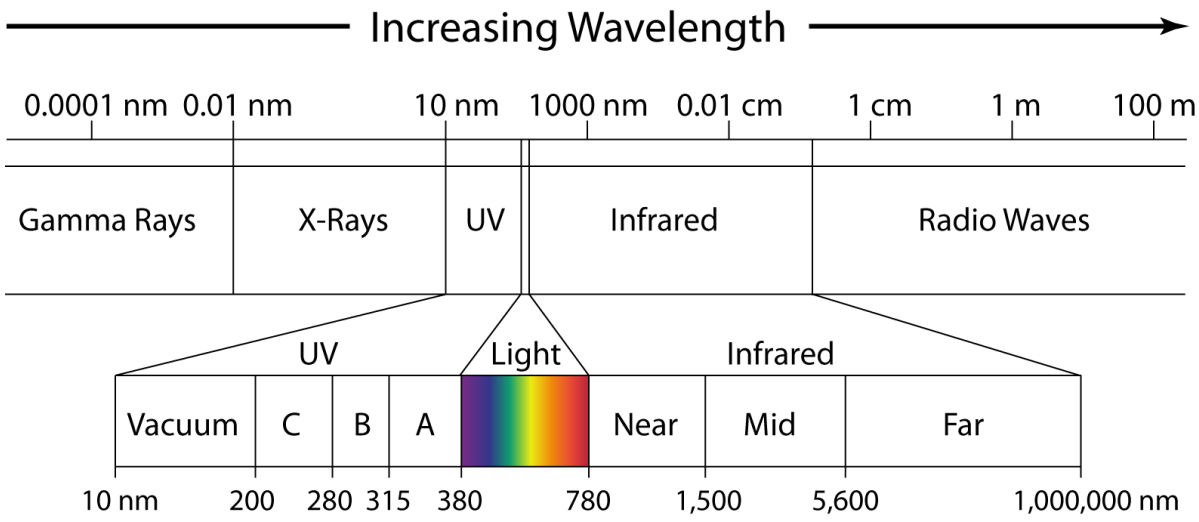
# INF250

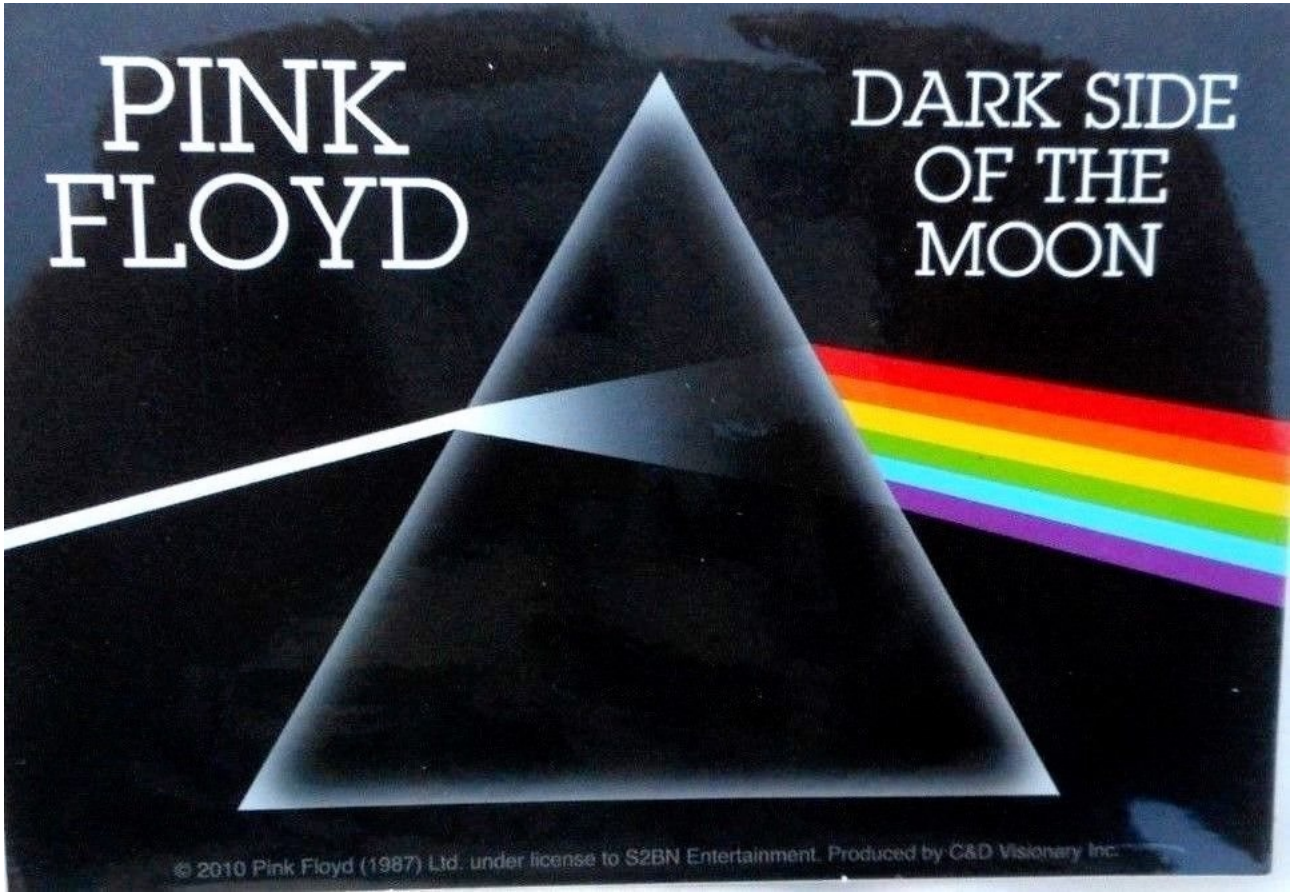
## Colour images

# Things you need to know

- RGB colour space – what is it and how do we represent it ?
- What is CIE and the CIE horseshoe ?
- Colour models you must be able to describe:
  - CIE  Lab colour space
  - RGB
  - Munsell
- Terms to know:
  - Hue
  - Chroma
  - Brightness
  - Lightness
  - Gamut

# Electromagnetic spectrum






Sir Isaac Newton discovered white light spectrum in 1666,

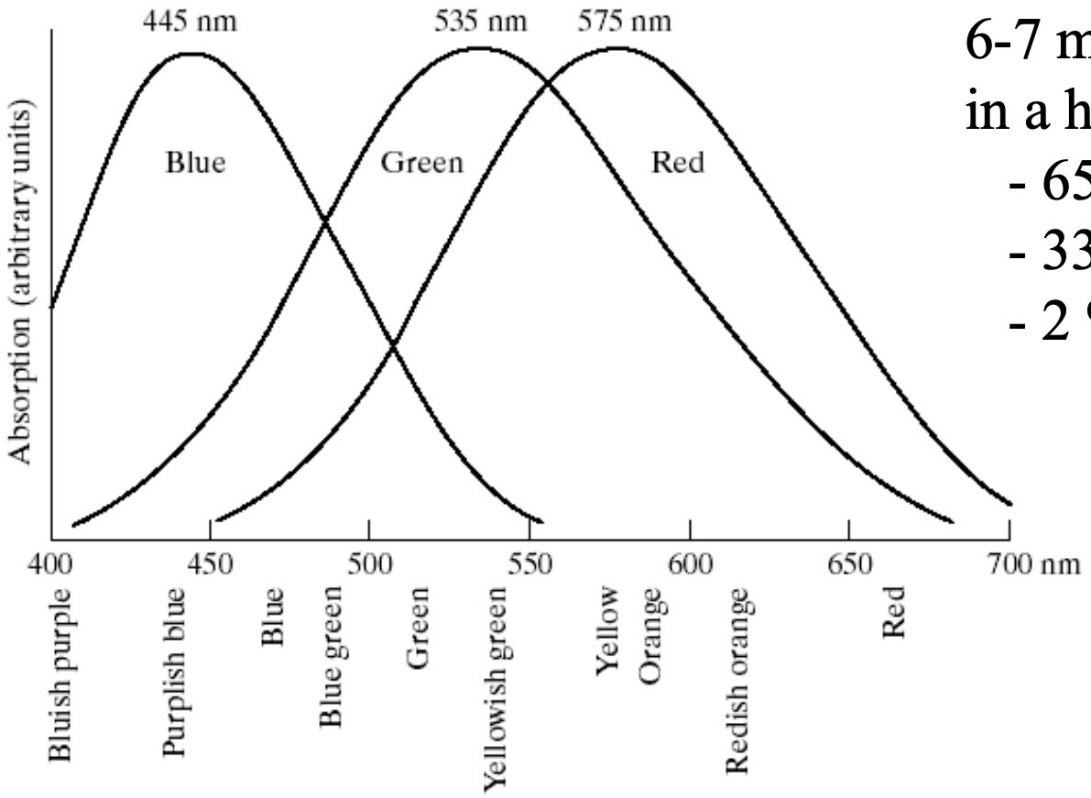
at the age of 24

# RGB colour space

red

green

blue



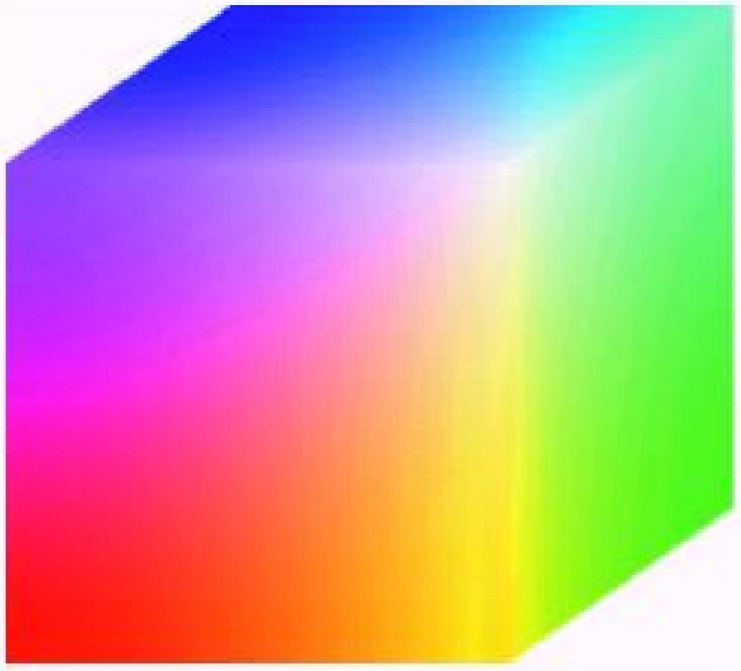

6-7 millions cones
in a human eye
- 65% sensitive to Red light
- 33% sensitive to Green light
- 2 % sensitive to Blue light

Primary colors:
Defined CIE in 1931
Red = 700 nm
Green = 546.1nm
Blue = 435.8 nm

CIE = Commission Internationale de l'Eclairage
(The International Commission on Illumination)

(Images from Rafael C. Gonzalez and Richard E. Wood, Digital Image Processing, 2nd Edition.

# RGB colour space



R = 8 bits
G = 8 bits
B = 8 bits

Color depth 24 bits
= 16777216 colors

$(R = 0)$ $(G = 0)$ $(B = 0)$

Hidden faces
of the cube

(Images from Rafael C. Gonzalez and Richard E. Wood, Digital Image Processing, 2nd Edition.

# Two ways of storing colours

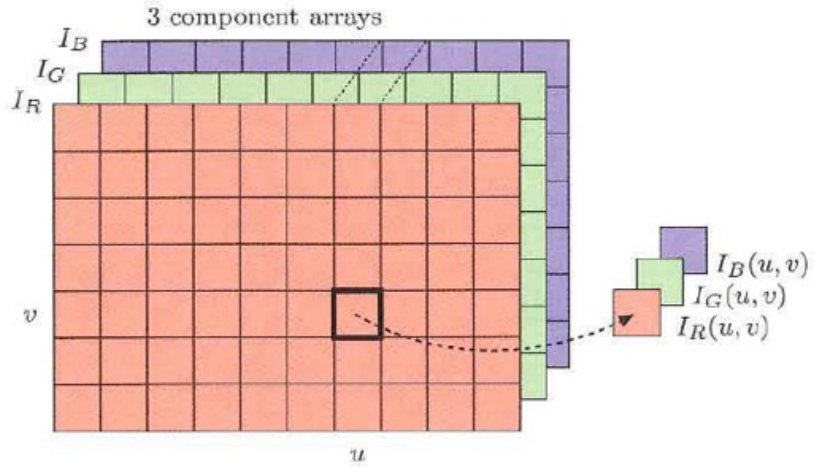



**Figure 8.3** RGB color image in component ordering. The three color components are laid out in separate arrays $I_R$, $I_G$, $I_B$ of the same size.

Component ordering

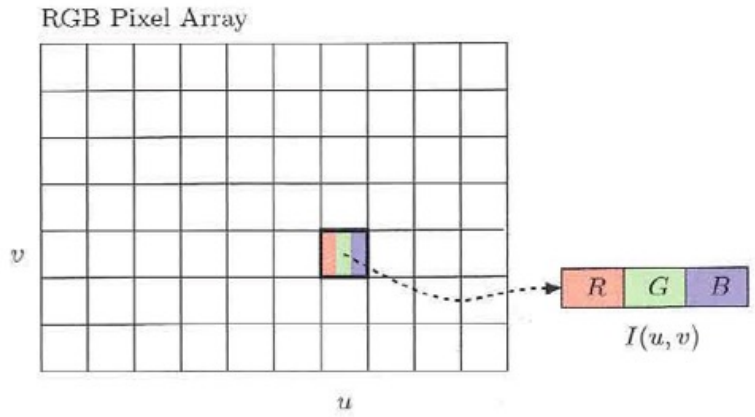
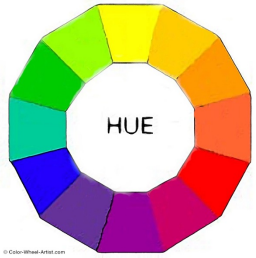



**Figure 8.4** RGB-color image using packed ordering. The three color components $R$, $G$, and $B$ are placed together in a single array element.

Packed ordering

- **Hue** – attribute of colours that permits them to be classed as red, yellow, green, blue or an intermediate between any contiguous pair of these




- **Brightness** – an attribute of visual perception in which an object appears to radiate or reflect light
- **Lightness** – value or tone of a colour
- **Chroma** – a measure of colour purity on the Munsell colour system
- **Gamut** – a complete subset of colours, within a certain colour space or within an output device

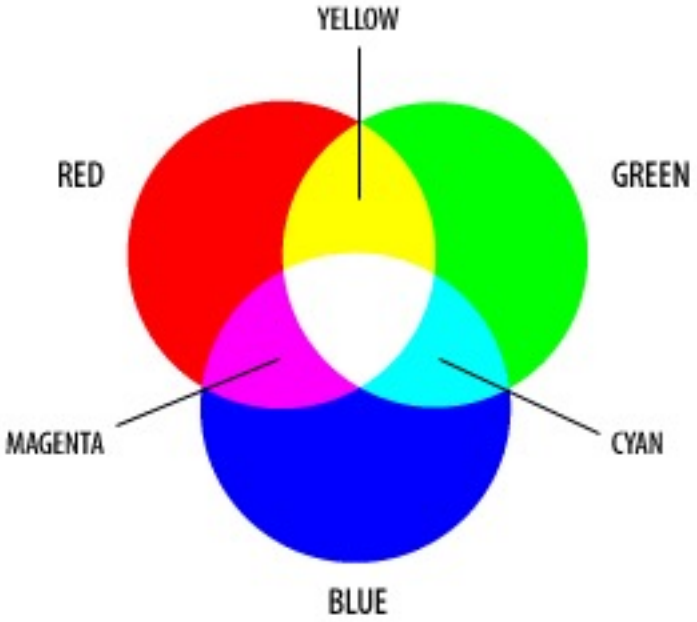
http://changingminds.org/explanations/perception/visual/lightness_variants.htm

# Colour models

- Colour models are used to classify colours and to qualify them according to attributes  such as hue, saturation, chroma, lightness, or brightness.
- They are further used for matching colors and are valuable resources for anyone working with color in any medium: print, video, or Web.

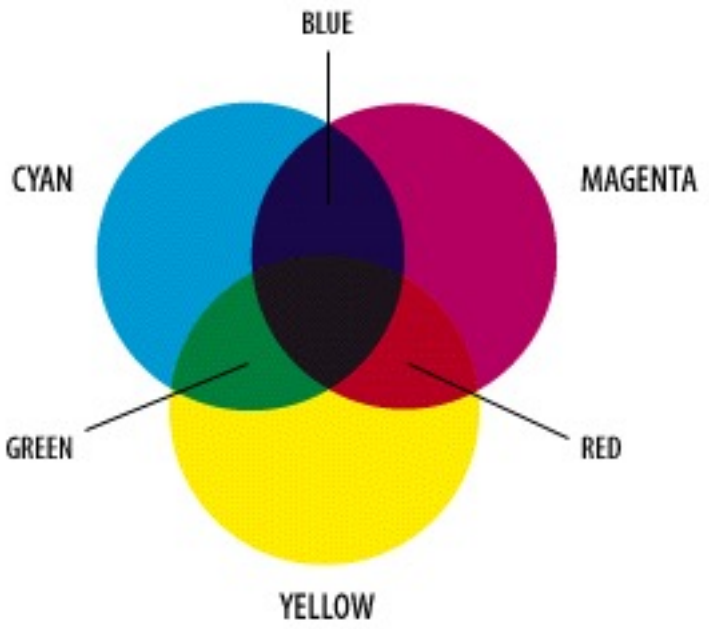
# RGB colour model

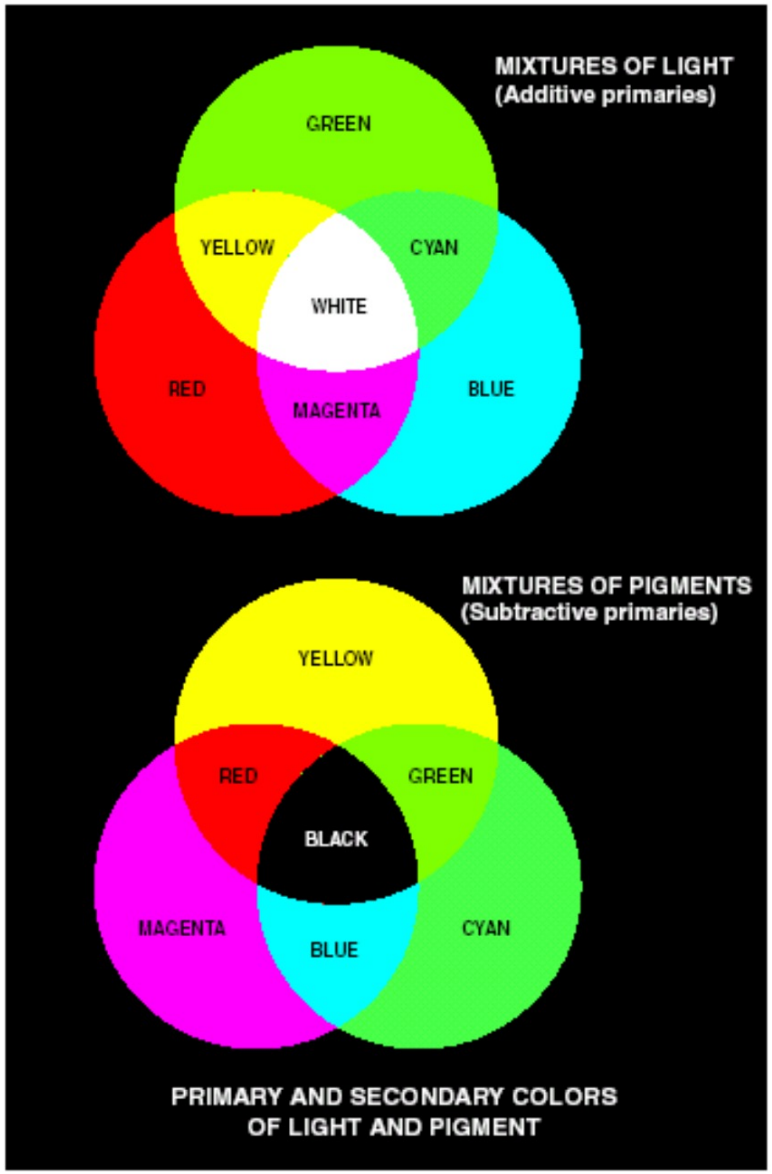
- Additive colours



# RGB colour model

- Subtractive colours CMY






Additive primary colors: RGB use in the case of light sources such as color monitors

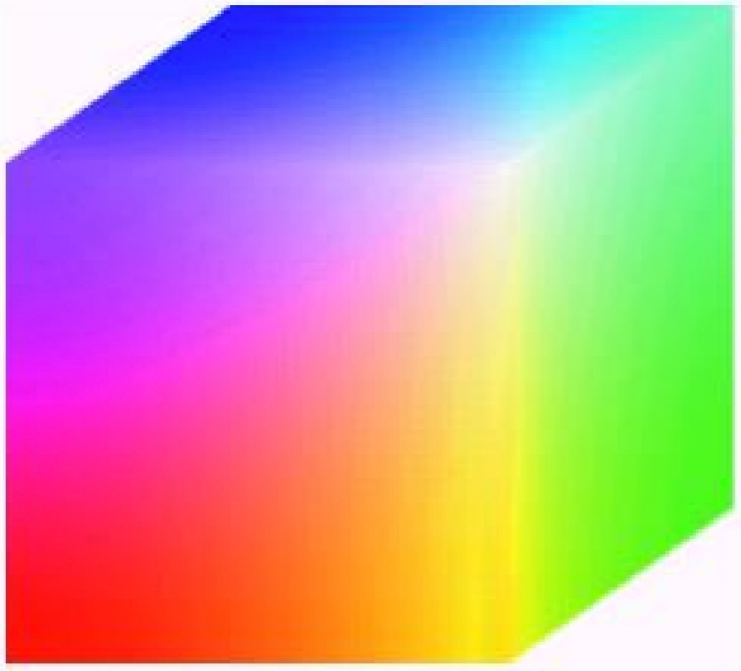
RGB add together to get white

Subtractive primary colors: CMY use in the case of pigments in printing devices

White subtracted by CMY to get Black

(Images from Rafael C. Gonzalez and Richard E. Wood, Digital Image Processing, 2nd Edition.

# RGB colour space



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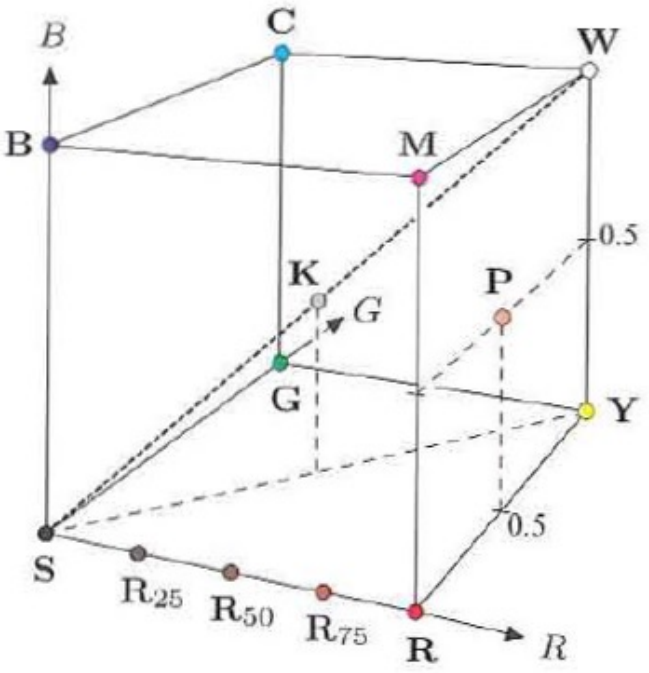
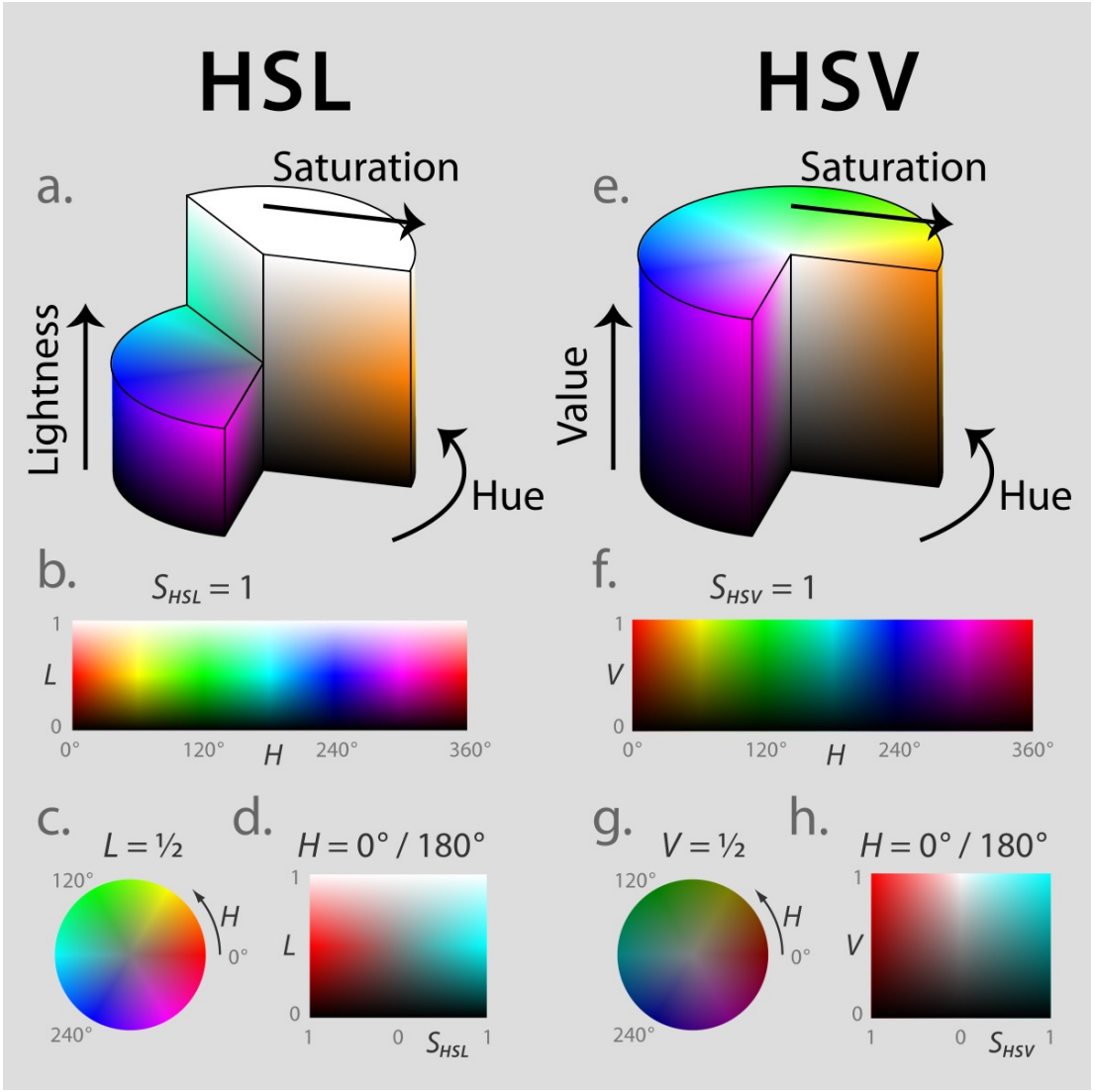
# Colour space




| Point | Color | RGB Value R | G | B |
|---|---|---|---|---|
| S | Black | 0.00 | 0.00 | 0.00 |
| R | Red | 1.00 | 0.00 | 0.00 |
| Y | Yellow | 1.00 | 1.00 | 0.00 |
| G | Green | 0.00 | 1.00 | 0.00 |
| C | Cyan | 0.00 | 1.00 | 1.00 |
| B | Blue | 0.00 | 0.00 | 1.00 |
| M | Magenta | 1.00 | 0.00 | 1.00 |
| W | White | 1.00 | 1.00 | 1.00 |
| K | 50% Gray | 0.50 | 0.50 | 0.50 |
| $R_{75}$ | 75% Red | 0.75 | 0.00 | 0.00 |
| $R_{50}$ | 50% Red | 0.50 | 0.00 | 0.00 |
| $R_{25}$ | 25% Red | 0.25 | 0.00 | 0.00 |
| P | Pink | 1.00 | 0.50 | 0.50 |

**Figure 8.1** Representation of the RGB color space as a three-dimensional unit cube. The primary colors red ($R$), green ($G$), and blue ($B$) form the coordinate system. The "pure" red color (**R**), green (**G**), blue (**B**), cyan (**C**), magenta (**M**), and yellow (**Y**) lie on the vertices of the color cube. All the shades of gray, of which **K** is an example, lie on the diagonal between black **S** and white **W**.



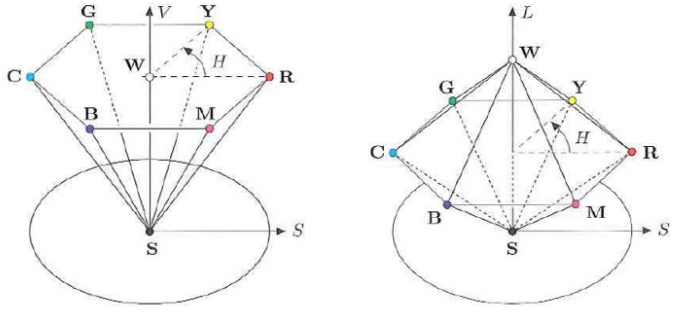
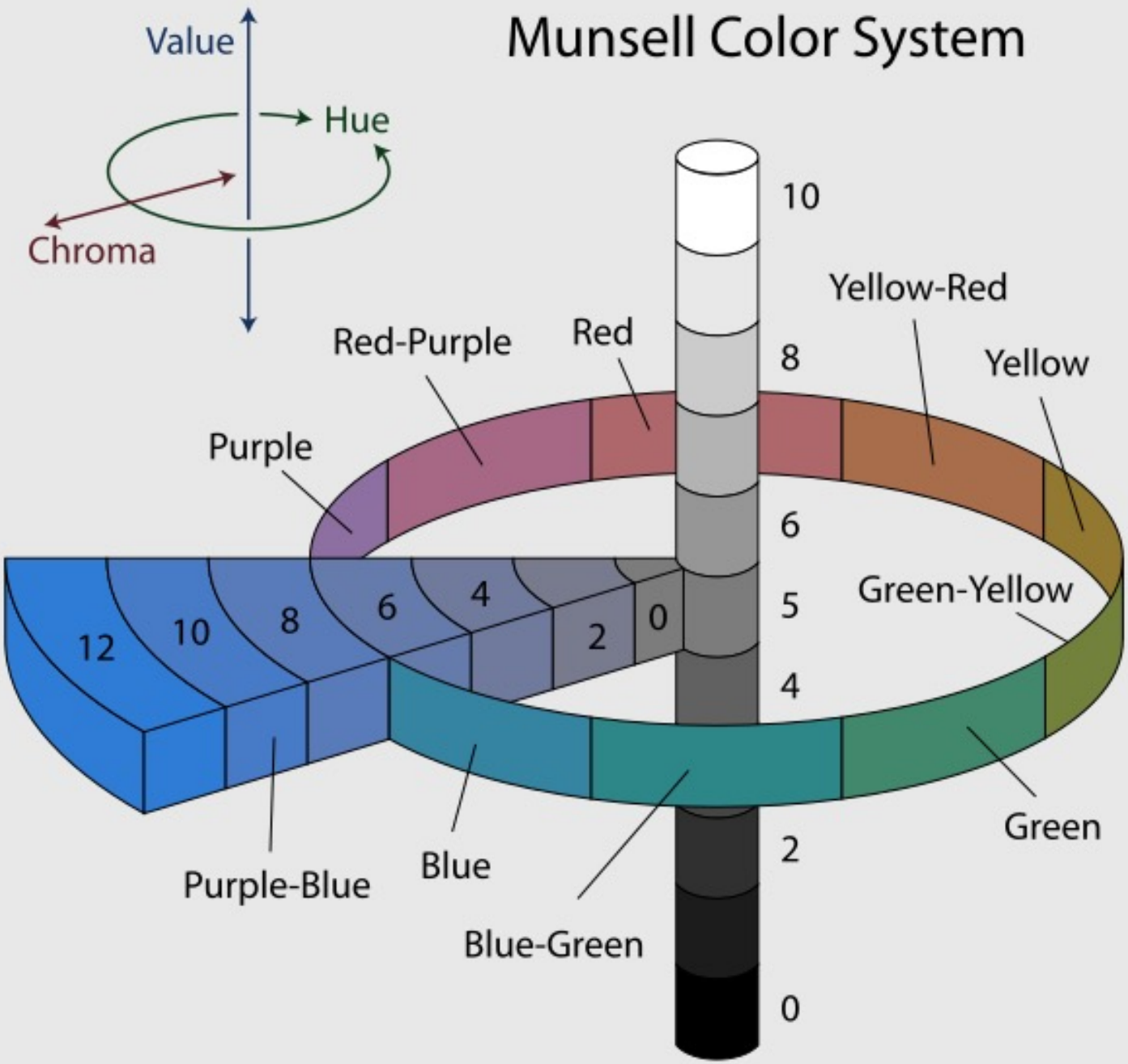




**Figure 8.11** HSV and HLS color space are traditionally visualized as a single or double hexagonal pyramid. The brightness $V$ (or $L$) is represented by the vertical dimension, the color saturation $S$ by the radius from the pyramid's axis, and the hue $h$ by the angle. In both cases, the primary colors red (**R**), green (**G**), and blue (**B**) and the mixed colors yellow (**Y**), cyan (**C**), and magenta (**M**) lie on a common plane with black (**S**) at the tip. The essential difference between the HSV and HLS color spaces is the location of the white point (**W**).


Munsell Color System
Value
Hue
Chroma
10
8
6
5
4
2
0
Red-Purple
Red
Yellow-Red
Yellow
Purple
Green-Yellow
12
10
8
6
4
2
0
Purple-Blue
Blue
Blue-Green
Green

# Distribution of colours in various spaces

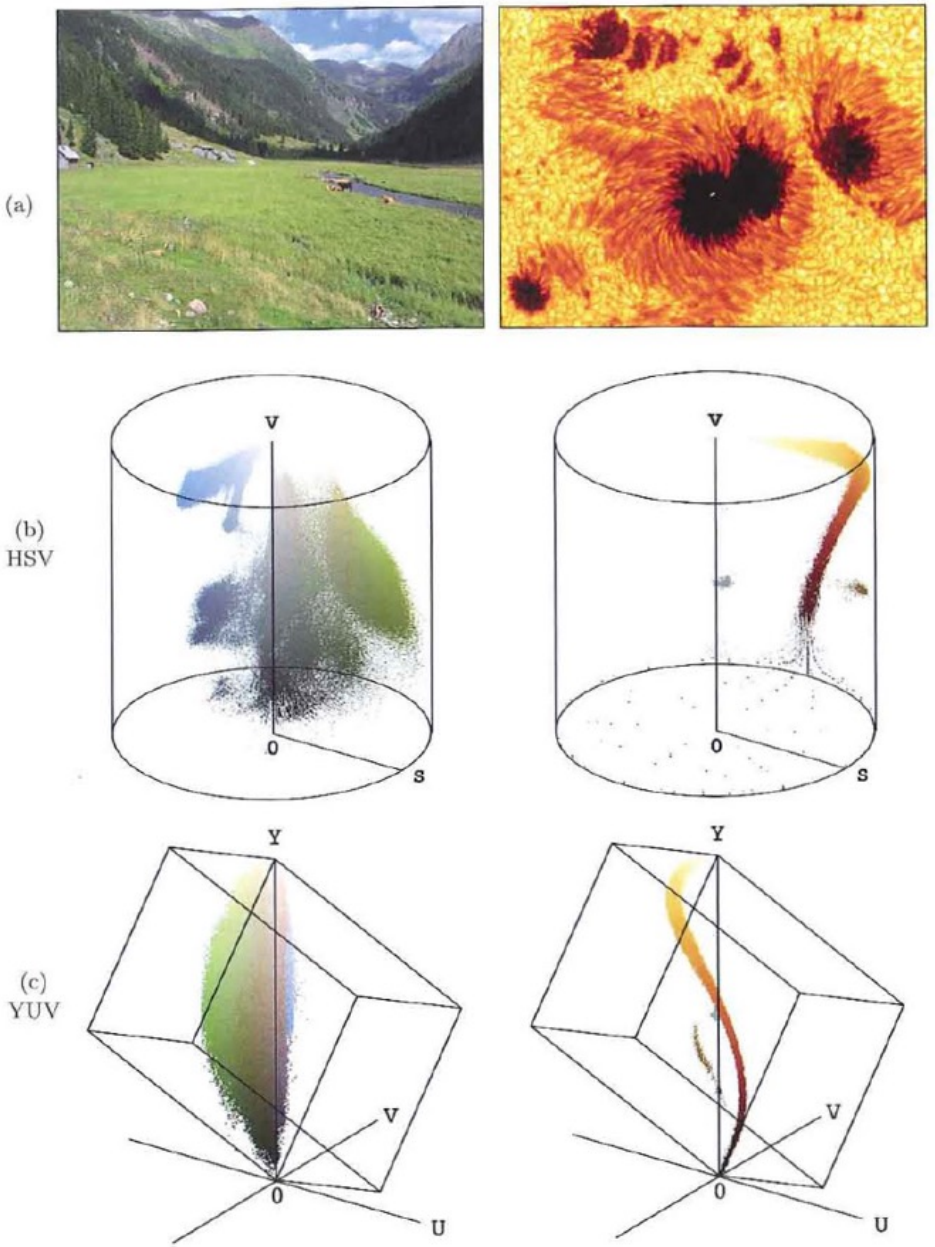



**Figure 8.18** Examples of the color distribution of natural images in different color spaces. Original images (a); color distribution in HSV- (b), and YUV-space (c). See Fig. 8.9 for the corresponding distributions in RGB color space.

# Color models

- RGB
  - The red, green, blue and cyan, magenta, yellow models are closely related, the primary colors of each form the secondary colors of the other. These are also the most representative models for additive and subtractive colors, respectively. RGB is also the basic color model for on-screen display.
- Munsell
  - The Munsell color system is one of the most influential systems developed for ordering colors that can be used for production. While its practical application is mostly outside of print production, it still forms the basis for most other work on color modeling.
- CIE
  - The CIE color models are highly influential systems for measuring color and distinguishing between colors. We will examine three CIE models: CIEXYZ, CIELUV, and CIELAB. The last of these, CIELAB, is very important to color management
- NCS
  - Natural Color System. (Jotun)

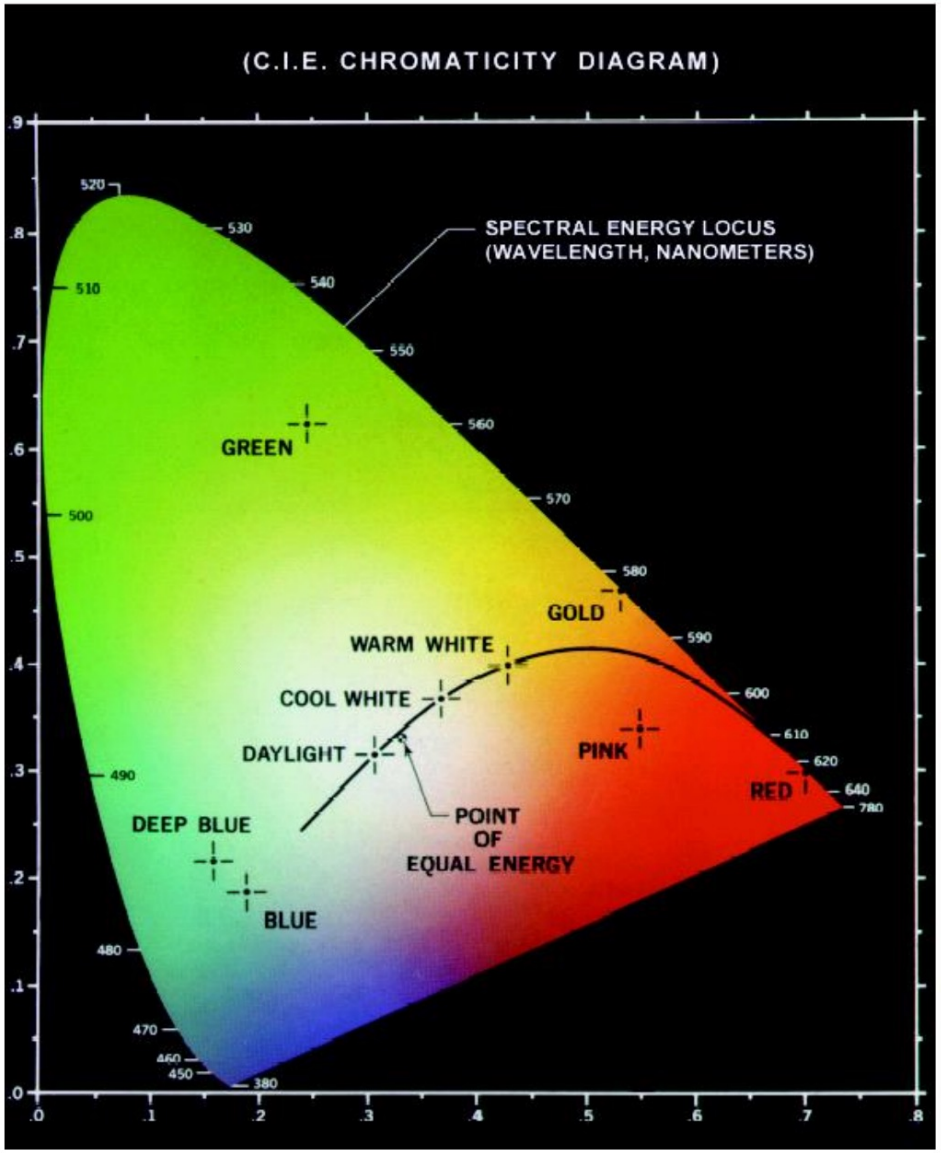
# CIE

- CIE stands for Comission Internationale de l'Eclairage (International Commission on Illumination). The commission was founded in 1913 as an autonomous international board to provide a forum for the exchange of ideas and information and to set standards for all things related to lighting.

- As a part of this mission, CIE has a technical committee, Vison and Colour, that has been a leading force in colorimetry since it first met to set its standards in Cambridge, England, in 1931.

# CIE

- Source A
  - A tungsten-filament lamp with a color temperature of 2854K
- Source B
  - A model of noon sunlight with a temperature of 4800
- Source C
  - A model of average daylight with a temperature of 6500K




y

x

# Trichromatic coefficients:

$$x = \frac{X}{X+Y+Z}$$

$$y = \frac{Y}{X+Y+Z}$$

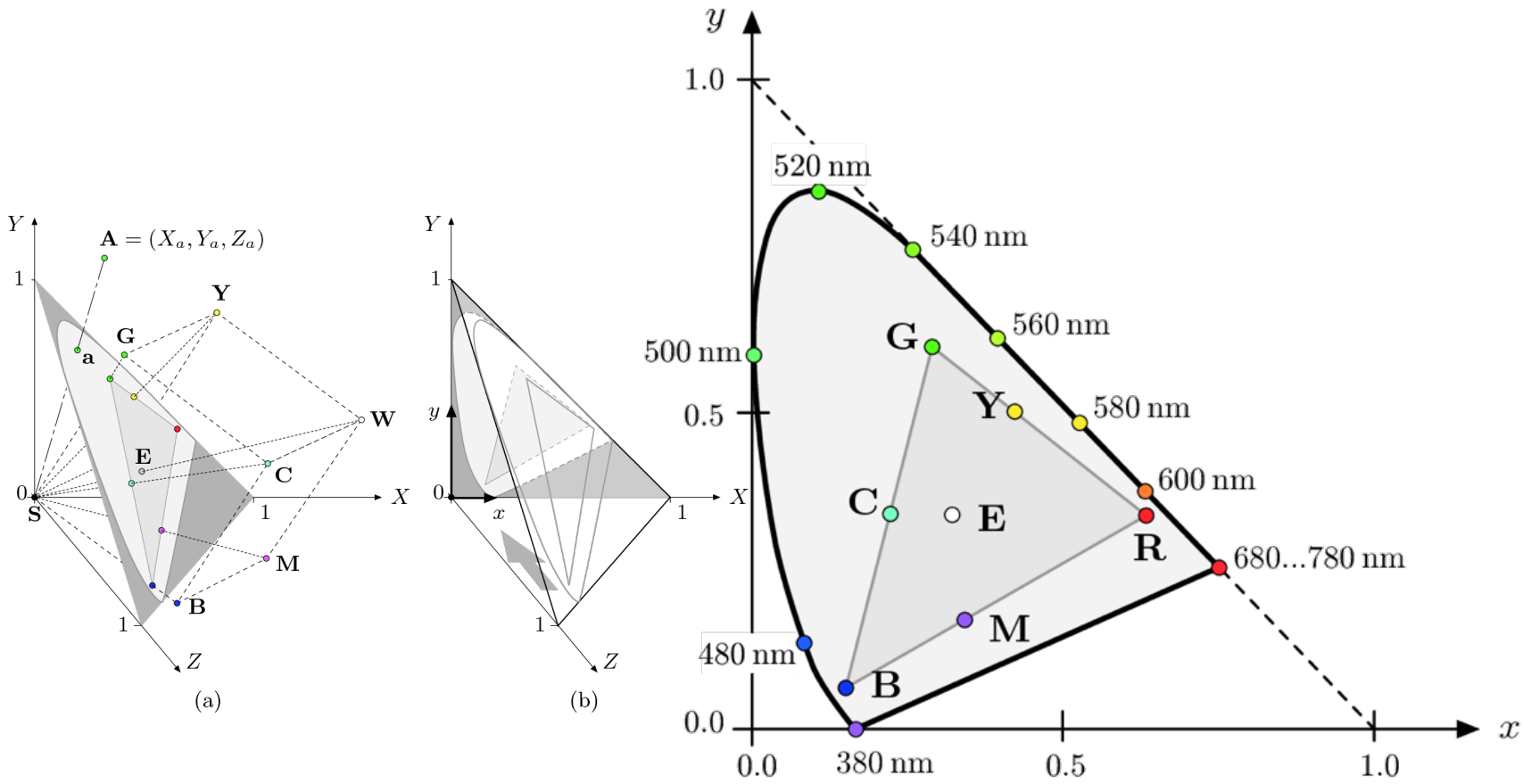
$$z = \frac{Z}{X+Y+Z}$$

$$x + y + z = 1$$

Points on the boundary are fully saturated colors

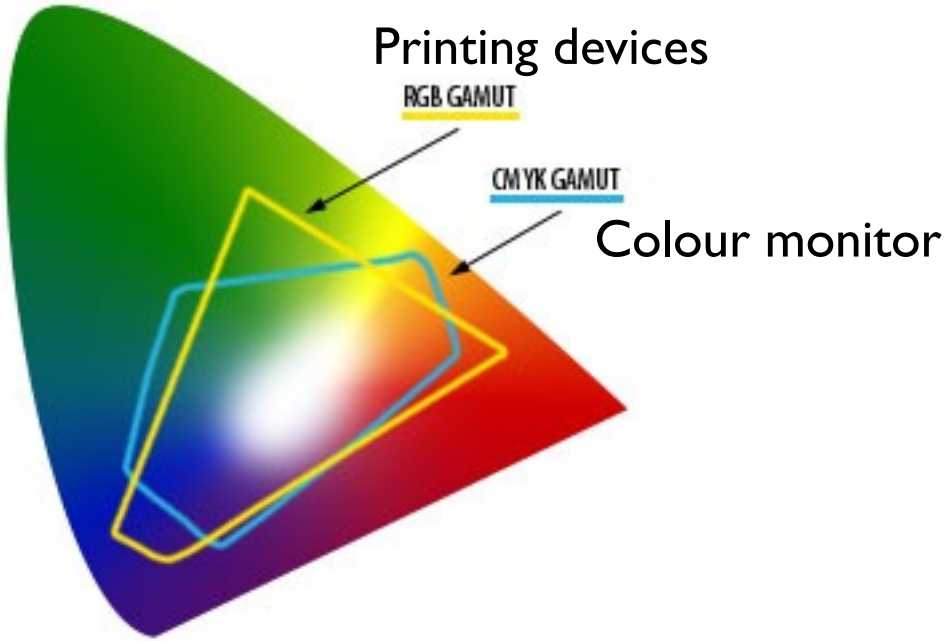
(Images from Rafael C. Gonzalez and Richard E. Wood, Digital Image Processing, 2nd Edition.

# CIE XYZ colour room



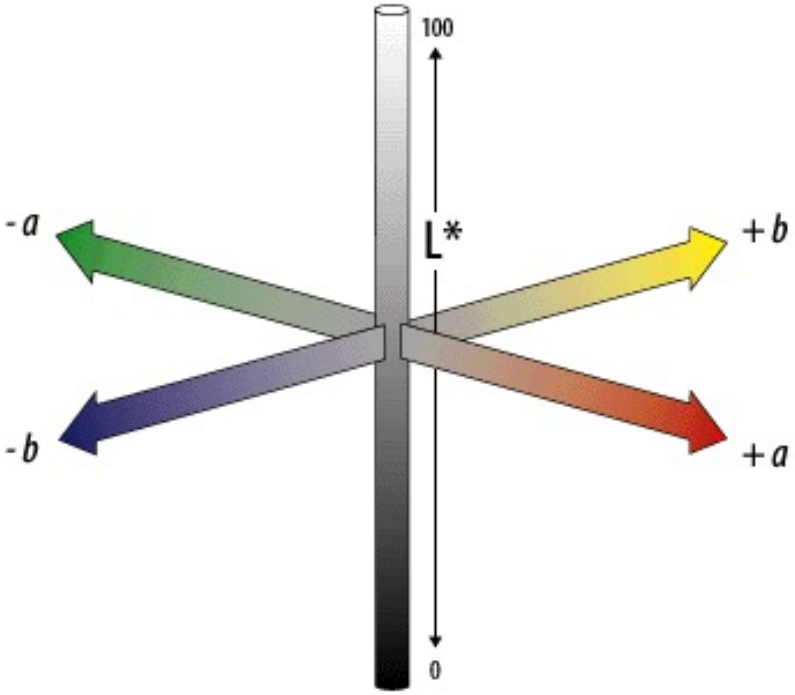
# RGB color model

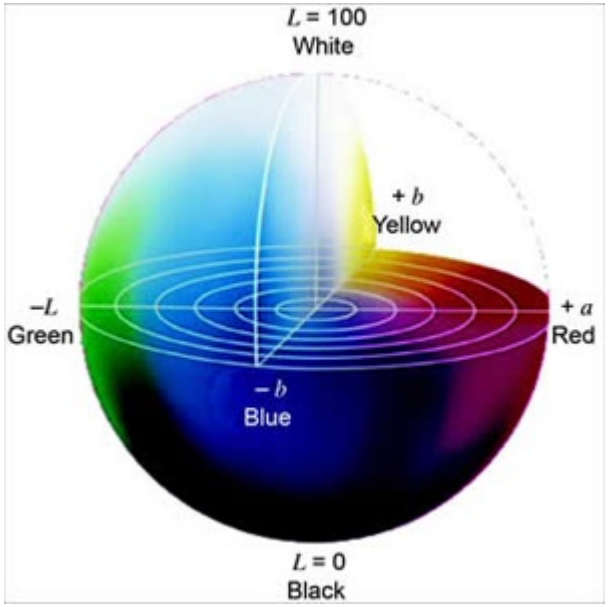
- Gamut constraint

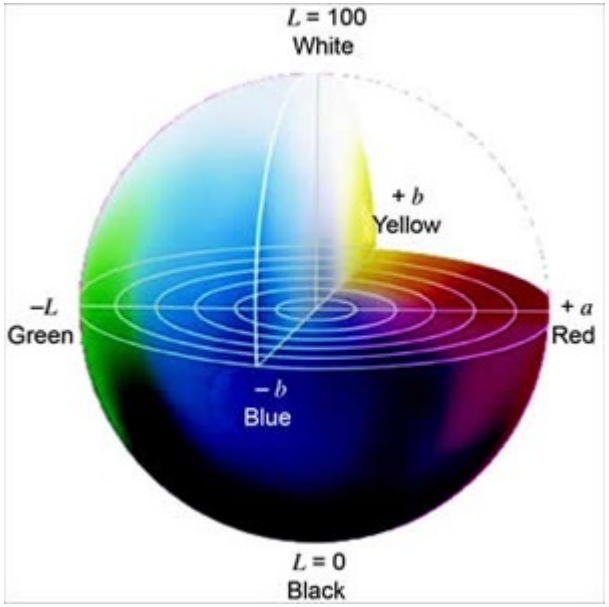



https://www.youtube.com/watch?v=O0nYJ0Mjx10

# CIE LAB color model






**Delta E, ΔE:**

Total colour difference $\Delta E^*_{ab}$ (Equation 1) from a reference colour ($L^*_1$, $a^*_1$, $b^*_1$) to a target colour ($L^*_2$, $a^*_2$, $b^*_2$) in the CIE Lab space is given by:

*Equation 1: Colour-difference formula.*

$$\Delta E^*_{ab} = \sqrt{(L^*_2 - L^*_1)^2 + (a^*_2 - a^*_1)^2 + (b^*_2 - b^*_1)^2}$$

# NCS (Natural Color System)

- Jotun paint
- Not direct transformations of RGB etc

- NCSCOLOUR.COM
  - http://ncscolour.com/design/work-digitally-with-ncs/colouring-to-a-new-level/

- EASYRGB.COM
  - http://www.easyrgb.com/index.php?X=SEEK

# COLOUR LAB

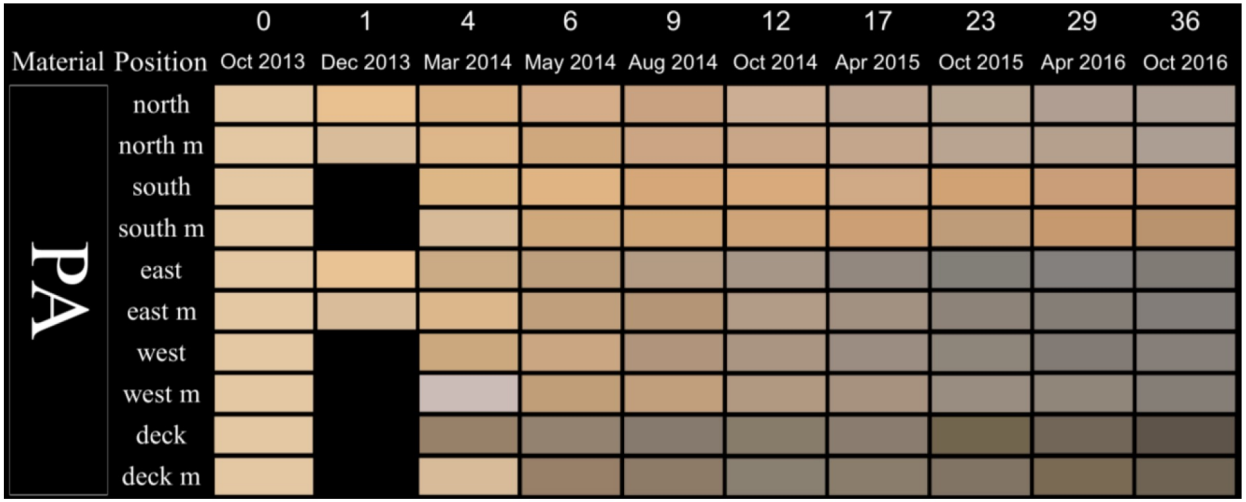
- https://www.ntnu.edu/colourlab#/view/about

COLOURLAB.NO

The Norwegian
**Colour and Visual Computing**
Laboratory

# LAB used to describe colour of wooden facades

*Figure 3: Visual appearance of façade in October 2013 (left) and October 2015 (right).*



# You need to know these terms

- RGB colour space
- CIE
- CIE  Lab colour space
- Hue
- Chroma
- Brightness
- Lightness
- Gamut