

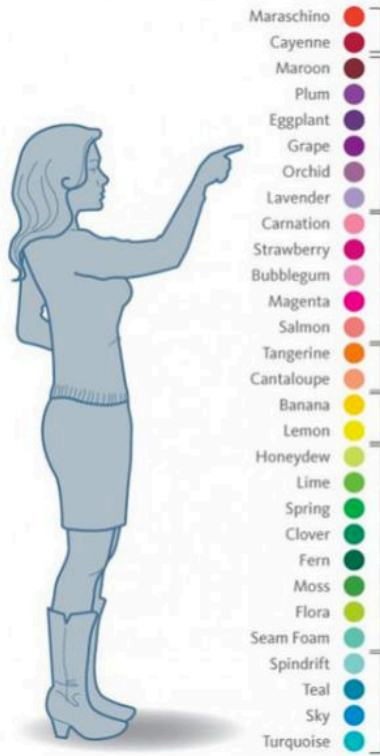


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DATA VISUALIZATION AND VISUAL ANALYTICS

How many color?

Female



Male



Dog



Programmer

- Gray #f94433
- Gray #ac203b
- Gray #85343d
- Gray #874994
- Gray #663c84
- Gray #8c2590
- Gray #a16799
- Gray #af99c7
- Gray #f38da3
- Gray #d2157b
- Gray #ec90b7
- Gray #e90086
- Gray #f57d7e
- Gray #f27727
- Gray #fc9b7b
- Gray #f7d305
- Gray #f1e311
- Gray #ccdf62
- Gray #68bd46
- Gray #0aae4f
- Gray #069665
- Gray #057054
- Gray #3ba246
- Gray #abc37
- Gray #68c3b2
- Gray #8bccd0
- Gray #0687a7
- Gray #078dca
- Gray #0fb8b5

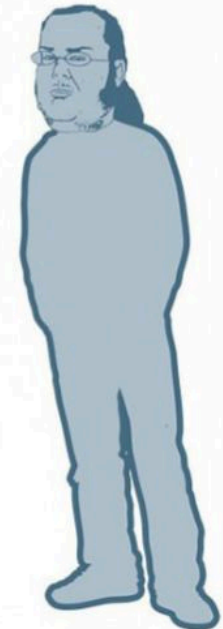


Photo Receptor Cells

- Two types of light sensitive cells
 - **Rod Cells** (~120M)
 - Provide low-light vision
 - Peripheral vision
 - Almost no role in color vision
 - **Cone cells** (~6M)
 - Provide normal vision
 - Three sub-types of cells
 - Sensitivity to different light wavelengths
 - Used for colored vision

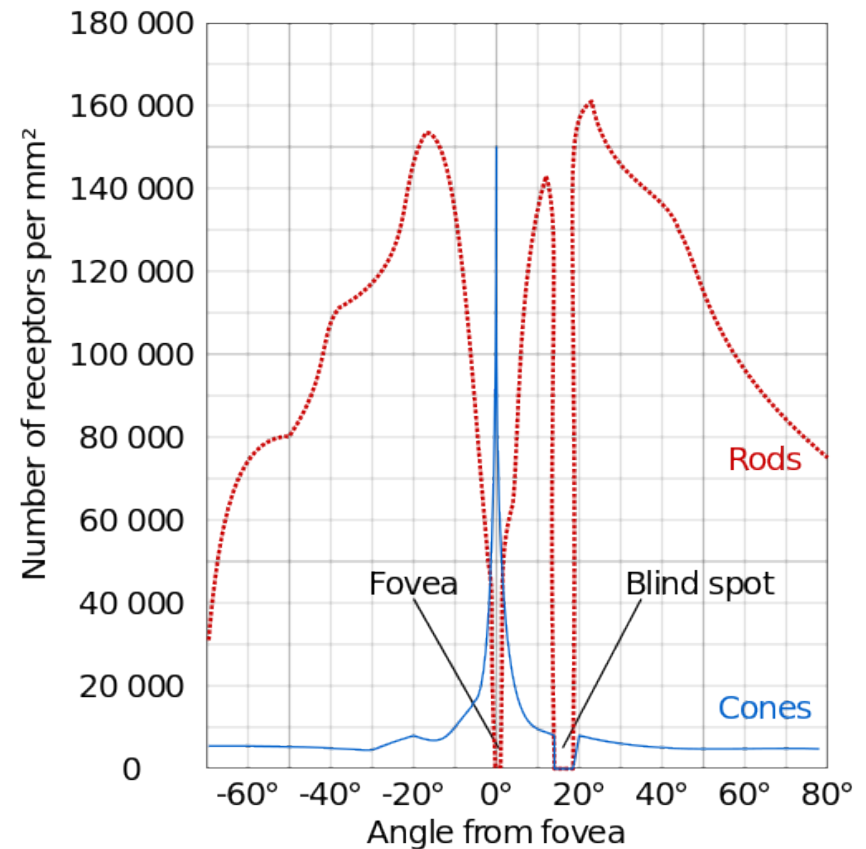
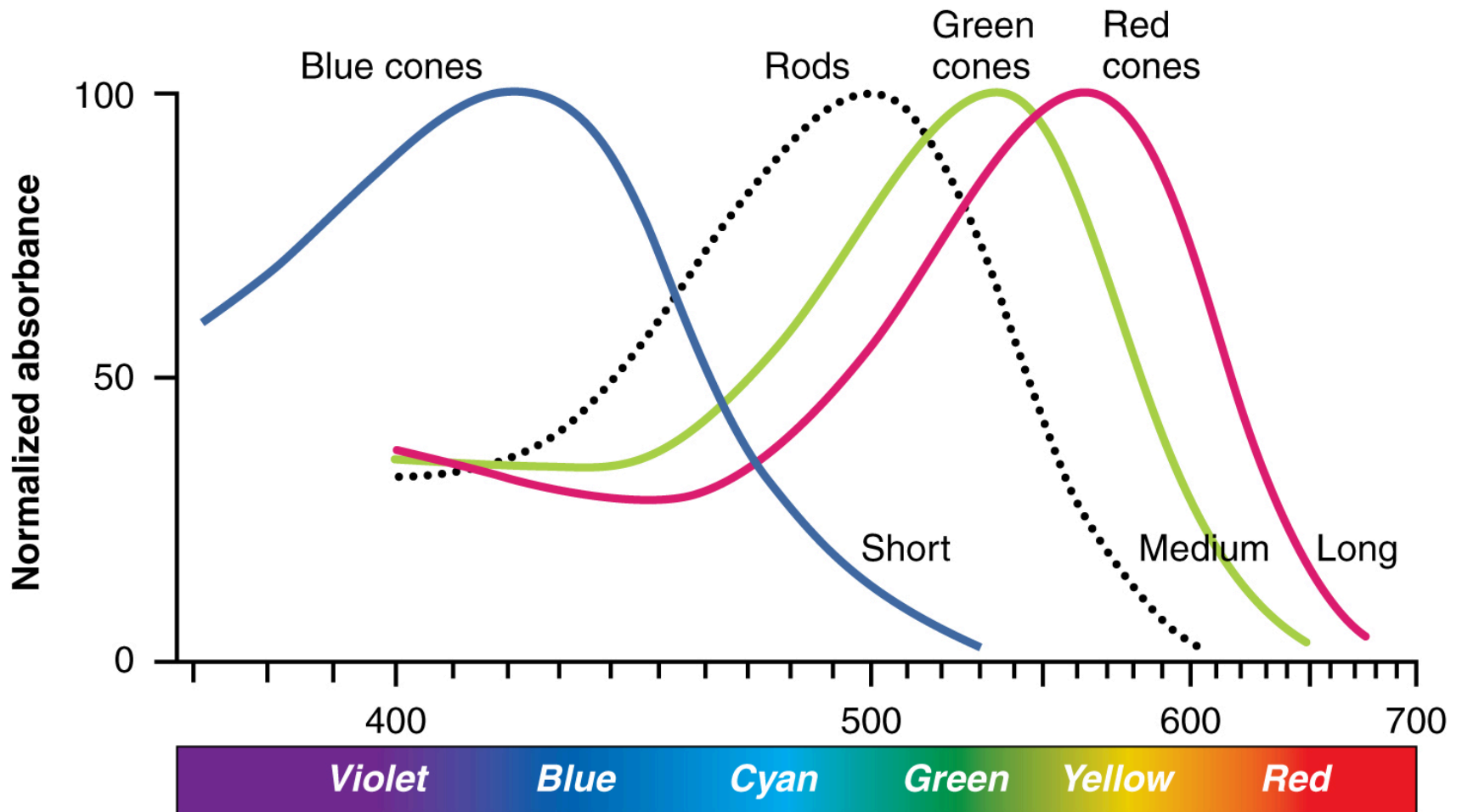


Photo Receptor Cells



Vision System(s)

- Low light vision is managed by rods
- Scotopic vision system
- Peak of efficiency around 500nm
- Cannot distinguish colors
- Activation requires a long time
- Normal light vision
- Photopic vision system
- Peak of efficiency at 560nm

Game #6

The image features two large, stylized parentheses, one on the left and one on the right, which serve as brackets for the central text. Each parenthesis is composed of multiple overlapping, semi-transparent curved bands in a rainbow color gradient. The left parenthesis transitions from yellow at the top to blue at the bottom. The right parenthesis transitions from yellow at the top to purple at the bottom. In the lower right portion of the right parenthesis, there is a small, solid black circle.

color

click to get started

<http://color.method.ac>

Color of the Year: 2016

COLOR FORMULA & GUIDES

PANTONE Color of the Year 2016 can be found in the following color systems:

ROSE QUARTZ

FASHION + HOME PANTONE 13-1520TCX

RGB for TCX

sR	sG	sB
247	202	201

CMYK for TCX

C	M	Y	K
0	24	15	0

HTML Values for TCX: F7CAC9

PANTONE Pastel 9281 C (Closest Match)

9281 C RGB

sR	sG	sB
242	221	222

CMYK for 9281 C

C	M	Y	K
0	14	9	0

HTML Values for 9281 C: F2DDDE

↓ Get Rose Quartz & Serenity and color pairings in [ASE file format](#) for Adobe® Applications.

Plastic

PQ-13-1520TCX

SERENITY

FASHION + HOME PANTONE 15-3919TCX

RGB for TCX

sR	sG	sB
146	168	209

CMYK for TCX

C	M	Y	K
42	24	3	0

HTML Values for TCX: 92A8D1

PLUS Series 7451 C (Closest Match)

Plus Series RGB

sR	sG	sB
137	171	227

Plus Series CMYK

C	M	Y	K
46	23	0	0

HTML Values for Plus Series: 89ABE3

↓ Download Rose Quartz and Serenity wallpaper for your mobile device or desktop.

Plastic

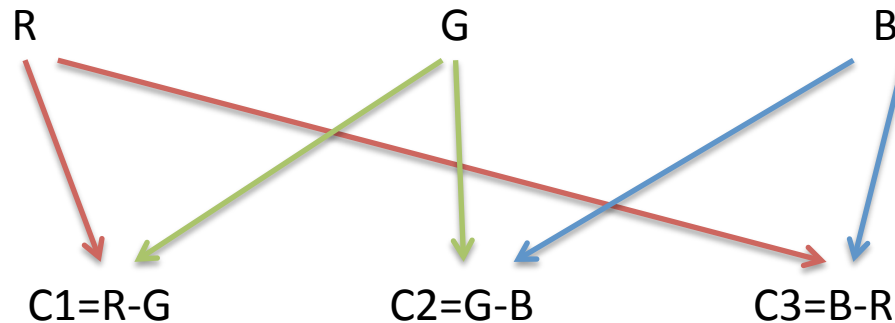
PQ-15-3919TCX

Color Model

- Young-Helmoltz Theory (19th century)
 - Separate Red, Green, Blue receptors
 - Actually, three receptors type exist
 - Red and Green are located mainly in green-yellow zone
 - Sometimes named as Long, Medium, Short wavelength receptors
 - Eye present different proportions of R,G,B receptors (40:20:1)

Opponent Color Theory

- Based on estimation of opposite readings
 - red-green comparison
 - blue-yellow comparison
 - dark-light comparison



$$C1+C2+C3=0$$

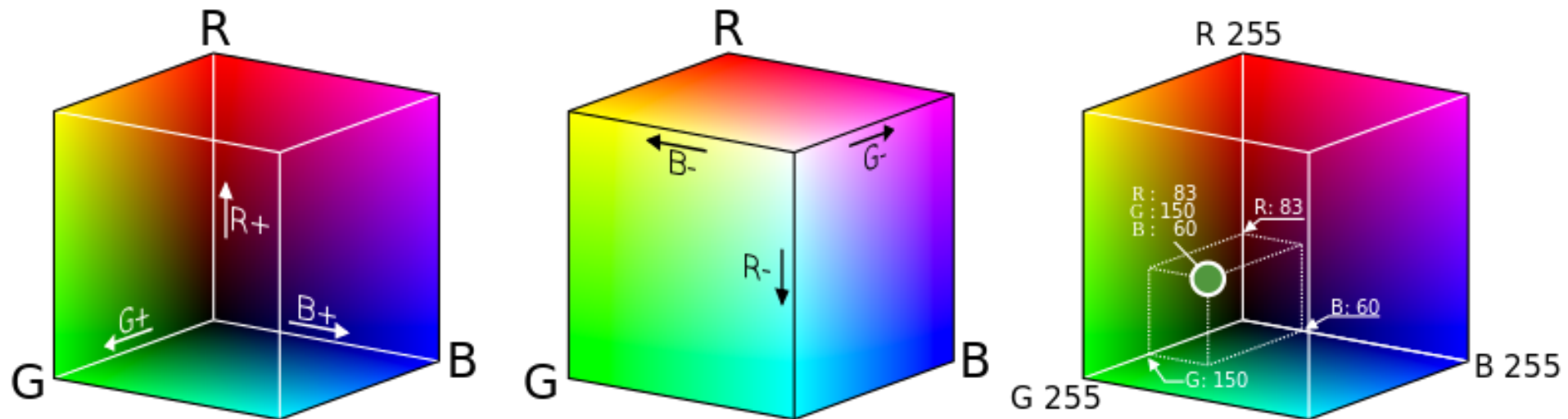
$$C1=R-G$$

$$C3-C2=B-R-G+B=2B-(R+G)$$

$$A = 2R+G+B/20$$

RGB Color Model

- Based on direct specification of three primary colors
- Additive model, each component is summed with the others

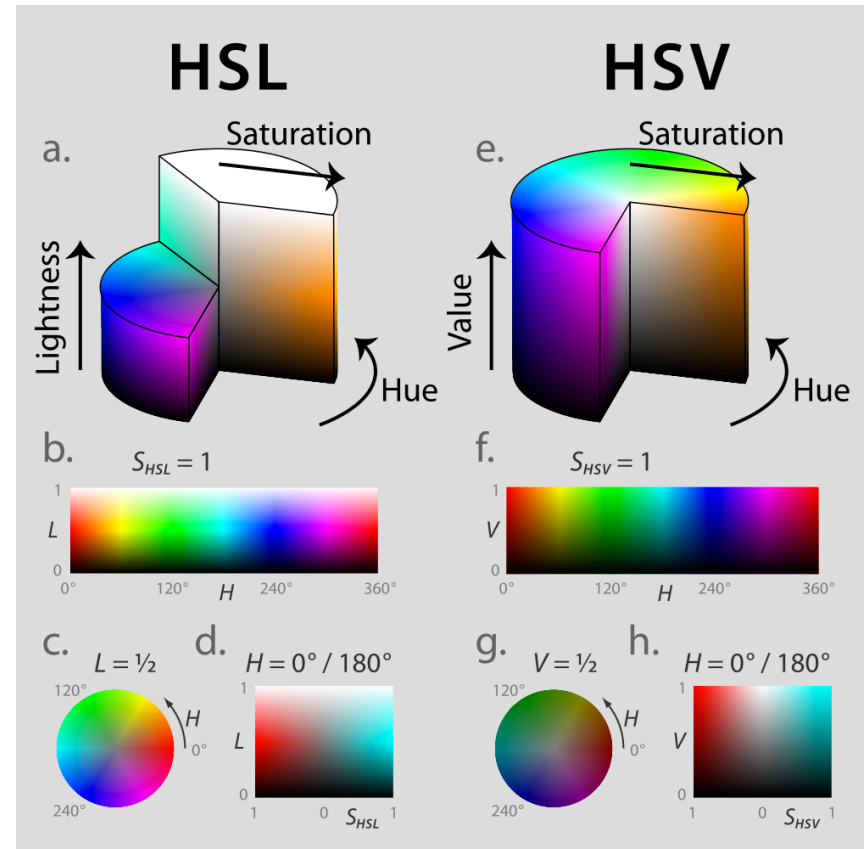


RGB Color Model

- R,G,B values may be expressed in range [0,1]
- Some applications use the range[0,255]
- Usually a hexadecimal notation is used for range [0,ff]
- Not really intuitive: how to define brown?

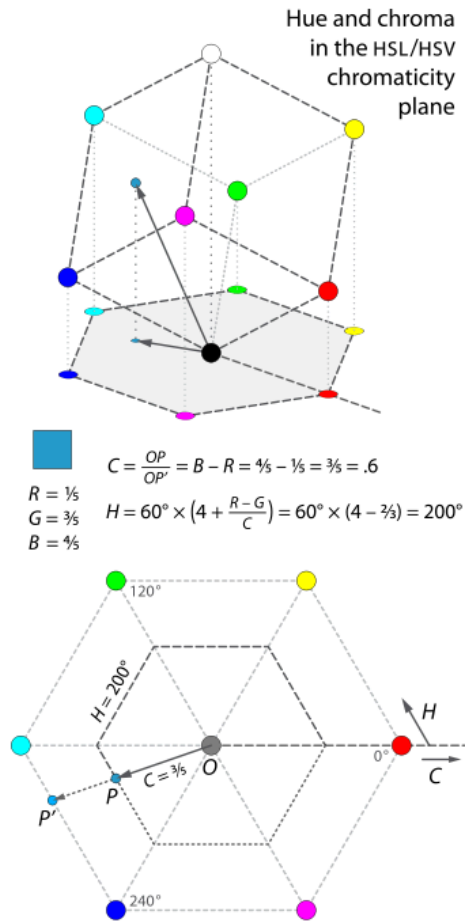
HSV Color Model

- Based on the intuitive concepts of
 - Hue
 - Saturation
 - Value
- Component values are expressed in ranges $[0,1]$ or $[0,255]$

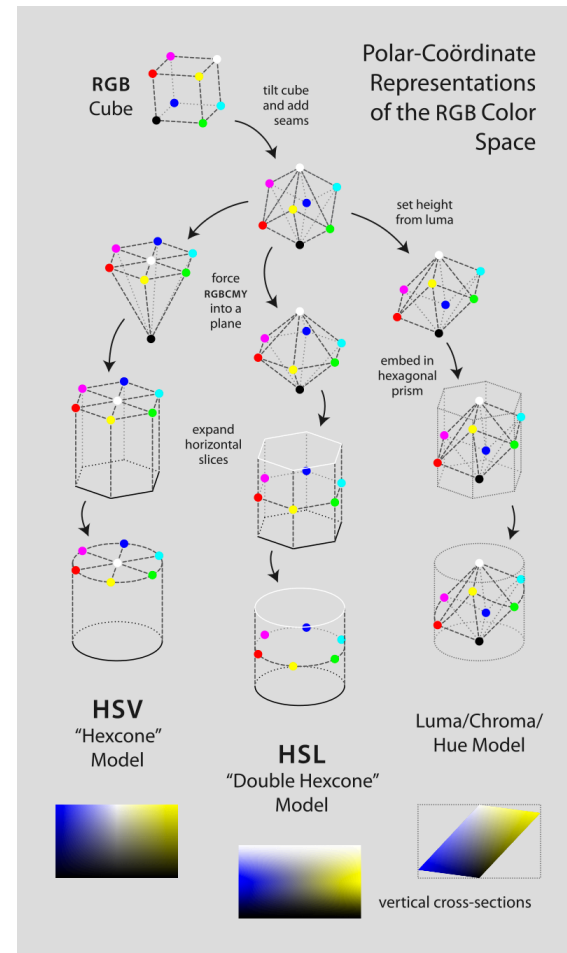


"Hsl-hsv models" by Jacob Rus - Own work. Licensed under CC BY-SA 3.0 via Wikimedia Commons - http://commons.wikimedia.org/wiki/File:Hsl-hsv_models.svg#/media/File:Hsl-hsv_models.svg

RGB and HSV



"HSL-HSV hue and chroma" by Jacob Rus - Own work. Licensed under CC BY-SA 3.0 via Wikimedia Commons - http://commons.wikimedia.org/wiki/File:HSL-HSV_hue_and_chroma.svg#/media/File:HSL-HSV_hue_and_chroma.svg



"Hsl-and-hsv" by Jacob Rus - Own work. Licensed under CC BY-SA 3.0 via Wikimedia Commons - <http://commons.wikimedia.org/wiki/File:Hsl-and-hsv.svg#/media/File:Hsl-and-hsv.svg>

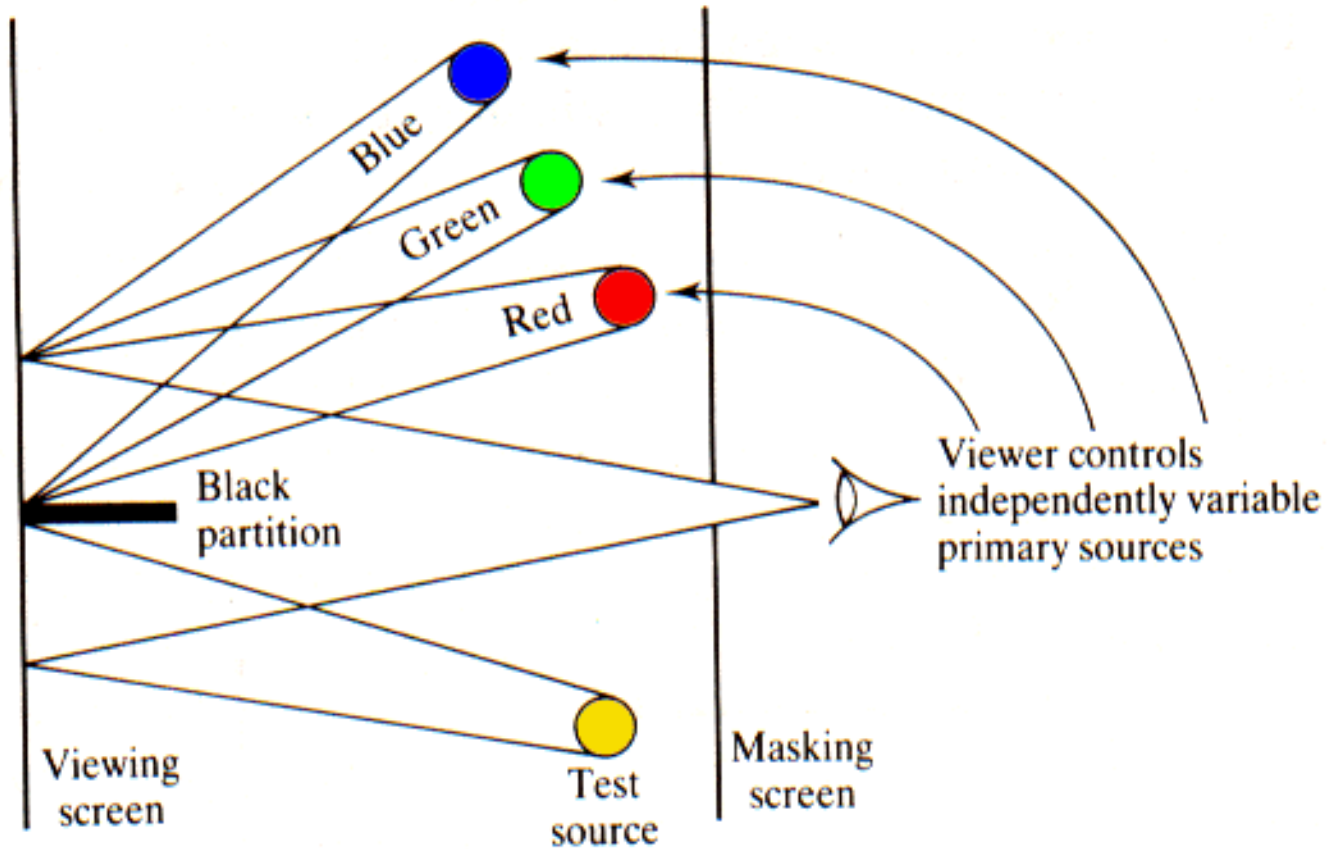


COLOURIMETRY

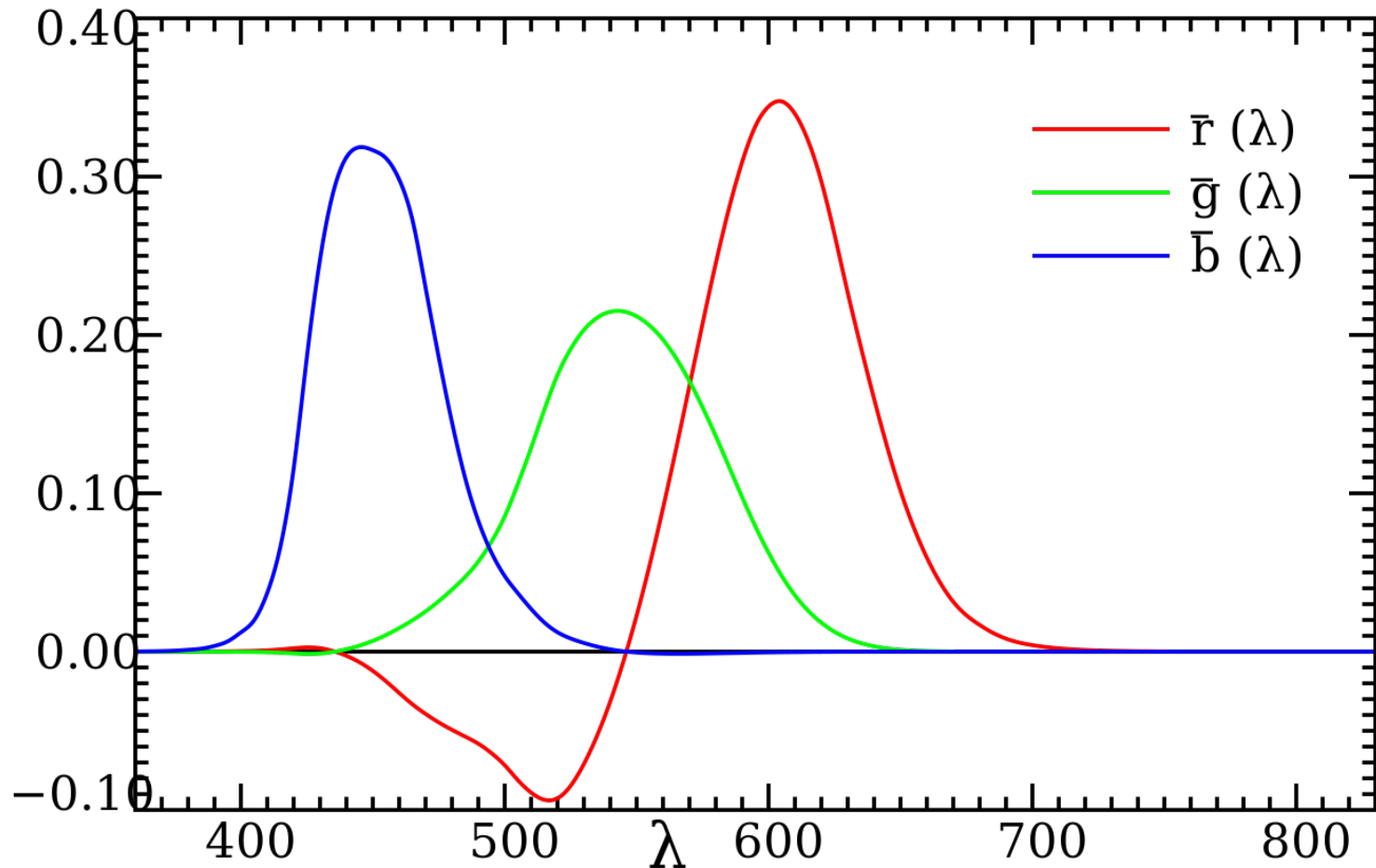
CIE Standard Observer

- CIE: International Commission on Illumination
- Definition of an objective color-mapping function:
 - Standard colorimetric observer
- Experiment
 - An observer is positioned in front of a bipartite screen
 - Observer can manipulate intensities of three primary color beams
 - Task: match the reference color

Standard Observer Experiment

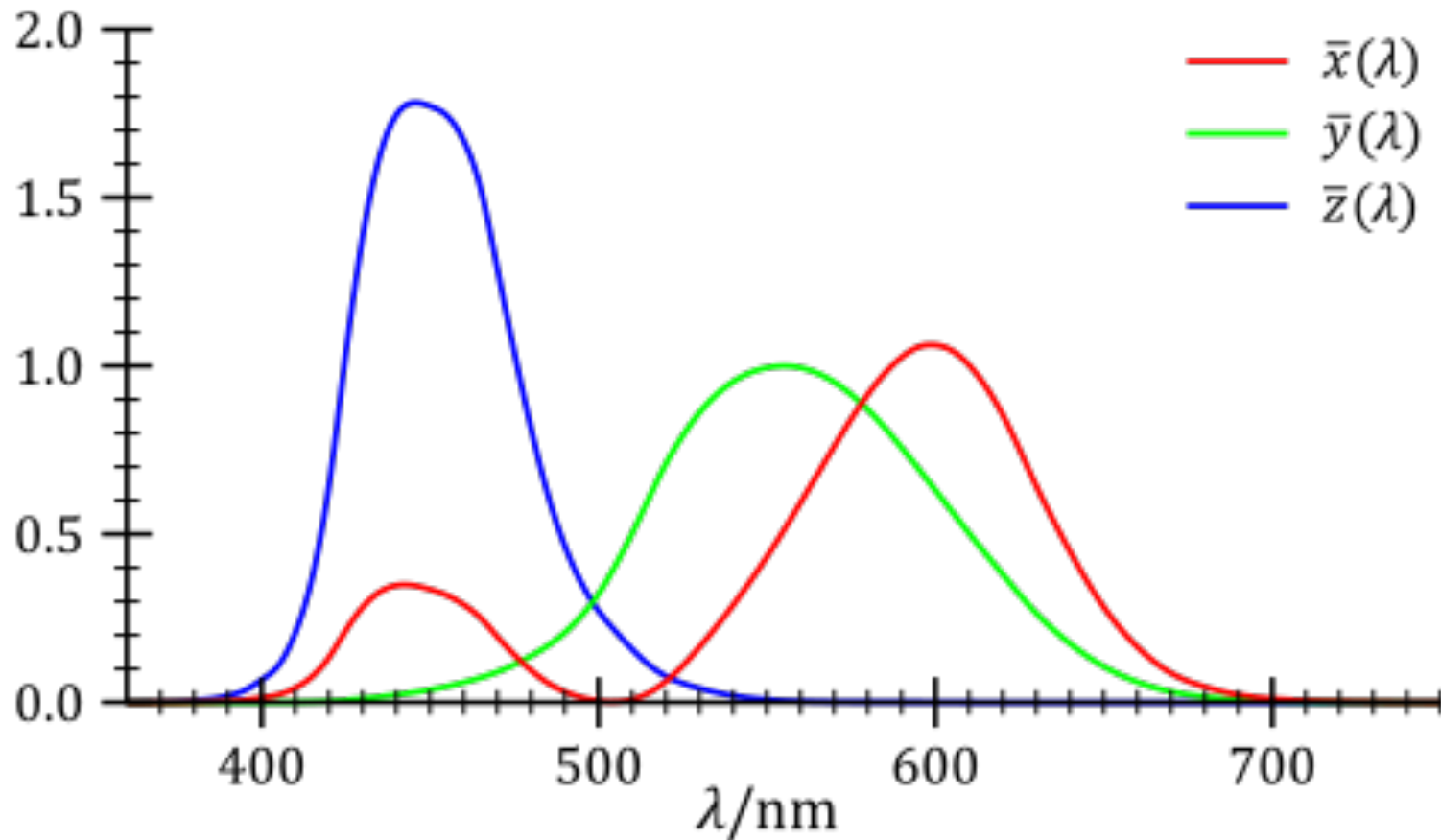


Standard Observer Results



"CIE1931 RGBCMF" by Original uploader was Marco Polo at en.wikipedia - Transferred from en.wikipedia; Transfer was stated to be made by User:Kanie.. Licensed under Public Domain via Wikimedia Commons - http://commons.wikimedia.org/wiki/File:CIE1931_RGBCMF.svg#/media/File:CIE1931_RGBCMF.svg

Color Matching Functions: imaginary primary colors



"CIE 1931 XYZ Color Matching Functions" by User:Ac dx - Own work. Licensed under GFDL via Wikimedia Commons - http://commons.wikimedia.org/wiki/File:CIE_1931_XYZ_Color_Matching_Functions.svg#/media/File:CIE_1931_XYZ_Color_Matching_Functions.svg

Tristimulus Values

- A color is defined by its spectral function $S(\lambda)$
- According to the matching function, we have:

$$X = \int \bar{x}(\lambda)S(\lambda)d\lambda$$

$$Y = \int \bar{y}(\lambda)S(\lambda)d\lambda$$

$$Z = \int \bar{z}(\lambda)S(\lambda)d\lambda$$

Chromaticities

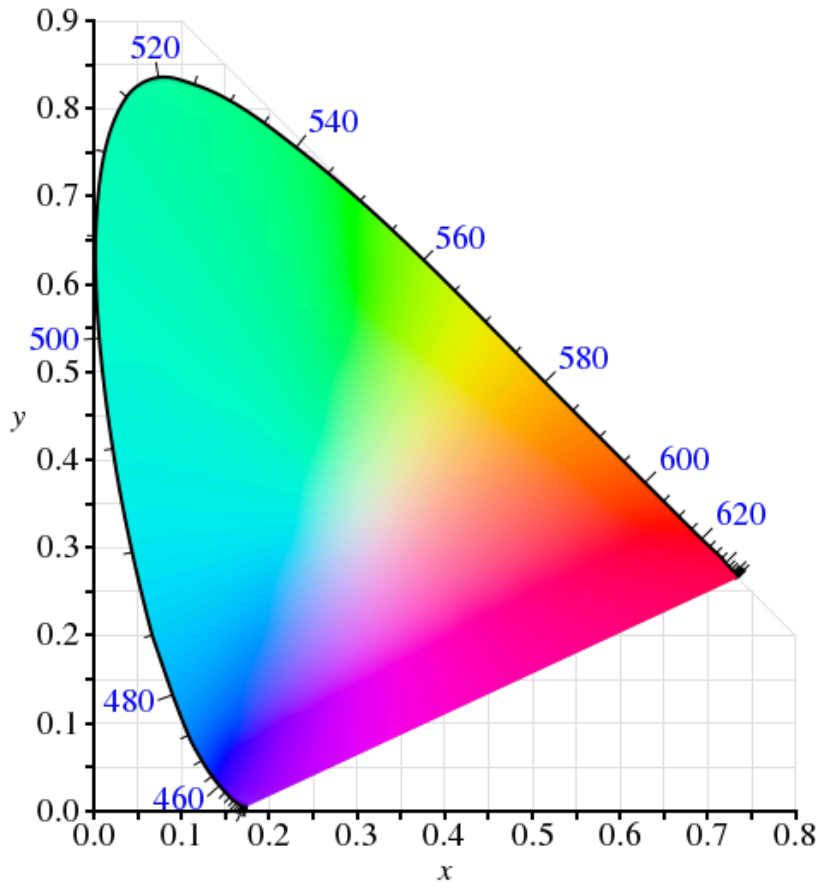
- Tristimulus values comprehend effects of hue, saturation and brightness
- We can filter out brightness with chromaticities:

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

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

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

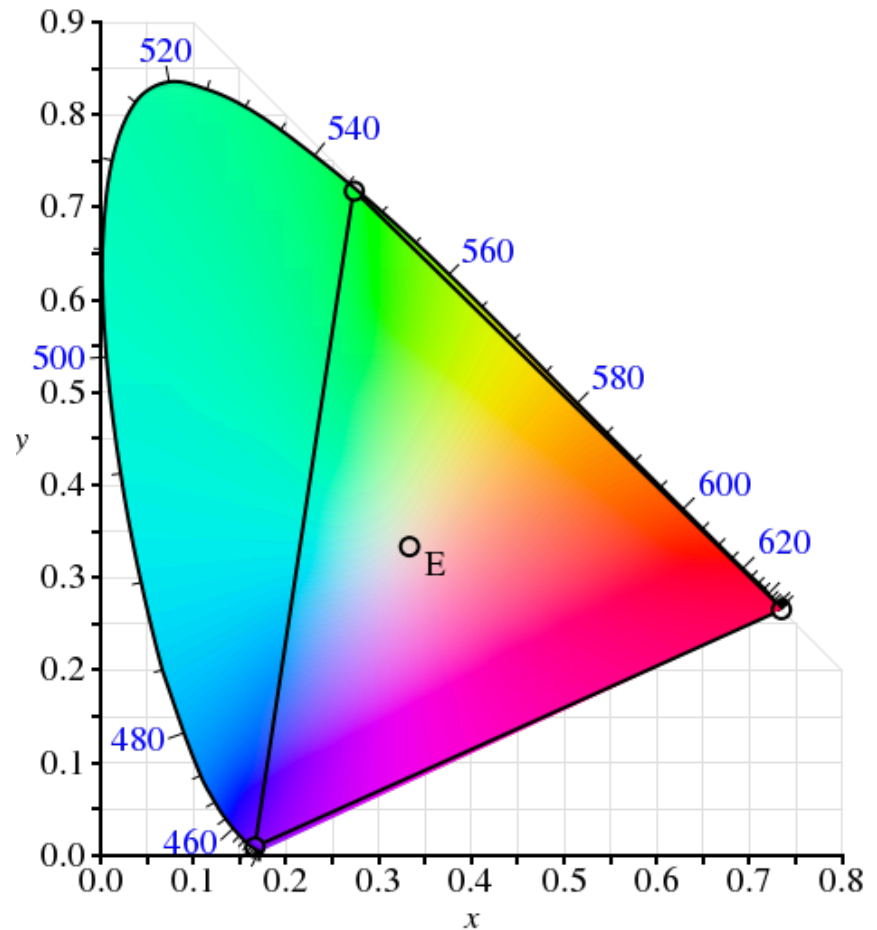
Chromaticity Diagram



- A mixture of two colors lies on the line connecting the two colors
- Chromaticity Diagram (**gamut**) is convex
- All visible colors are non-negative combination of x , y , and z
- An equal combination of two colors does not lie in the mid-point

Color Mixing

- Given three primary colors, the corresponding triangle cannot cover the whole gamut



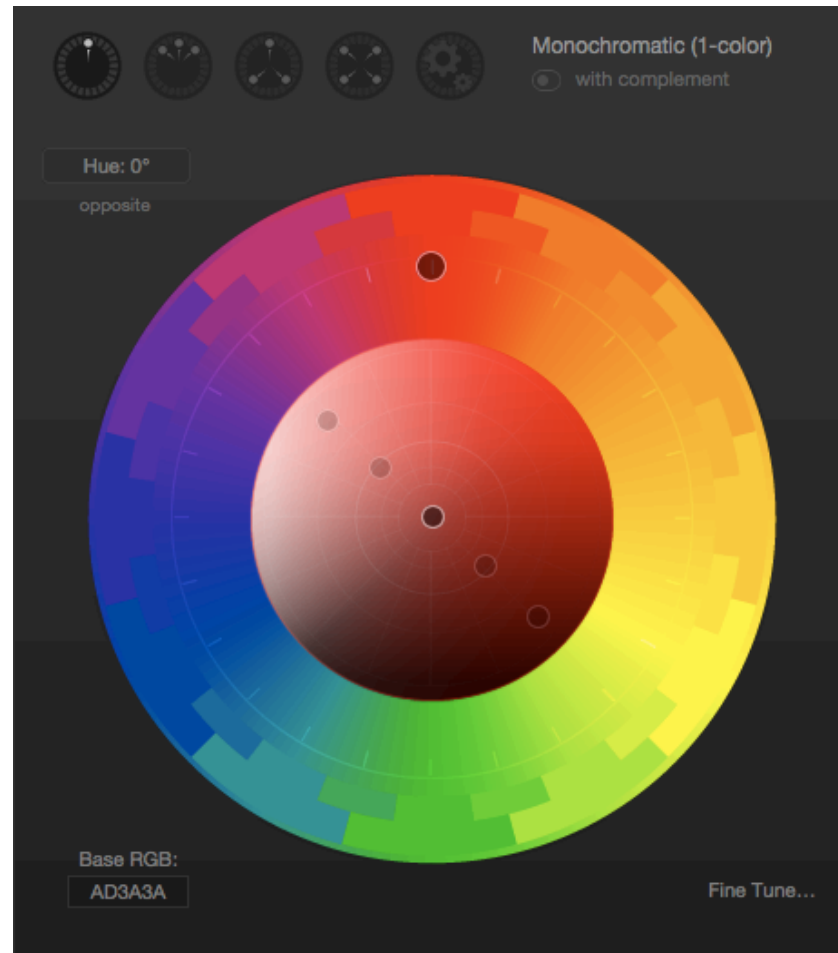
"CIE1931xy CIERGB" by BenRG - Own work, inspired by
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PALETTE

Color Schemes

Cold colors



Warm colors

<http://paletton.com/>

Color Schemes for Cartography

The screenshot displays the ColorBrewer 2.0 web application interface. At the top right, the text "COLORBREWER 2.0" is prominently displayed in white and orange, with the tagline "color advice for cartography" below it. Navigation links for "how to use", "updates", "downloads", and "credits" are visible in the top left of the main panel.

The interface is divided into several control panels on the left side of a large map preview area:

- Number of data classes:** A dropdown menu is set to "3".
- Nature of your data:** Three radio buttons are present: "sequential" (unselected), "diverging" (unselected), and "qualitative" (selected).
- Pick a color scheme:** A grid of 12 different color scheme thumbnails is shown.
- Only show:** Three checkboxes are present: "colorblind safe" (unchecked), "print friendly" (unchecked), and "photocopy safe" (unchecked).
- Context:** Three checkboxes are present: "roads" (unchecked), "cities" (unchecked), and "borders" (checked).
- Background:** Two radio buttons are present: "solid color" (selected) and "terrain" (unselected).
- Color transparency:** A horizontal slider is located at the bottom left of the control panels.
- 3-class Set1:** A legend for the selected scheme shows three colors: red (#e41a1c), blue (#377eb8), and green (#4daf4a).
- EXPORT:** A vertical button is located between the legend and the map.

The main map area shows a geographical map with a 3-class qualitative color scheme applied. The map is divided into numerous small, irregular polygons, each colored either red, blue, or green. The red areas are concentrated in the upper left and lower right, while blue and green areas are more widely distributed.

<http://colorbrewer2.org/>

Takeaway Messages

- Different color models and encodings
- Color palettes to represent scales of values