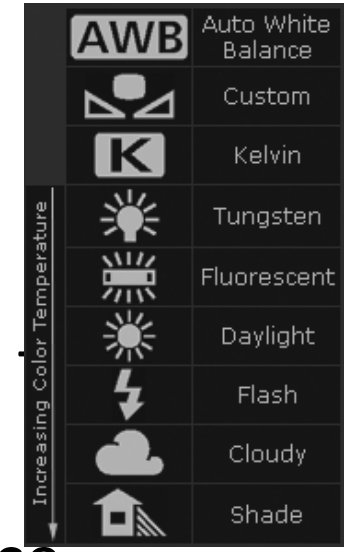
incorrect white balance

correct white balance

http://www.cambridgeincolour.com/tutorials/white-balance.htm

White balance

- Film cameras:
  - Different types of film or different filters for different illumination conditions
- Digital cameras:
  - Automatic white balance
  - White balance settings corresponding to several common illuminants
  - Custom white balance using a reference object



http://www.cambridgeincolour.com/tutorials/white-balance.htm

Slide: F. Durand