

Nano-Imaging and Human Color Vision

Hirohisa Yaguchi

Additive and Subtractive Color Mixture

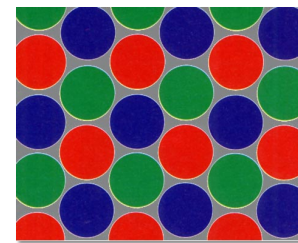


(Billmeyer and Saltzman's principles of color technology, Roy S. Berns)

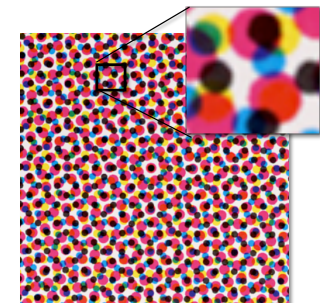
Contents

- Principle of color reproduction
- Human color vision model
- CIE colorimetry
- Advanced colorimetry

Color Reproduction

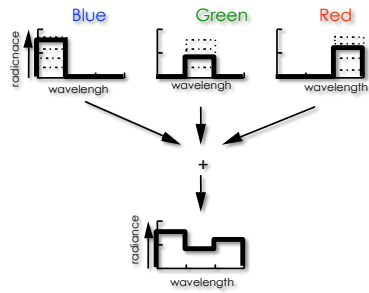


Display (CRT, LCD, etc.)
(additive color mixture)

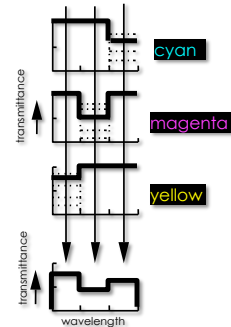


Printing, Photography
(subtractive color mixture)

Spectral Color Reproduction of Additive and Subtractive Color Mixture

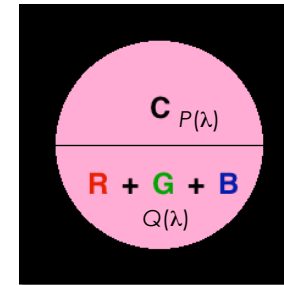


Additive color mixture

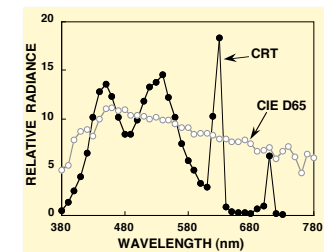


Subtractive color mixture

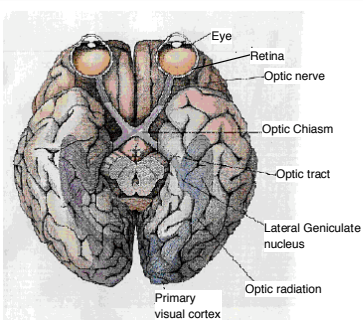
Color Matching and Metamerism



$$P(\lambda) \neq Q(\lambda)$$

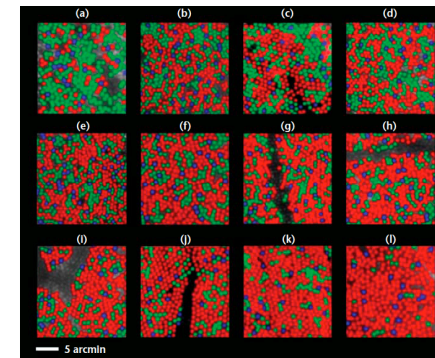


Human Visual Information Processing



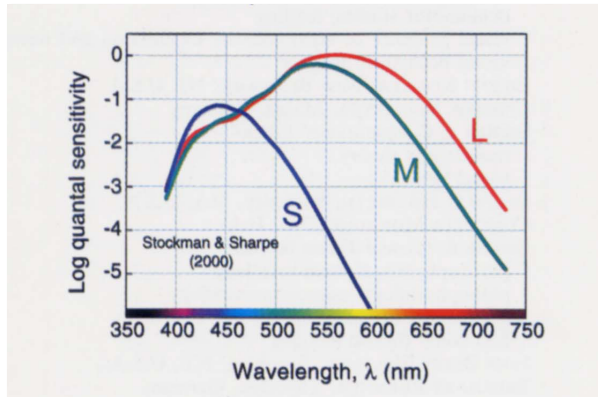
- Eye balls: Optical system
- Retina: High intelligent input device
 - Photoreceptors (Rods and Cones)
 - Luminance and chromatic channels (Horizontal cells)
 - Contrast (Ganglion cells)
- LGN: Parallel information processing
 - Magno path (where?): place, motion, depth
 - Parvo path (what?): shape, color, texture, detail
- Primary visual cortex
- Parietal stream and Inferotemporal stream

Cone Mosaic

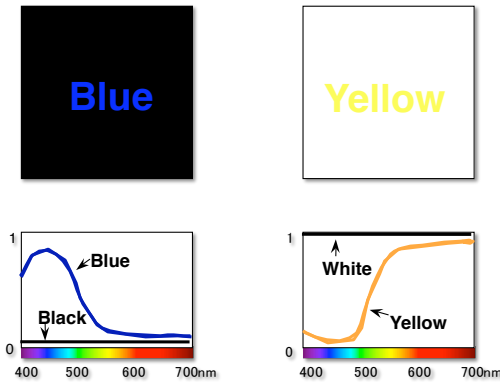


Joseph Carroll, Daniel C. Gray, Austin Roorda and David R. Williams, Optics & Photonics News, vol. 16, 36-41 (2005)

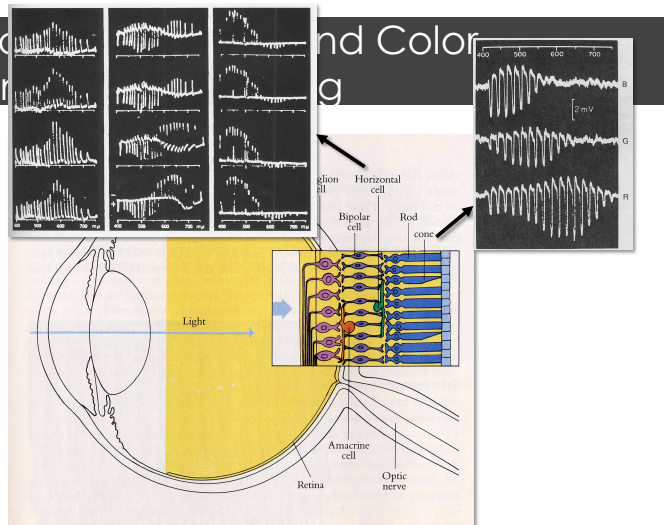
Spectral Sensivities of Cone



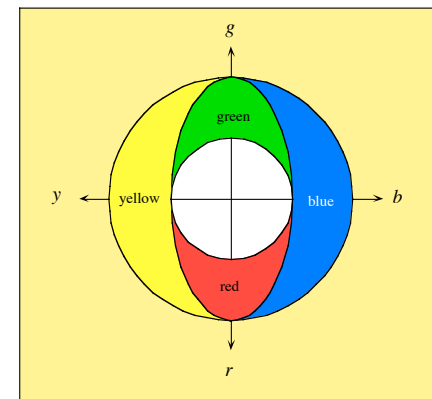
Why blue on black and yellow on white look blurred?



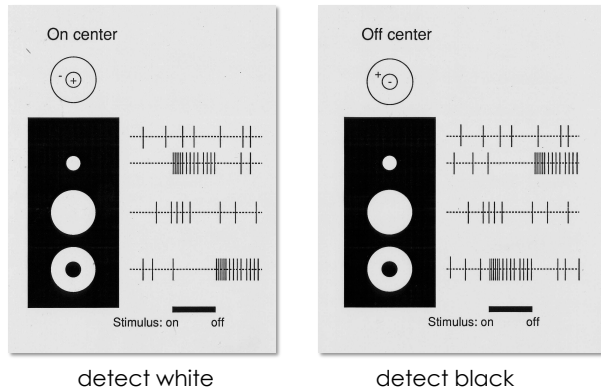
Structure and Color Information



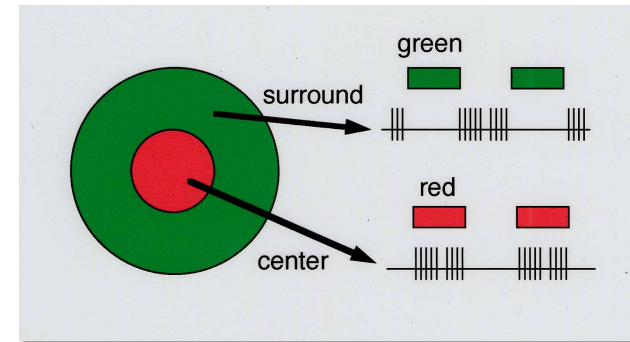
Opponent Color Theory Hering's Color Circle



Receptive Fields of Retinal Ganglion Cells

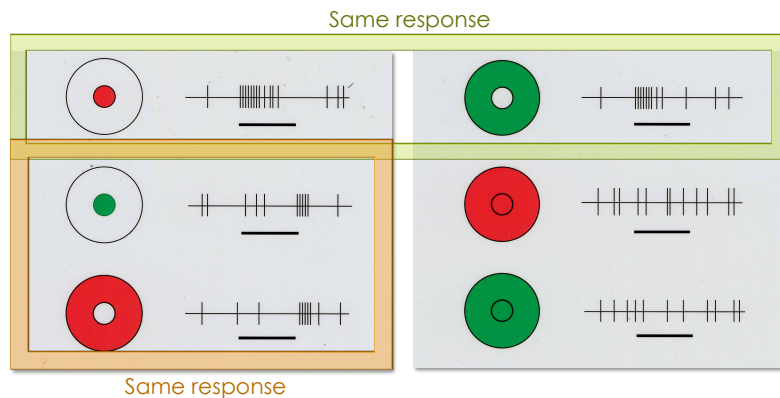


A Color Opponent Cell of the Retinal Ganglion Cell

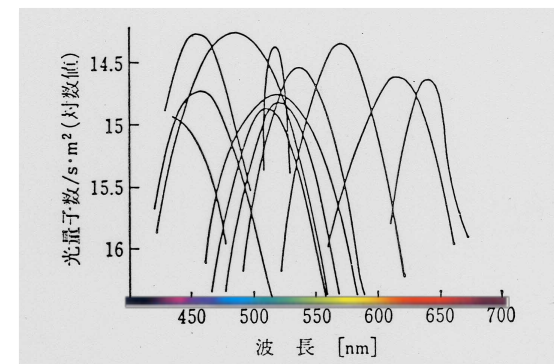


Red sensitive and green inhibited

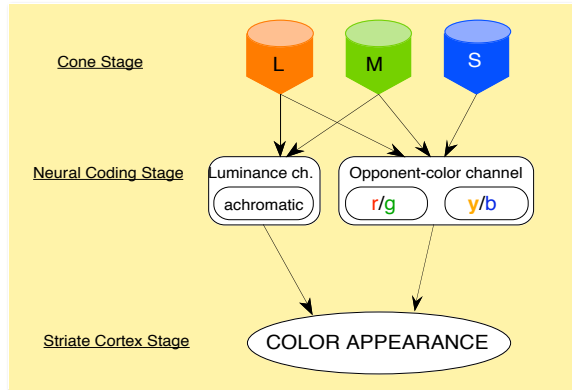
Double Opponent Color Cell



Spectral Selectivity of the V4 Cells in the Visual Cortex (Zeki)



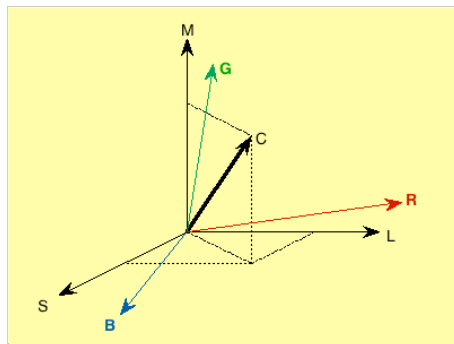
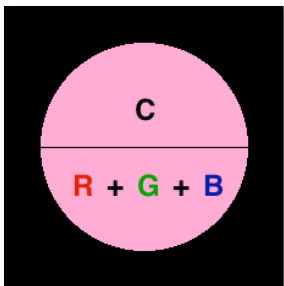
Color Vision Model



Basic Colorimetry Gunter Wyszecki (1973)

- Colorimetry is a tool used to making a prediction on whether two lights of different spectral power distributions will **match in color** for certain given conditions of observation. The prediction is made by determining the tristimulus values of the two visual stimuli. If the tristimulus values of a stimulus are identical to those of the other stimulus, a color match will be observed by an average observer with normal color vision.

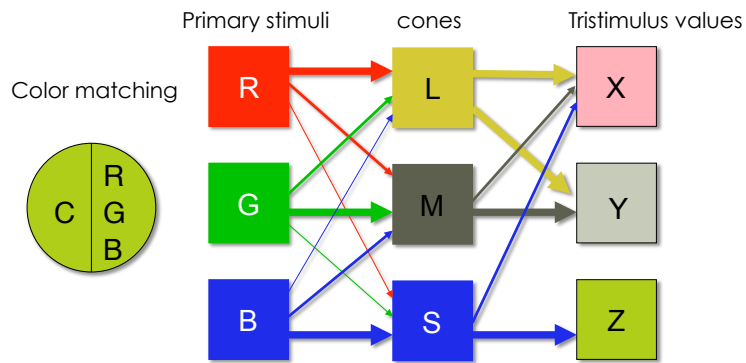
Color Matching Experiment



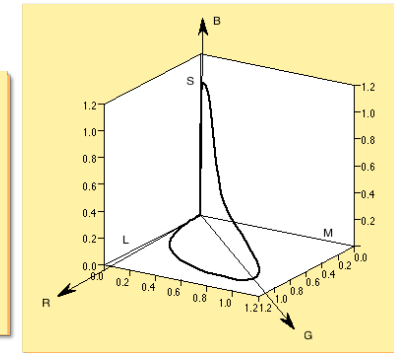
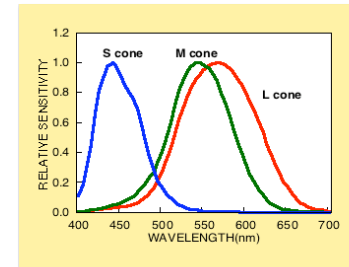
Basic Colorimetric System

- LMS (Physiological system)**
 - How many photons are absorbed in L, M, and S cone system?
- RGB (Physical system)**
 - How much red, green and blue light are needed to make a color match?
- XYZ (Mathematical system)**
 - To make a color match using three imaginary stimuli

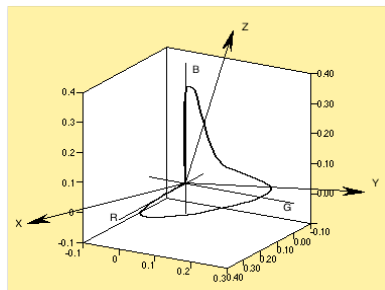
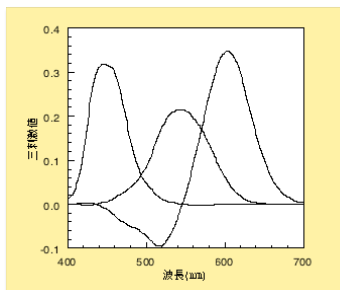
Color Matching and Tristimulus Values



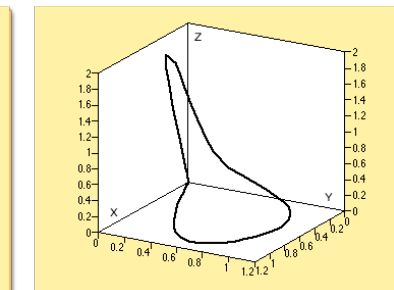
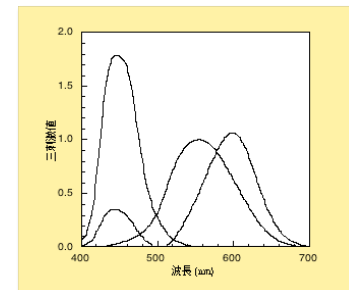
LMS: Physiological Colorimetry



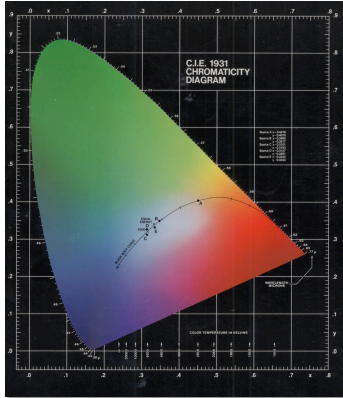
RGB: Physical Colorimetry



XYZ: Mathematical Colorimetry



CIE 1931 (x, y) Chromaticity Diagram



Girl with a Pearl Earring (Vermeer)

Advanced Colorimetry Gunter Wyszecki (1973)

- Colorimetry in its broader sense includes methods of assessing the **appearance of color** stimuli presented to the observer in complicated surroundings as they may in occur in everyday life. This is considered the ultimate goal of colorimetry, but because of its enormous complexity, this goal is far from being reached.

CIELAB (CIE 1976 L*a*b*)

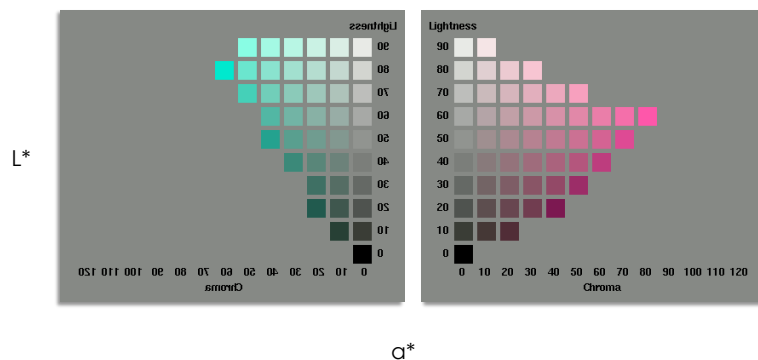
$$L^* = 116 \left(\frac{Y}{Y_n} \right)^{\frac{1}{3}} - 16$$

$$a^* = 500 \left\{ \left(\frac{X}{X_n} \right)^{\frac{1}{3}} - \left(\frac{Y}{Y_n} \right)^{\frac{1}{3}} \right\}$$

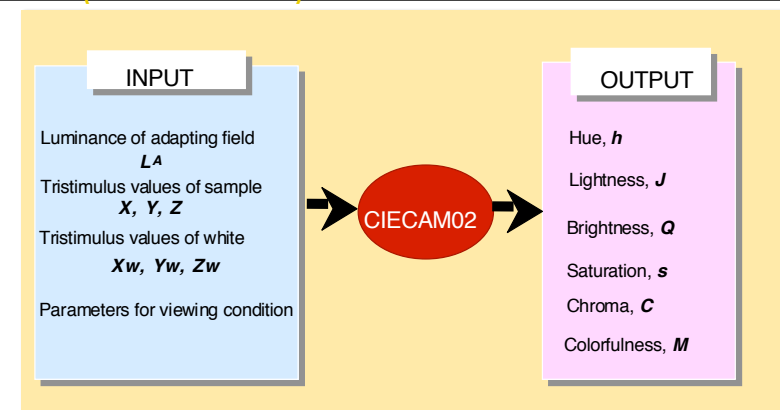
$$b^* = 200 \left\{ \left(\frac{Y}{Y_n} \right)^{\frac{1}{3}} - \left(\frac{Z}{Z_n} \right)^{\frac{1}{3}} \right\}$$

- Color adaptation
 - White is always white
- Non-linearity
 - Physical unit to psychological unit
- Color opponency
 - Luminance and chromaticness

CIELAB Color Space UCS: Uniform Color Space



CIE Color Appearance Model (CIECAM02)

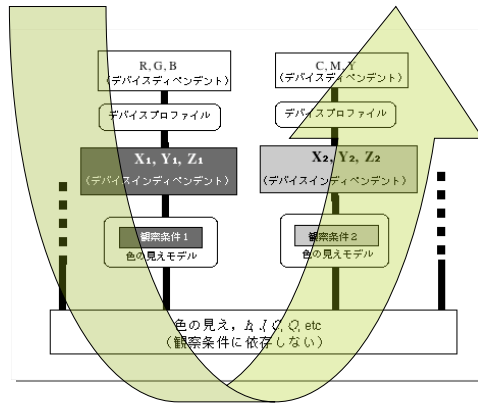


Application of CIECAM02

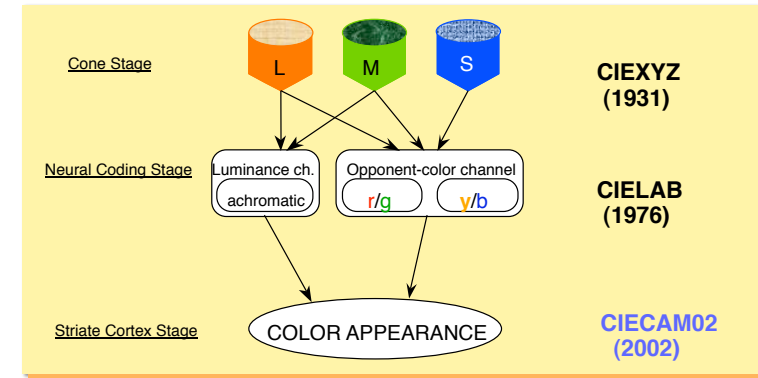
Color reproduction between different imaging media

Display

Print



Human Color Vision and Advance of Colorimetric System



Assignment

- Discuss relation between your research project and color using the following keywords;
 - Nano-imaging
 - Color reproduction
 - Colorimetry
- Report
 - Dead line; December 21, 2009
 - Send by e-mail; yaguchi@faculty.chiba-u.jp
 - Your report should be written in English with MS word or pdf.

The Material of this Lecture

- Available at <http://vision-lab.tp.chiba-u.jp/~yaguchi/>