The Mystery of Color

March 25, 2021

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Overview

Visible spectrum

Atomic picture

Mixing

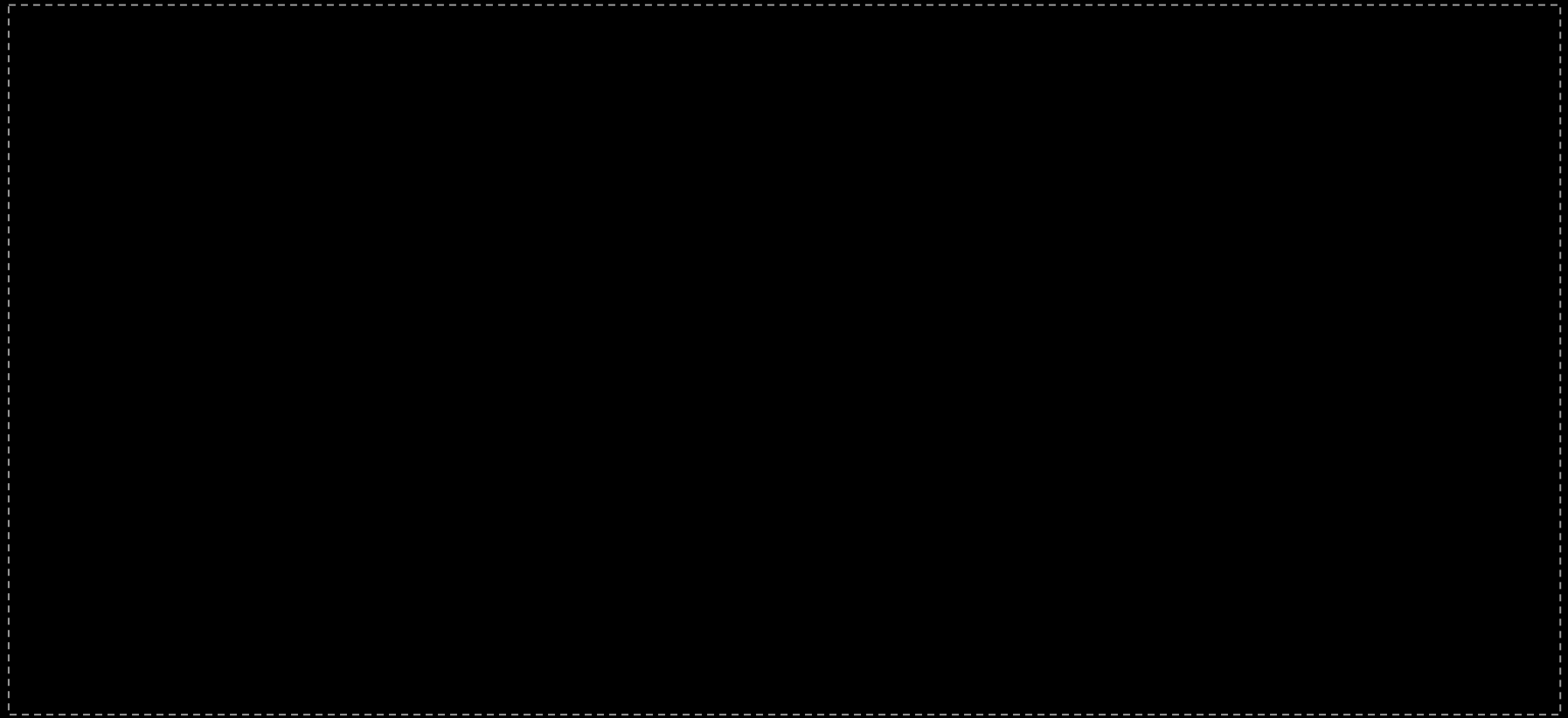
Eye anatomy

Color spaces

Role of the brain

More confusion

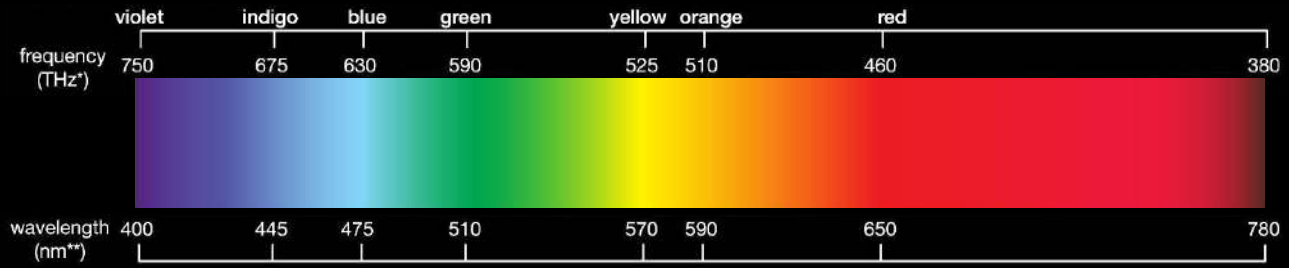
What Is Color?



The Visible Spectrum

Newton (1665) − white light decomposed into a color spectrum

Why can’t we see outside of the 400−780 nm range?



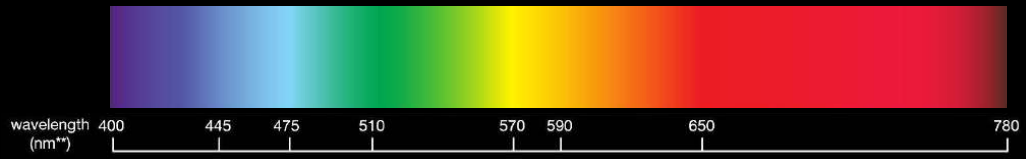
Visible spectrum - Britannica

Emission Spectrum

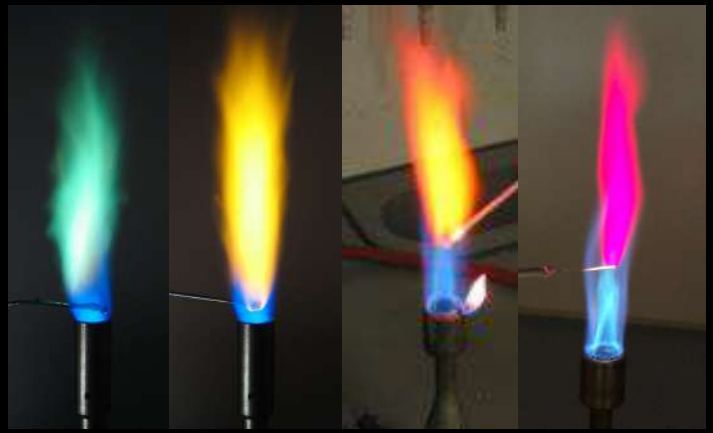
Configuration	Term	J	Level (cm^{-1})
3s	^{2}S	1/2	0.000
3p	^{2}P°	1/2	16956.172
		3/2	16973.368
4s	^{2}S	1/2	25739.991
3d	^{2}D	5/2	29172.839
		3/2	29172.889
4p	^{2}P°	1/2	30266.99
		3/2	30272.58
4f	^{2}F°	5/2,7/2	34586.92
5p	^{2}P°	1/2	35040.38
		3/2	35042.85
Na II $2s^2\ 2p^6$ (^{1}S$_0$)	**Limit**		**41449.451**

[Energy levels of sodium − NIST]

Let's heat some table salt. What color would we observe?



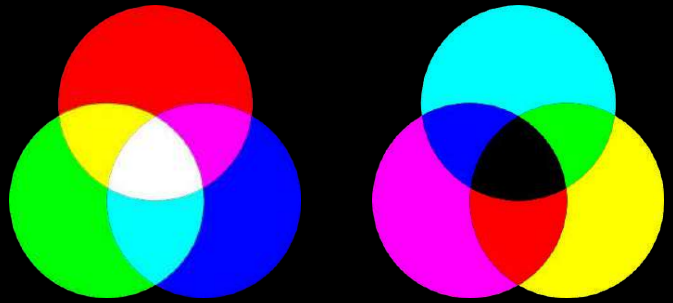
Salt Flame Demo



Do you see the yellow?

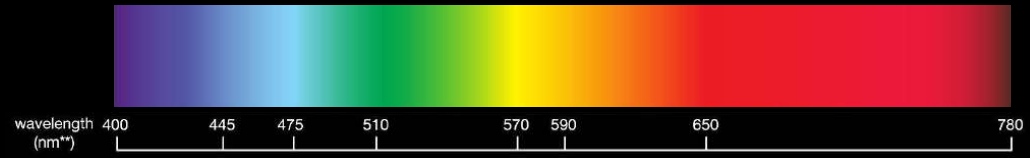
Colored flames from left to right: $CuSO_4$, NaCl, CuCl, LiCl

Mixing of Light

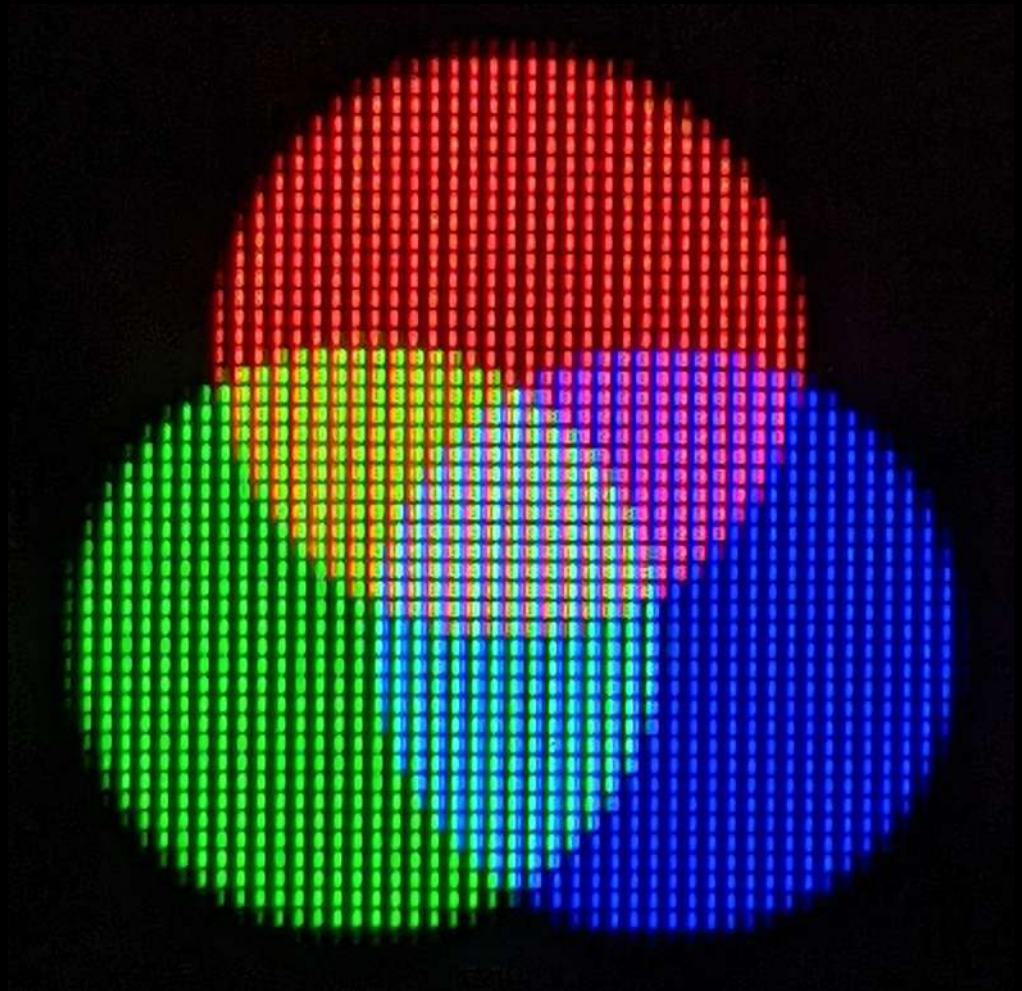


Additive and subtractive mixing of light

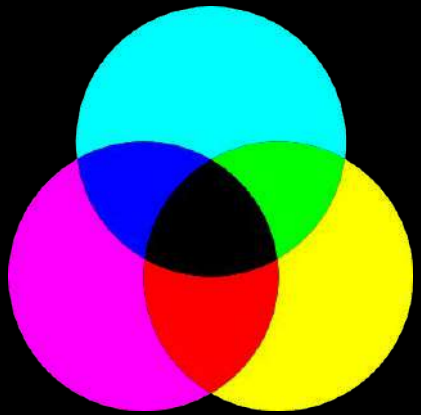
Where on the visible spectrum do we find magenta?



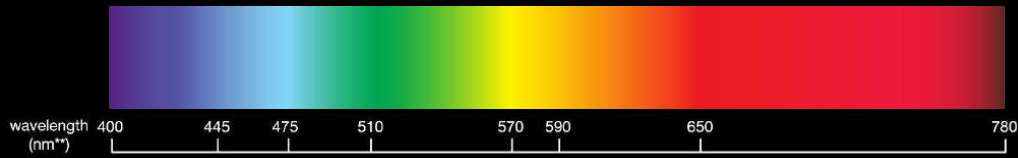
RGB Pixels



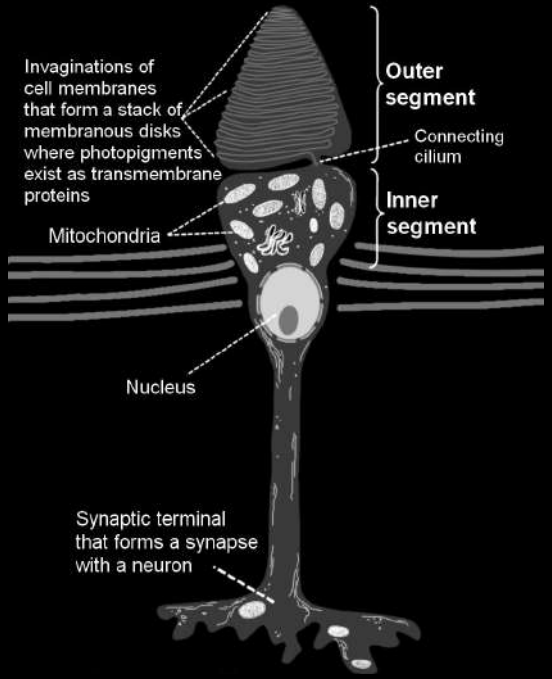
Color Mixing Demo



What should we try?



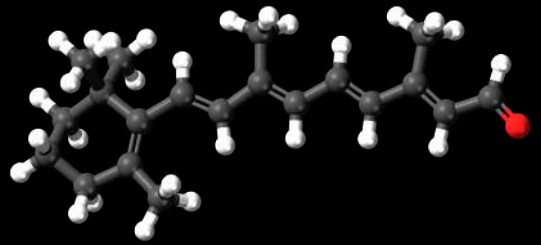
Human Eye Anatomy



Cone cell anatomy

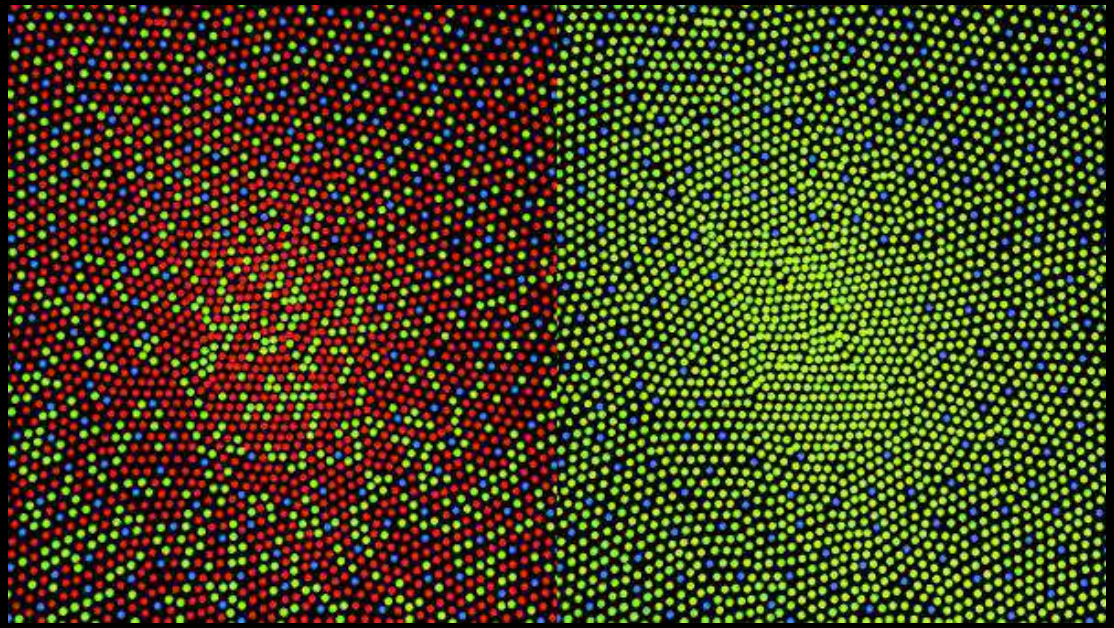
Ganglion, rod, and cone cells
Retinal + photopsins

Three photopsins: photoreceptor proteins
L, M, S opsins



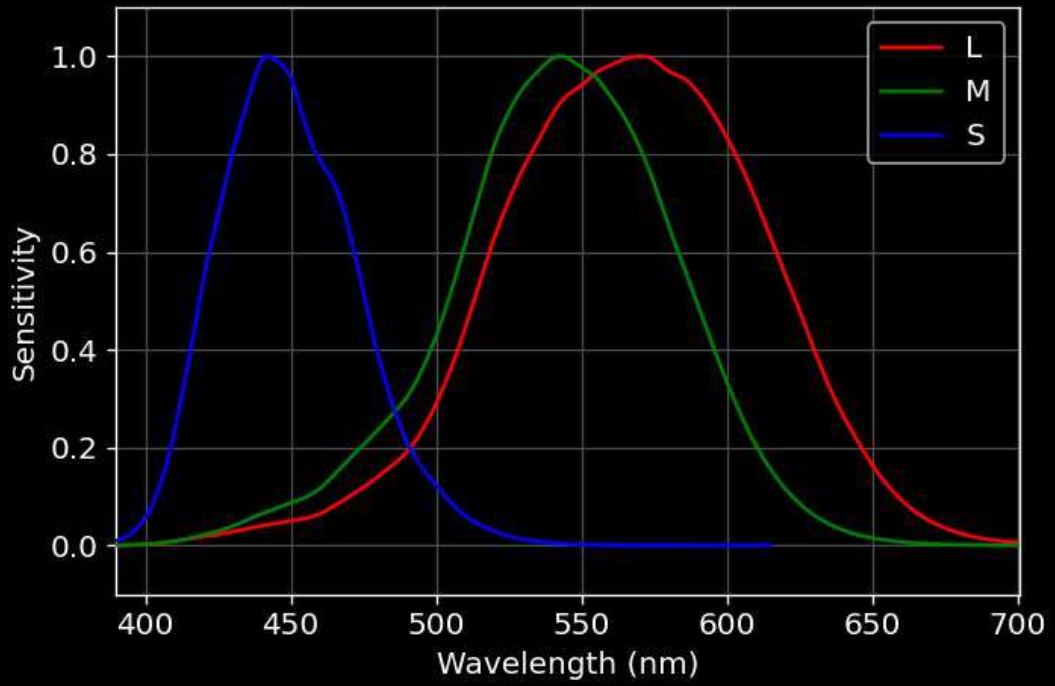
Retinal molecule structure

Cone Cell Distribution



Cone cell distribution in the fovea: normal color vision (left), color blind protanopic (right)

LMS Cone Fundamentals

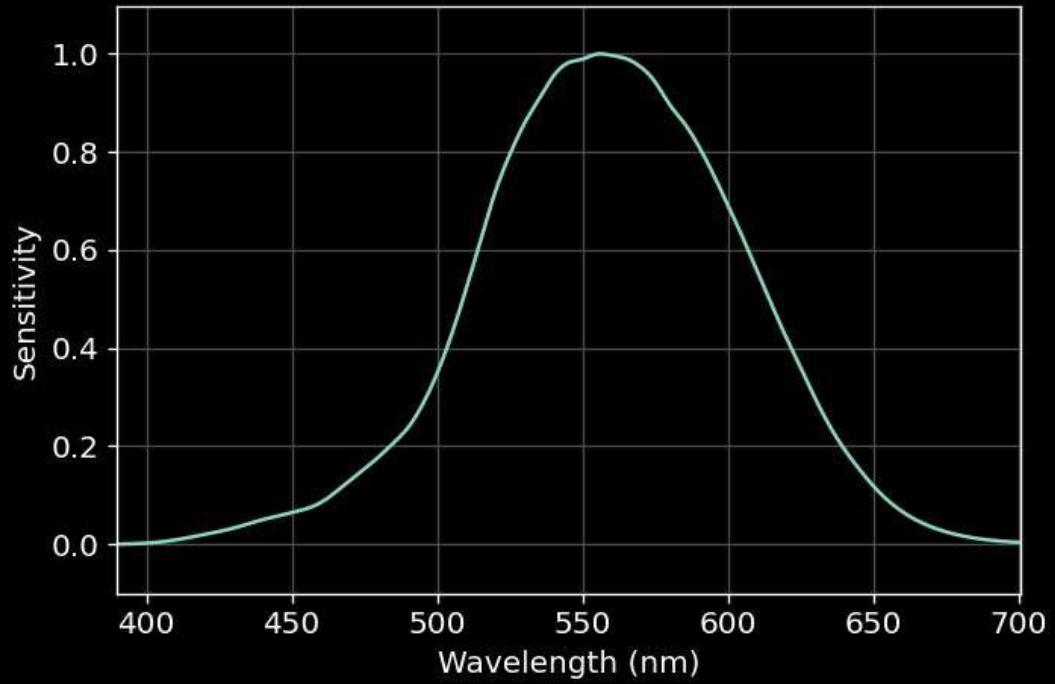


CIE 2006 cone fundamentals

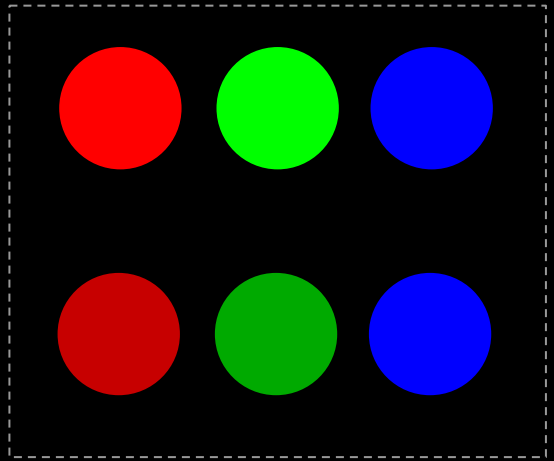
International Commission on Illumination − Vienna

What wavelength are our eyes most sensitive to?

Photopic Luminous Efficiency Function

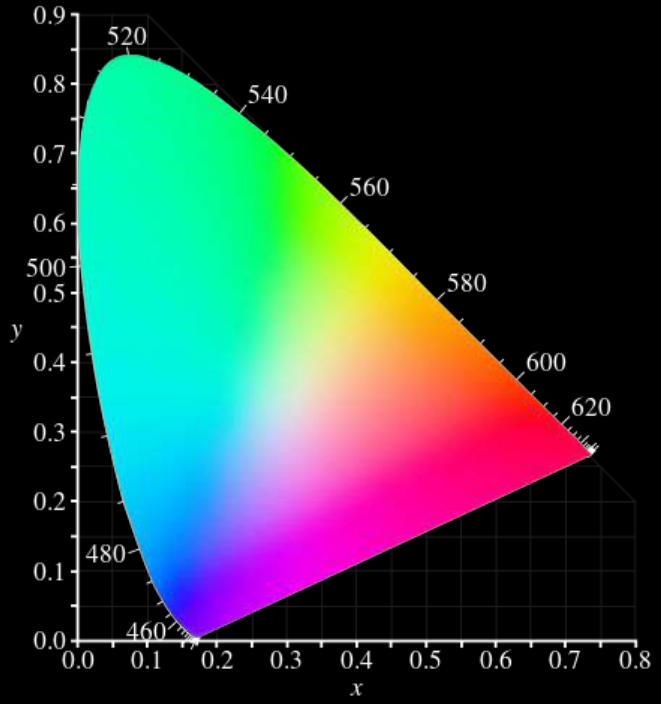


Select the brightest circle in each row.



CVRL functions

CIE xyY Color Space



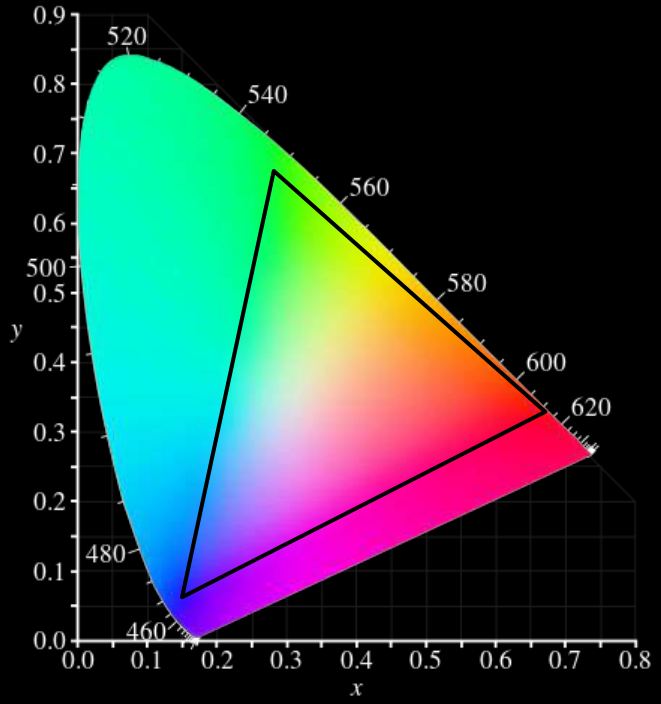
CIE 1931 color space

Chromaticity and brightness

$$X = 1.9474\,L - 1.4144\,M + 0.3648\,S$$
$$Y = 0.6899\,L + 0.3483\,M$$
$$Z = 1.9349\,S$$

$$x = X / (X + Y + Z)$$
$$y = Y / (X + Y + Z)$$

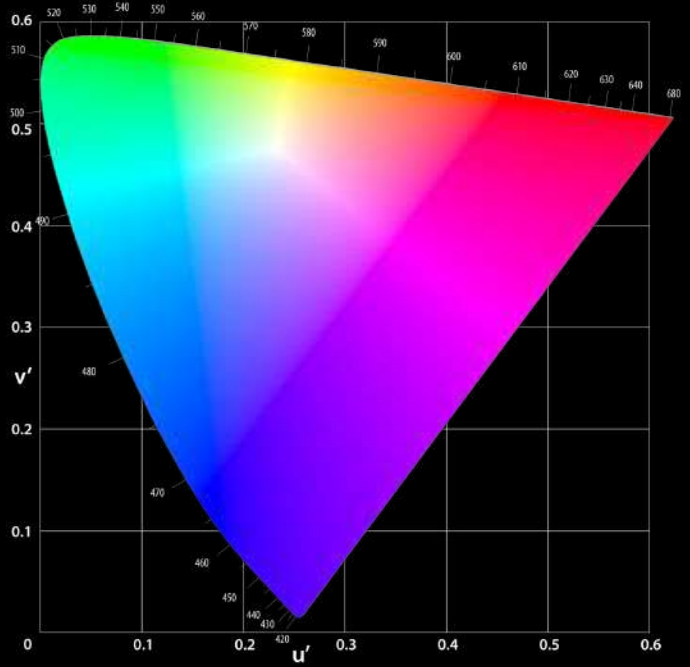
Another Color Space



DCI-P3 color space

DCI-P3 only covers about 45% of chromaticities

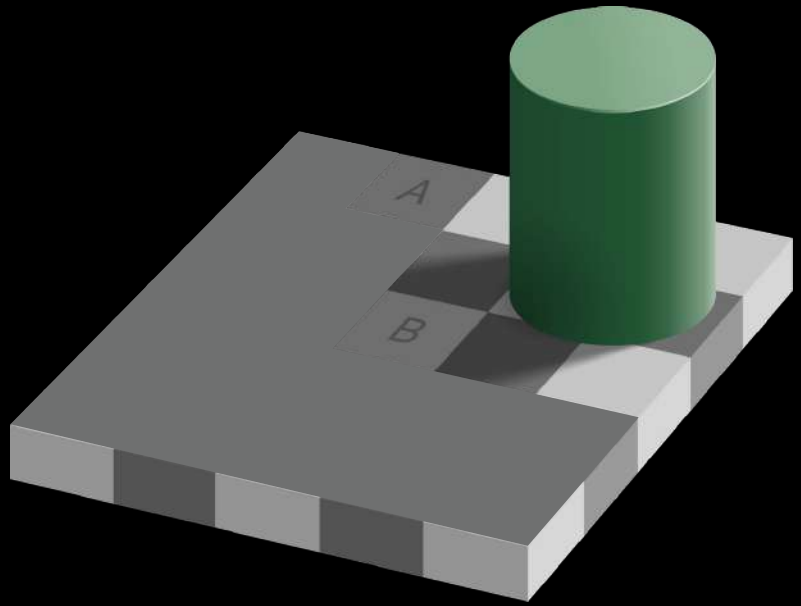
Yet Another Color Space



CIELUV color space

Perceptually uniform presentation of chromaticity

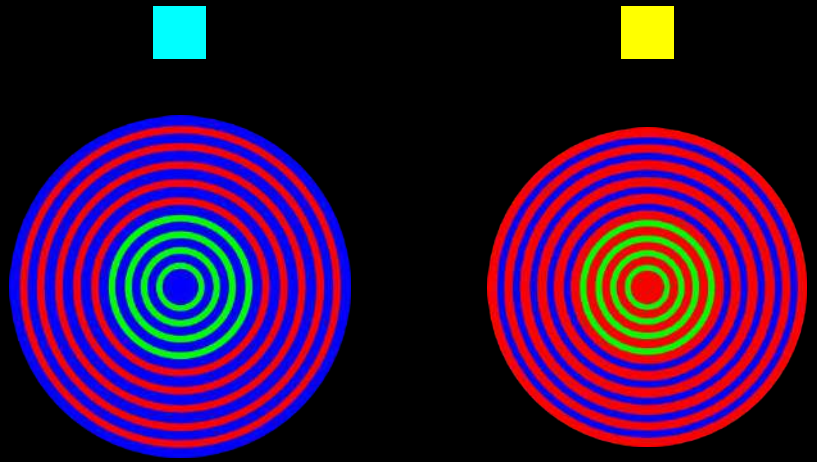
Role of The Brain



Checker shadow illusion − Edward H. Adelson

Which one is darker? A or B?

A Fun Illusion

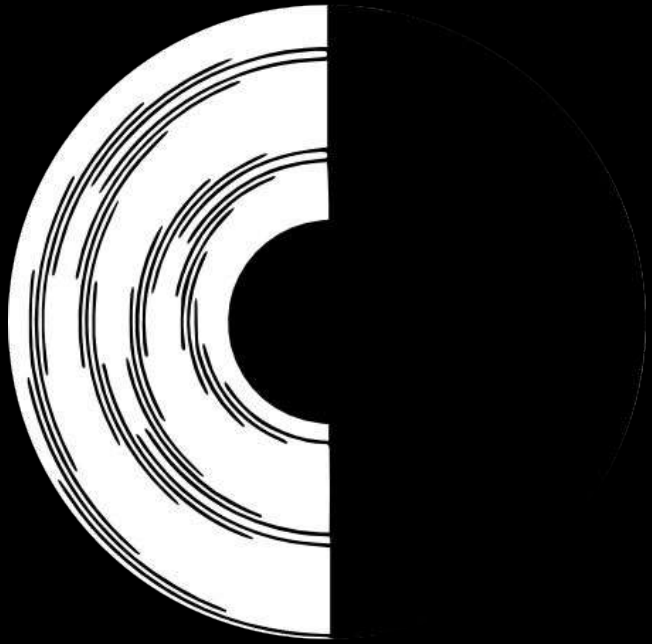


Measuring color − Andrew Hanson

Fechner Demo − Flicker Warning!

Benham top − Do you see the colors?

Fechner Color Effect



Fechner color effect − Charles Benham

Thank You!

What is color?

The dress − Cecilia Bleasdale