Multimedia Datenbanken
Colors & Color Models

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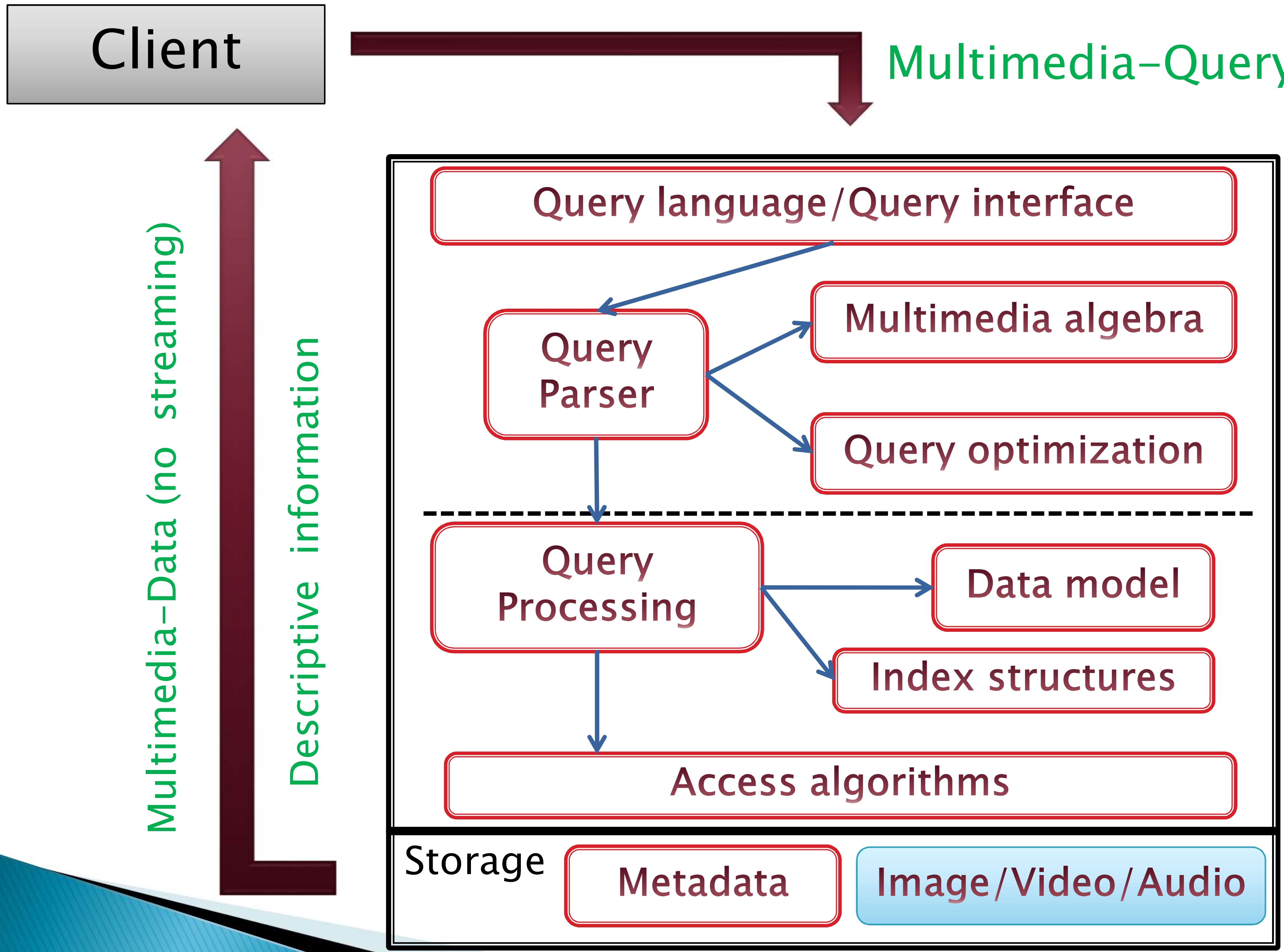
Client
Multimedia-Query
Multimedia-Data (no streaming)
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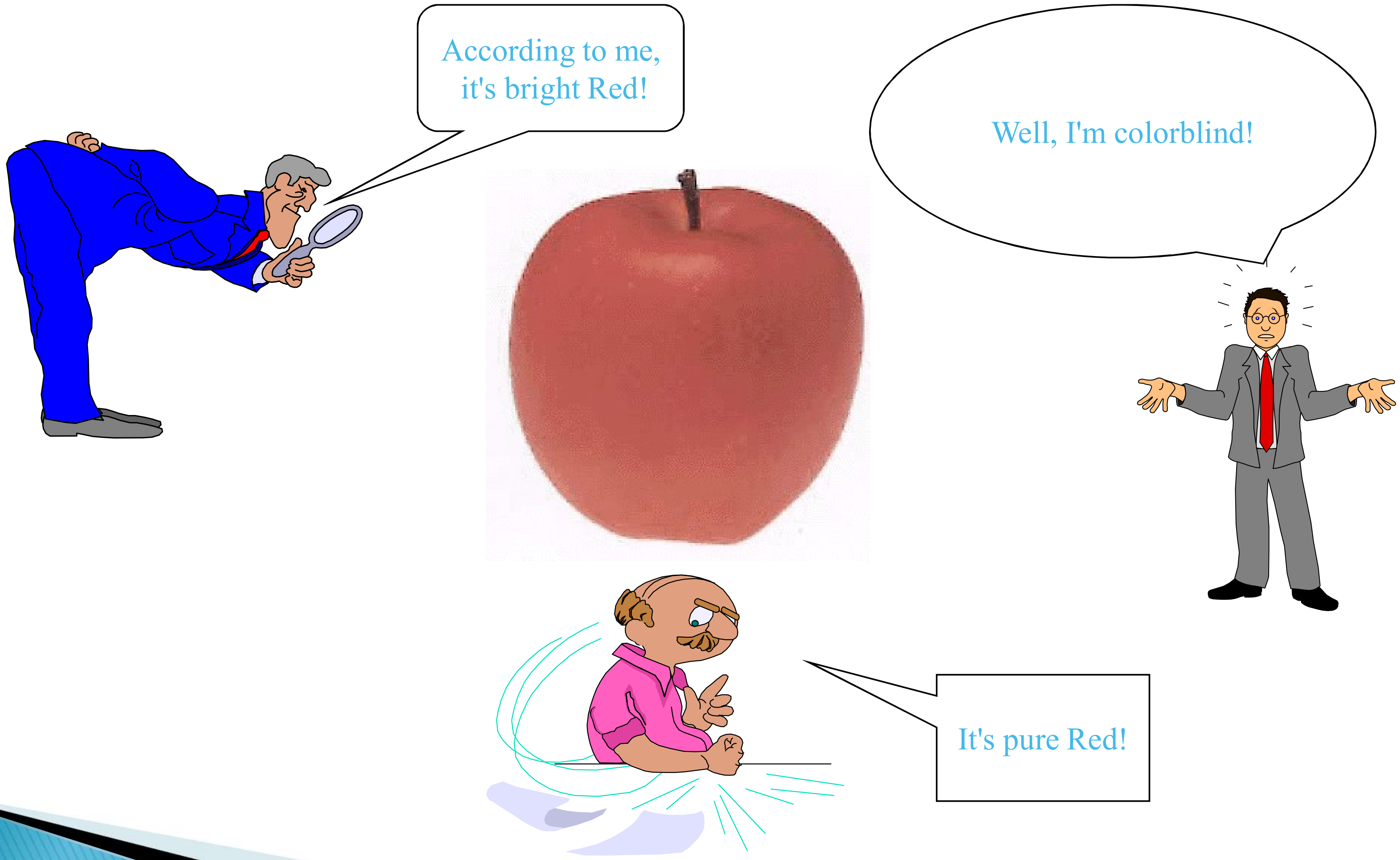
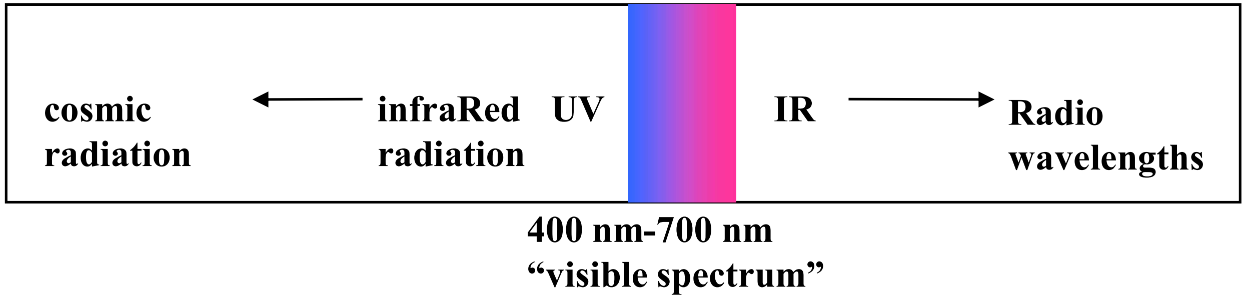
Color Perception
Colors: Subjective perception



Color Perception

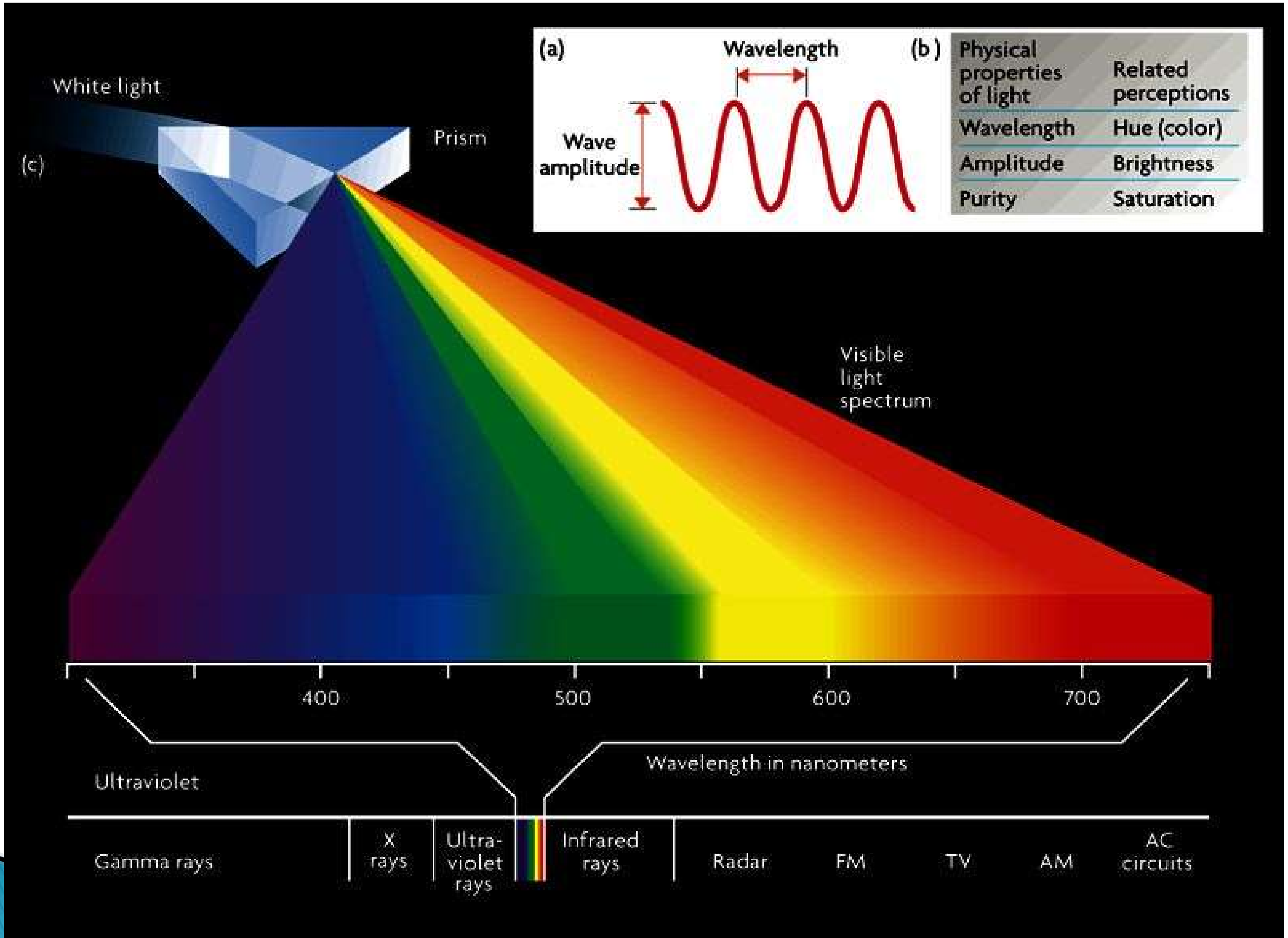
Visible light is a specific part of a large electro-magnetic spectrum

- Light is a kind of electromagnetic radiation
- Visible light lays between 400nm and 700nm



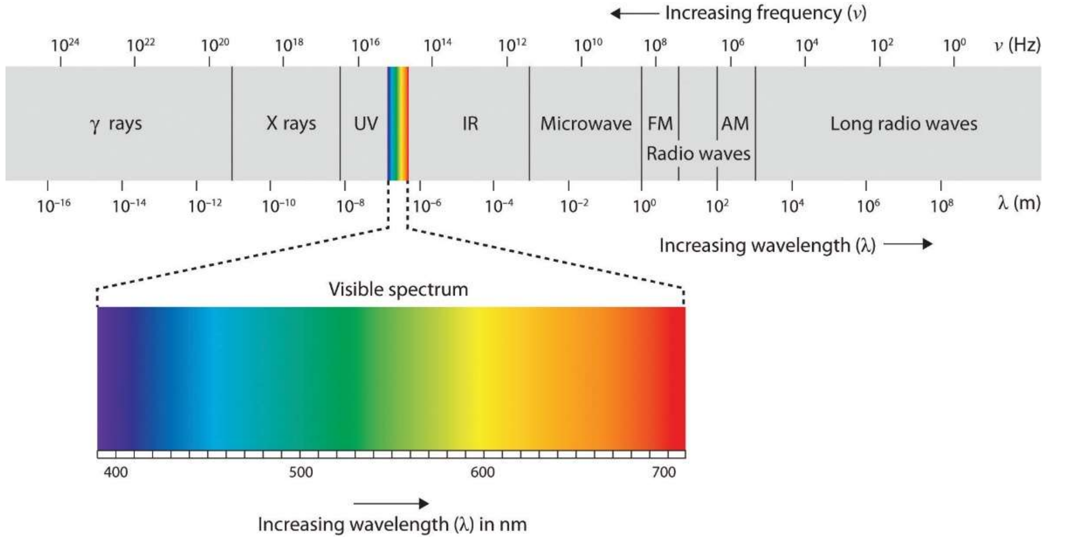
- Direction of light propagation
  - Straight-lined propagation
    - Scattered (ex. light bulbs)
    - Directional (ex. laser)
- Frequency
  - Color
  - Visible spectrum: 385 to 789 THz (Wavelength: 380 to 750 nm)
- Amplitude
  - Intensity of the wave (brightness)

Light is Color



Color Perception
Anatomy of the eye: 3 types of cone celles

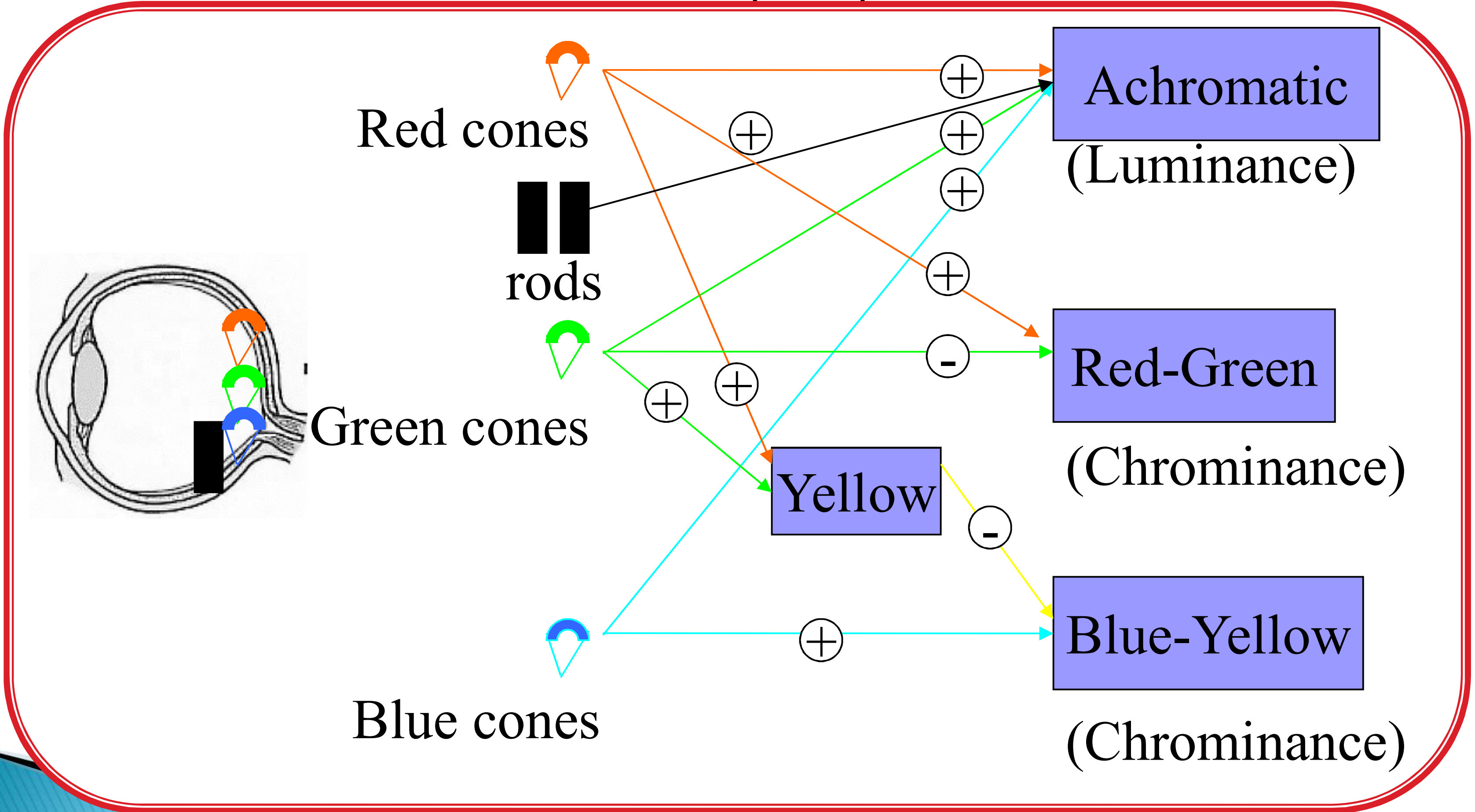
- S-cones
  - – S: short wave length, ca. 430 nm
  - – cover the blue-domain
- M-cones
  - – M: middle wave length, ca. 530 nm
  - – cover the green-domain
  - – genetically closely related to L-cones
  - – usual cause of color brightness



- L-cones
  - – L: long wave length,
  - ca. 560 nm
  - – cover the red-domain

Color Perception
Luminance and Chrominance

- The eye is very sensitive to luminance
- 120 Million Rods and 5 Million Cones per Eye



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Why color models?

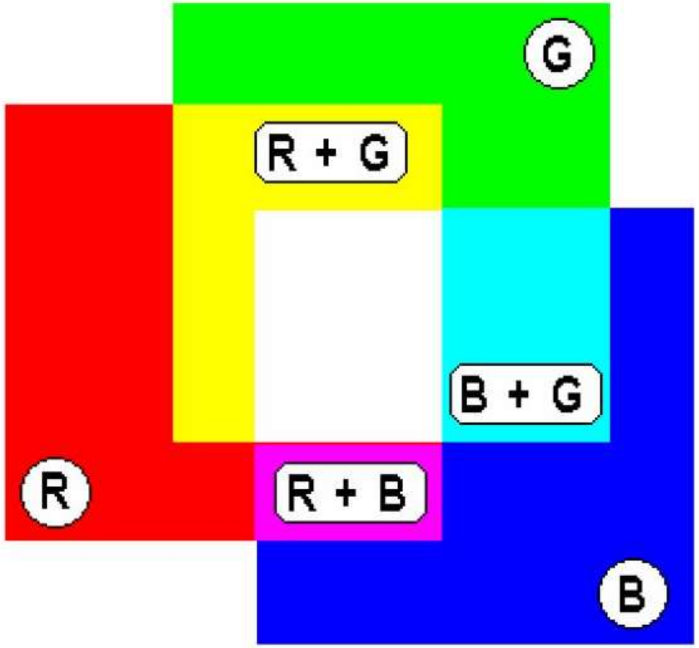
- The number of spectral colors / mixes of primary colors is theoritically infinite

- Color models are used to capture the widest possible part of perceivable colors
  - Goal: Describe reality in a simple yet relatively exact way

- Main categories of models
  - Additive color systems
  - Substractive color systems

Additive color

- Primary colors
  - Red	Green	Blue
  - Cyan	Magenta	Yellow
- Complementary colors
  - Difference between color and white
- Color mixes
  - Red + Green = Yellow
  - Red + Blue = Magenta
  - Blue + Green = Cyan



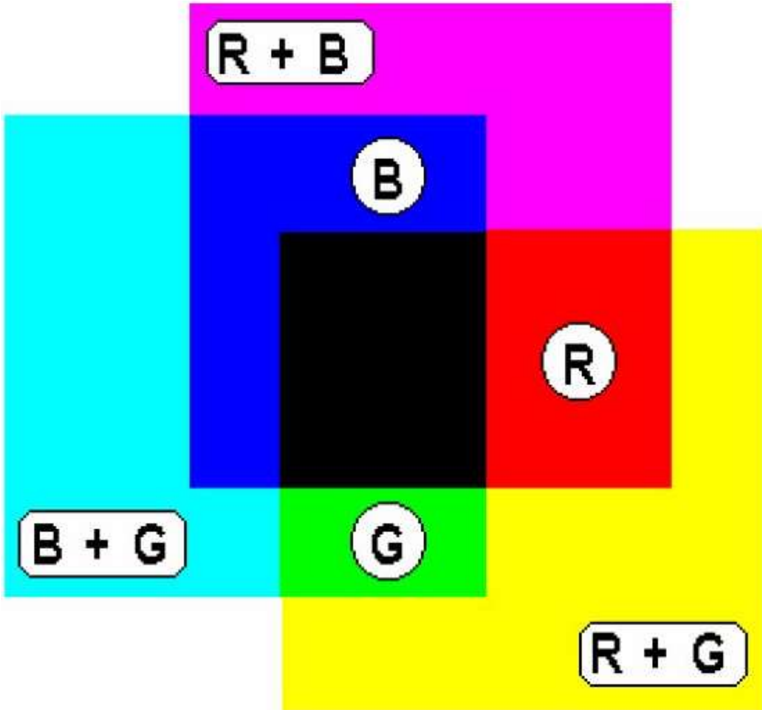
Subtractive color

- Primary colors
  - Cyan ⇕ Red
  - Magenta ⇕ Green
  - Yellow ⇕ Blue

  Complementary colors

- Absorption of the complementary colour

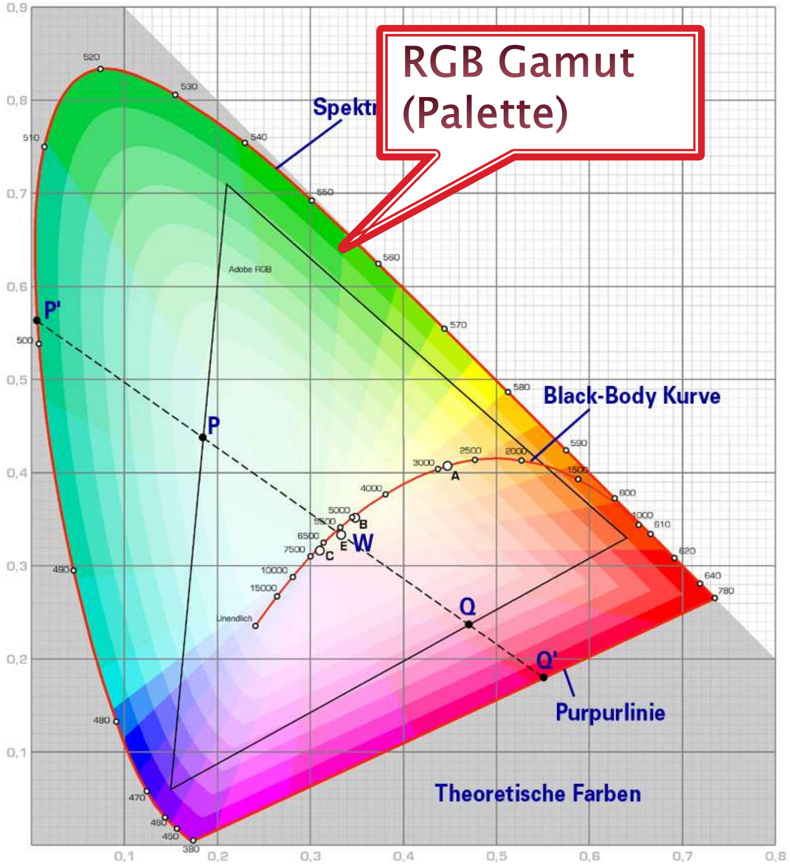
- Color mixes
  - Cyan + Magenta = Blue
  - Cyan + Yellow= Green
  - Yellow+ Magenta = Red



Color models

CIE-Normalized color table

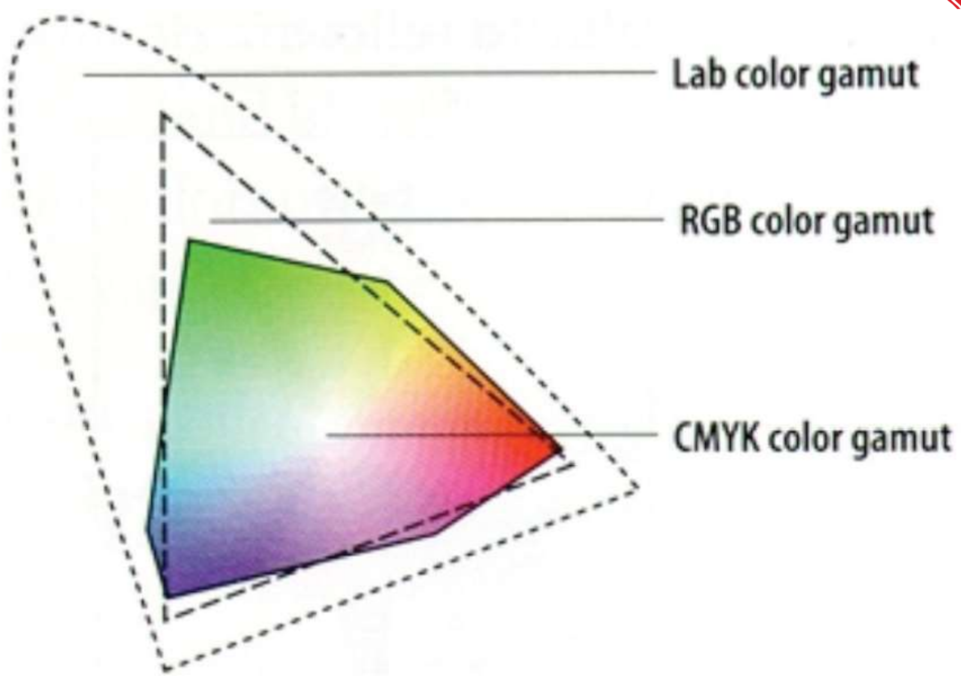
- Set of theoritically possible colors
- x- and y-share (from the normalized theor. primary colors X, Y and Z – computed before)
- Main condition: $x + y + z = 1$
  - then: $z = 1 - x - y$
- Reference point: White point W
  - Depending on illumination conditions, it can practically be located anywhere inside the horseshoe
  - Not all colors are actually representable
  - Here Adobe-RGB in the black triangle



Quelle: http://de.wikipedia.org/wiki/Bild:CIE-Normfarbtafel.png
Diese Datei wurde unter der GNU-Lizenz für freie Dokumentation veröffentlicht.

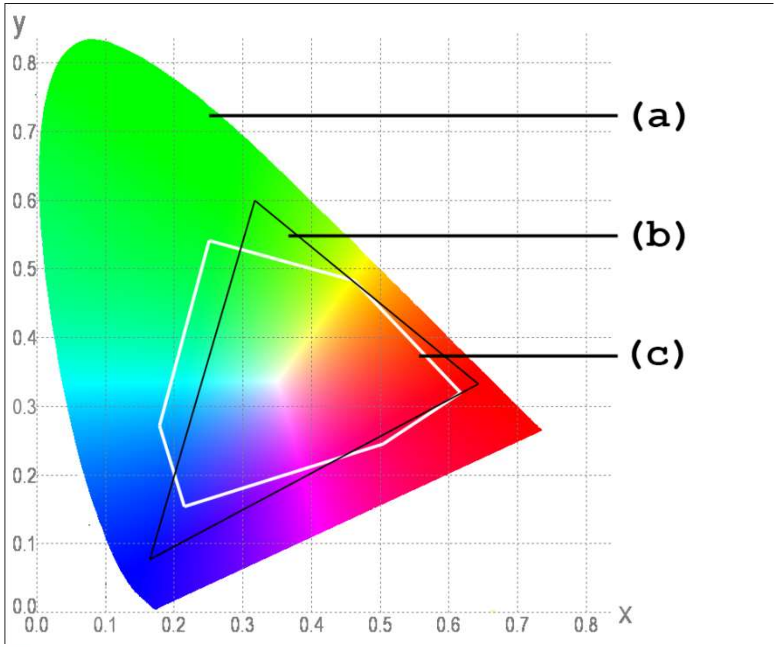
Color models
Gamut

- Domain of colors that can be accurately reproduced by a device (body of colors in a color space that can be produced through color mixing)



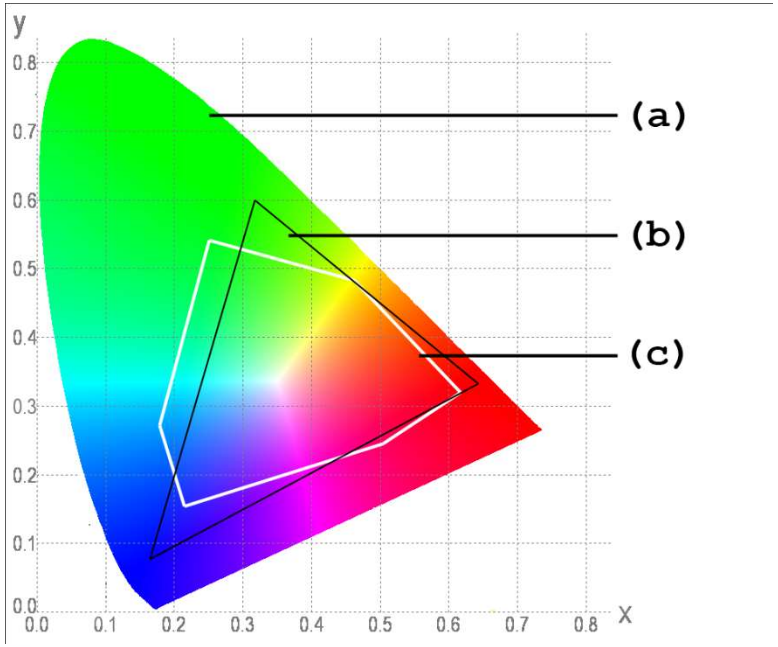
Color Gamuts

a) Colors that human can see
b) RGB color gamut of typical CRT monitors
c) CMYK color gamut of typical inkjet printers



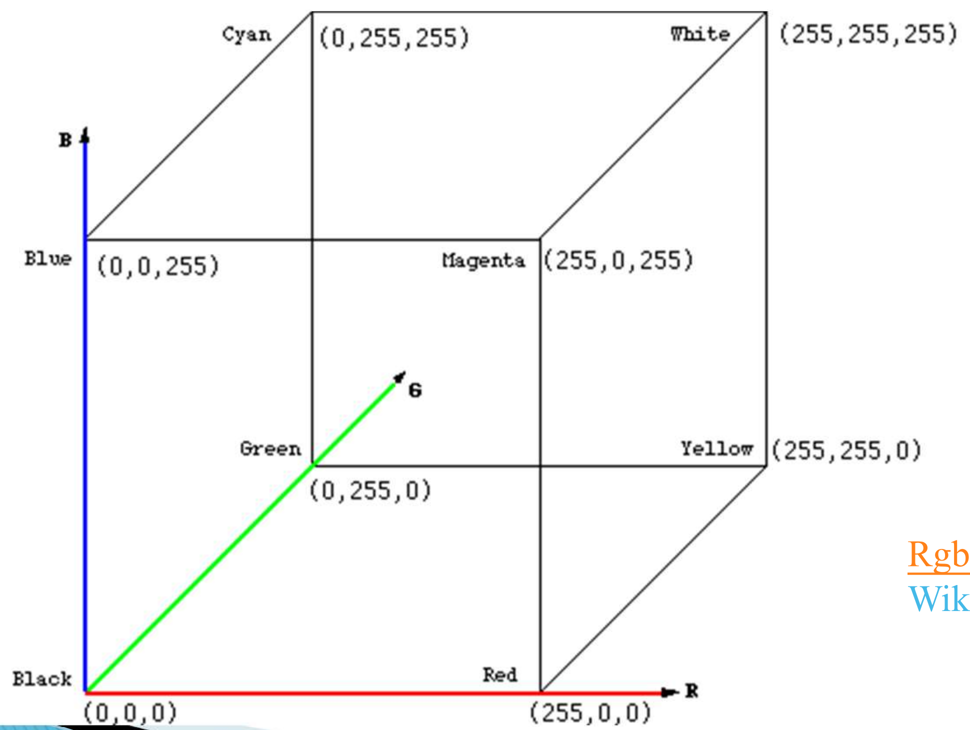
Color Gamuts

- Monitors and inkjet printers cannot reproduce all the colors that human can see
- Some of the colors that monitors can reproduce cannot be reproduced by inkjet printers. Most of these colors lie at the corners of the color gamut of the monitor, which means these are highly saturated colors.



Color models
RGB color cube

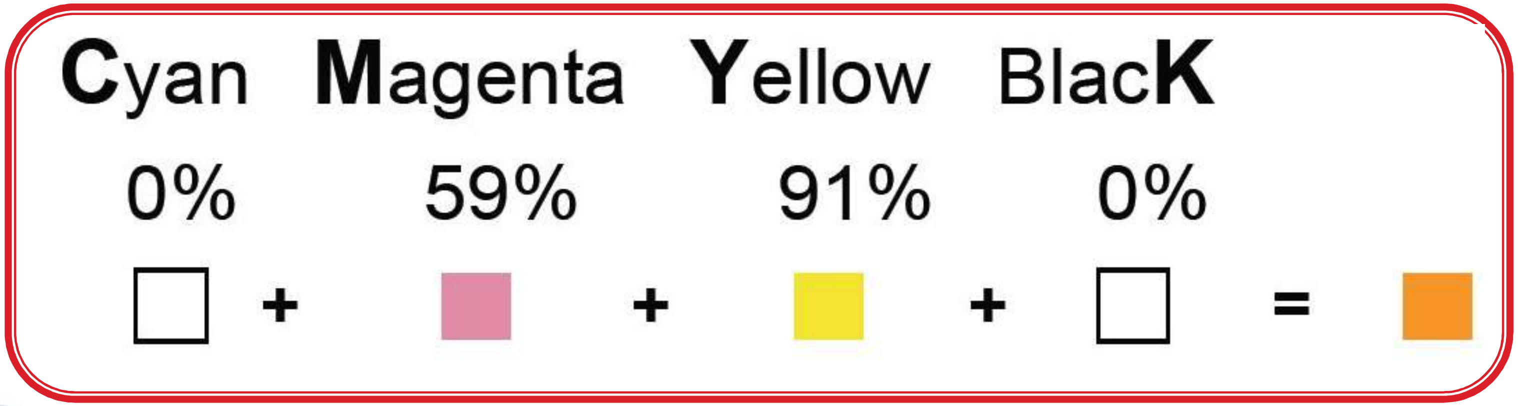
- Additive color model
- The primary colors Red, Green, Blue correspond to the axes of the coordinate system; they stretch to a color cube.



Rgb-cube.gif
Wikimedia

Color models
CMYK

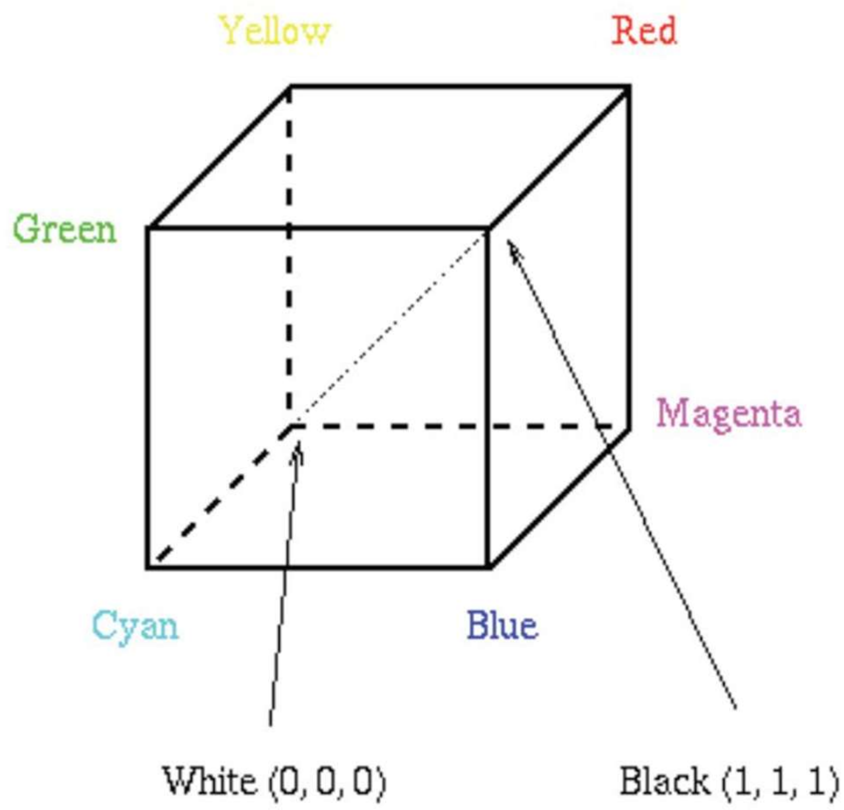
- passive (subtractive) color mixing used in printing
- Four color channels: (the additional component (black) to produce dark colors)
- Technical basis of the modern four-color printing technology



Color models
Conversion between RGB and CMY (color separation)

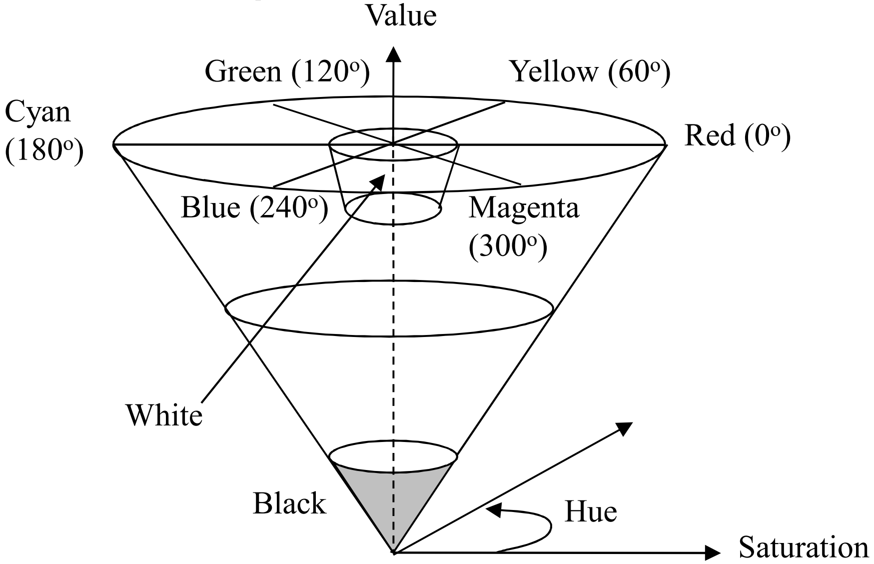
$$\begin{pmatrix} C \\ M \\ Y \end{pmatrix} = \begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix} - \begin{pmatrix} R \\ G \\ B \end{pmatrix}$$

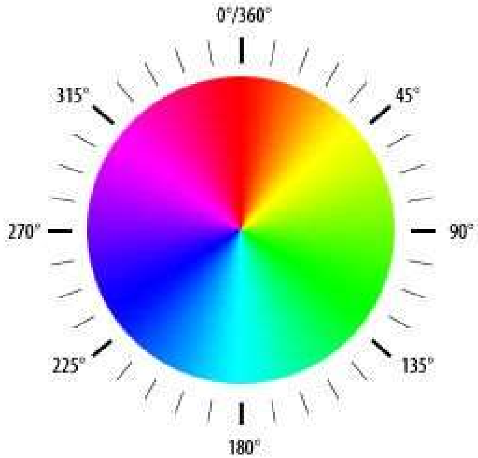
$$\begin{pmatrix} R \\ G \\ B \end{pmatrix} = \begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix} - \begin{pmatrix} C \\ M \\ Y \end{pmatrix}$$

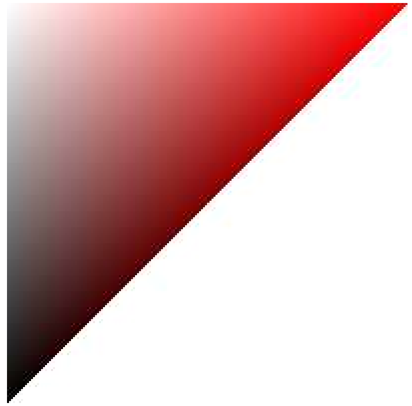


Color models
HSB/HSV/HSI

- Hue H (Color tone) (0–360°)
- Saturation S (Color saturation) (0–100%)
- Brightness B (Helligkeit)
  or Value (Darkness level)
  or Intensity (brightness) (0–100%)







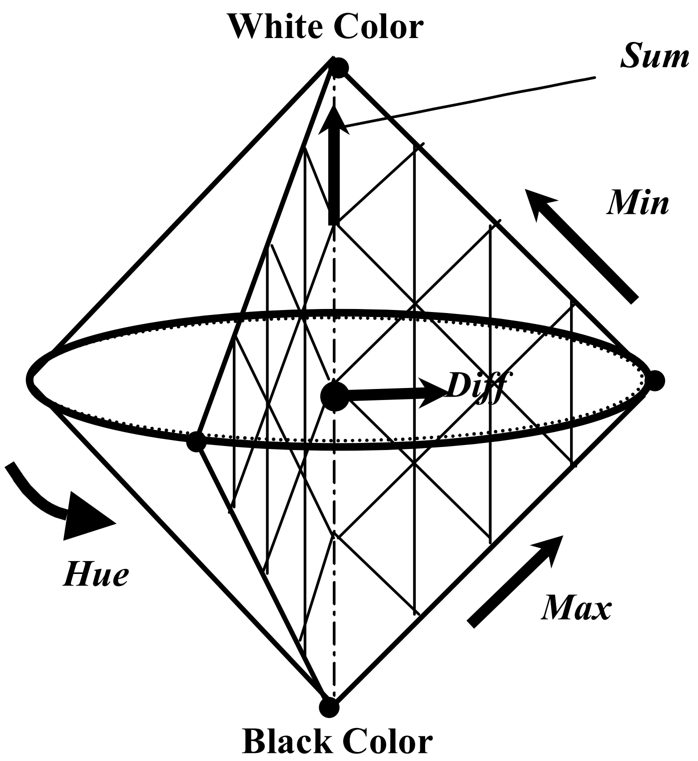
Color models
Converting RGB to HSV

- Conversion RGB -> HSV (from Gonzalez and Woods)
  1. $Compute\ White-ratio\ W\ =\ \min(R,G,B)$
  2. $(R',G',B') := (R-W, G-W, B-W) has\ only\ 2\ colorvalues\ <>\ 0$
  3. $Let\ B' = 0:\ Hue - the\ value\ lies\ between\ R\ and\ G:$
     $$H = G' * \frac{120}{R' + G'}$$
     $Let\ R' = 0:\ Hue - the\ value\ lies\ between\ G\ and\ B:$
     $$H = B' * \frac{120}{G' + B'} + 120$$
     $Let\ G' = 0:\ Hue - the\ value\ lies\ between\ B\ and\ R:$
     $$H = R' * 120/(R' + B') + 240$$
  4. $S\ =\ (\max(R,G,B)\ -\ W\ )/\max(R,G,B)$
  5. $V\ =\ \max(R,G,B).$

Color models
HMMD-color space

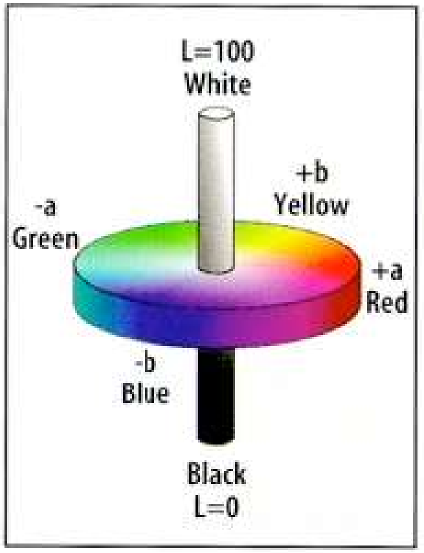
- HMMD (Hue-Max-Min-Diff) color space is closer to a perceptually uniformen color space
  - Min = min(R,G,B); Max = max(R,G,B);
  - Diff = Max - Min; Sum = (Max + Min)/2; Hue as in HSV

Max: gives how much "black" the color has, evaluates its darkness.
Min: gives how much "white" the color has, evaluates its pallor.
Diff: gives how much "gray" the color has and its degree of proximity to a pure color, evaluates its chrominance.
Sum: represents the brightness of the color.



Color spaces
CIE-Lab-System

- 3-dimensional color space with the following axes:
  - L* = Brightness (0 = black, 100 = Weiß)
  - a* = Red – Green (-128 = Green, +127 = Red)
  - b* = Yellow – Blue (-128 = Blue, +127 = Yellow)
- Enhancement of the CIE color model
- Oriented towards the physiological properties of human (color) perception rather than physically measurable indicators (colorimetry)



Lab model

Color models
CIE-Lab-System

- Standardized, equidistant, device independent, based on human perception
- Contains all possible device-dependent color spectra
- Enables lossless conversion form color information from a system to another

Color models
YUV/YCbCr-color space

- Y is the Luminance and U and V are the Chrominance-values of the color space
  - U (Cb): color difference Luminance - Blue, V (Cr): Color difference Luminance - Red
- Separates intensity and color information
- A monochrome color representation only needs the Y-value
- Model that is very close to the human perception
- Luminance can be computed from Red, Green, Blue based on physiology: $Y = 0.59G + 0.30R + 0.11B$; $V = (R - Y)/1.14$; $U = (B - Y)/2.03$

Color models
conversion RGB -> YUV

- Transformation
  - $Y = 0{,}299 \cdot R + 0{,}587 \cdot G + 0{,}114 \cdot B$
  - $U = 0{,}492 \cdot (B - Y)$
  - $V = 0{,}877 \cdot (R - Y)$

- Reverse transformation
  - $R = Y + 1.13983 \cdot V$
  - $G = Y - 0.39466 \cdot U - 0.5806 \cdot V$
  - $B = Y + 2.03211 \cdot U$

The end