Computational Vision
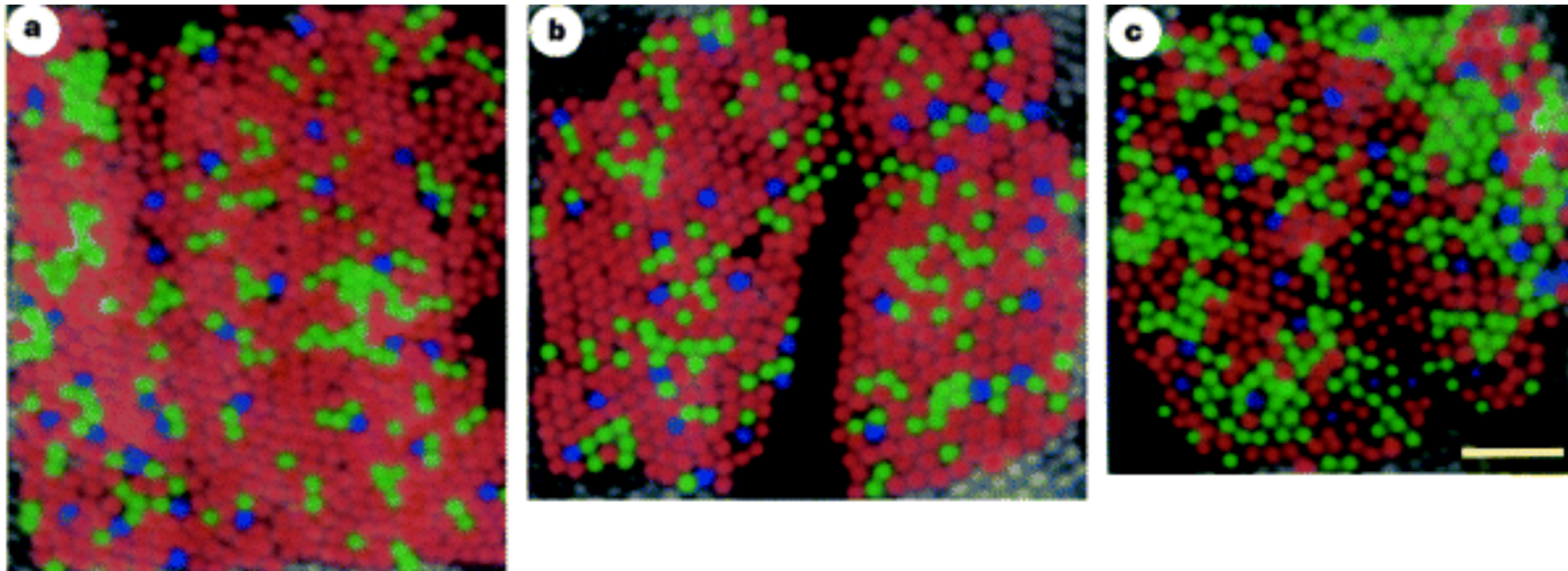
Foundations

- Retina cont'd:

- Trichromaticity theory

- Basic image manipulation in matlab
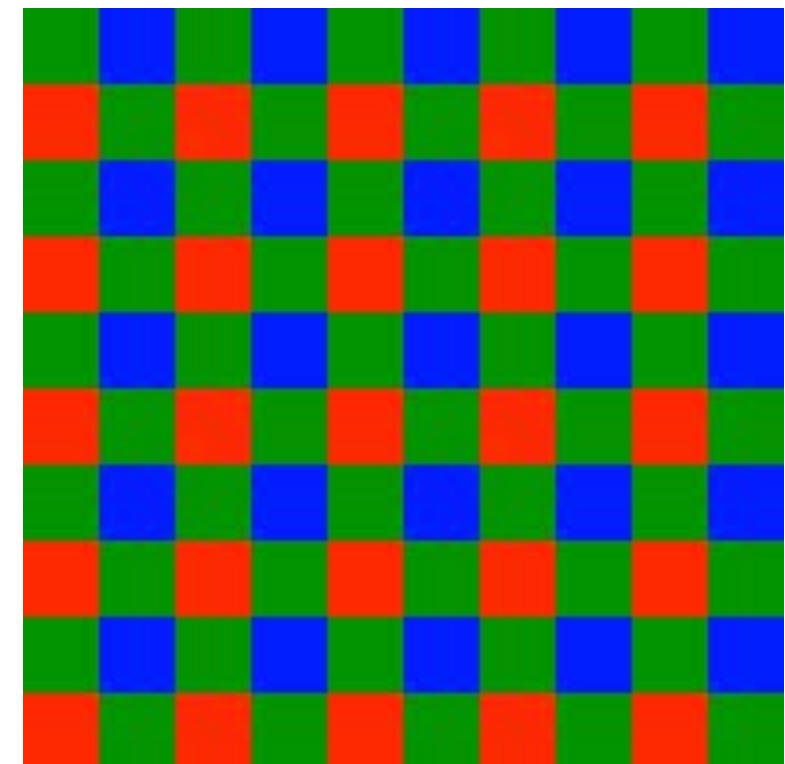
Human retina vs. CCD chip

Roorda & Williams 1999

CCD matrix

On the role of color
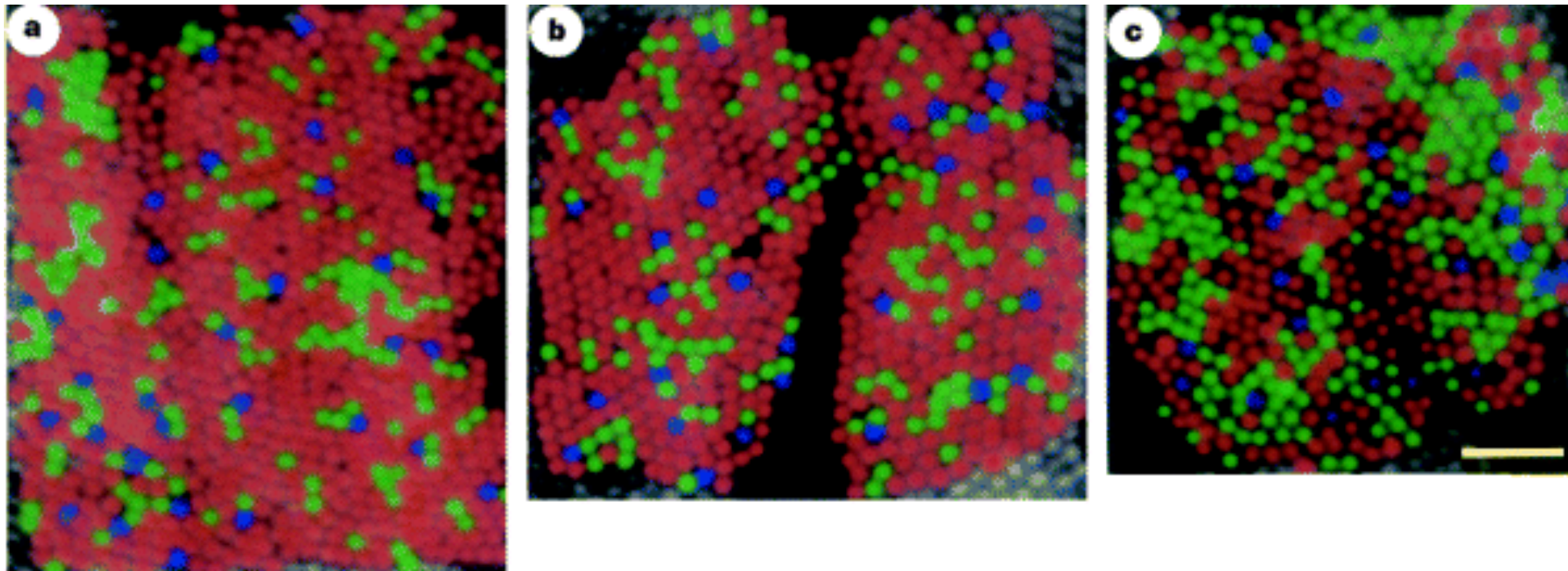
- Most mammals have two types of cones

- Owl monkeys (nocturnal) only have one type of cones

- Tetrachromats (pigeons and some women)

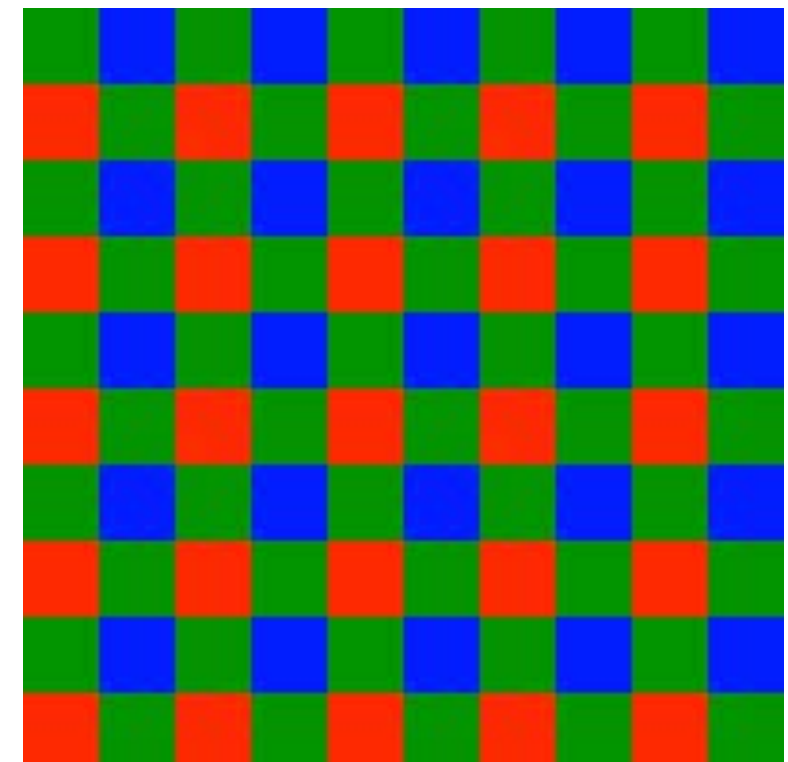- Mantis shrimp with 15 types of cones!

On the role of color

Roorda & Williams 1999

CCD matrix

Acuity of color vs. form

Triple dip by Ben Shahn (1952)
(http://farm5.static.flickr.com/
4009/4529726695_9a18deae2a.jpg)

Isadora Duncan #29 by A. Walkowitz
(http://farm5.static.flickr.com/
4009/4529726695_9a18deae2a.jpg)

source: Margaret Livinstone

On the role of color

Clap in your hand if you see something to eat here?

On the role of color

Clap in your hand if you see something to eat here?

On the role of color

- Why do we care about the color of the raspberries?

- Evolutionary fitness argument:

    - color helps us find it amongst the leaves that surround it

Source: Frisby & Stone

On the role of color

- Similarly color of moldy piece of meat warns us not to eat it!

On the role of color

- Photopigments in the receptors of fruit-eating monkeys tuned to task of picking out fruits amongst leaves in their ecological niche
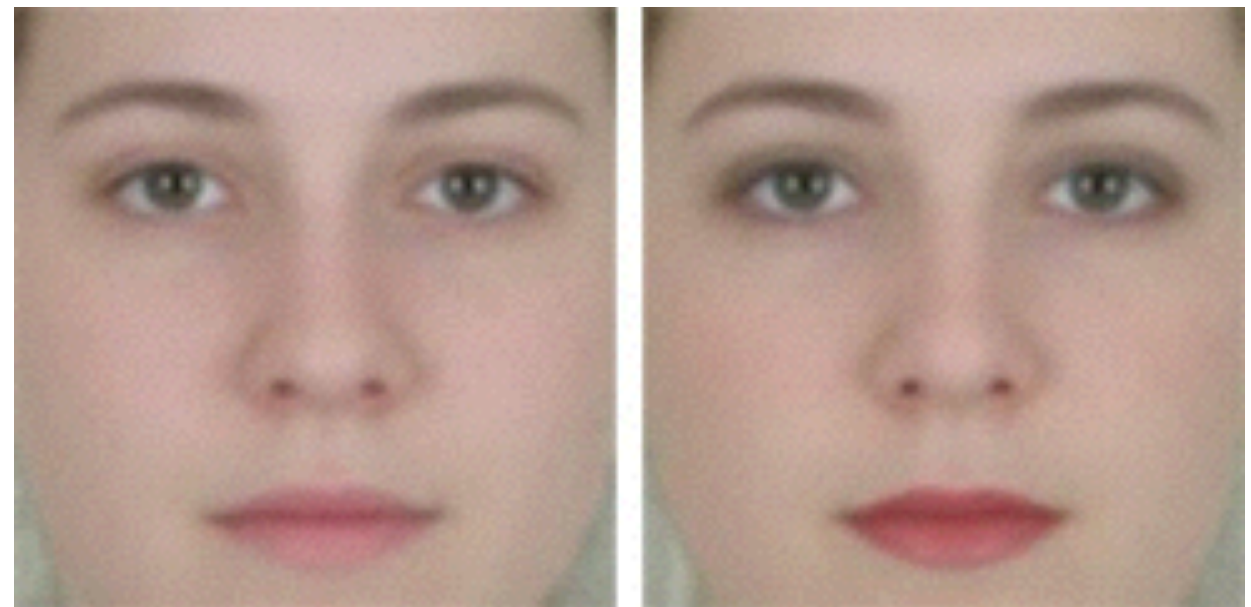
On the role of color

- Trichromats tend to be bare faced…

- Skin spectral modulations of conspecifics may help discriminate emotional states, socio-sexual signals and threat displays

On the role of color

- Male skin darker than female skin

- Greater contrast in female faces between the eyes, mouth and the rest of the face

- Cosmetics exaggerate these differences (and makes women more attractive to men!)

On the role of color

- Two dimensions of skin spectral modulations:

    - Blood volume and level of oxygen

- Trichromats but not dichromats are sensitive to each

- M and L cone maximum sensitivities for routine trichromats optimized for discriminating variations in blood oxygen saturation
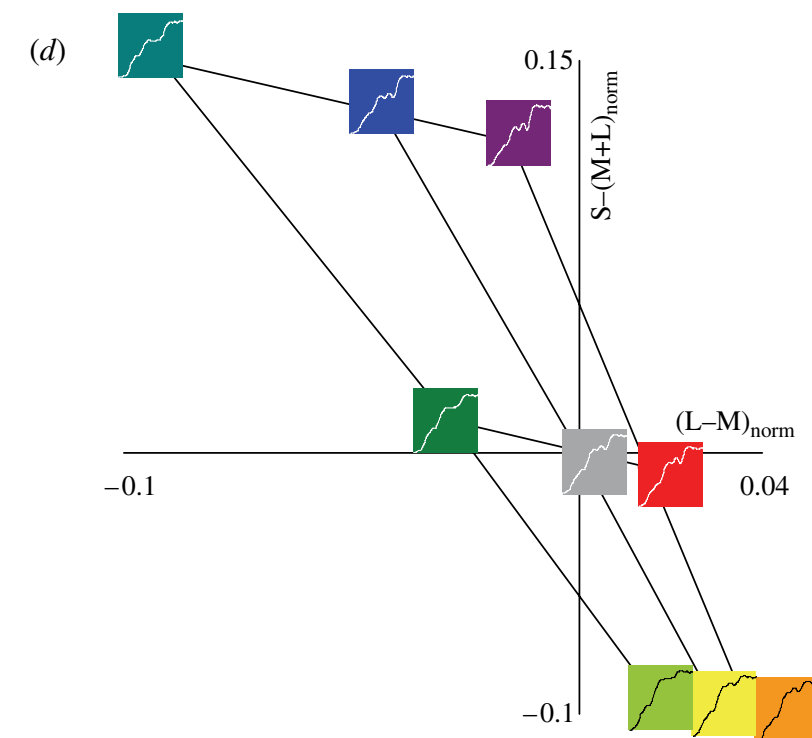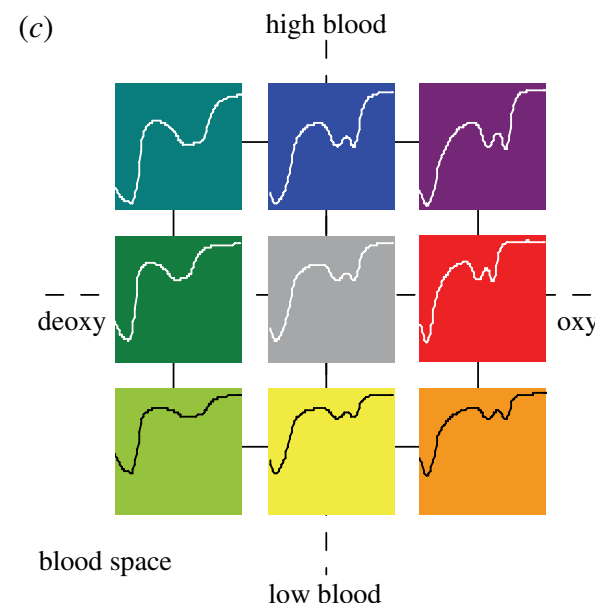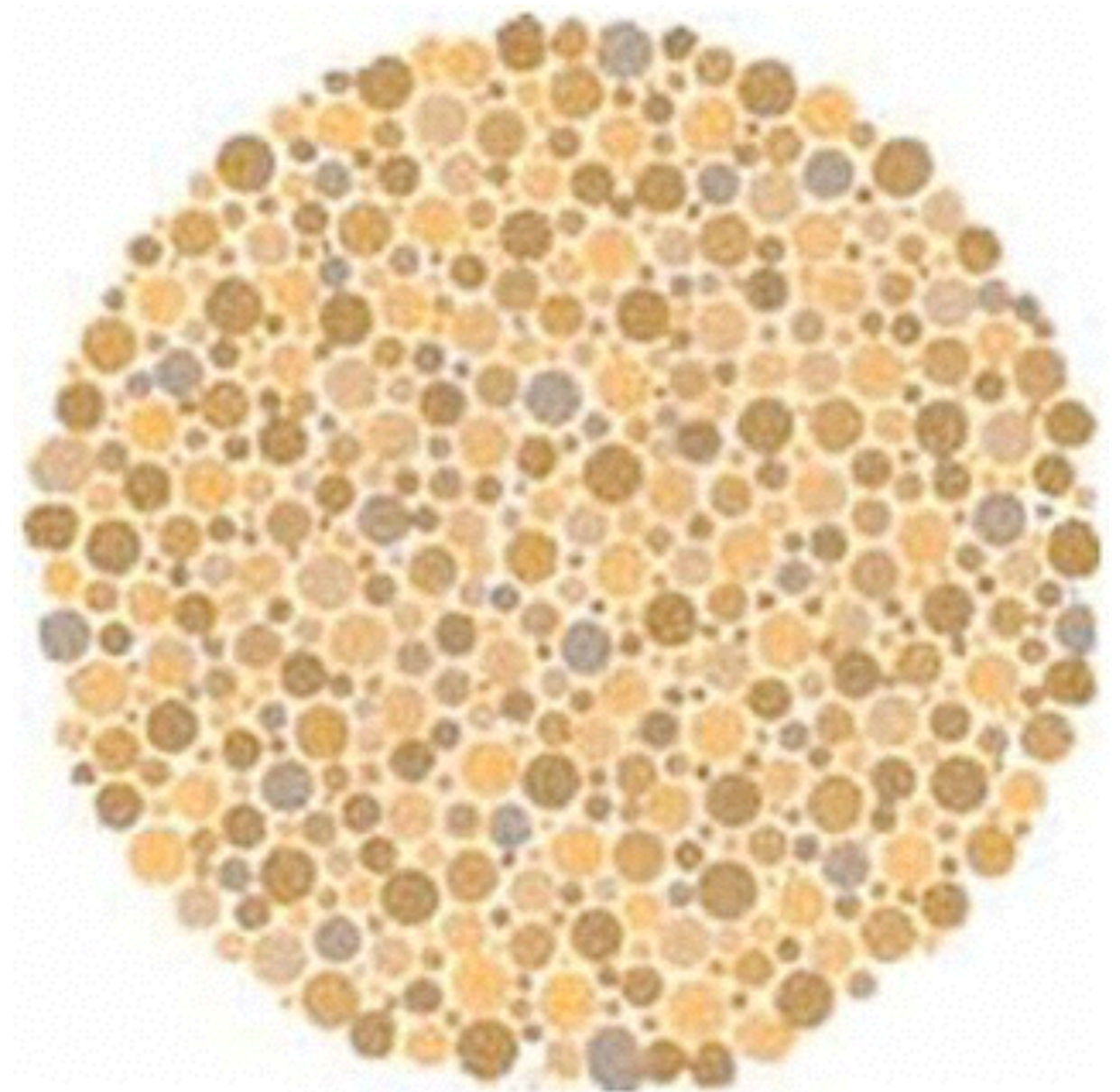
Color blindness (red-green)

- Males:

  - 8 our of 100 Caucasians

  - 5 out of 100 Asians

  - 3 out of 100 Africans

- Females:

  - Probability is 10 times less

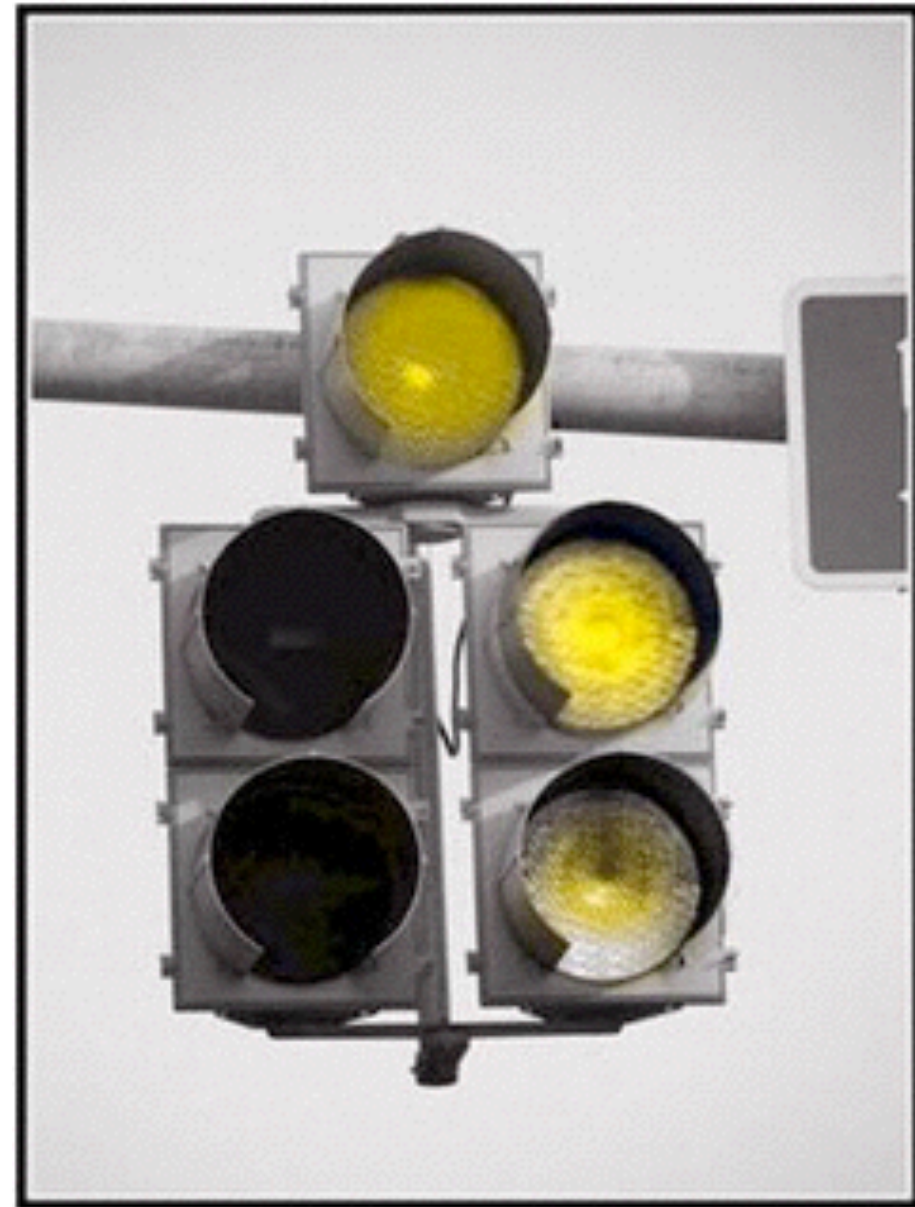# Color blindness (red-green)

Color blindness (red-green)
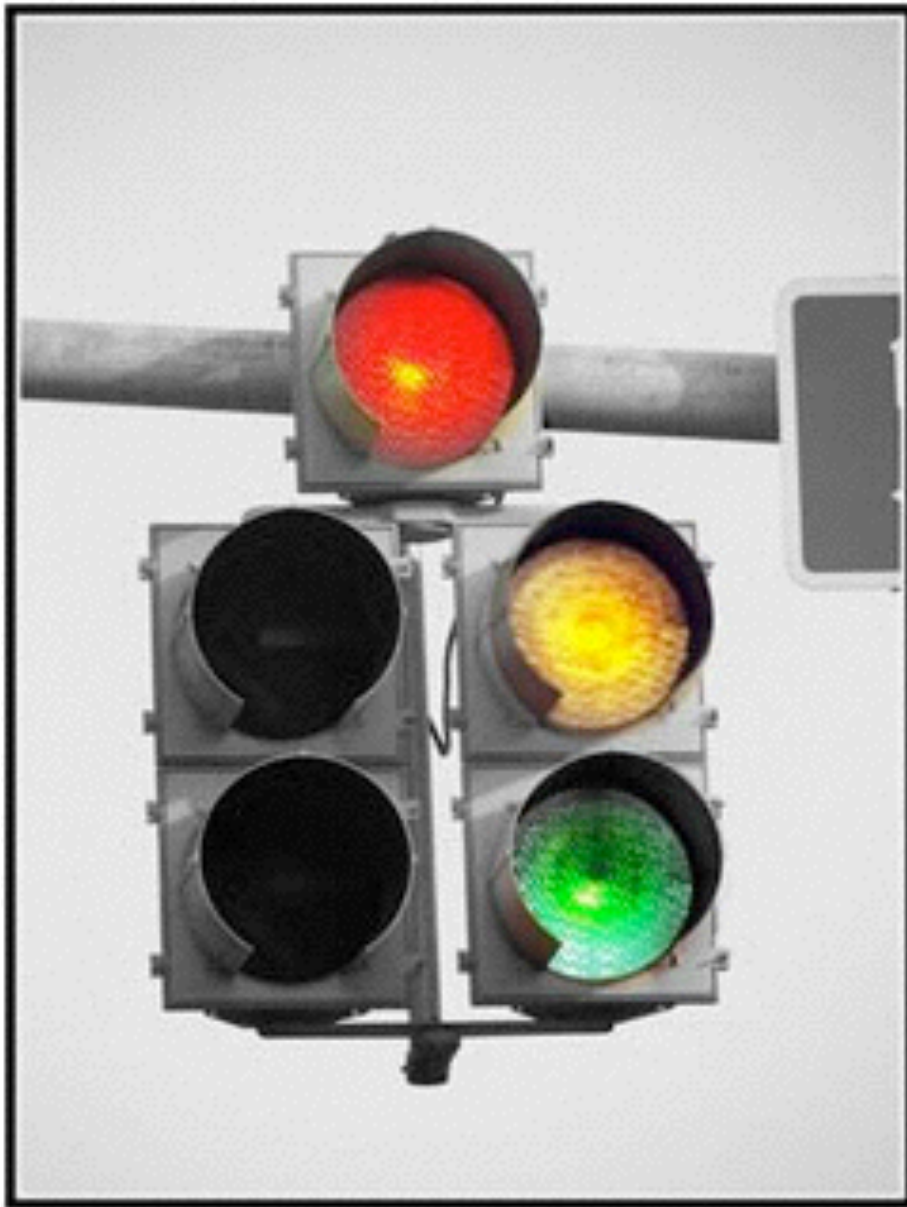
Color blindness (red-green)
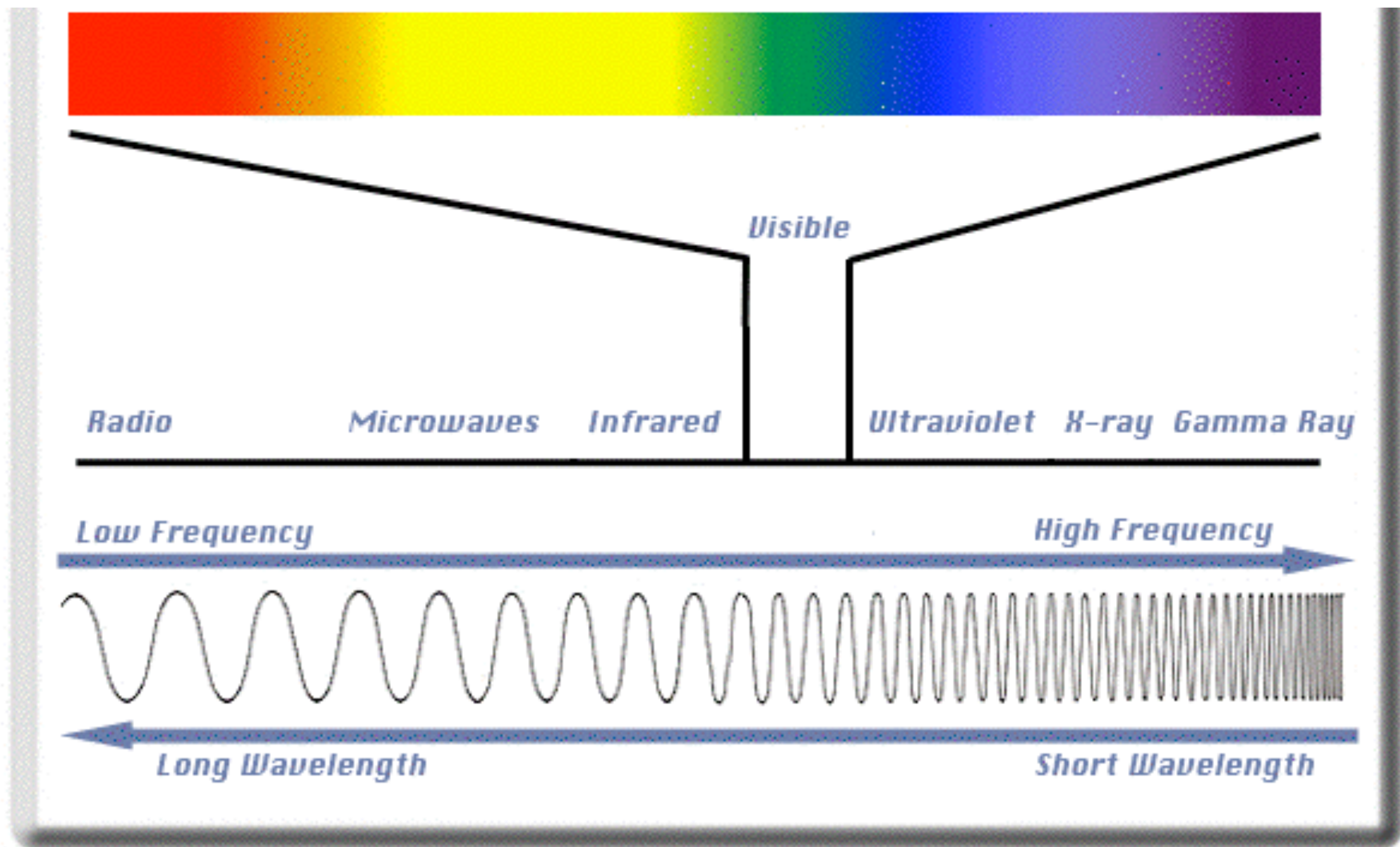
Monochromats

Electromagnetic spectrum

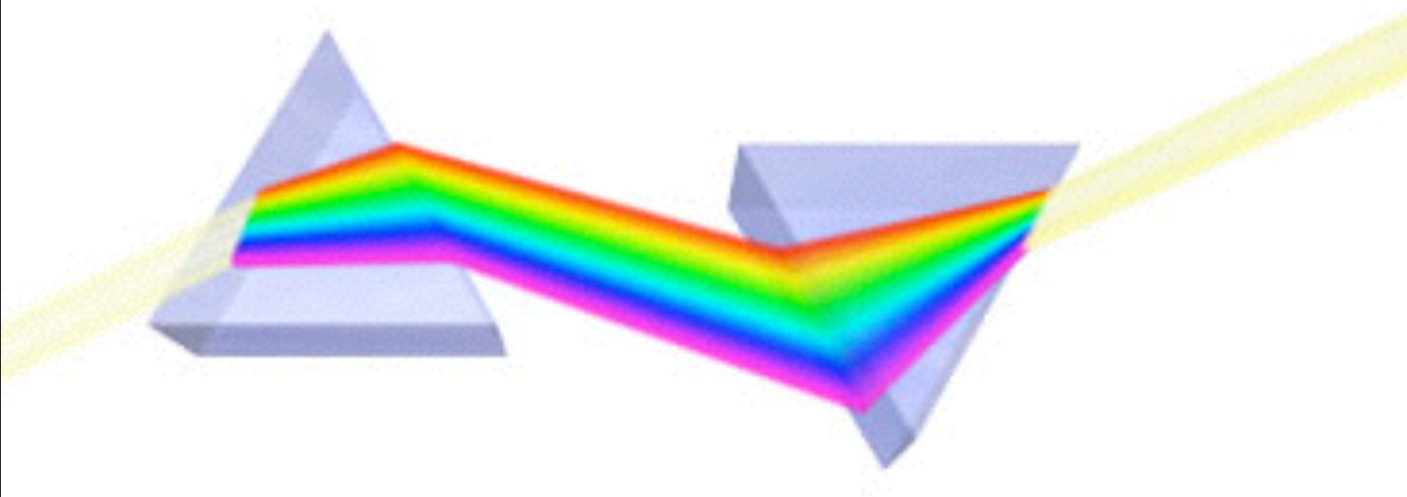700 nm   400 nm

Newton's crucial experiment

- Newton divided light into many components using prisms

- Newton showed that light can be deconstructed and then reconstructed

Source: http://jessicacrabtree.com/journal1/wp-content/uploads/2009/09/newton_prism.jpg
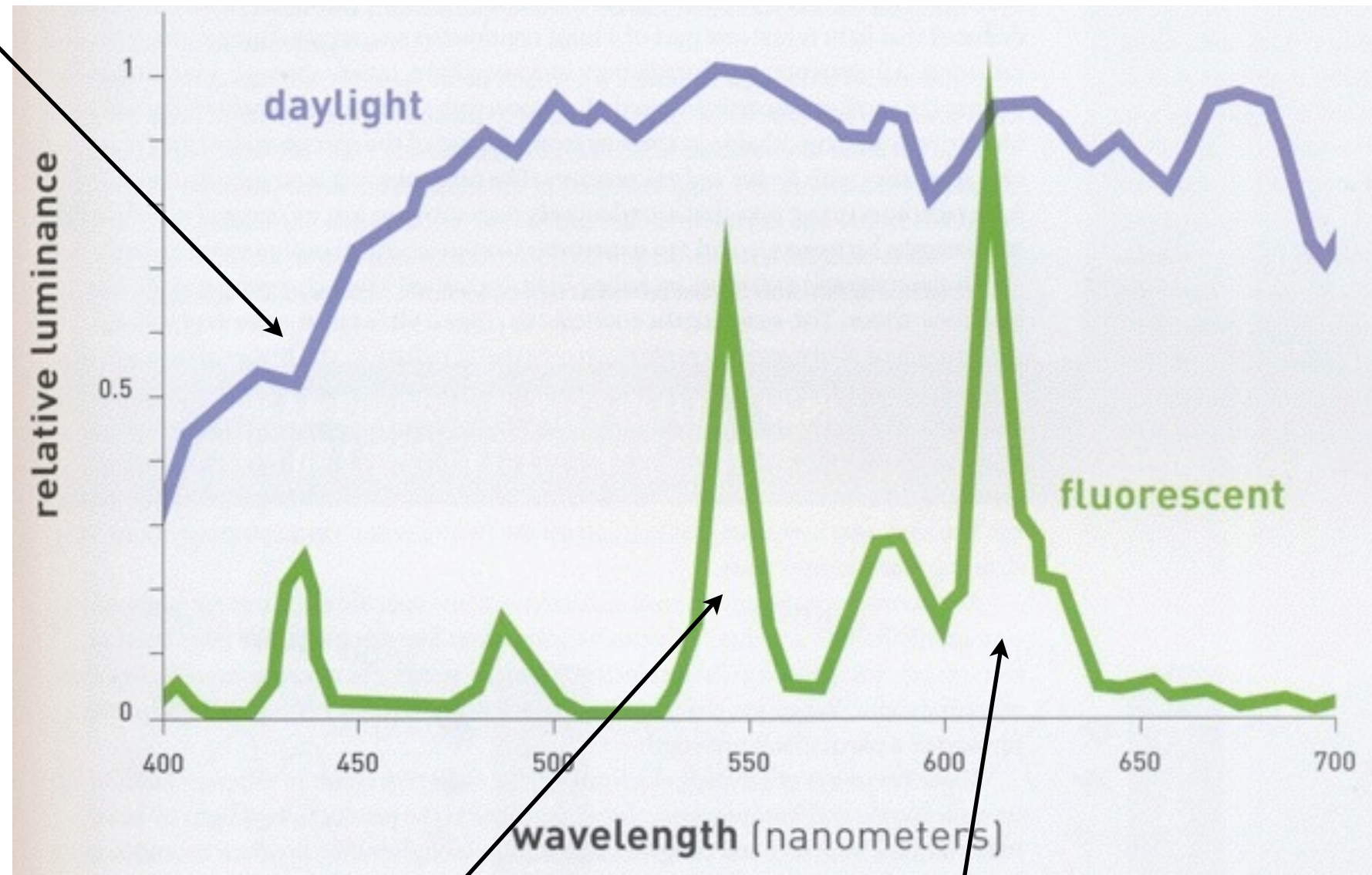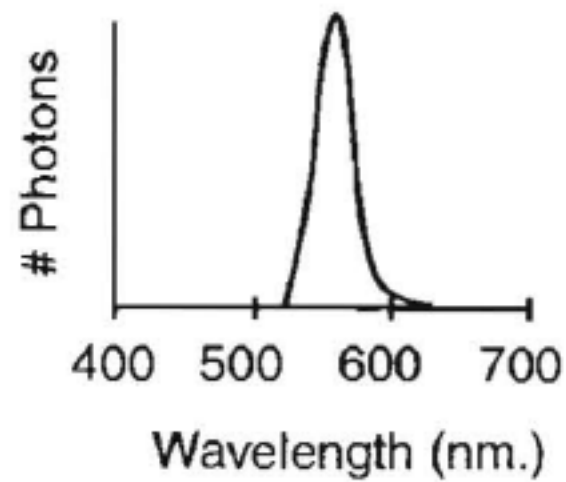http://micro.magnet.fsu.edu/primer/java/scienceopticsu/newton/index.html

Wavelengths in daylight and fluorescent light

Polychromatic light

Monochromatic light

B. Gallium Phosphide Crystal

Greenish yellow   **reddish orange**

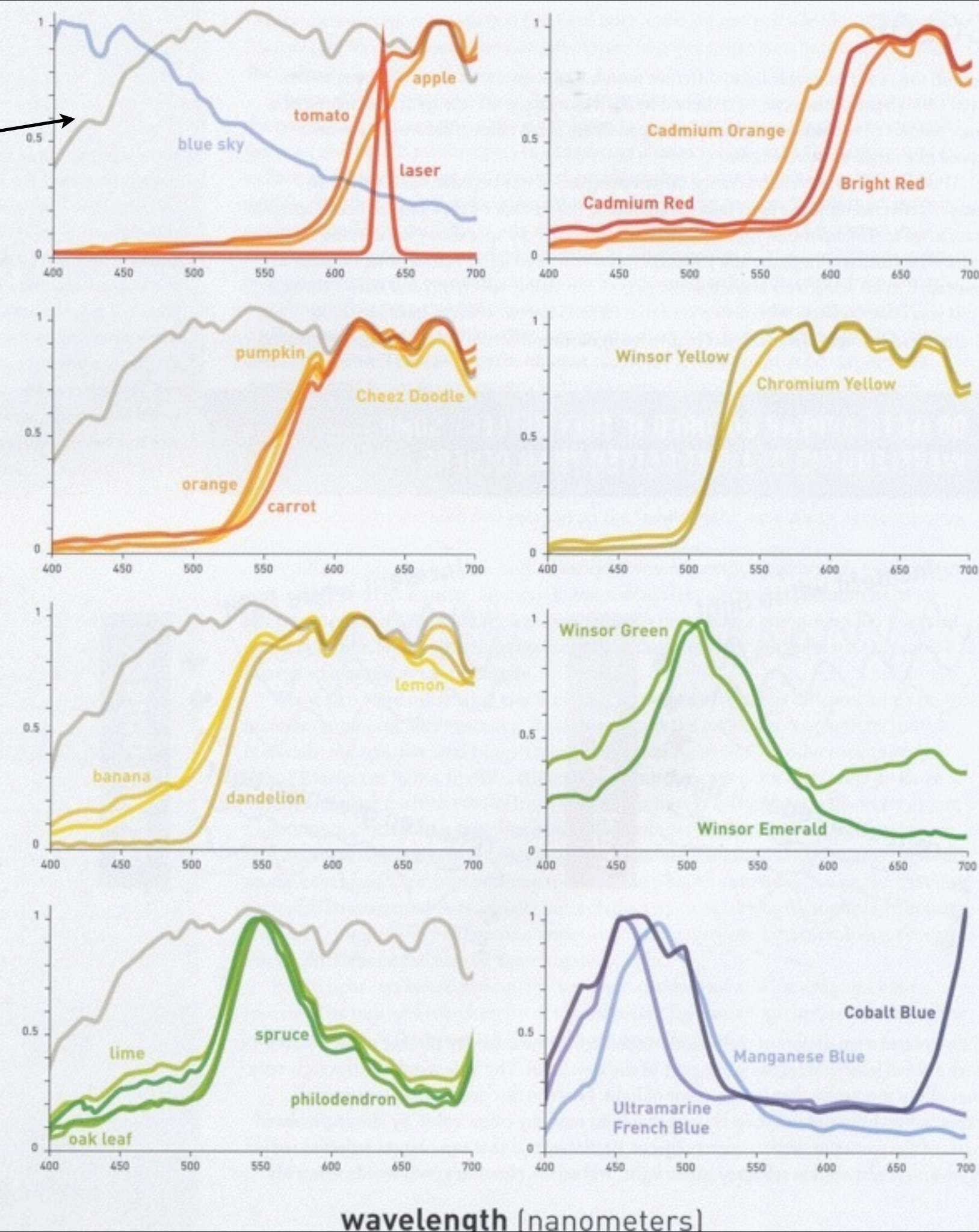# Objects appear colored if they reflect some wavelengths of light better than others

red object

green object

light reflected by a white piece of paper

Wavelength of light reflected from common objects and oil paints
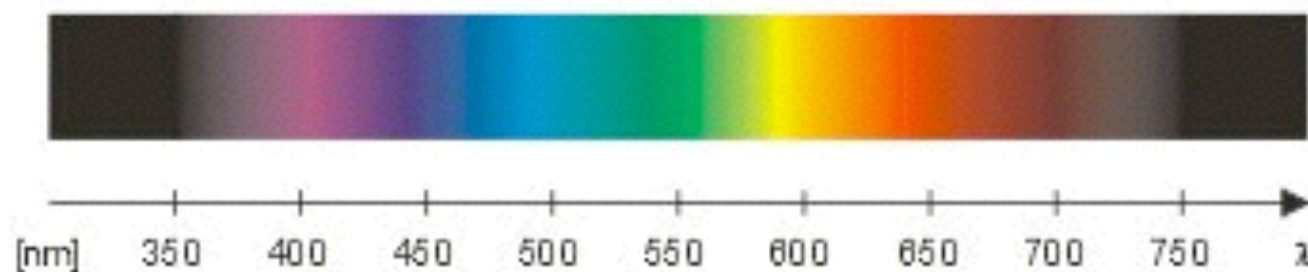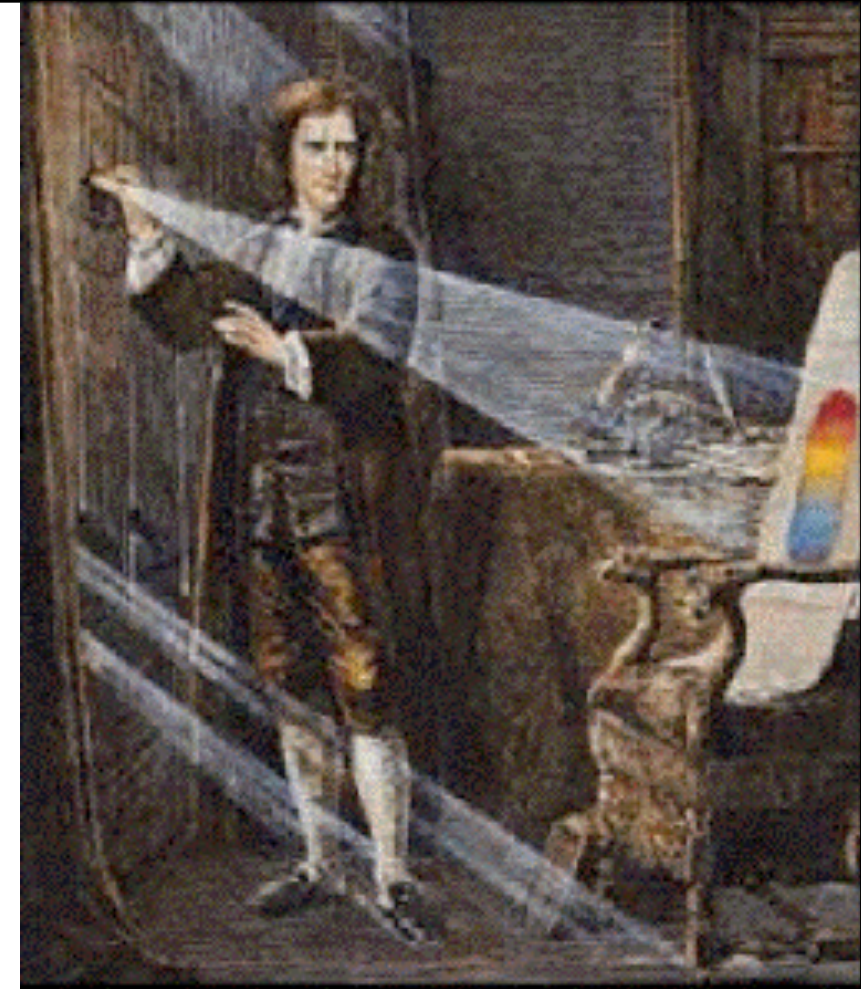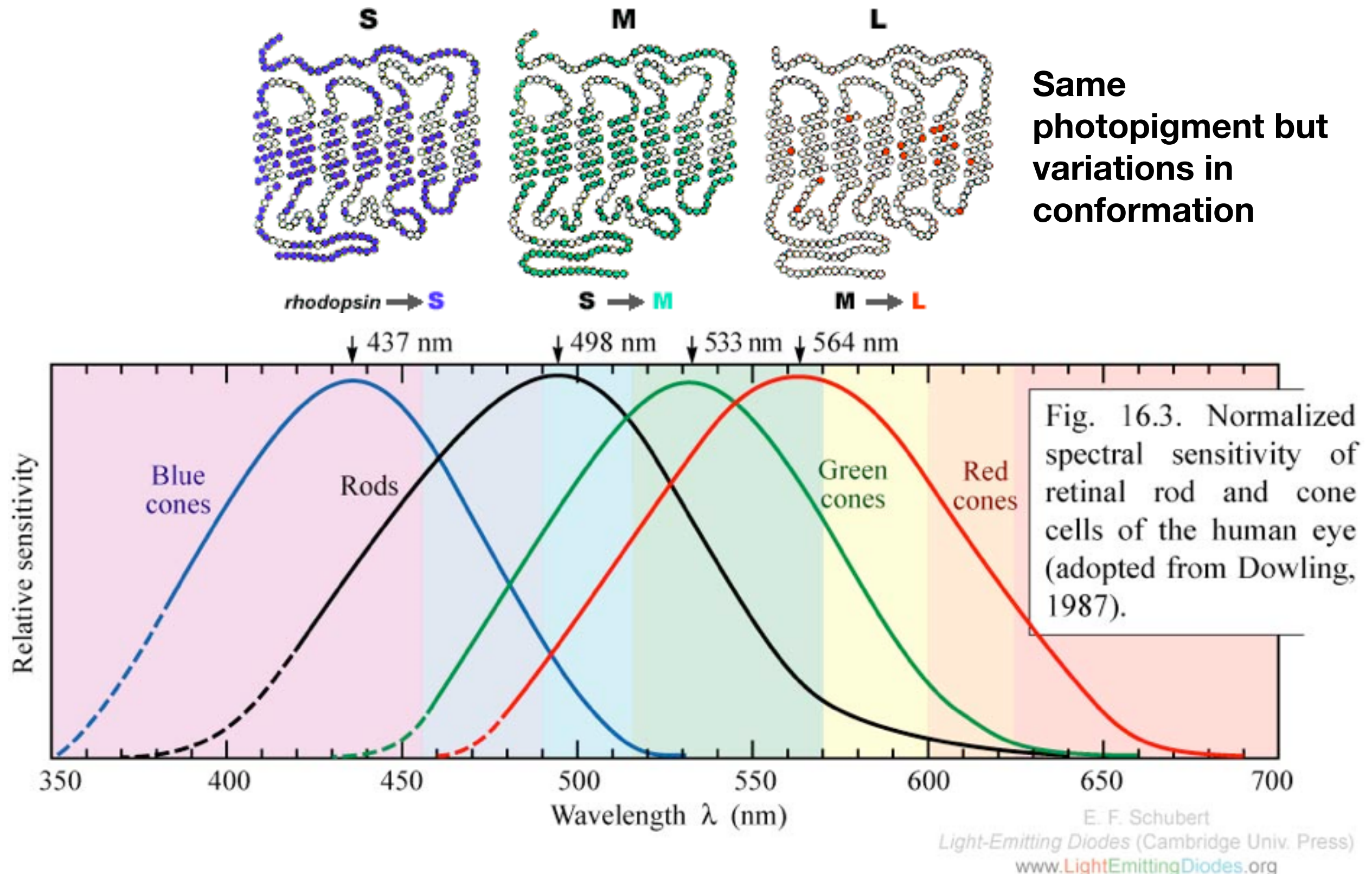
Source: Marge Livingston

Newton's crucial experiment

- "the rays are, to speak properly, not colored"

- Color becomes relevant only when light enters the eye of the observer who is equipped with the proper sort of visual nervous system to experience it
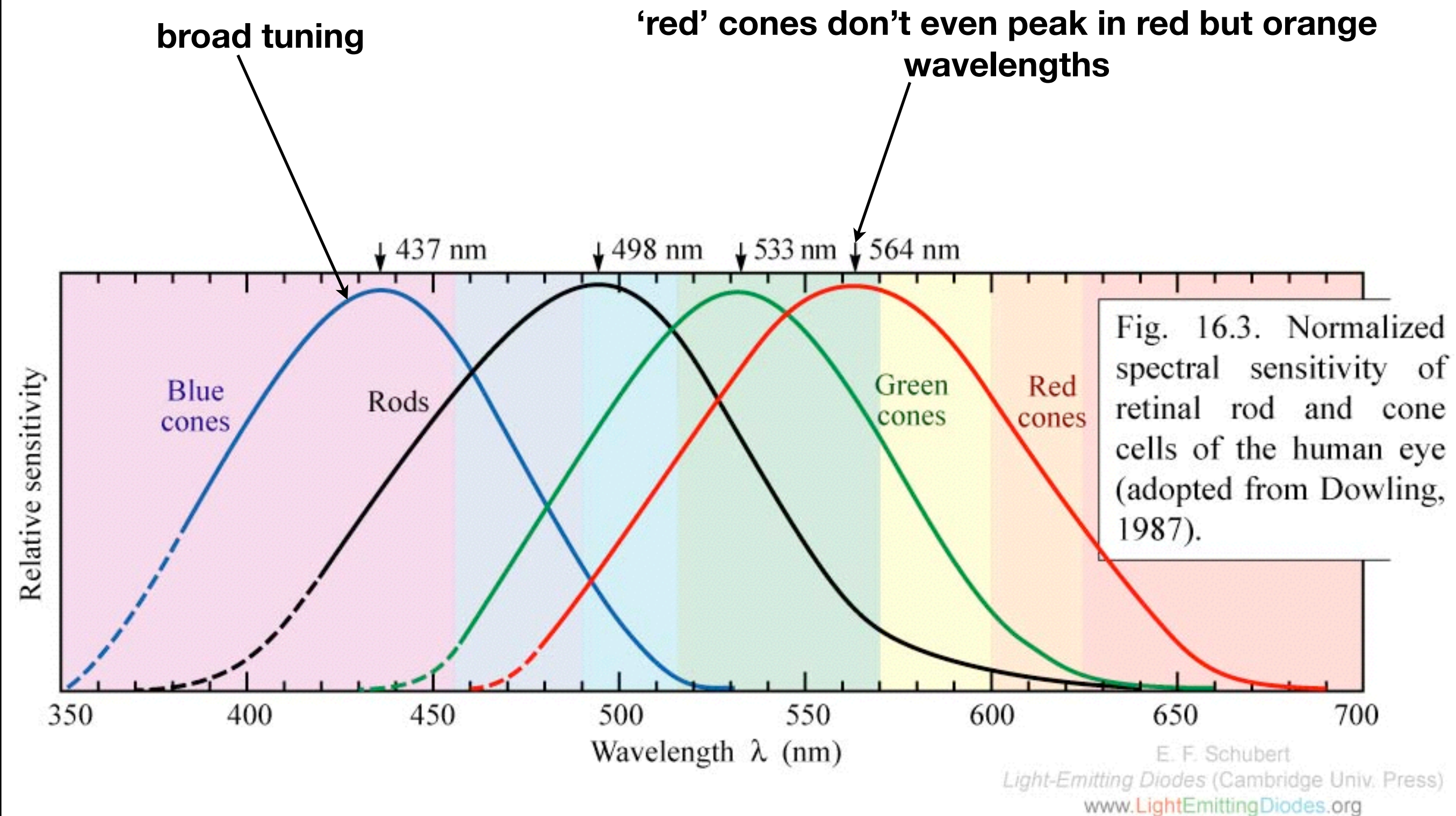
Responses of the cones and rods to wavelengths of light

Same photopigment but variations in conformation

Fig. 16.3. Normalized spectral sensitivity of retinal rod and cone cells of the human eye (adopted from Dowling, 1987).

Responses of the cones and rods to wavelengths of light

broad tuning

'red' cones don't even peak in red but orange wavelengths

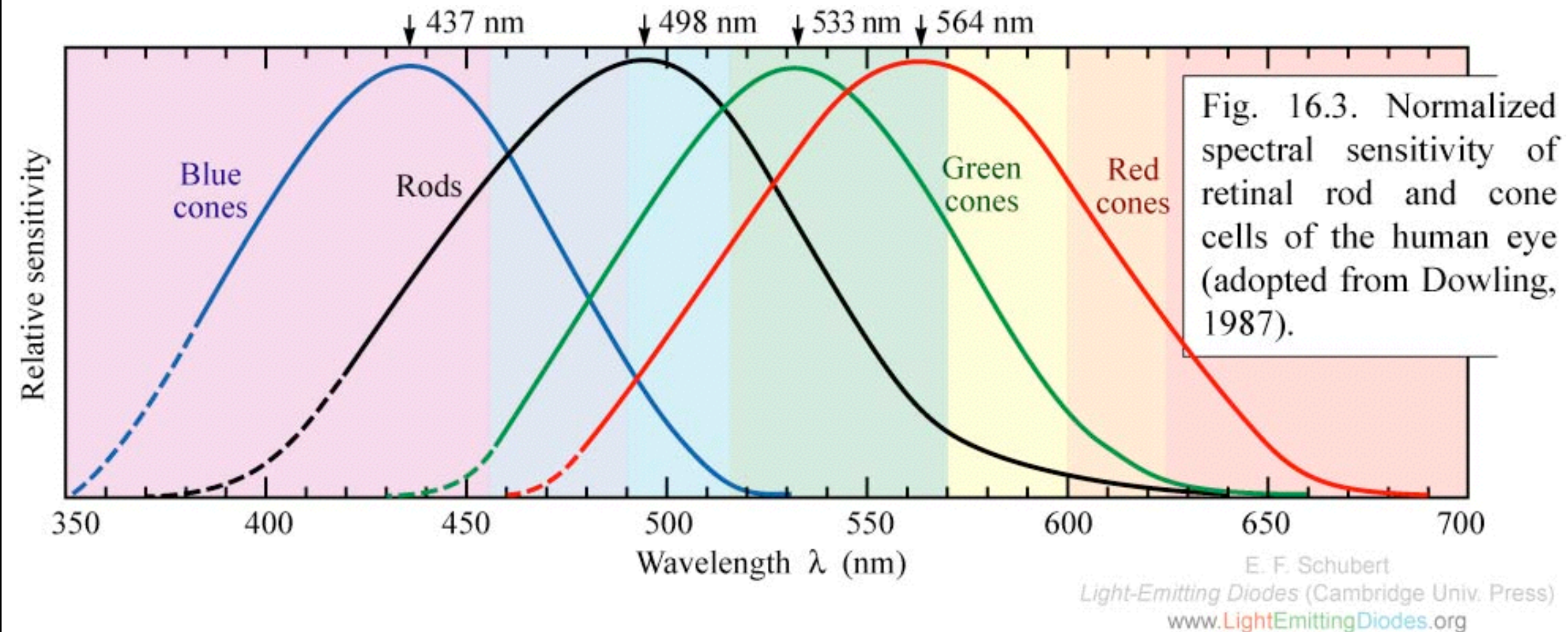Fig. 16.3. Normalized spectral sensitivity of retinal rod and cone cells of the human eye (adopted from Dowling, 1987).
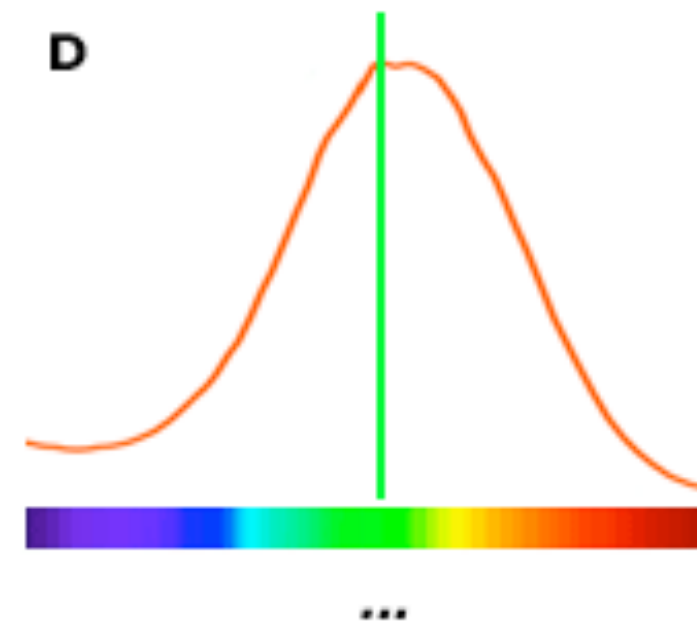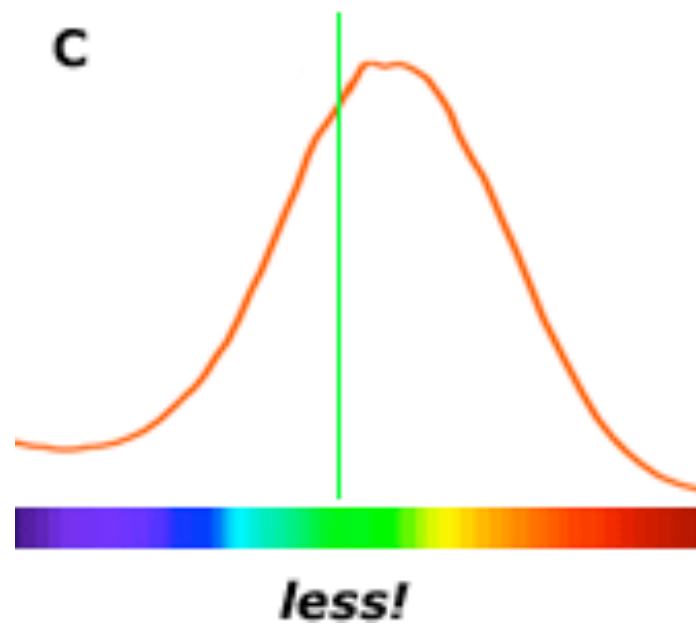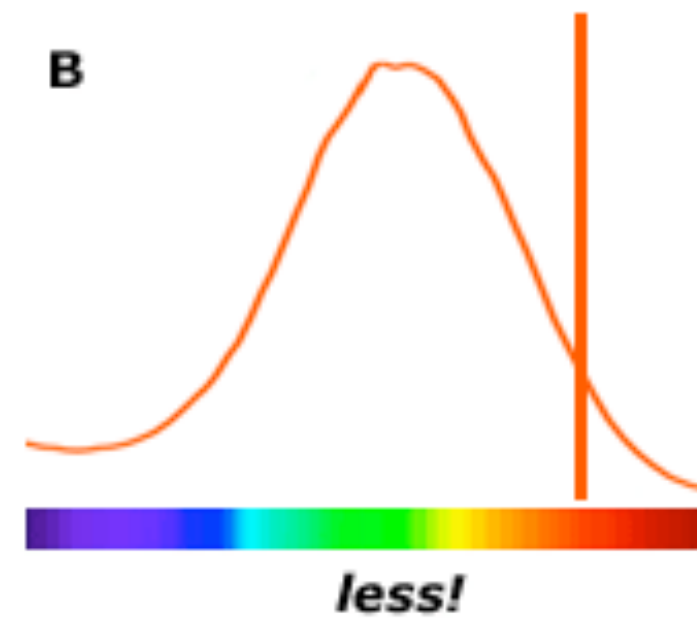
Responses of the cones and rods to wavelengths of light

Response of a single cone type is ambiguous!

Fig. 16.3. Normalized spectral sensitivity of retinal rod and cone cells of the human eye (adopted from Dowling, 1987).
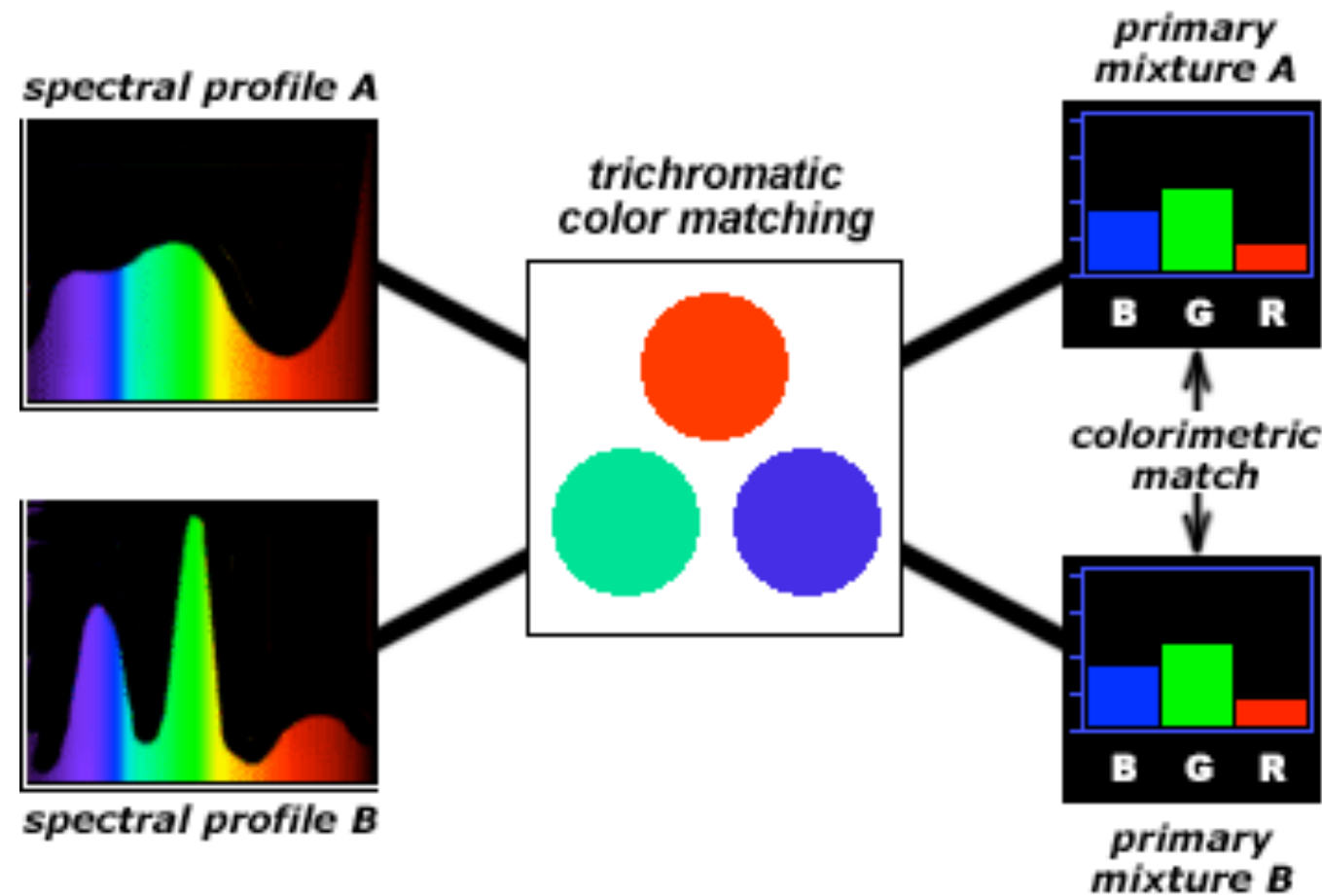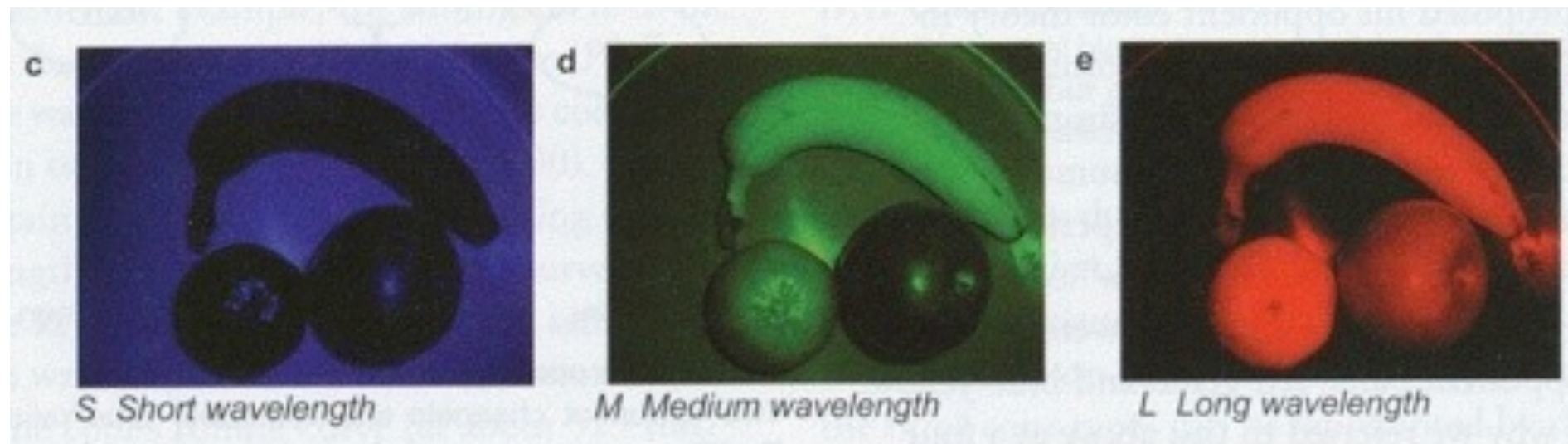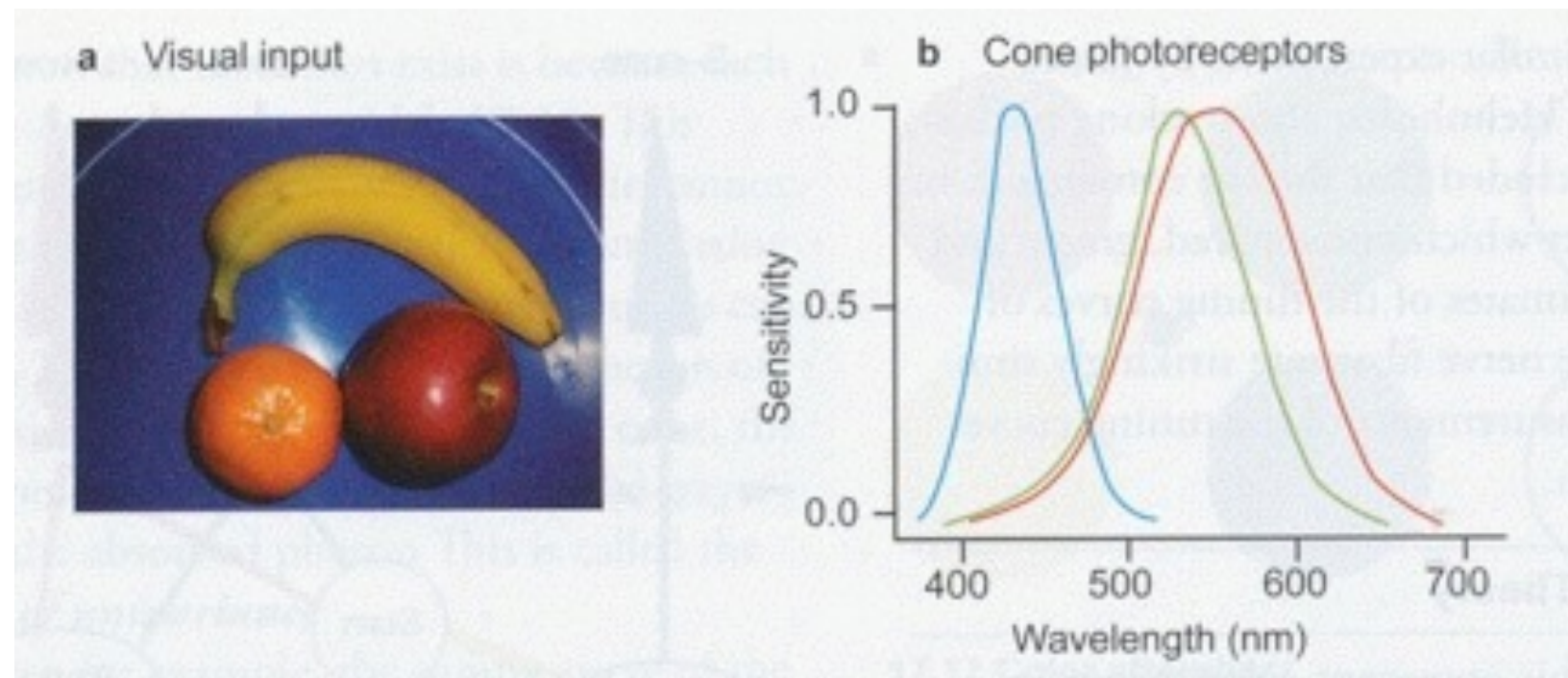
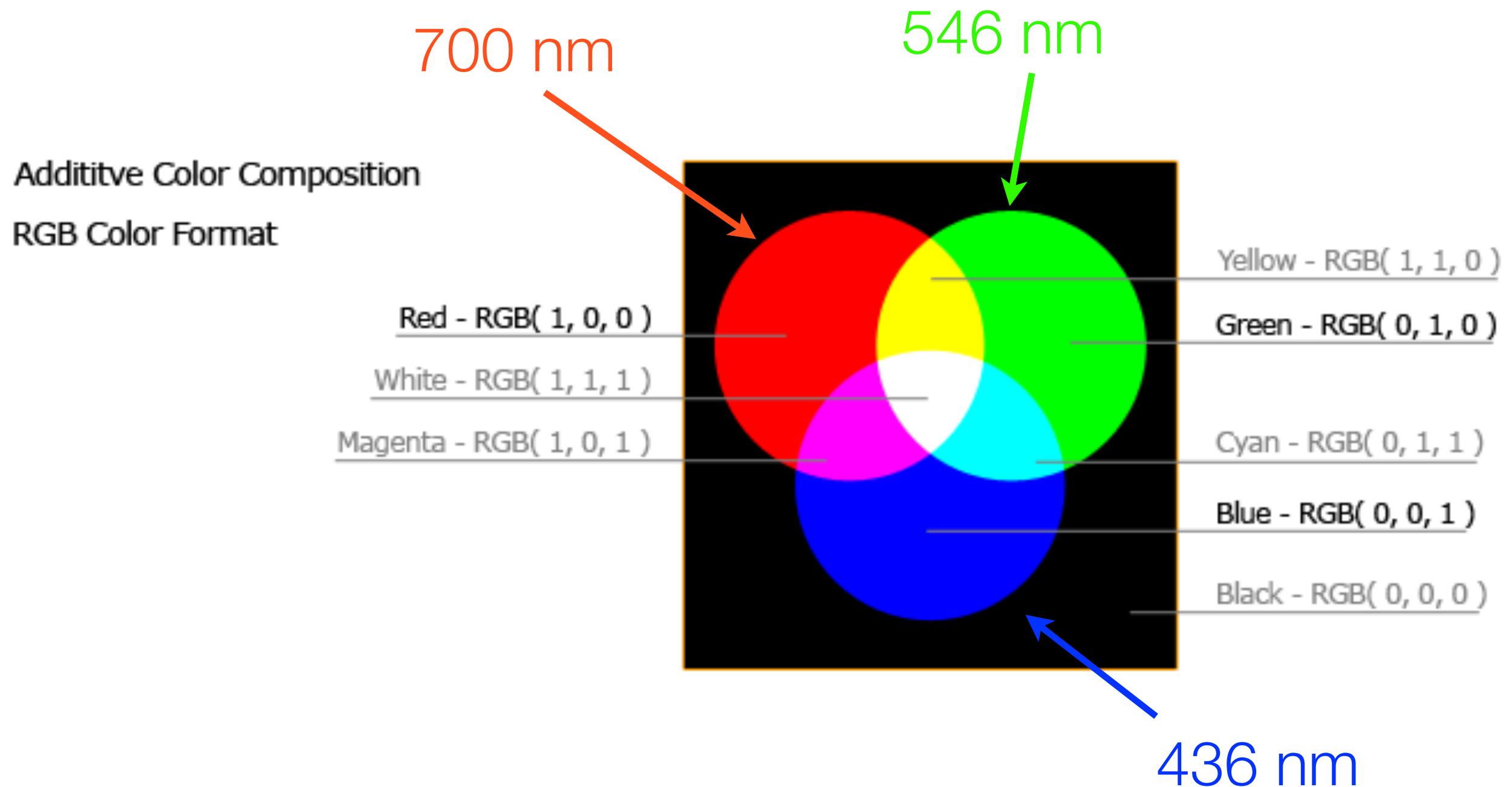# Univariance principle
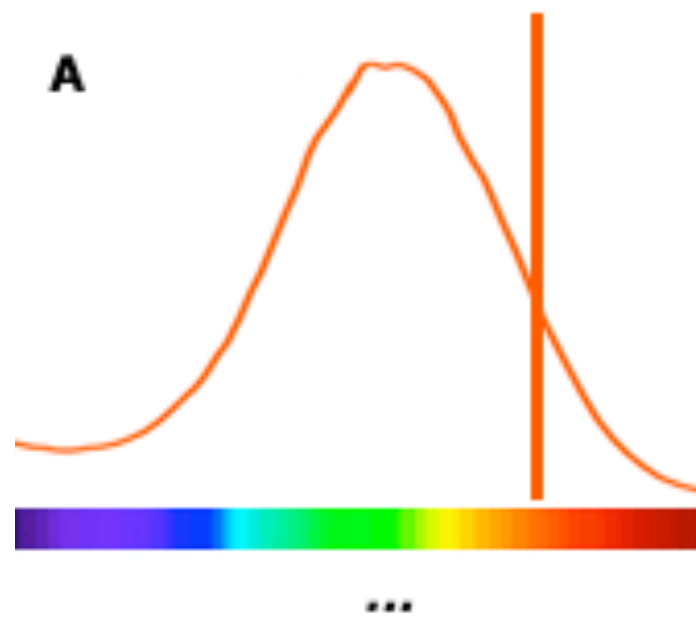
Metamerism
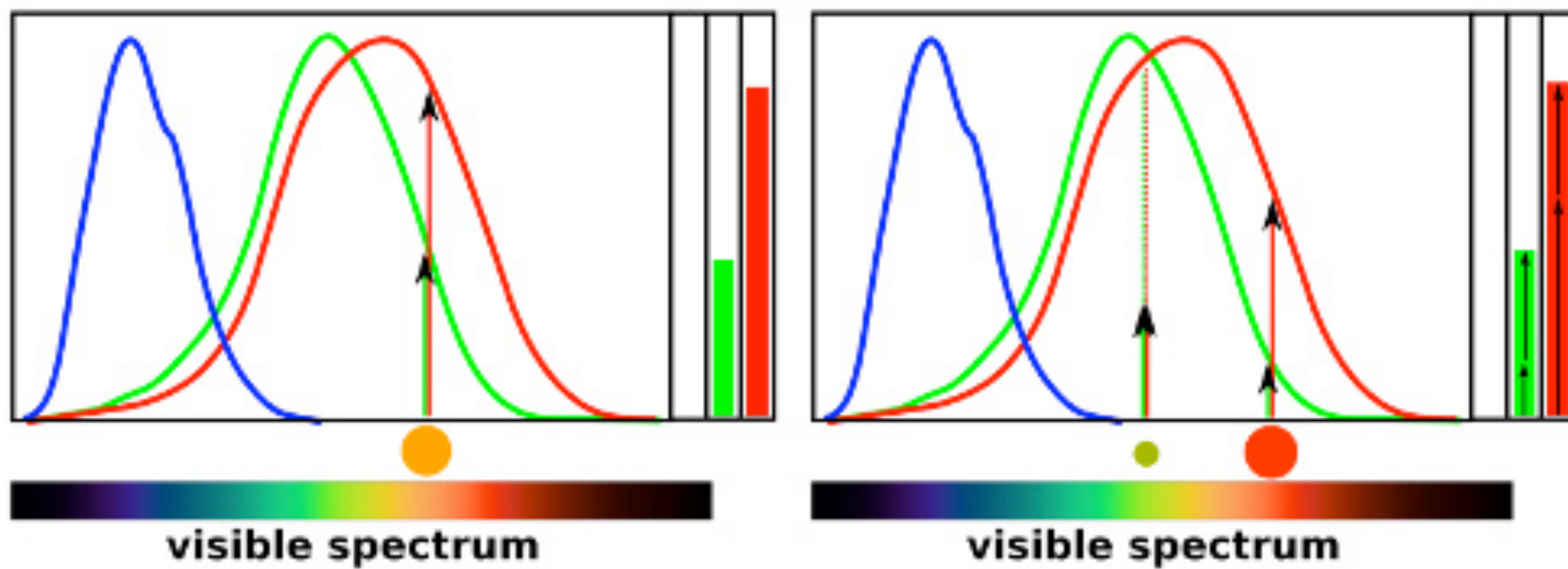
Metamerism

Many physically different lights will look the same!!!
Same indeterminacy problem as with understanding 3D world from 2D retinal projections

Trichromaticity

a Visual input

b Cone photoreceptors

c S Short wavelength

d M Medium wavelength

e L Long wavelength

Representing colors: RGB space

700 nm

546 nm

Addititve Color Composition

RGB Color Format

Red - RGB(1, 0, 0)

White - RGB(1, 1, 1)

Magenta - RGB(1, 0, 1)

Yellow - RGB(1, 1, 0)

Green - RGB(0, 1, 0)

Cyan - RGB(0, 1, 1)

Blue - RGB(0, 0, 1)

Black - RGB(0, 0, 0)

www.equasys.de

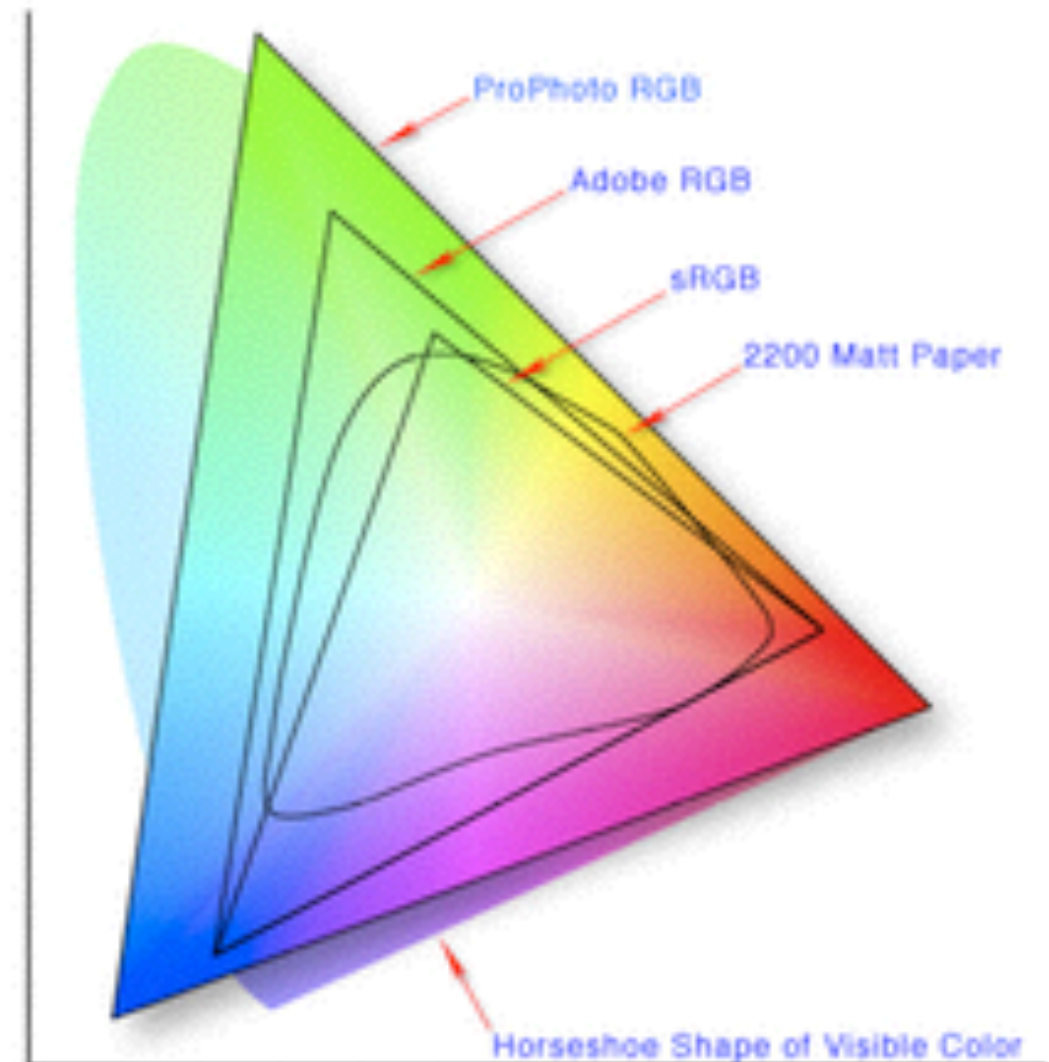436 nm

each color component corresponds
to a specific wavelength

Representing colors: RGB space

- Ideally each component represented with floating point in the range (0,1)

- In practice: 8 bits per component or 24 bits per color, i.e., 16M possible colors

- For higher accuracy people use 10 bits or even 12 bits
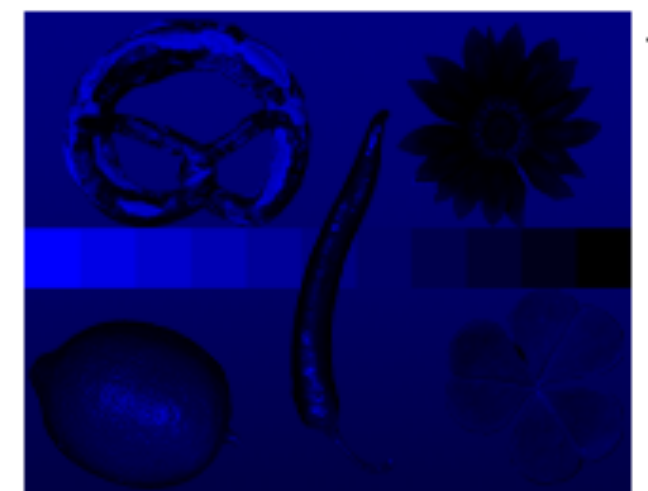
Source: wikipedia

Original Image
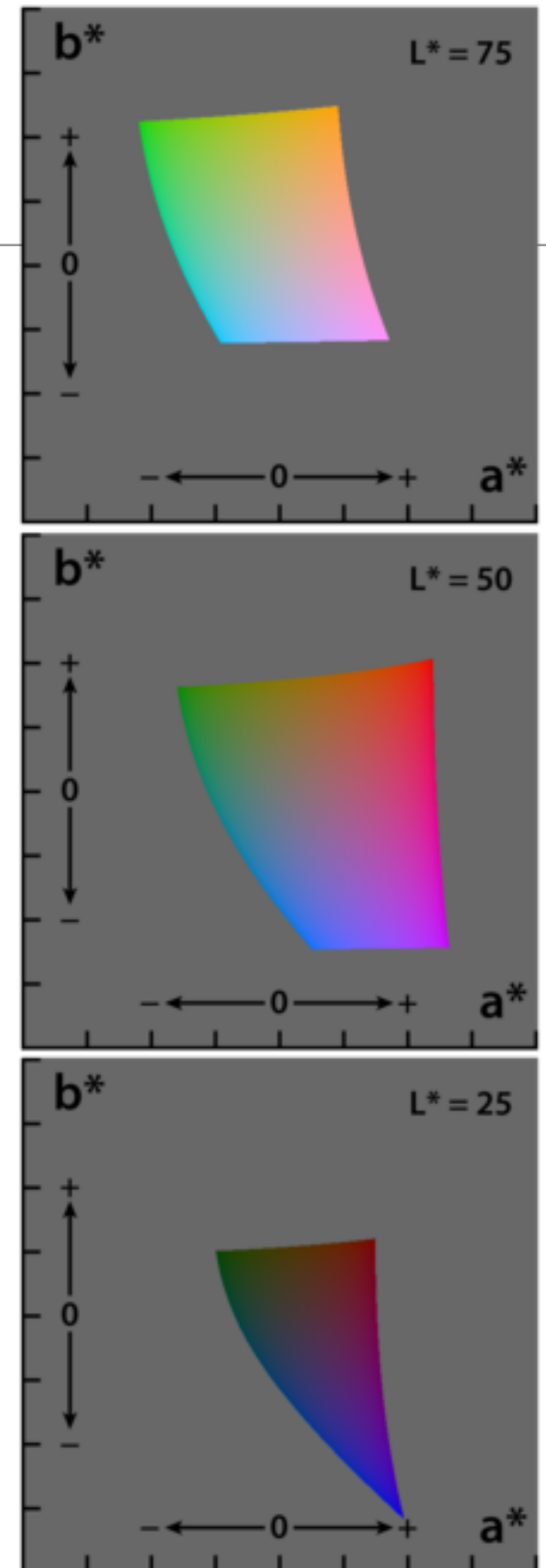
Red Color Component

Green Color Component

Blue Color Component

Representing colors cont'd

- LAB space

  - L: lightness (matched to human lightness sensitivity)

  - A & B correspond to opponent channels (more next)

- LMS space:

  - Long, Medium and Short wavelength based on primate cone sensitivity

- HSV space:

  - Hue, Saturation and Value

- etc etc

Representing colors

- Color space conversions correspond to matrix multiplications

types used in `makecform`	Color spaces
`'lab2lch'`, `'lch2lab'`	L*a*b* and L*ch
`'lab2srgb'`, `'srgb2lab'`	L*a*b* and sRGB
`'lab2xyz'`, `'xyz2lab'`	L*a*b* and XYZ
`'srgb2xyz'`, `'xyz2srgb'`	sRGB and XYZ
`'upvpl2xyz'`, `'xyz2upvpl'`	u′v′L and XYZ
`'uvl2xyz'`, `'xyz2uvl'`	uvL and XYZ
`'xyl2xyz'`, `'xyz2xyl'`	xyY and XYZ