Color Appearance, Color Order, & Other Color Systems

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ISCC/AIC Munsell 2018 — Boston

RIT

ISA

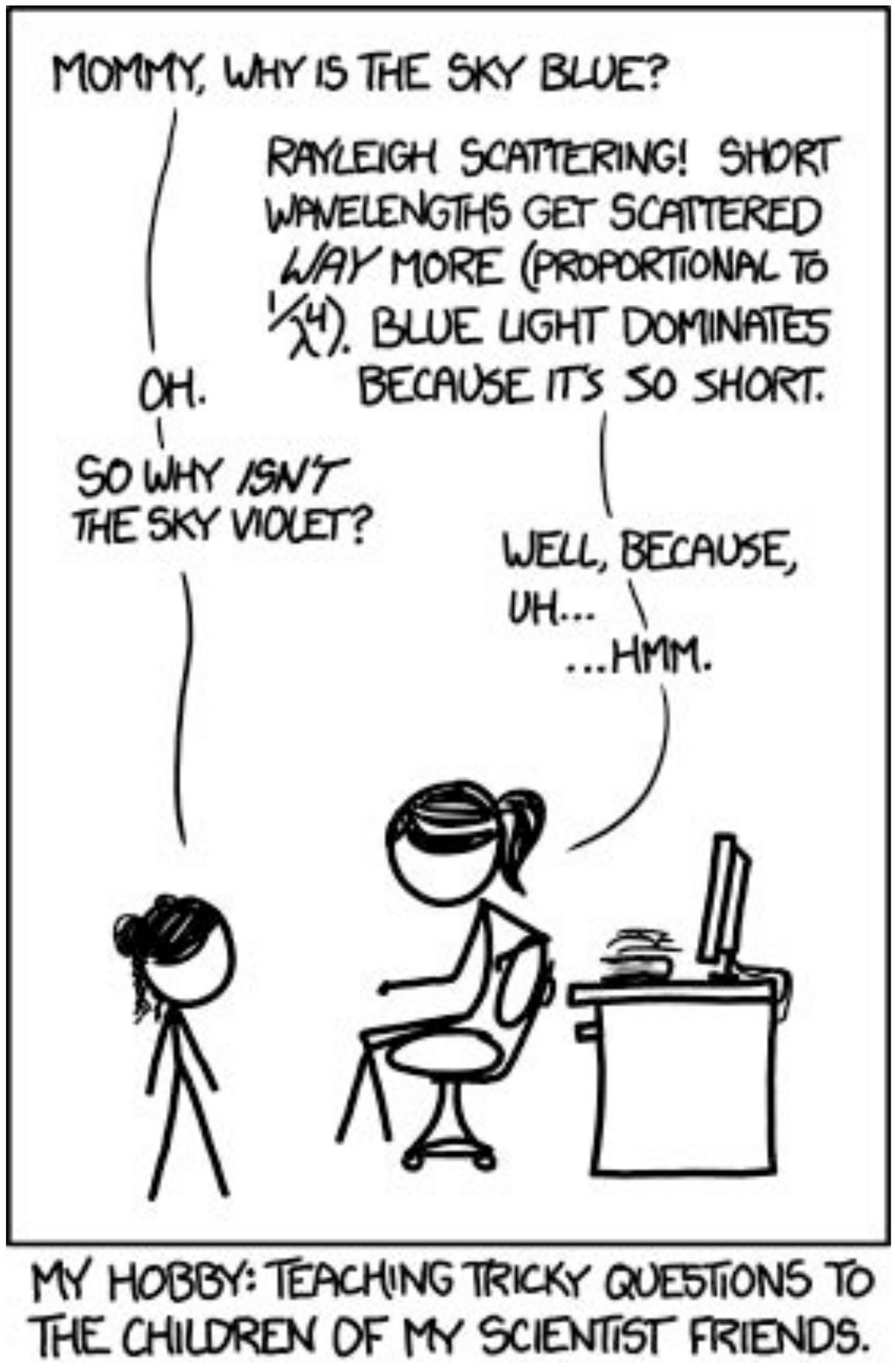
Integrated Sciences Academy

PoCS / MCSL

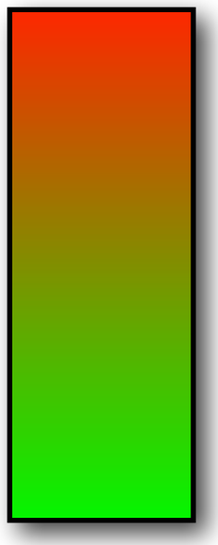
Color Terms

Color Definition

Color is an attribute of visual sensation …



Hue



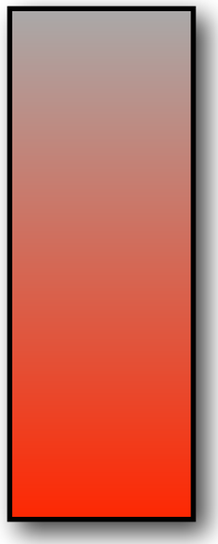
Attribute of a visual sensation according to which an area appears to be similar to one of the perceived colors, red, yellow, green, and blue, or to a combination of two of them.

Brightness, Lightness

Brightness: Attribute of a visual sensation according to which an area appears to emit more or less light.

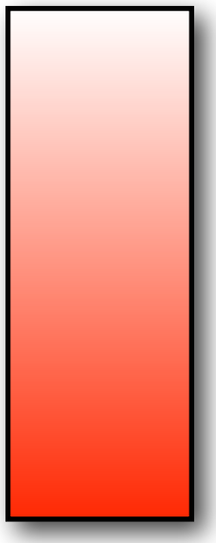
Lightness: The brightness of an area judged relative to the brightness of a similarly illuminated area that appears to be white or highly transmitting.

Colorfulness

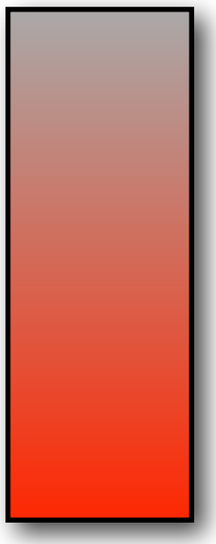


Attribute of a visual sensation according to which the perceived color of an area appears to be more or less chromatic.

Saturation, Chroma

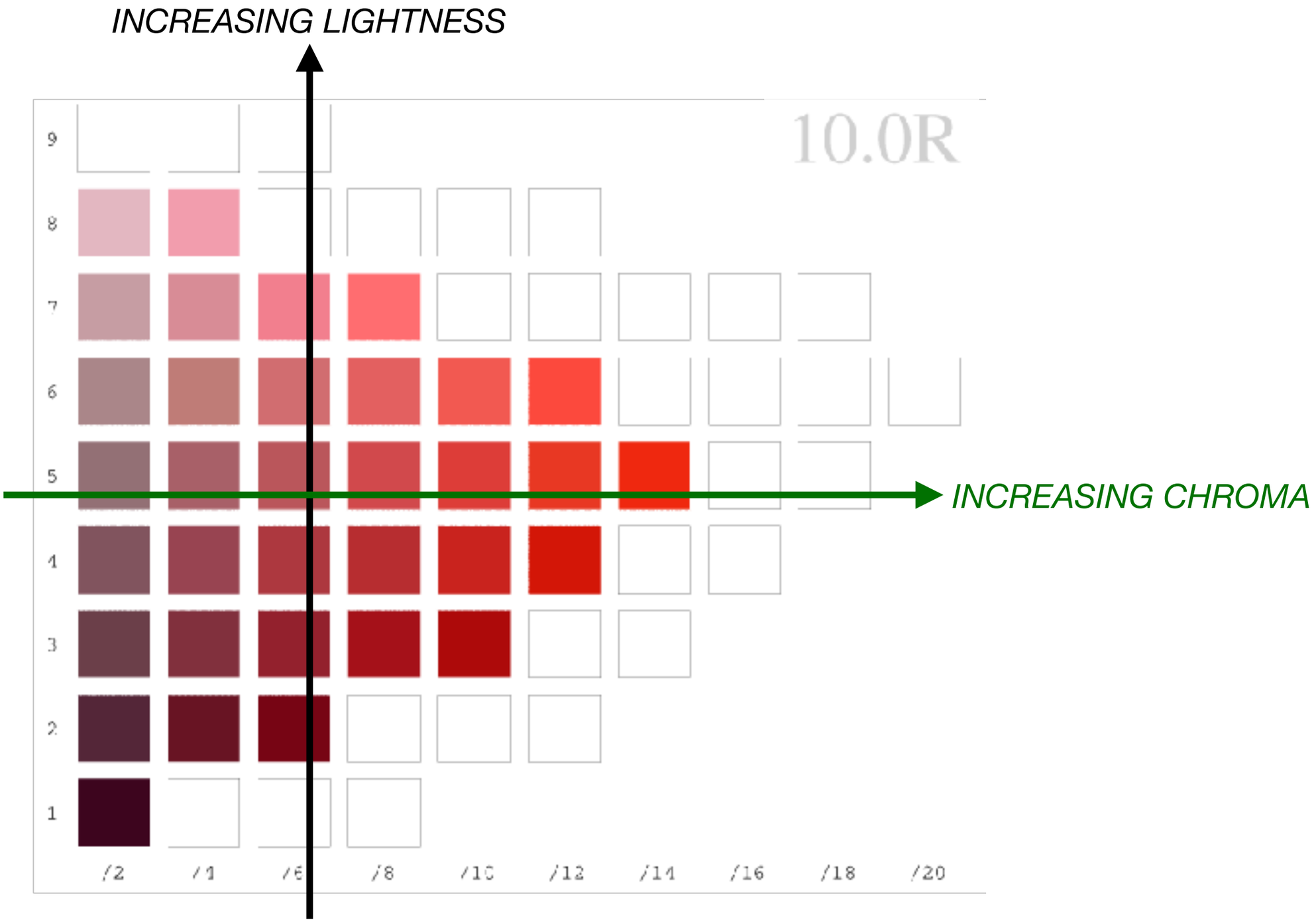


Saturation: Colorfulness, chromaticness, of an area judged in proportion to its brightness.

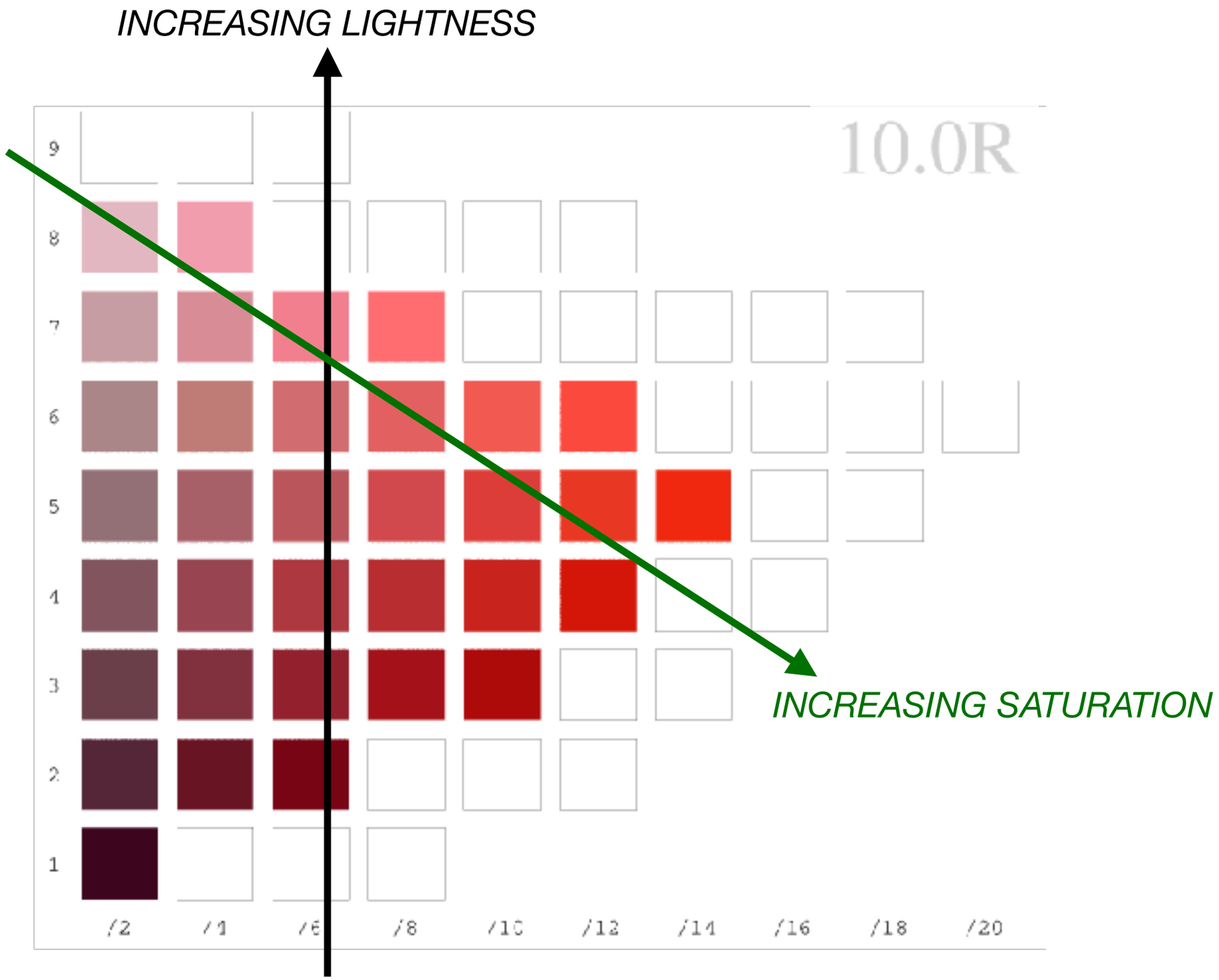


Chroma: Colorfulness of an area judged as a proportion of the brightness of a similarly illuminated area that appears white or highly transmitting.

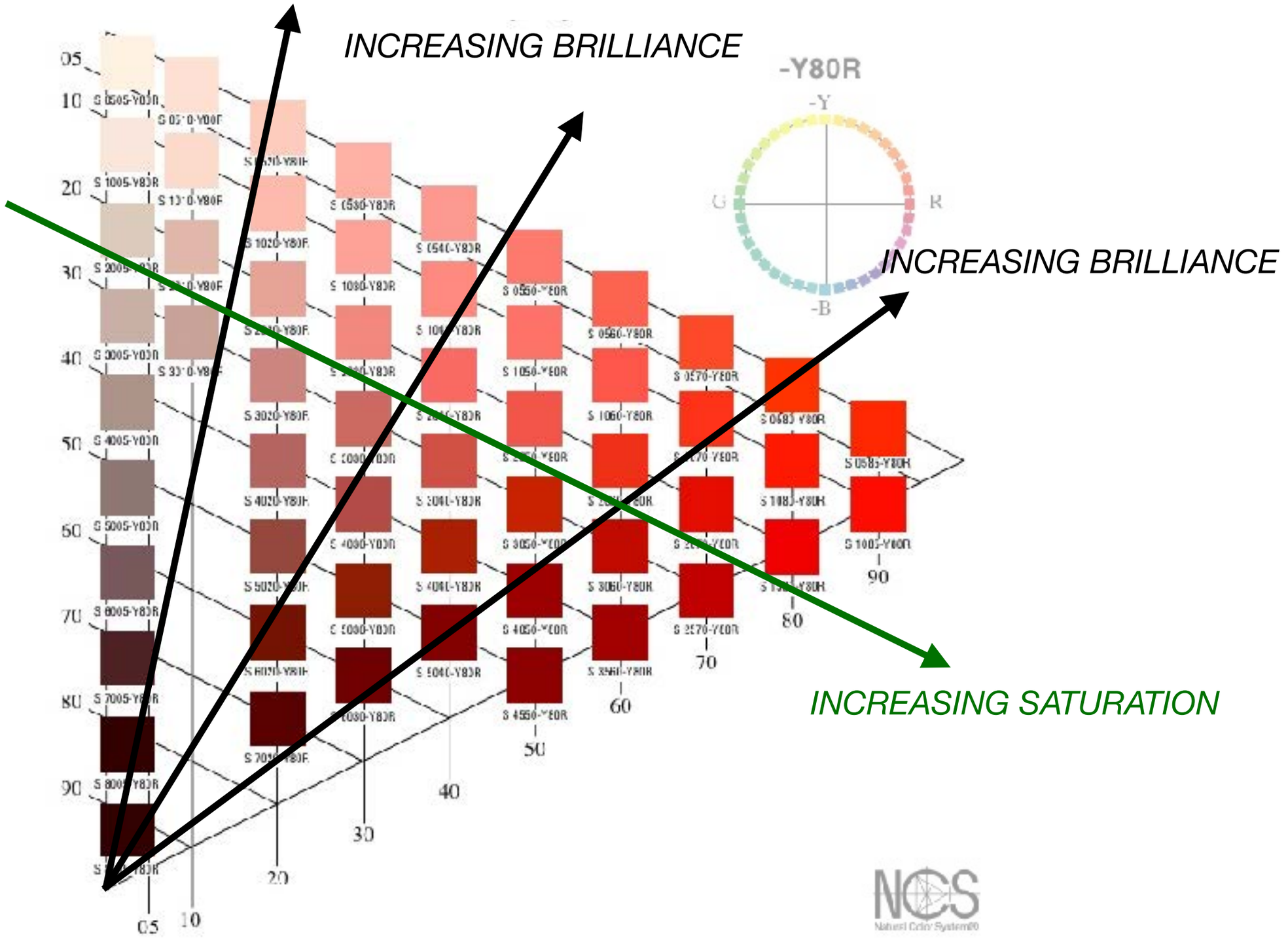
Hue, Lightness, Chroma



Hue, Lightness, Saturation



Hue, Brilliance, Saturation



Hue, Brilliance, Saturation

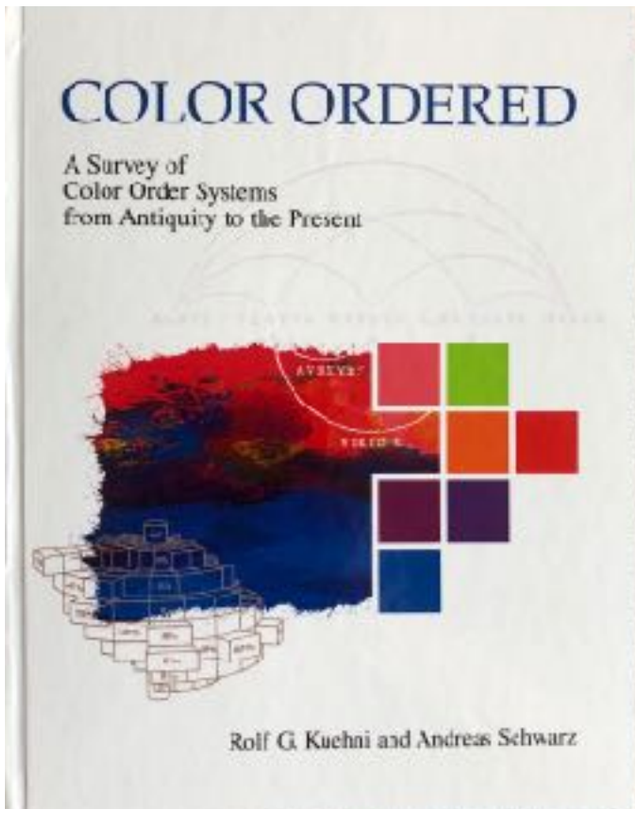
E. Hering: *Zur Lehre vom Lichtsinne* (1878)

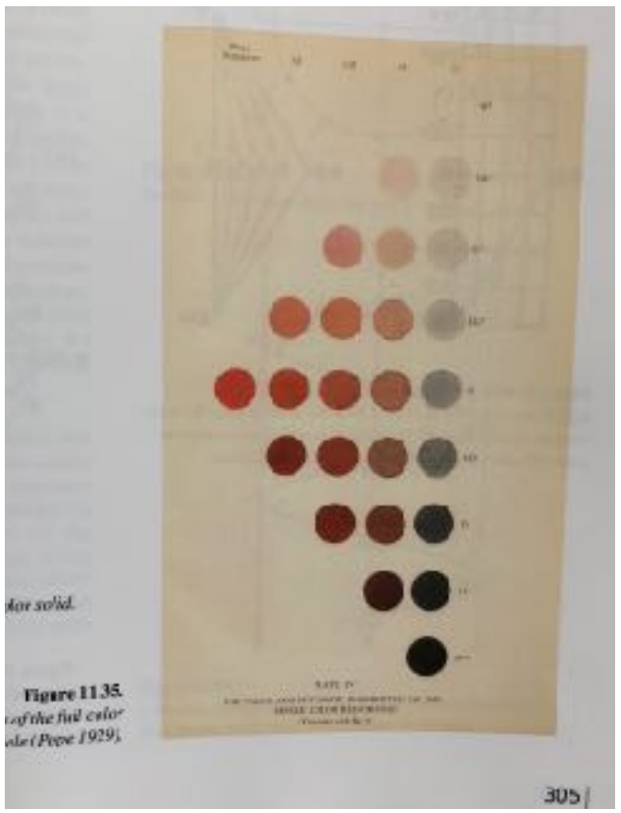
A. Pope: *Tone Relations in Painting* (1922)

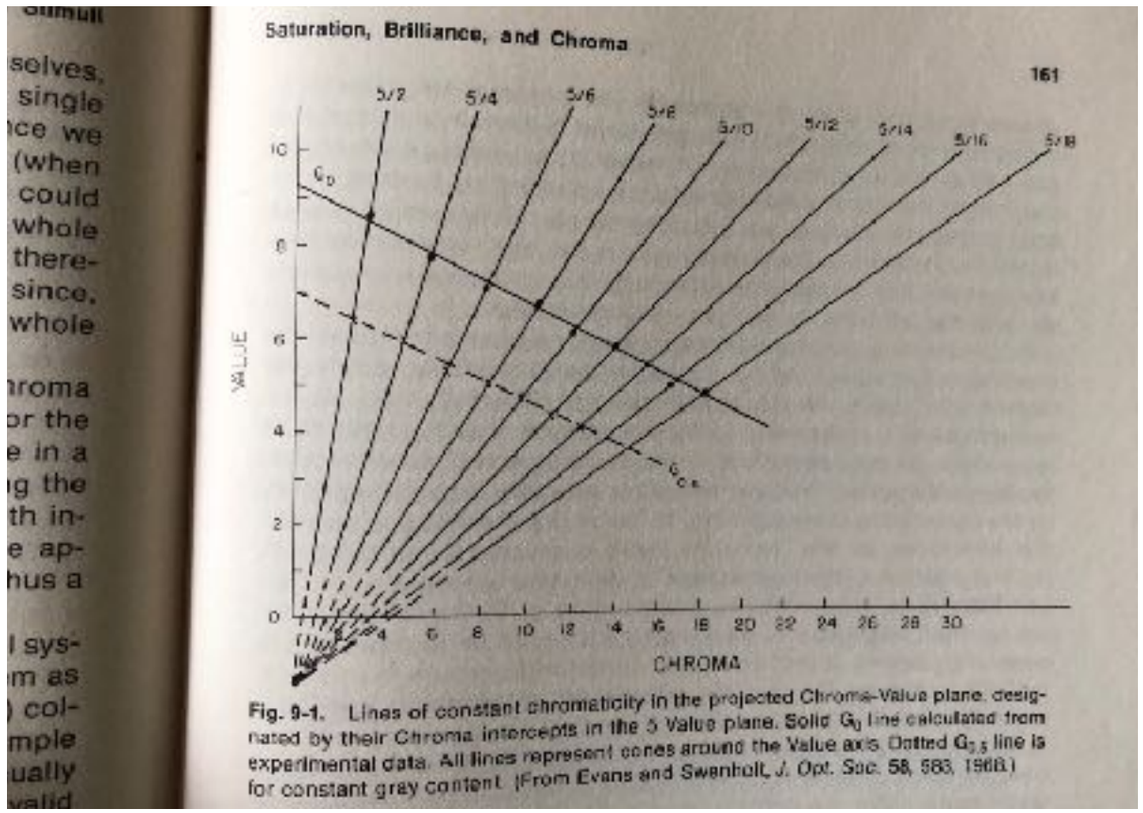
R. Evans: *The Perception of Color* (1974)

Scandinavian Colour Institute: *Natural Color System* (1978)

M. Fairchild & R. Heckaman: *Deriving Appearance Scales* (2012)



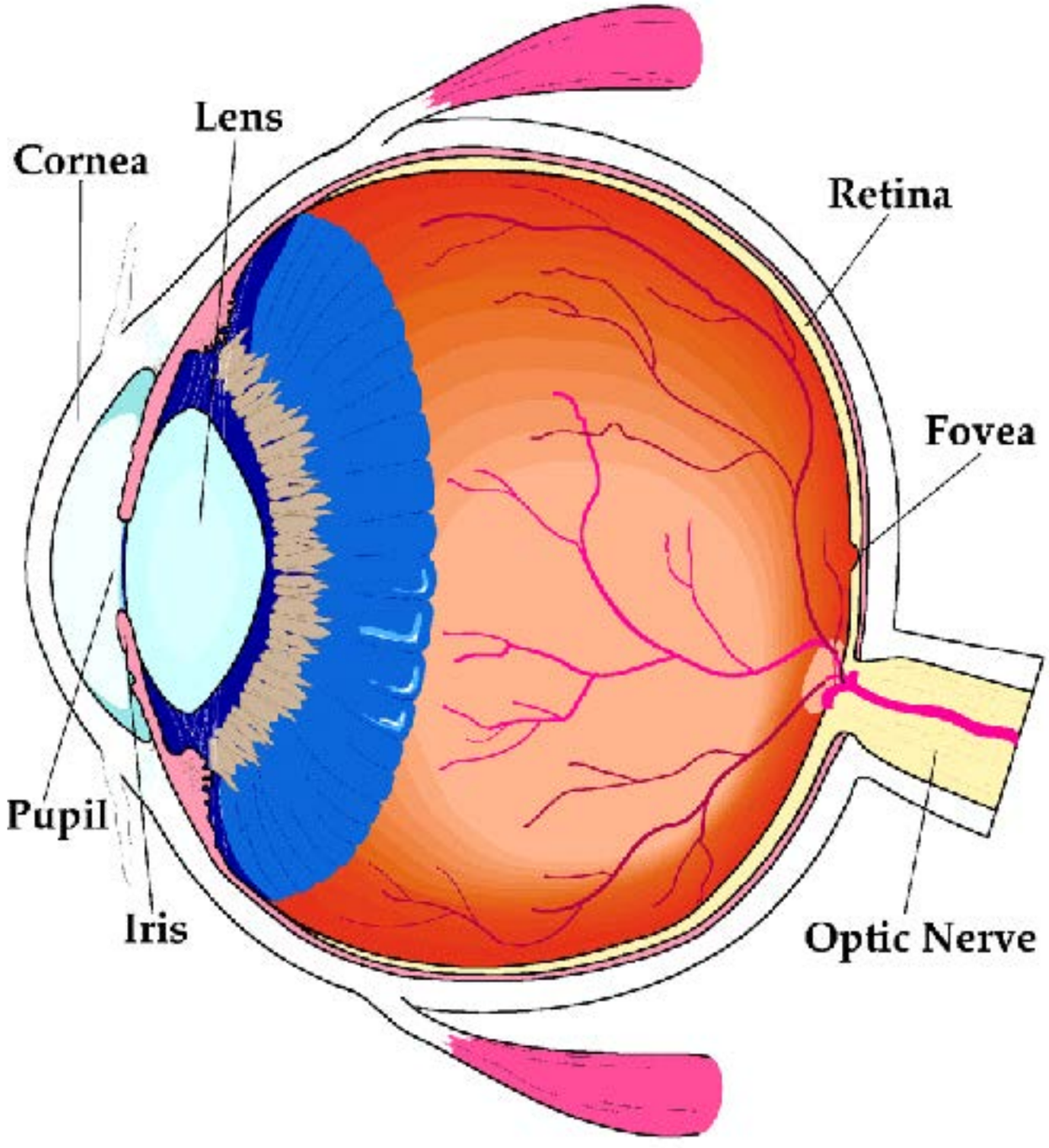




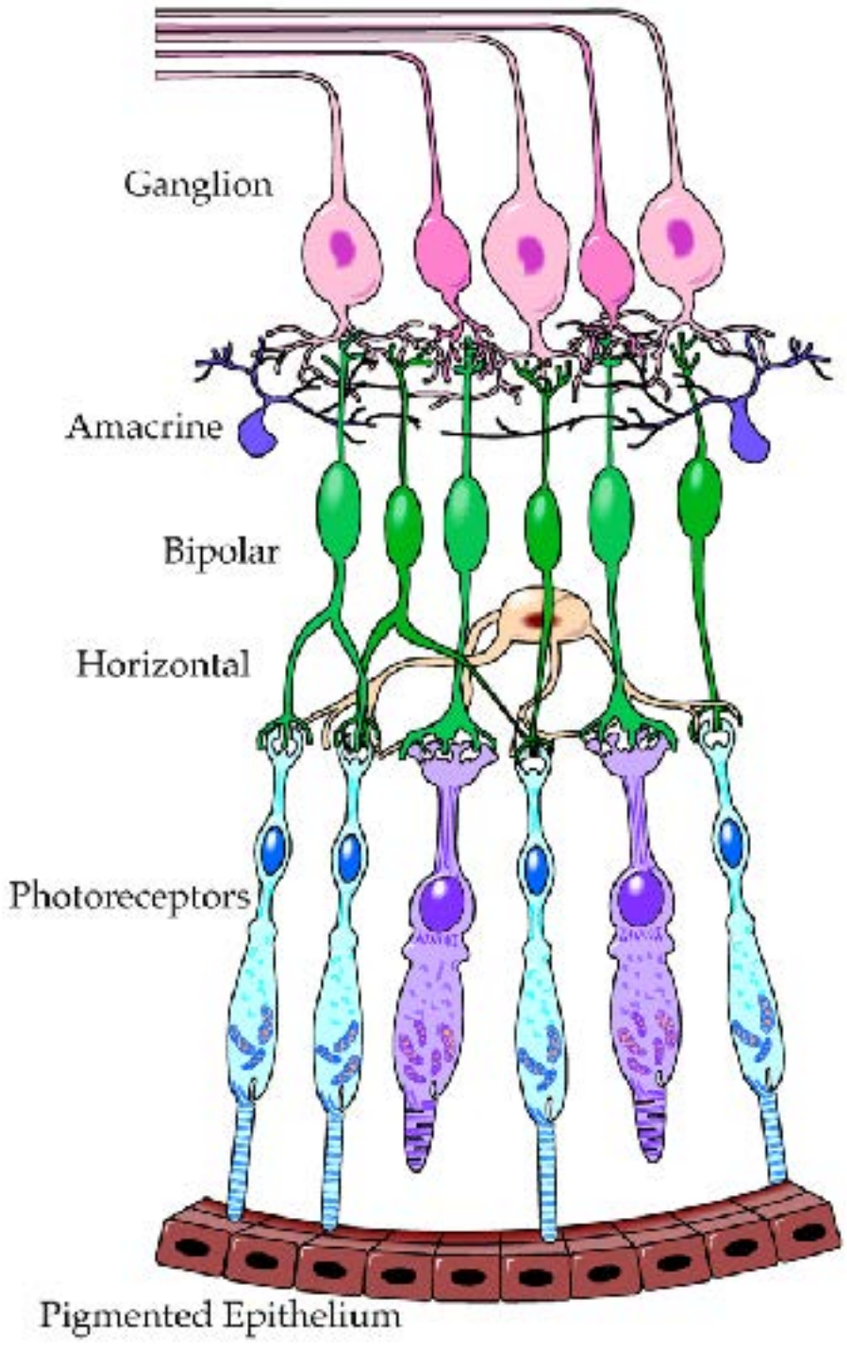
Color Perception

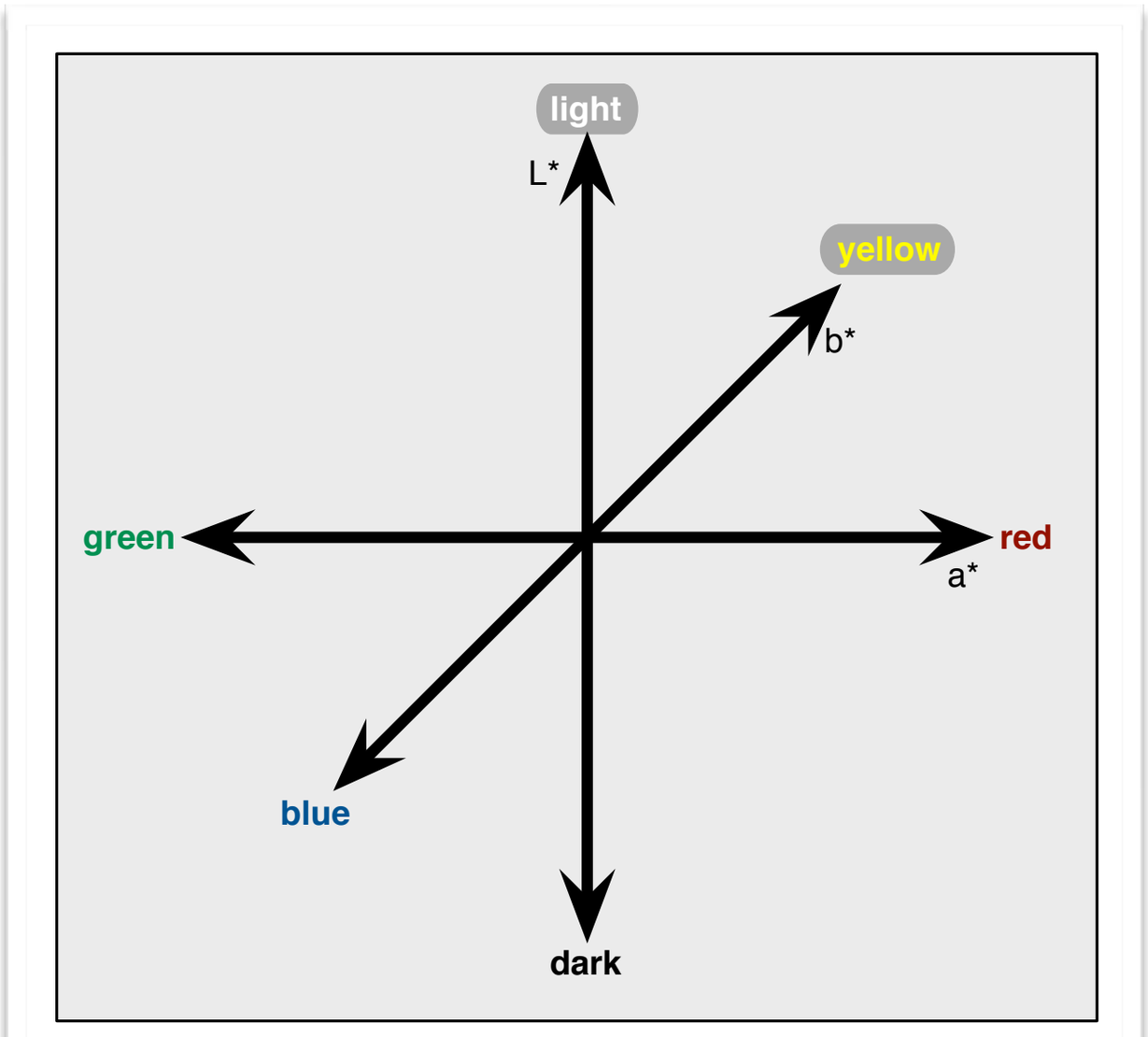
Color Science

The Eye

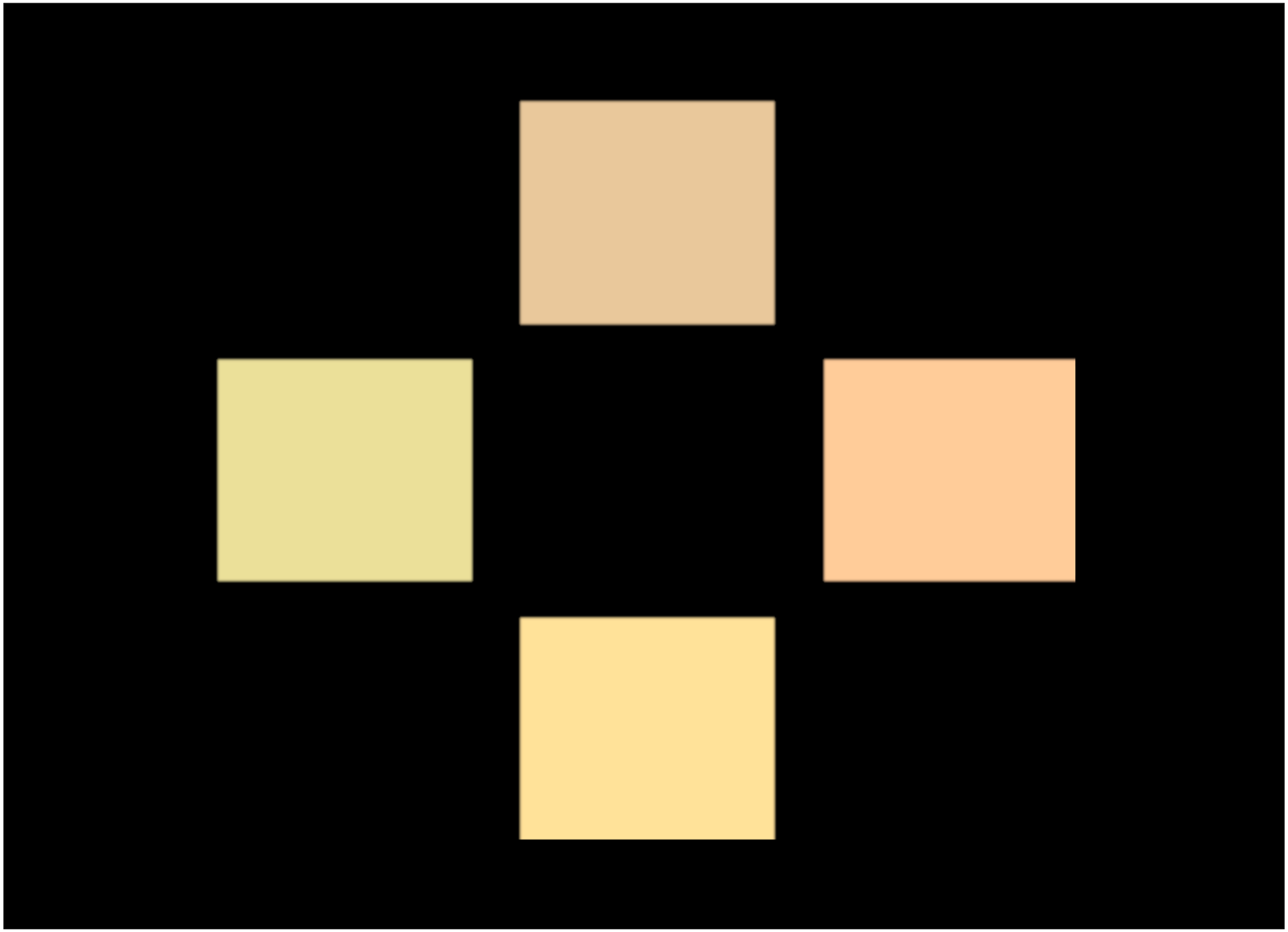


The Retina


Ganglion
Amacrine
Bipolar
Horizontal
Photoreceptors
Pigmented Epithelium


light
L*
yellow
b*
green
red
a*
blue
dark

Skin Color Variations

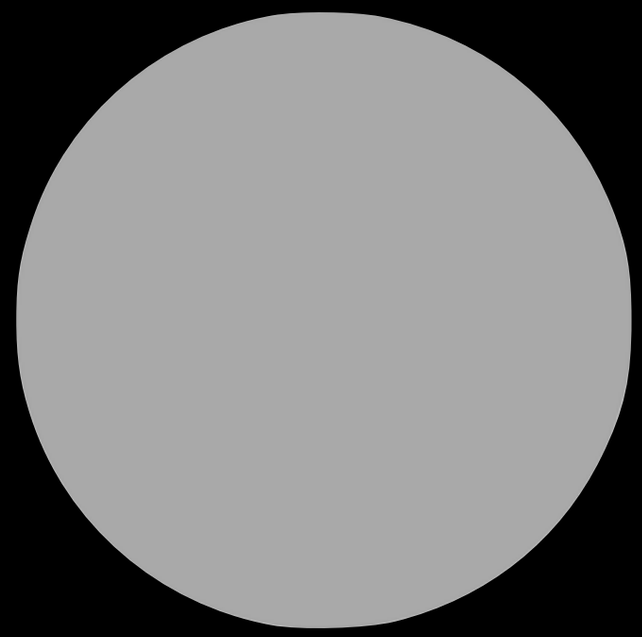


One Person — Hemoglobin Level and Oxygenation (Melanin Fixed)

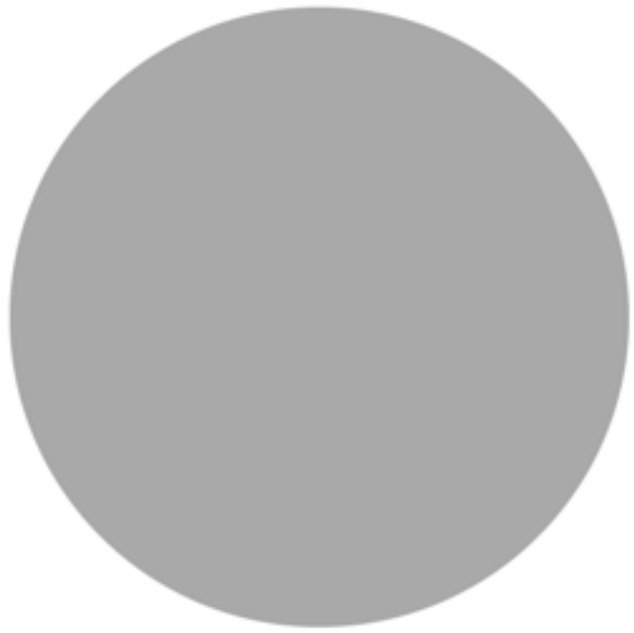
Mean Color Background

Credit — Chris Thorstenson (RIT & UR)

Simultaneous Contrast

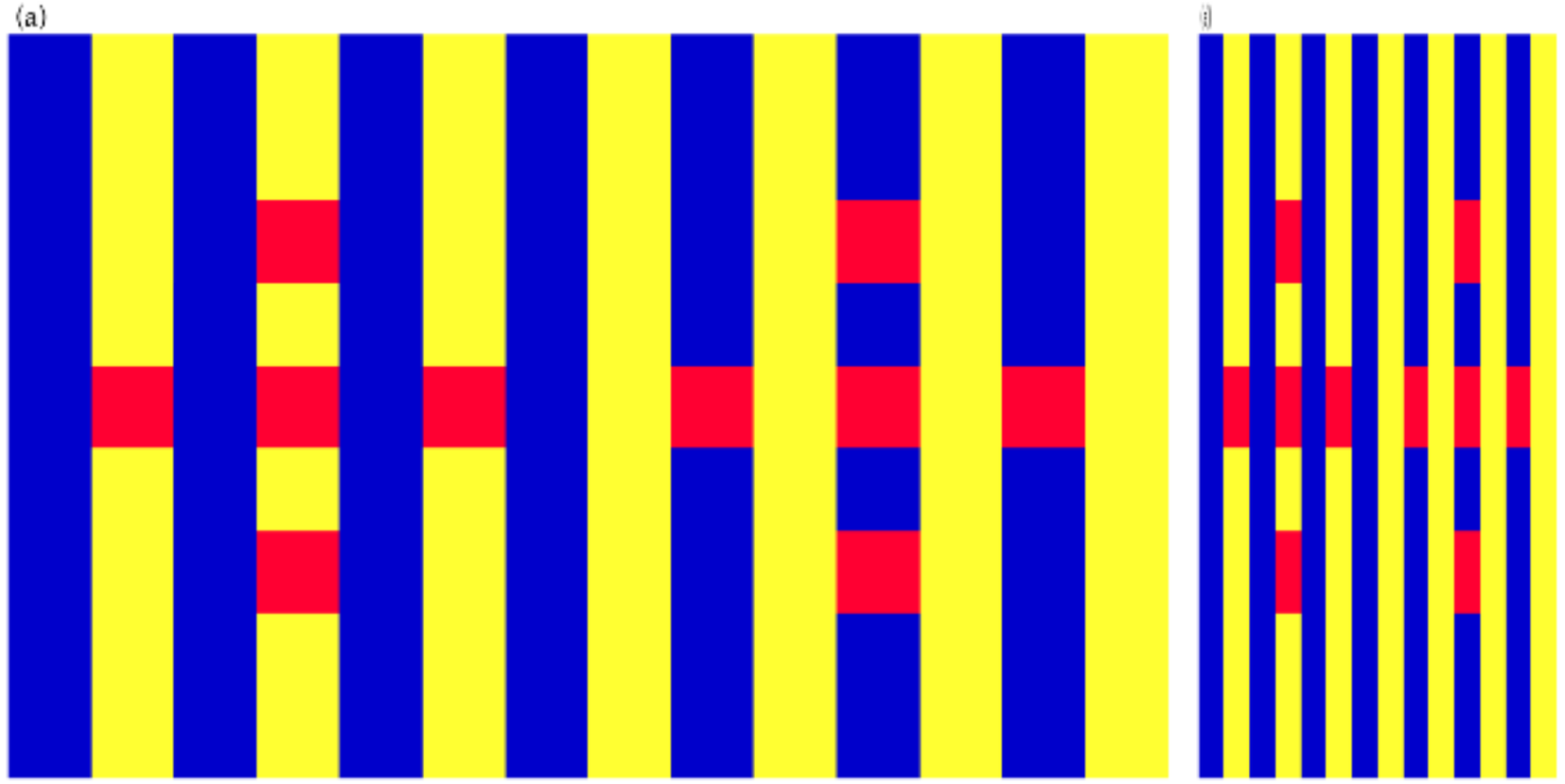


Simultaneous Contrast

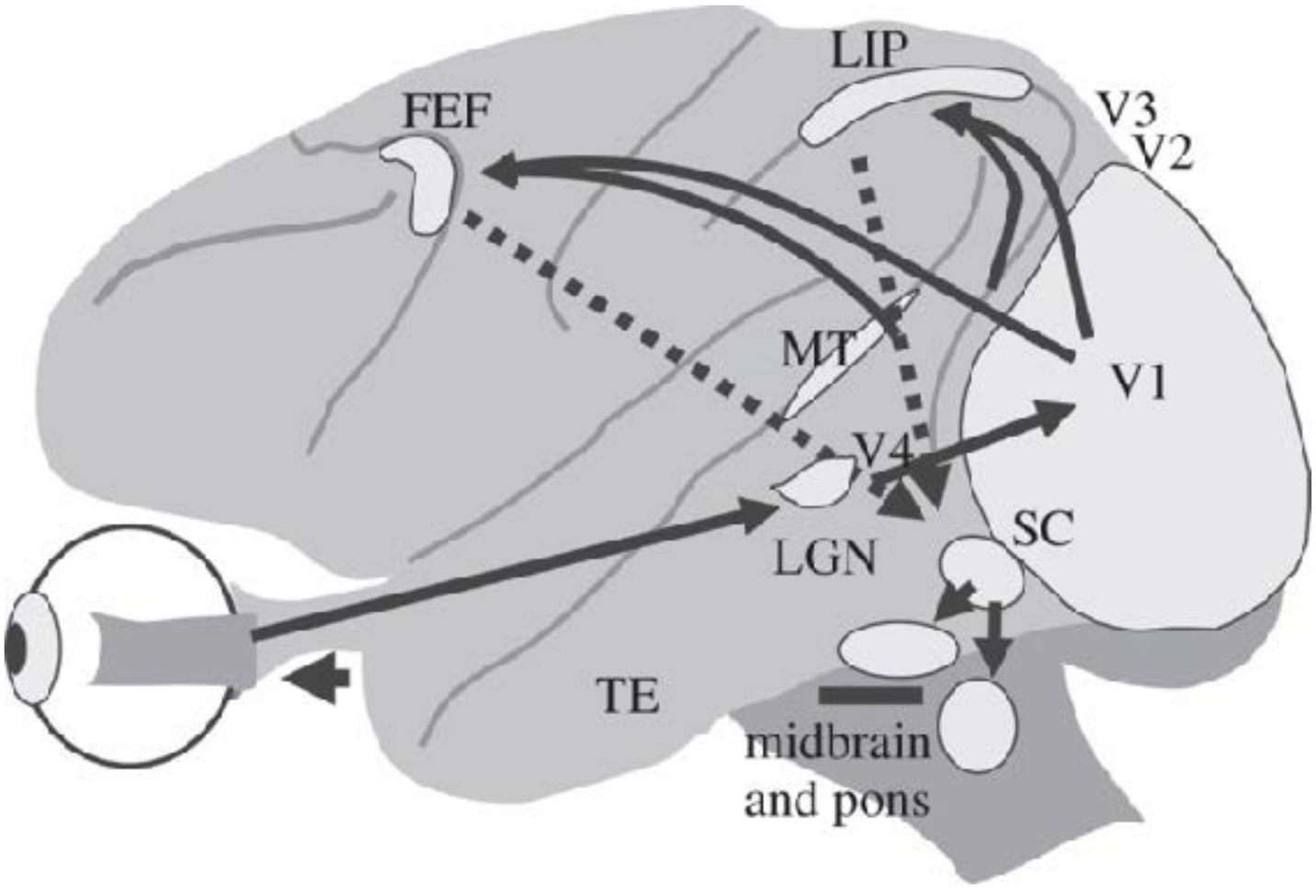


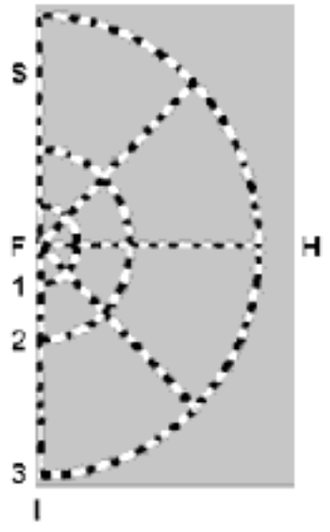
Simultaneous Contrast

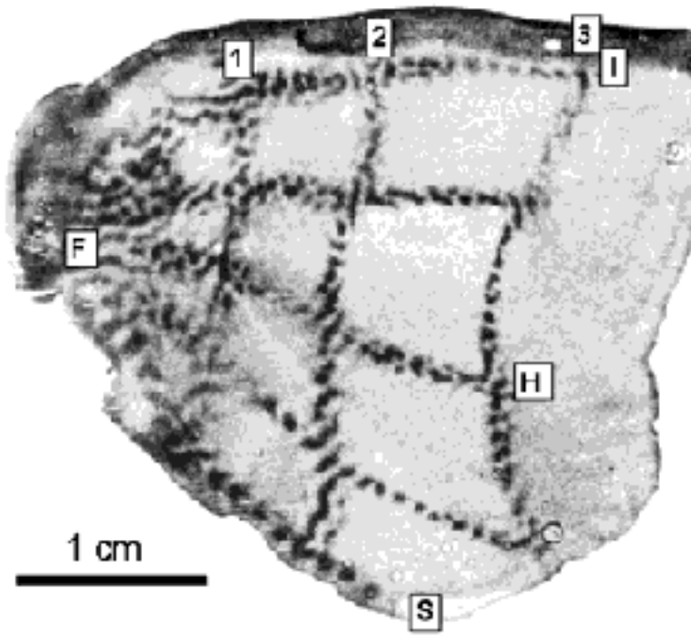
White’s



The Brain


LIP
FEF
V3
V2
MT
V1
V4
SC
LGN
TE
midbrain
and pons


S
F
H
1
2
3
I


1
2
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I
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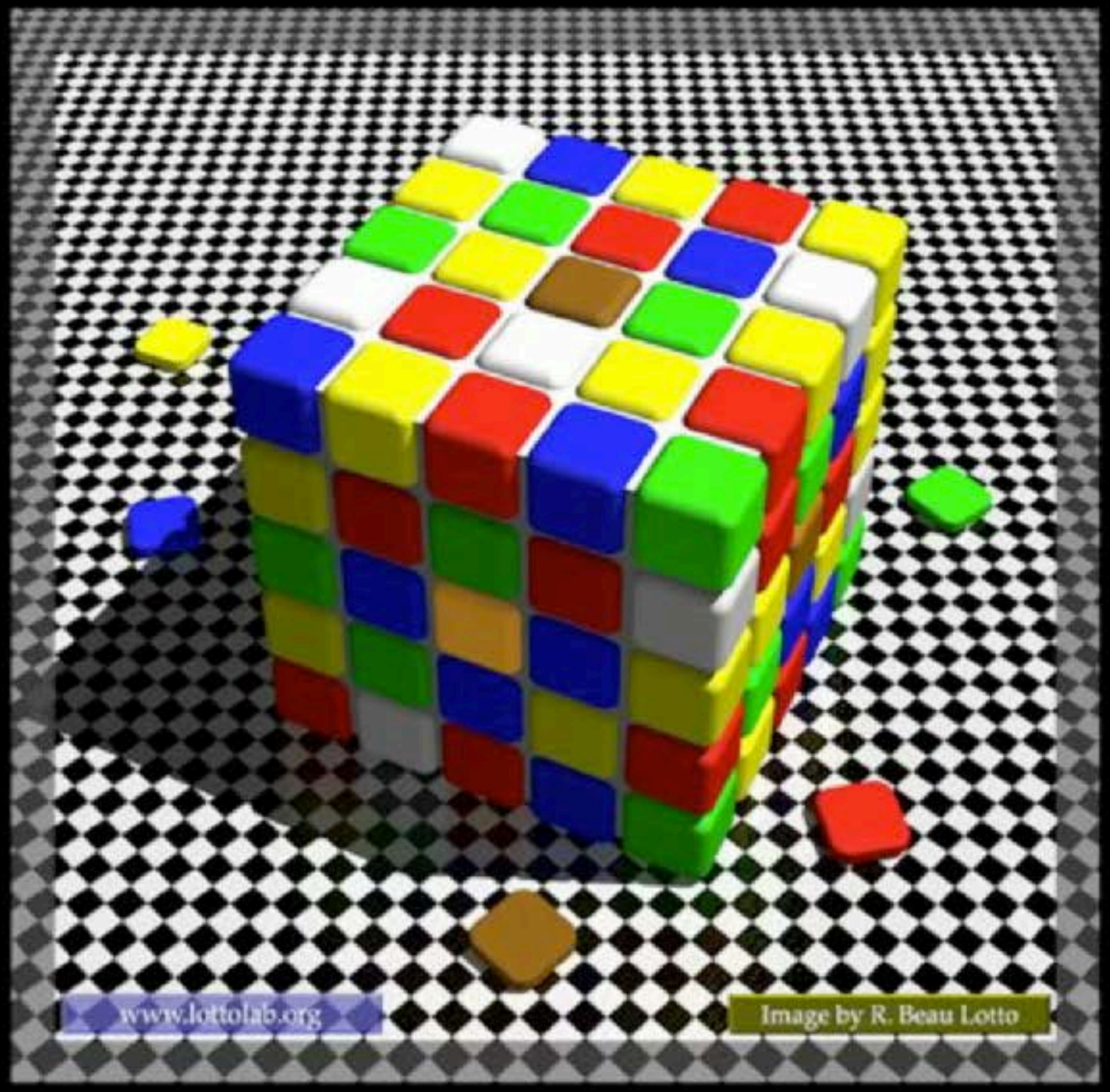
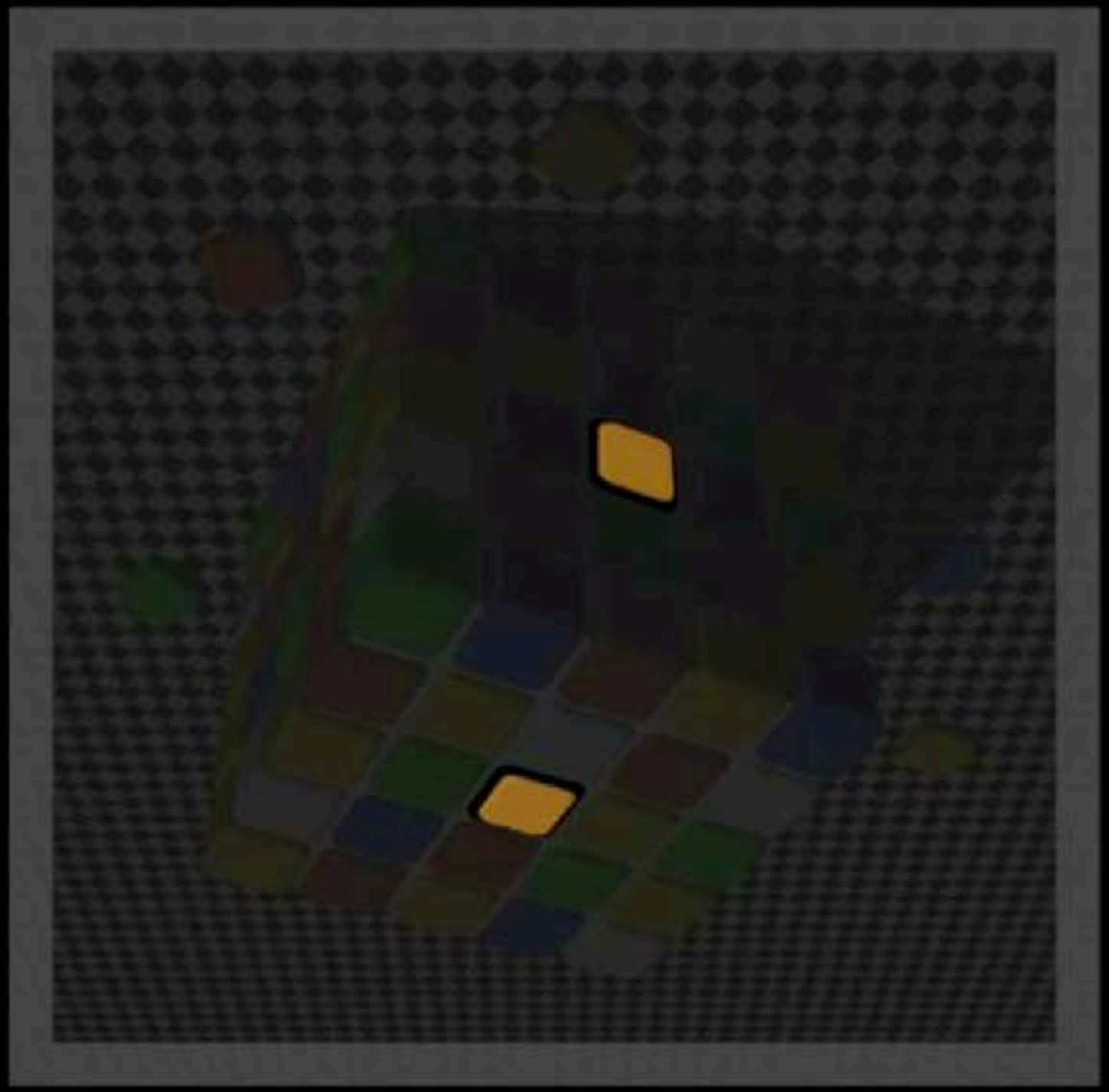
S
1 cm


www.lottolab.org
Image by R. Beau Lotto



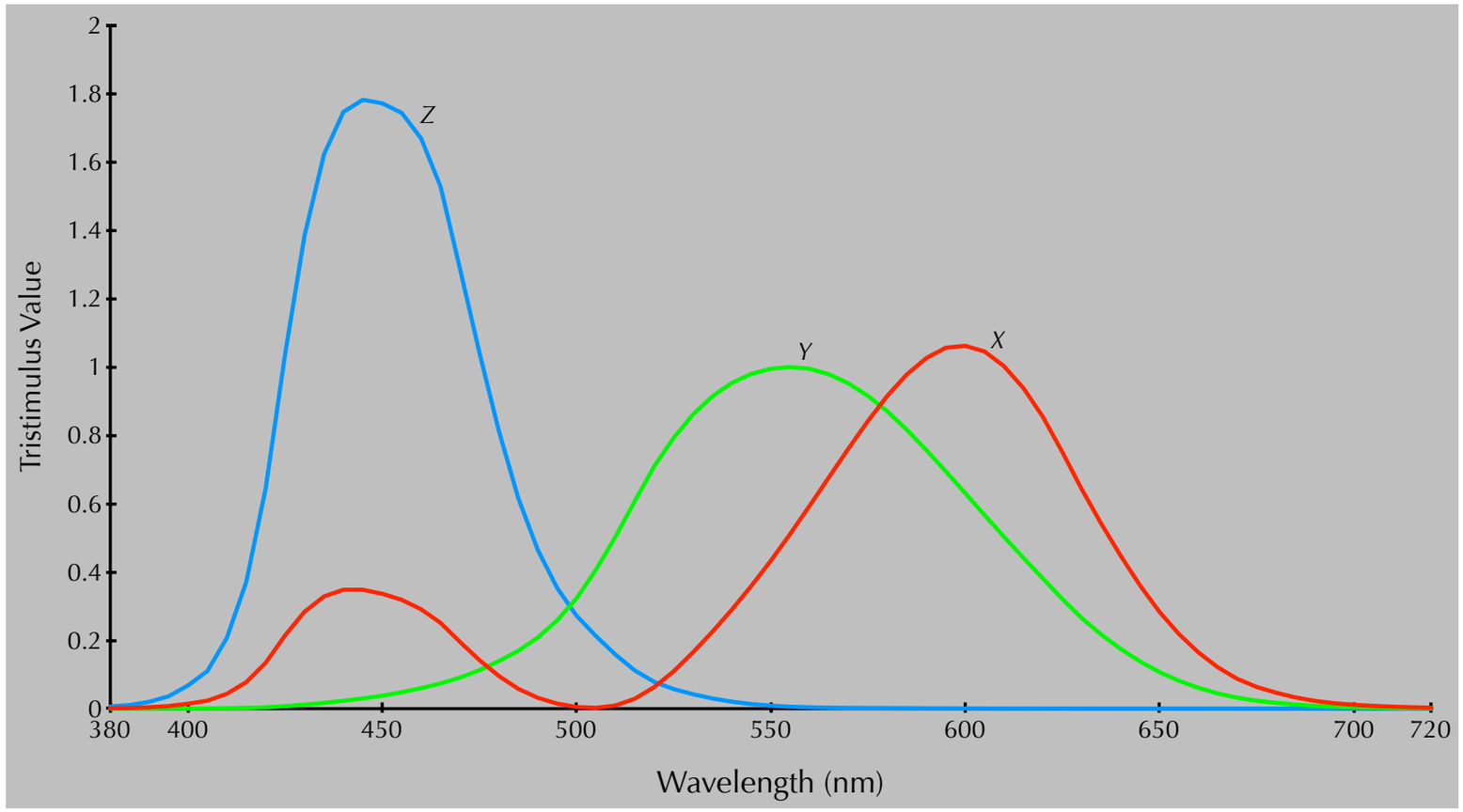
Chromatic Adaptation

A CYAN FILTER

Cognition

Colorimetry

CIE XYZ

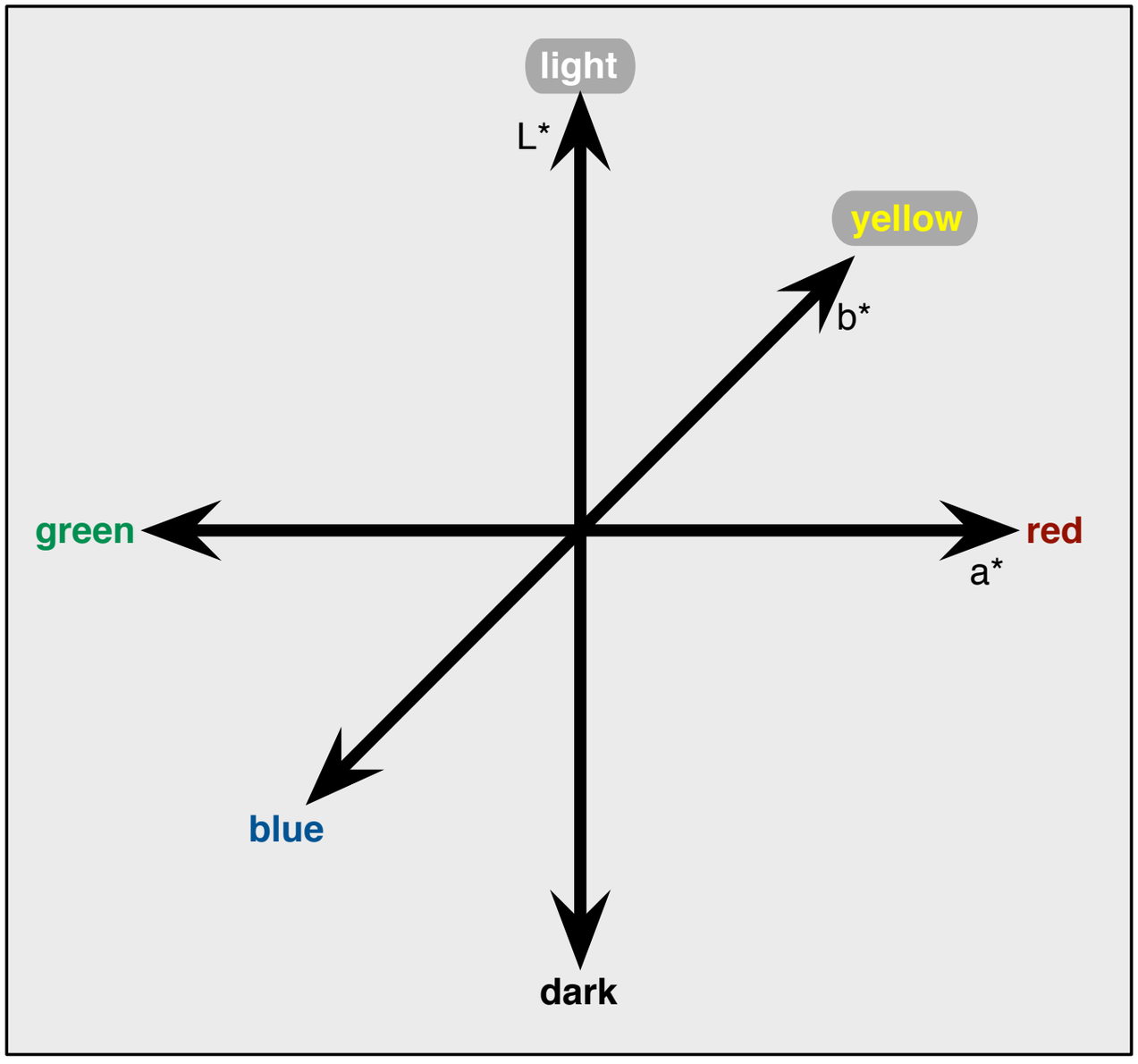


Nominal Scaling

Color Matches

No Differences or Appearance

CIELAB

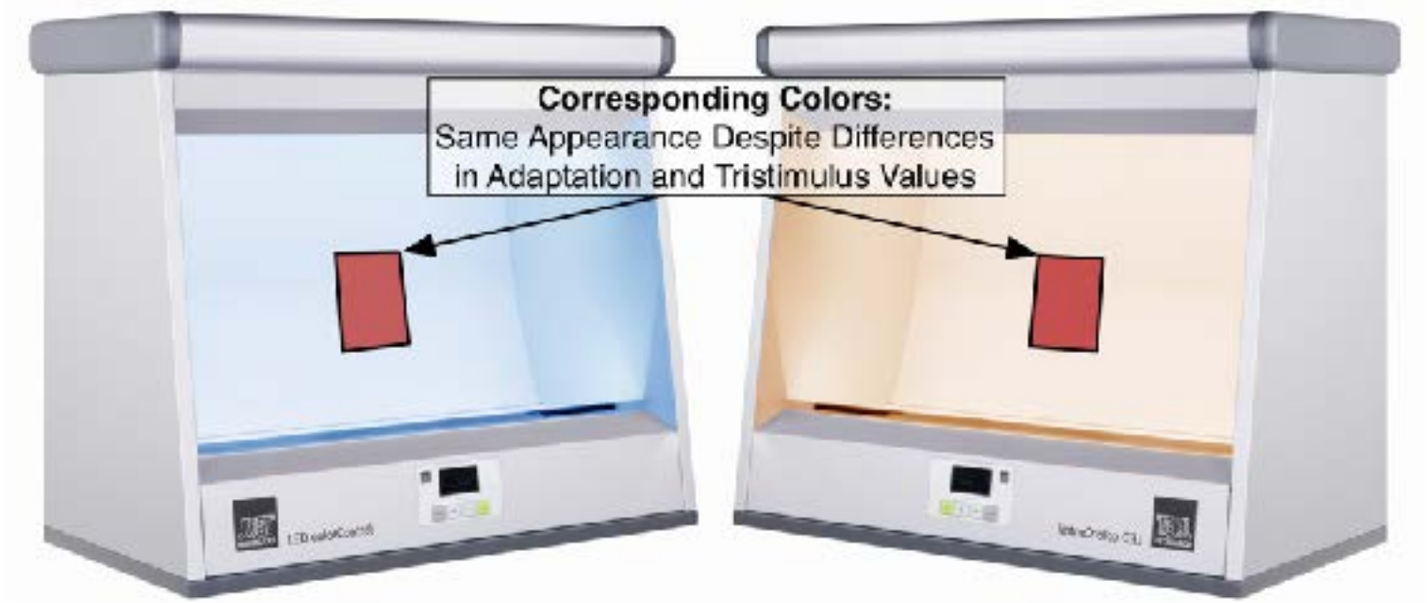


Ratio and Interval Scaling

Color Differences

Approximate Appearance

CIECAM02



Ratio and Interval Scaling

Color Appearance

More Dimensions

Color Systems

Types of Color Systems

Color Naming Systems: Color is defined and specified according to some, essentially arbitrary, naming system (*e.g*., Pantone, Trumatch, Paint Color Cards).

Color Mixing Systems: Color is defined according to the properties of a given system (*e.g*., RGB, CMYK, HSV, DIN, XYZ, *etc*.)

Hybrid Systems: Color is defined by a combination of systems (*e.g*., appearance and additive mixing in Colorcurve).

Color Appearance Systems: Color is defined according to various appearance attributes (*e.g.*, Hue, Value, Chroma in Munsell, Hue, Blackness, Chromaticness in NCS, Color differences in OSA UCS).

Color Order Systems

Color Order Systems

Systems that define ***color appearance*** according to some orderly arrangement to facilitate the naming and communication of colors (among other applications).

Often the systems define colors using perceptual variables.

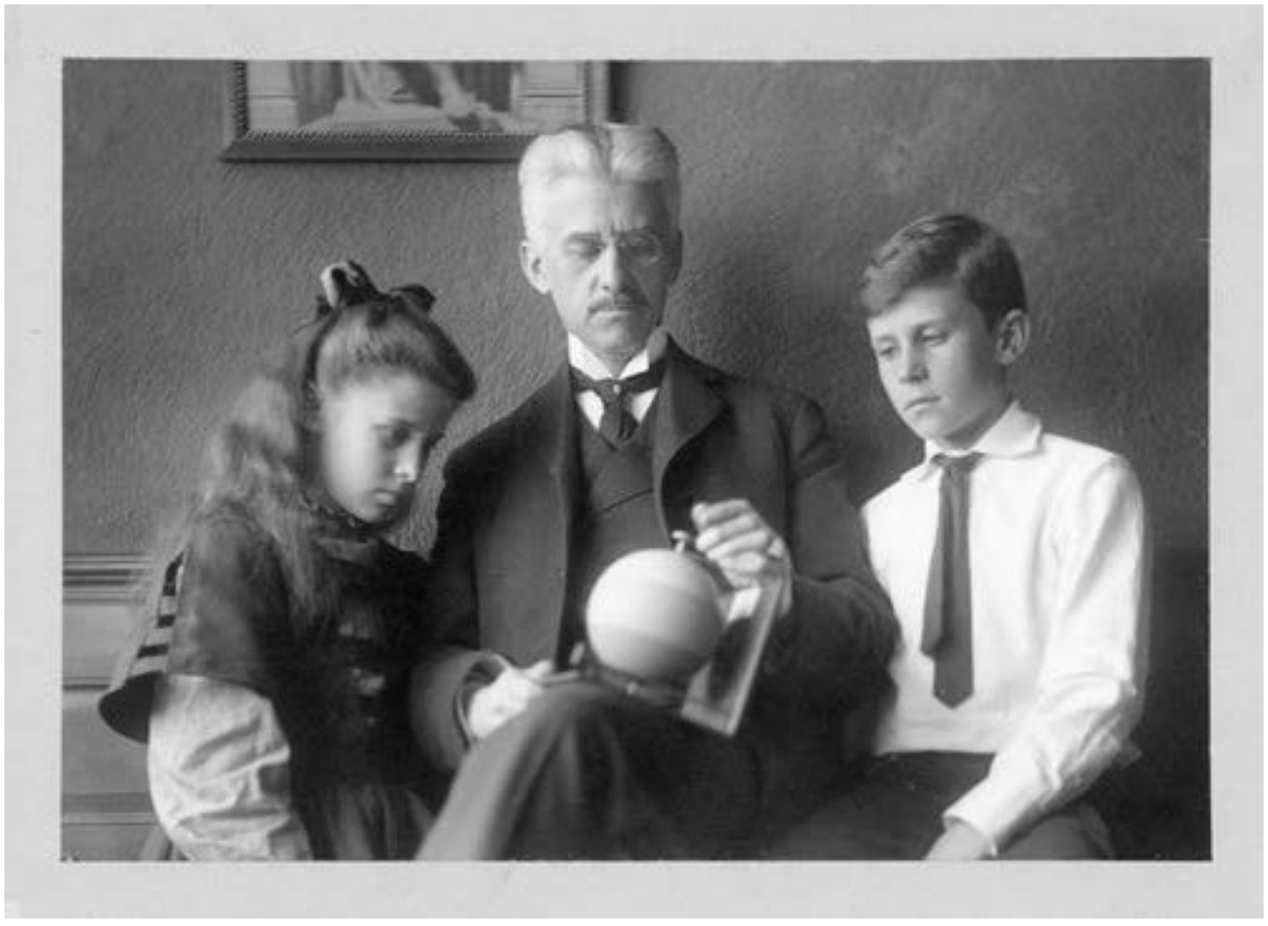
Such systems are typically embodied with atlases of color samples rather than through mathematical relationships to colorimetric coordinates.

Color Appearance Systems

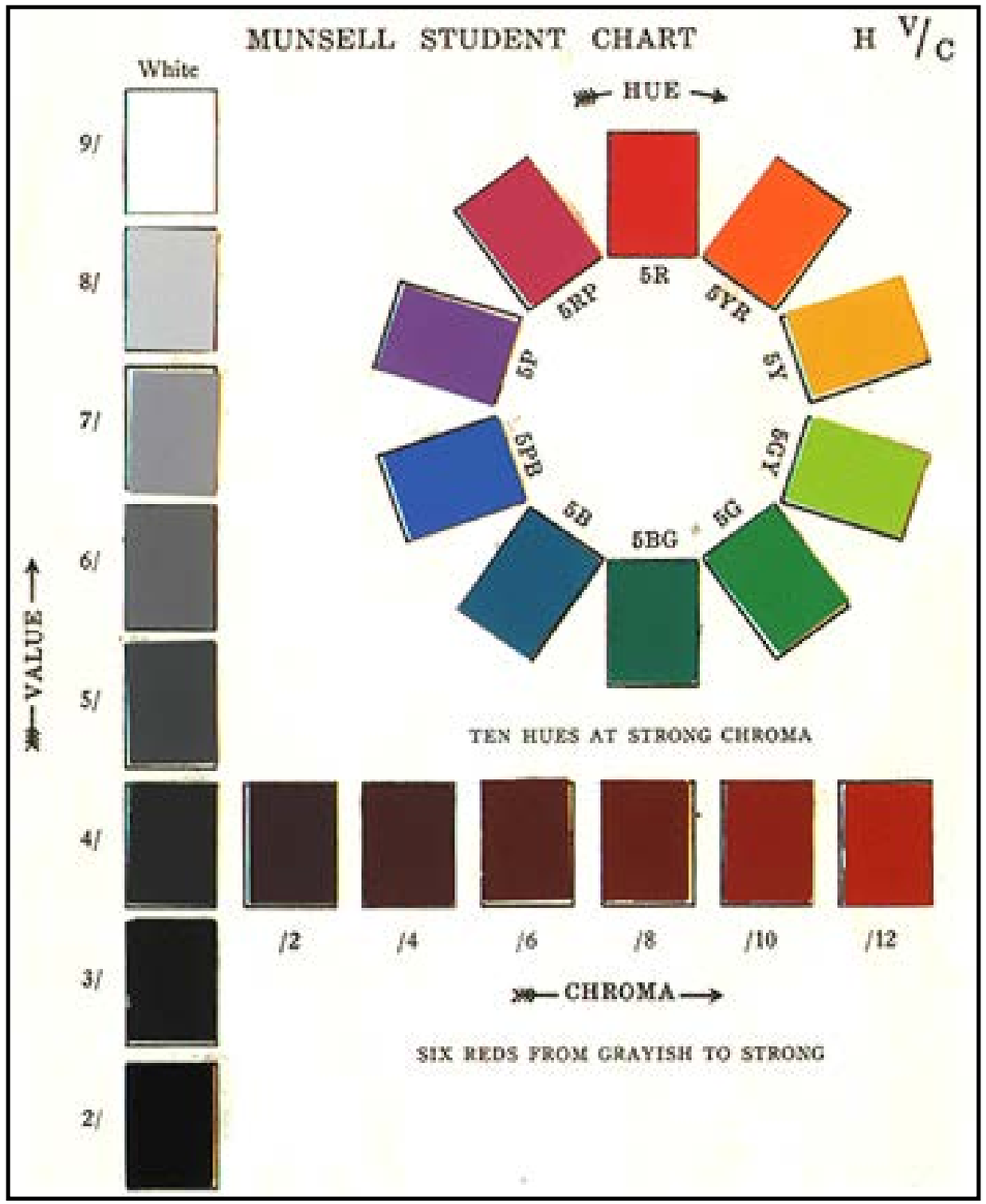
The Munsell system (***Munsell Book of Color***) and Swedish Natural Color System (***NCS***) provide two important examples of systems defined by color appearance.

Thus their scales, while not defined mathematically can be used to develop and test color appearance models.

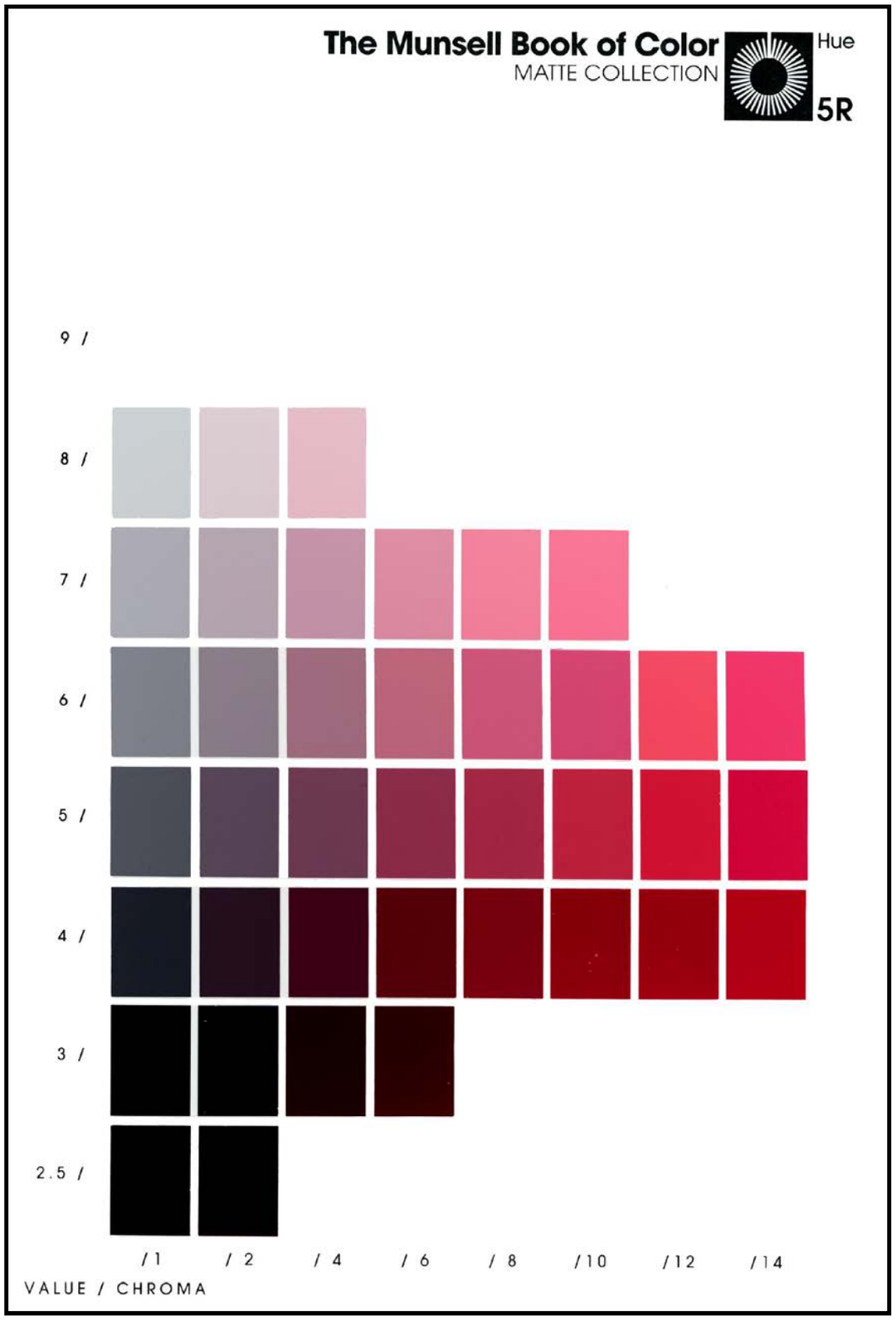
Munsell

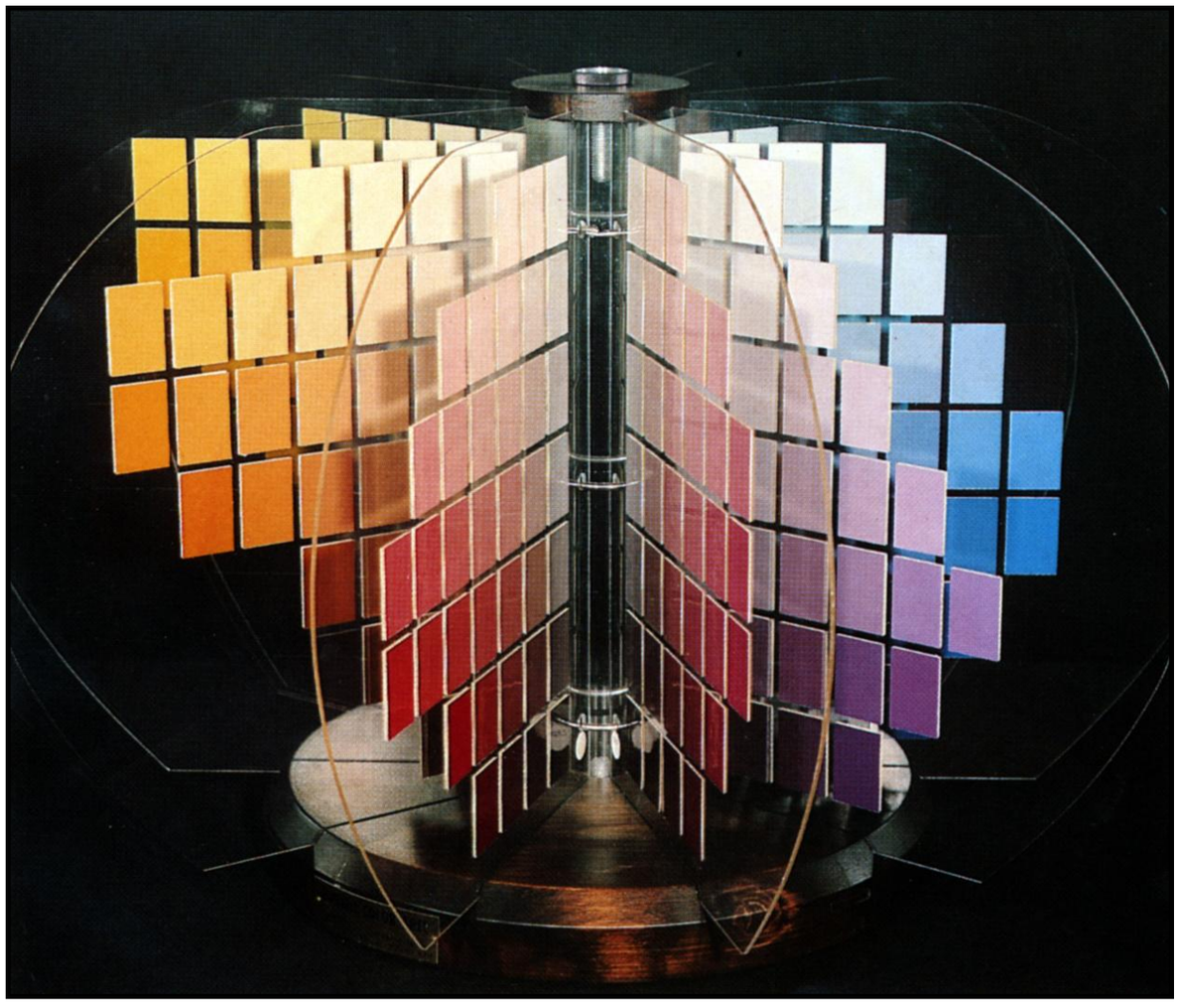


Munsell Book of Color

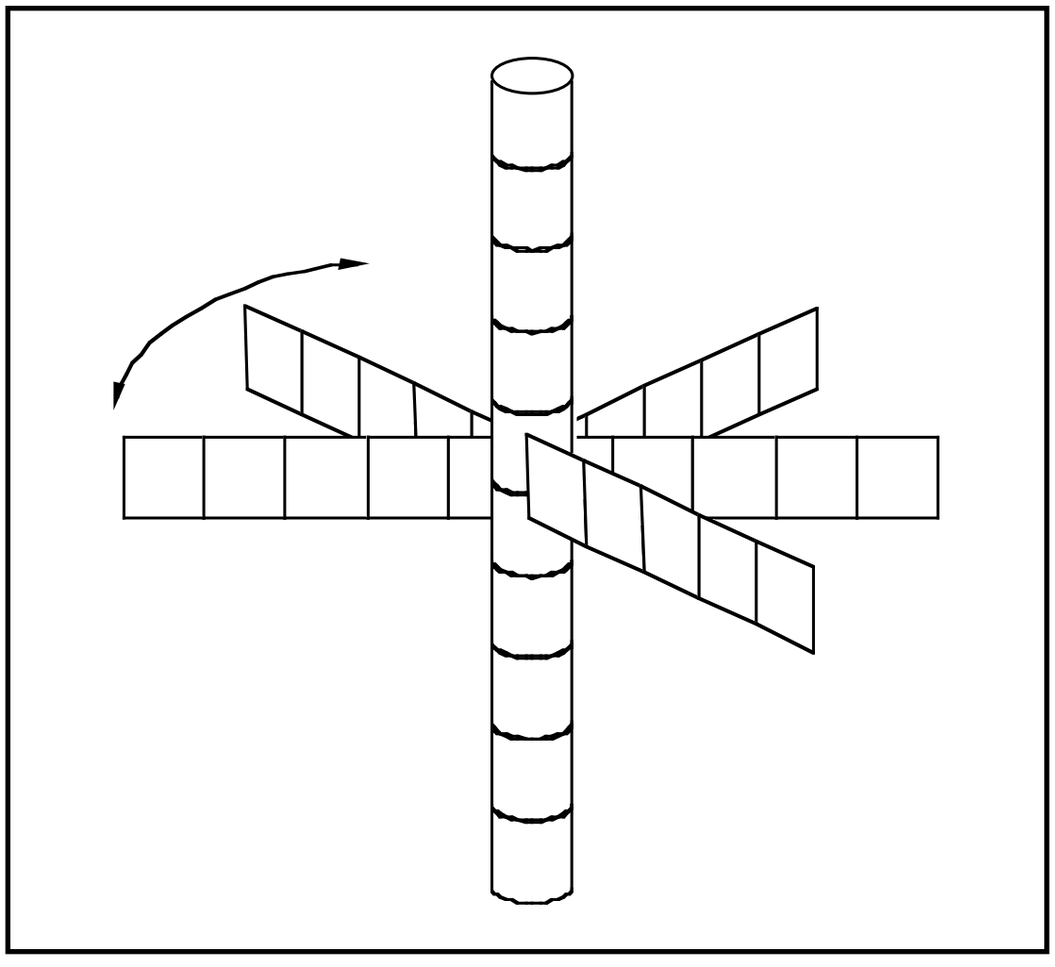


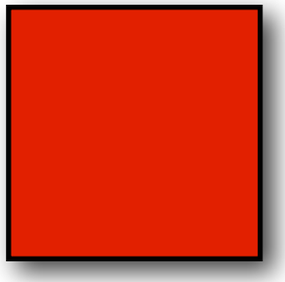
Munsell Constant-Hue Page





Munsell Notation





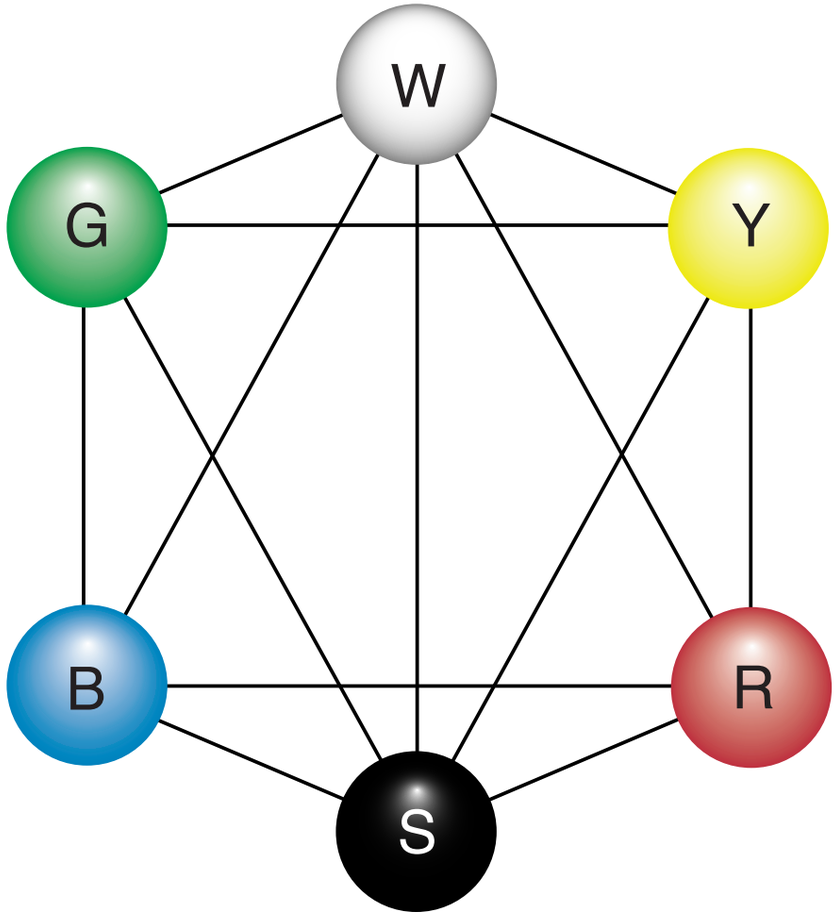
Munsell Notation
7.5R 5/10
Hue Value/Chroma

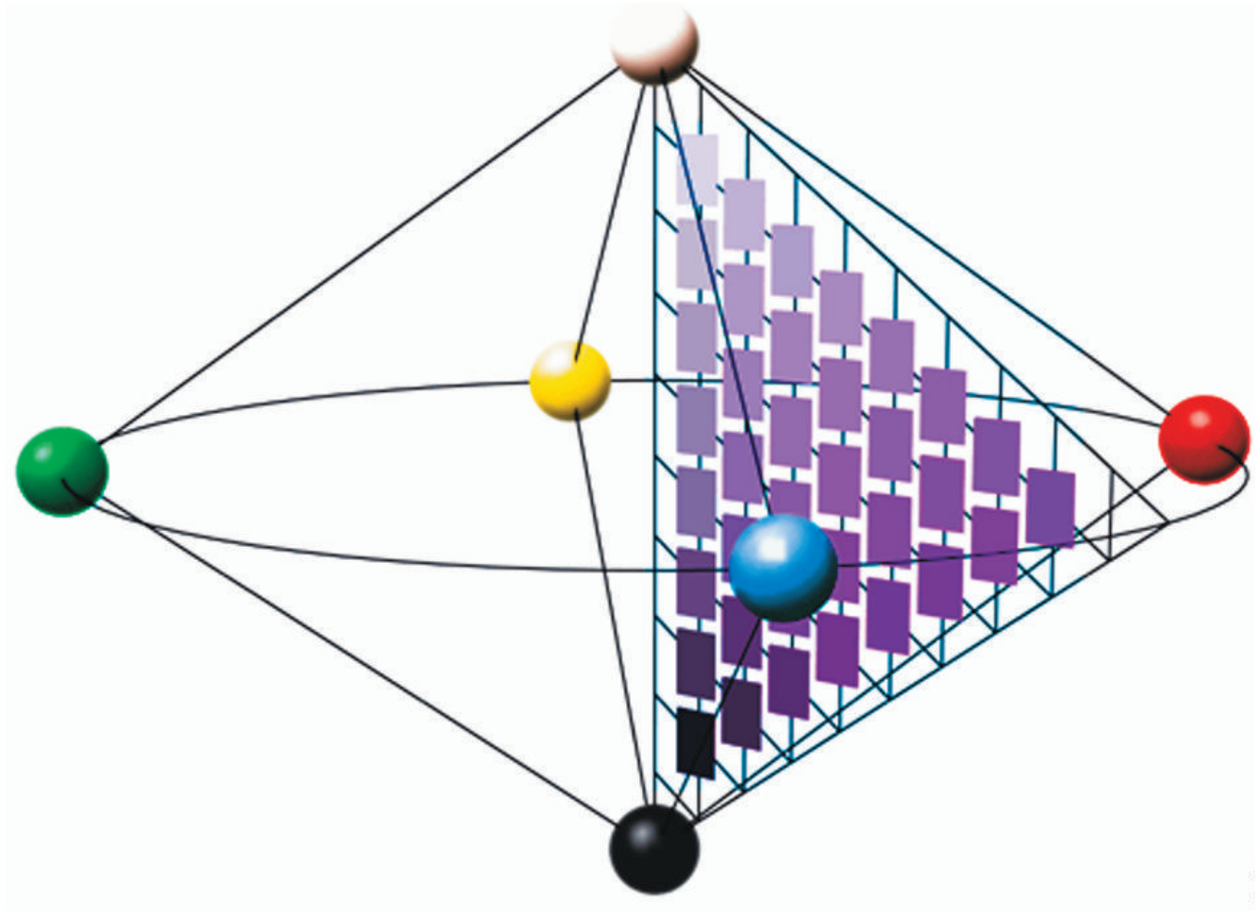
NCS

Inspired by
Ewald Hering

Realized by
Dr Lars Sivik, Prof Gunnar Tonnquist and Dr. Anders Hård,
1997 AIC Judd Award

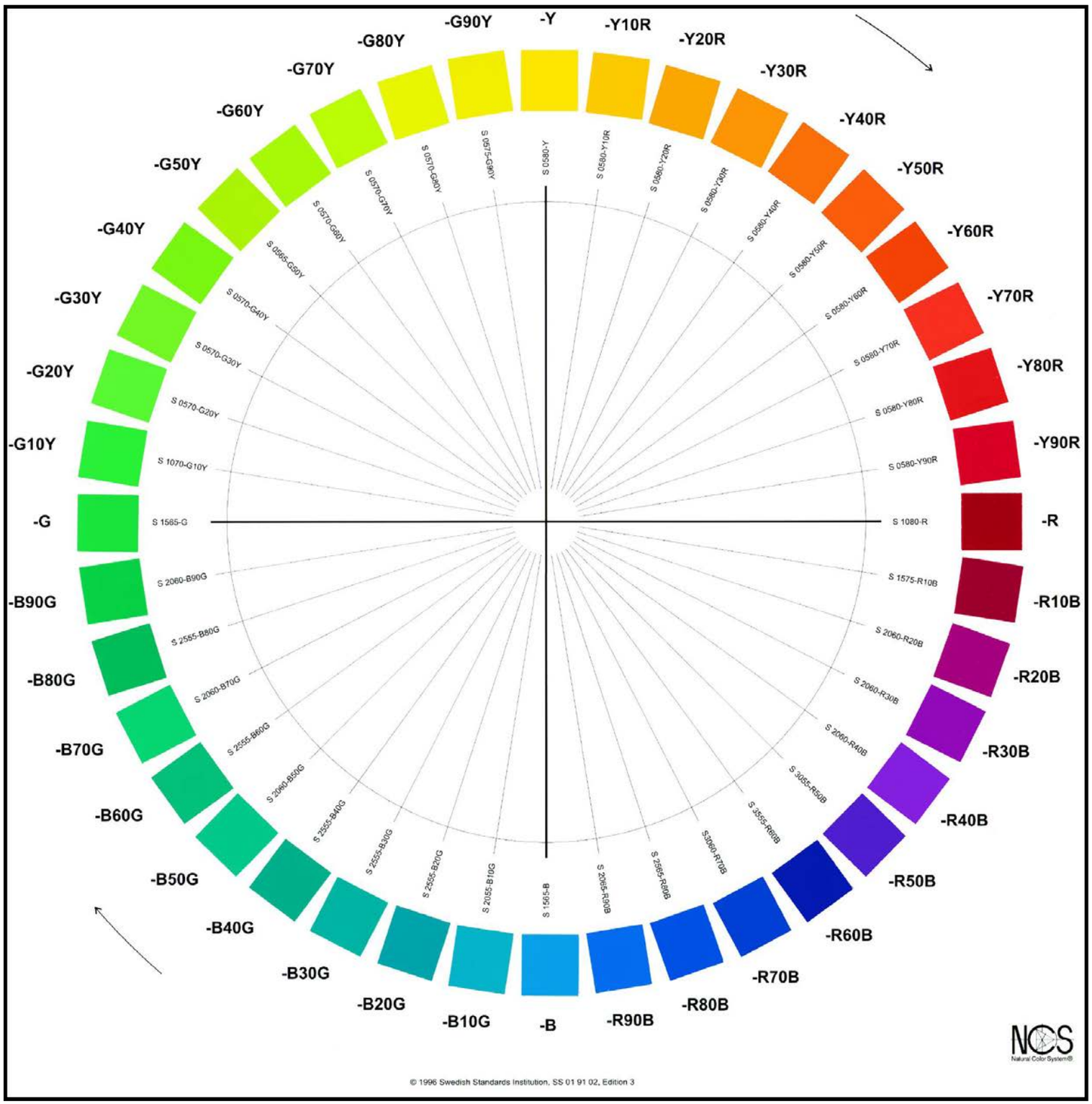
Swedish NCS



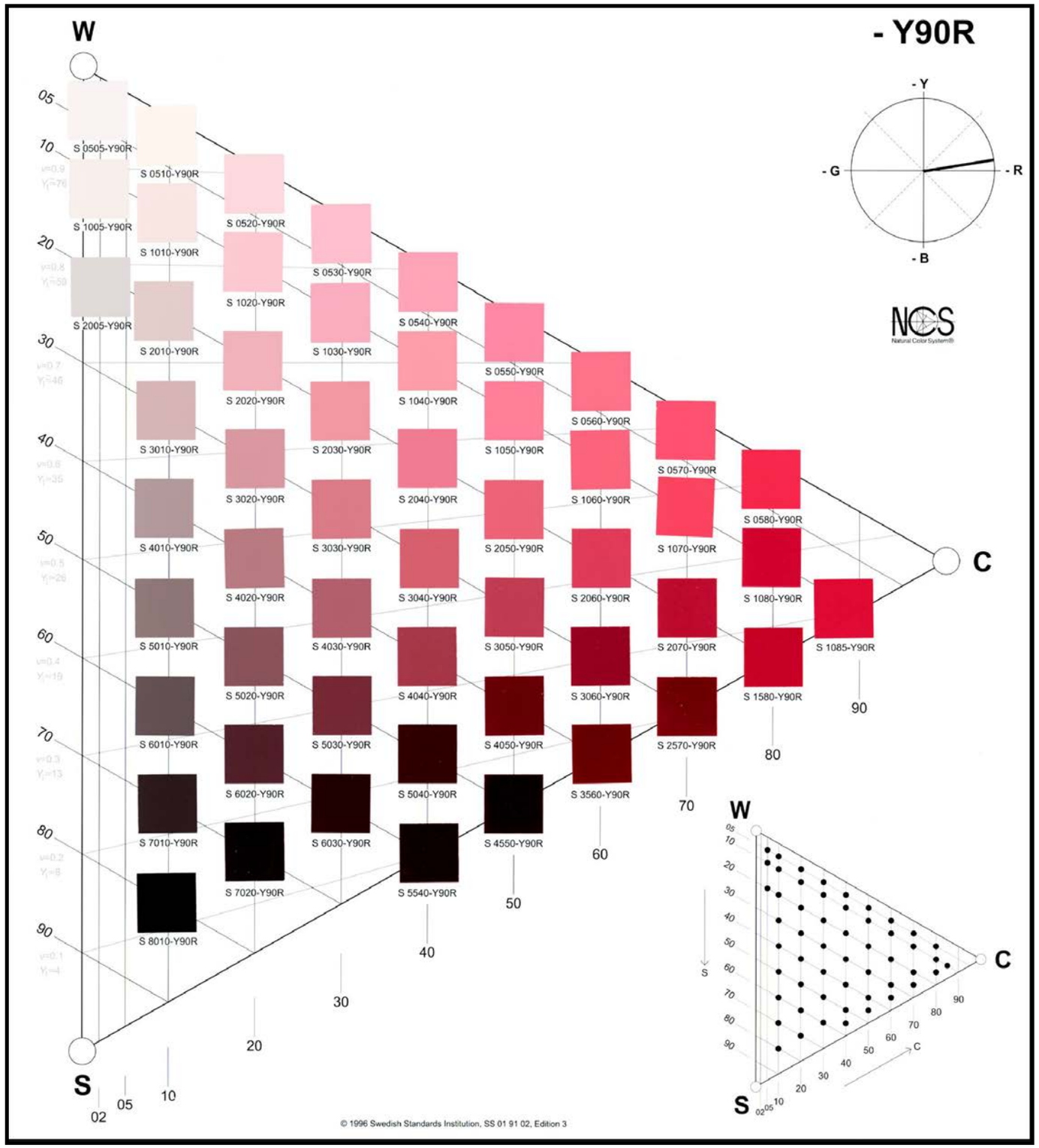


Based on Hering’s Opponency

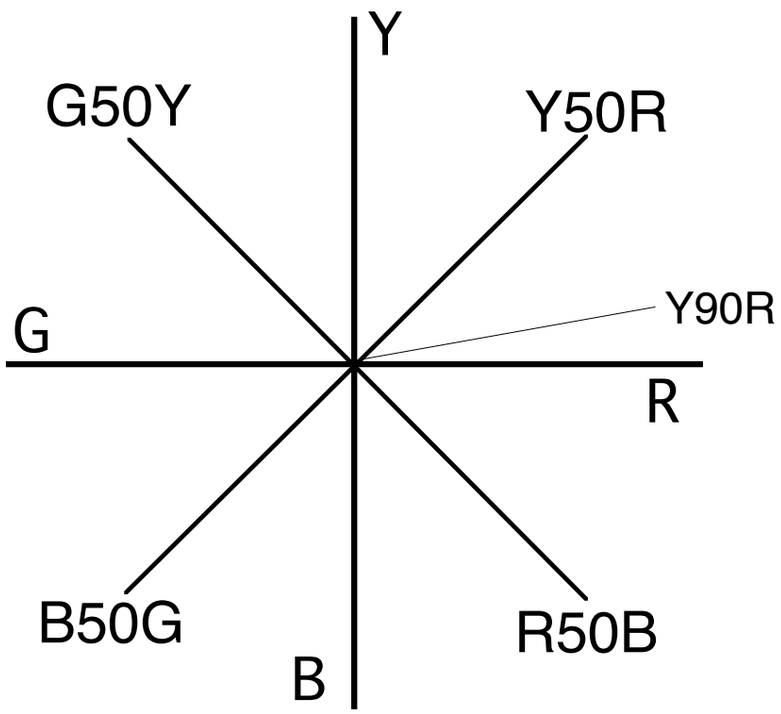
NCS Hue Circle

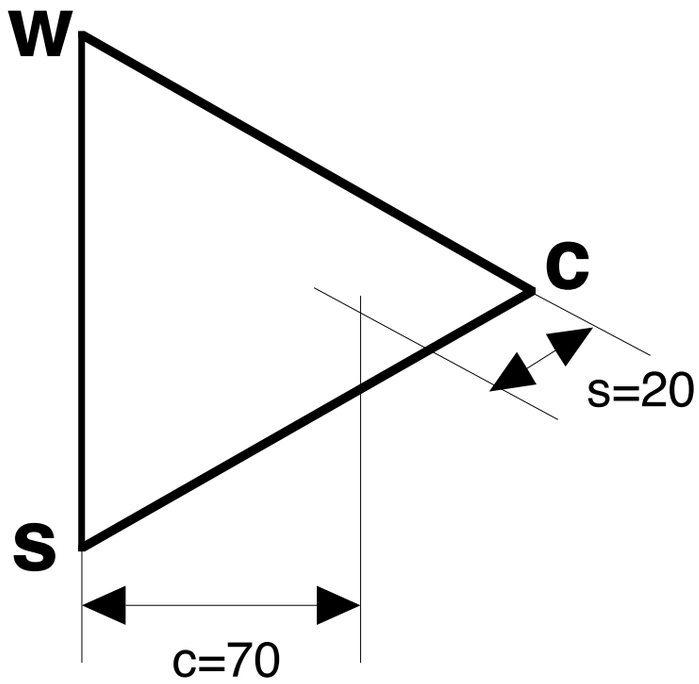


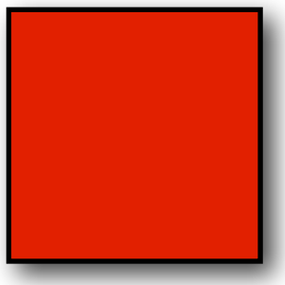
NCS Constant-Hue Page



Natural Color System (NCS)





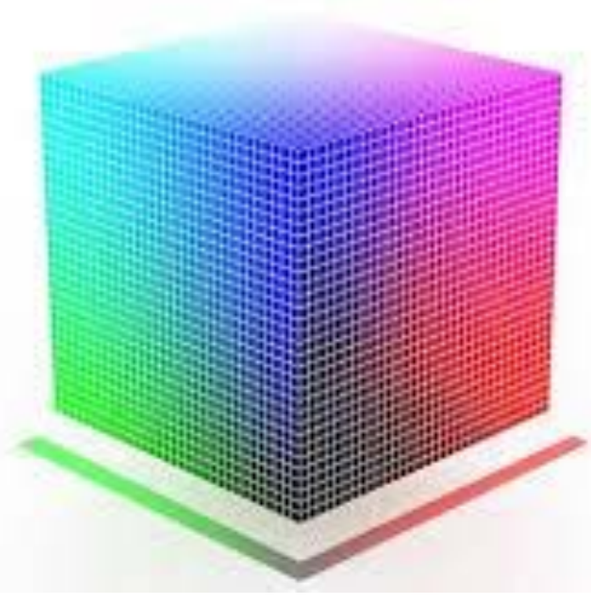


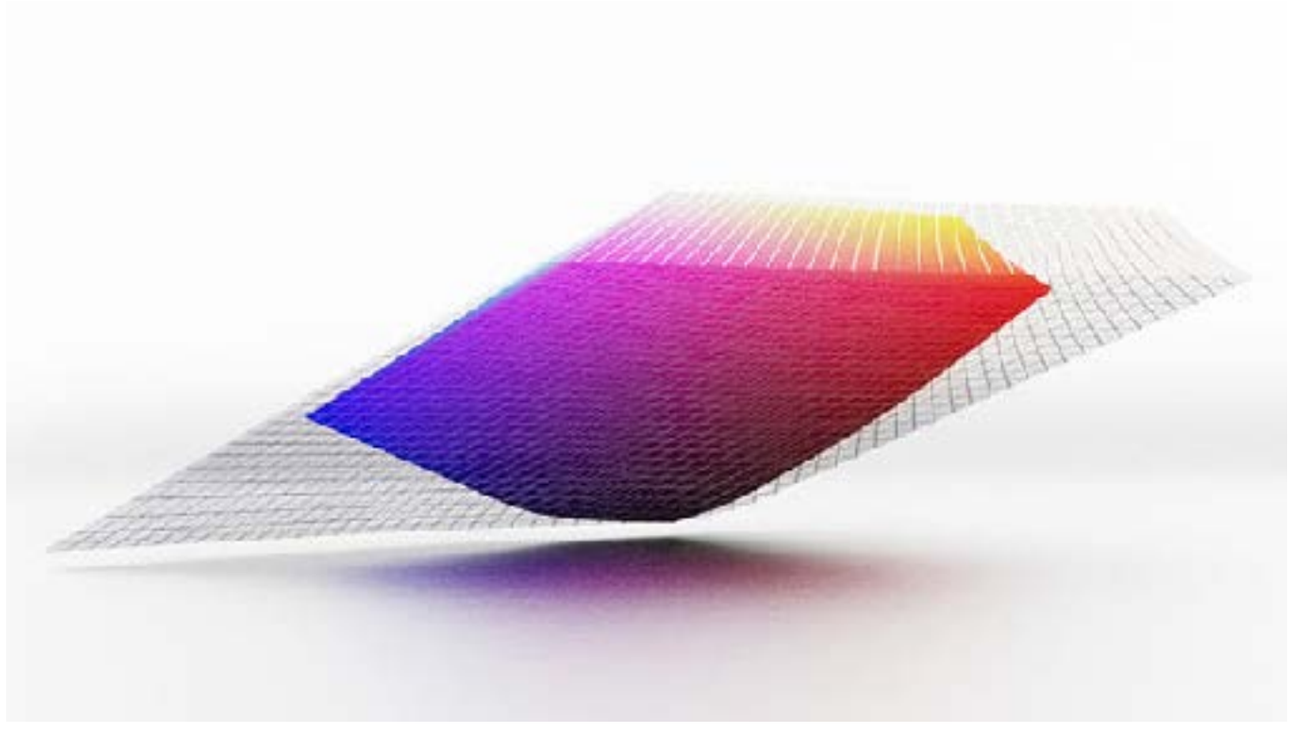
NCS Notation

20, 70, Y90R

Blackness (s), Chromaticness (c), Hue

Other Systems





Pantone

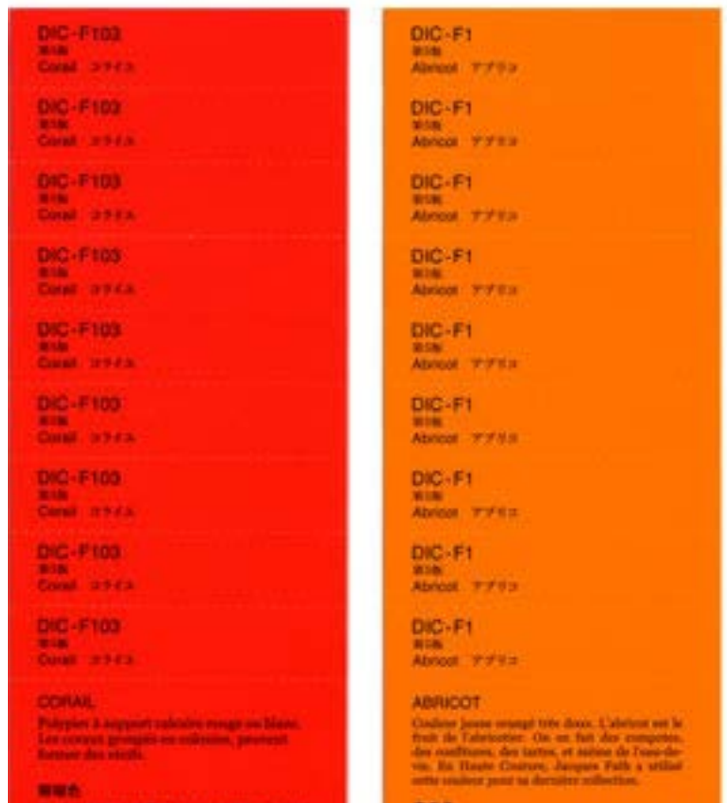
Color Specifications
Proprietary
Visual Reference, Not Appearance Scales

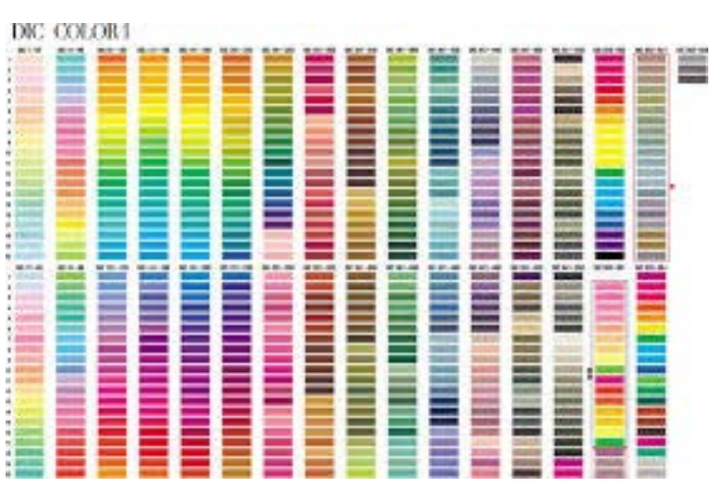
RAL

Color Specifications
Proprietary
Visual Reference, Not Appearance Scales

DIC

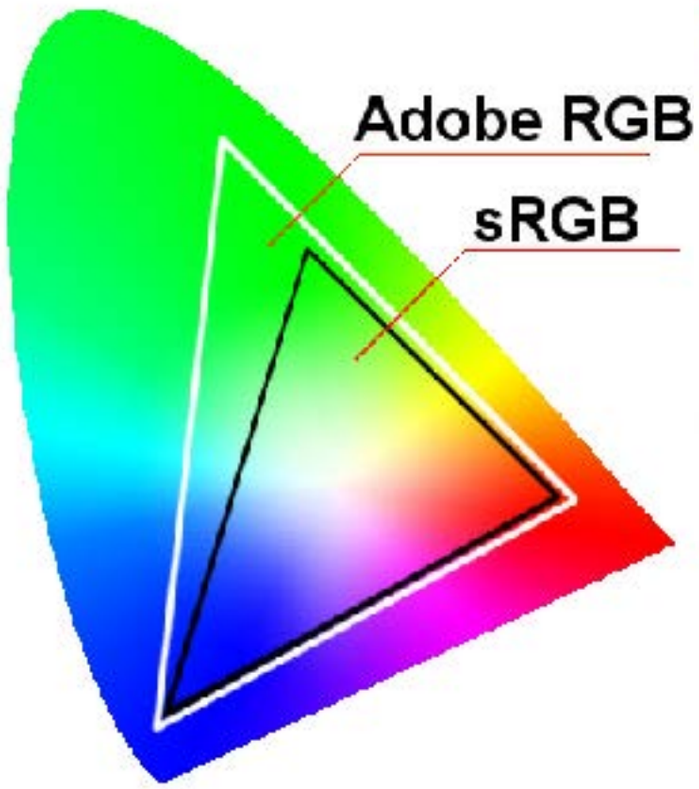
Color Specifications
Proprietary
Visual Reference, Not Appearance Scales

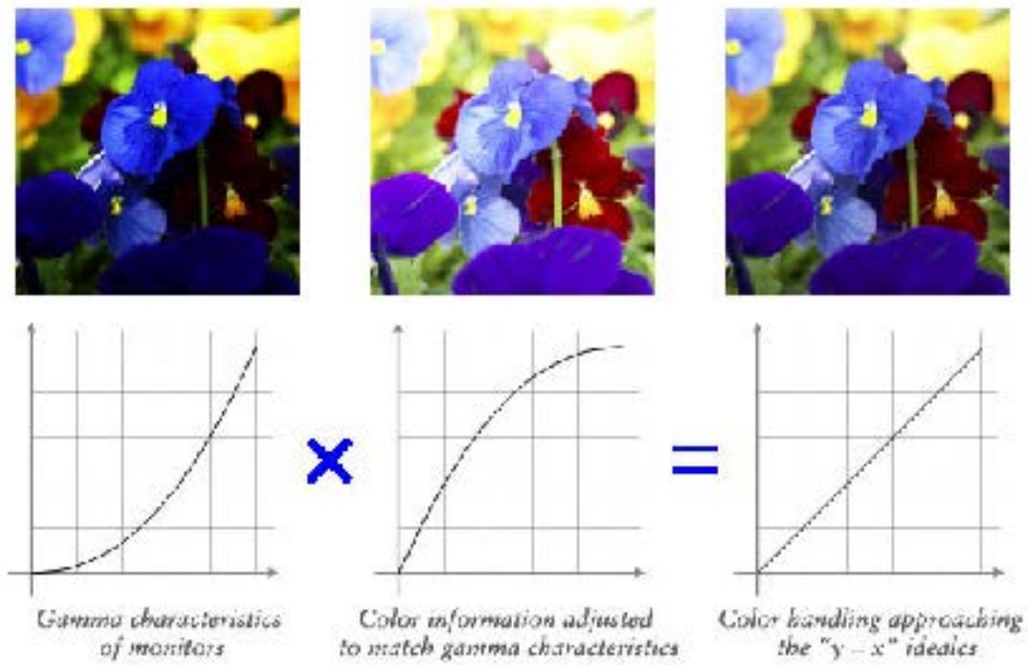


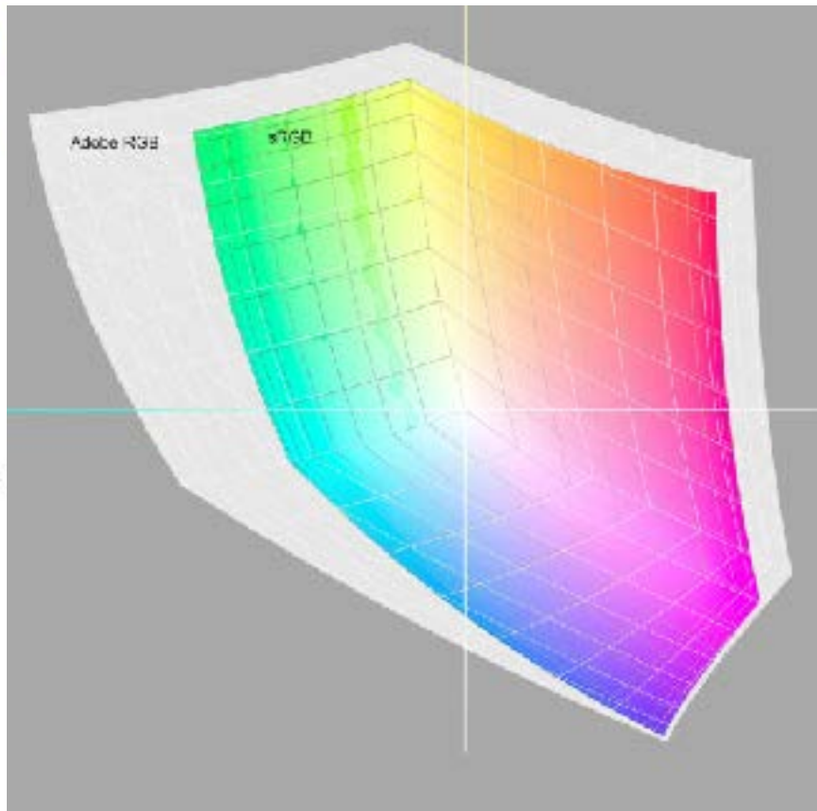


sRGB, AdobeRGB

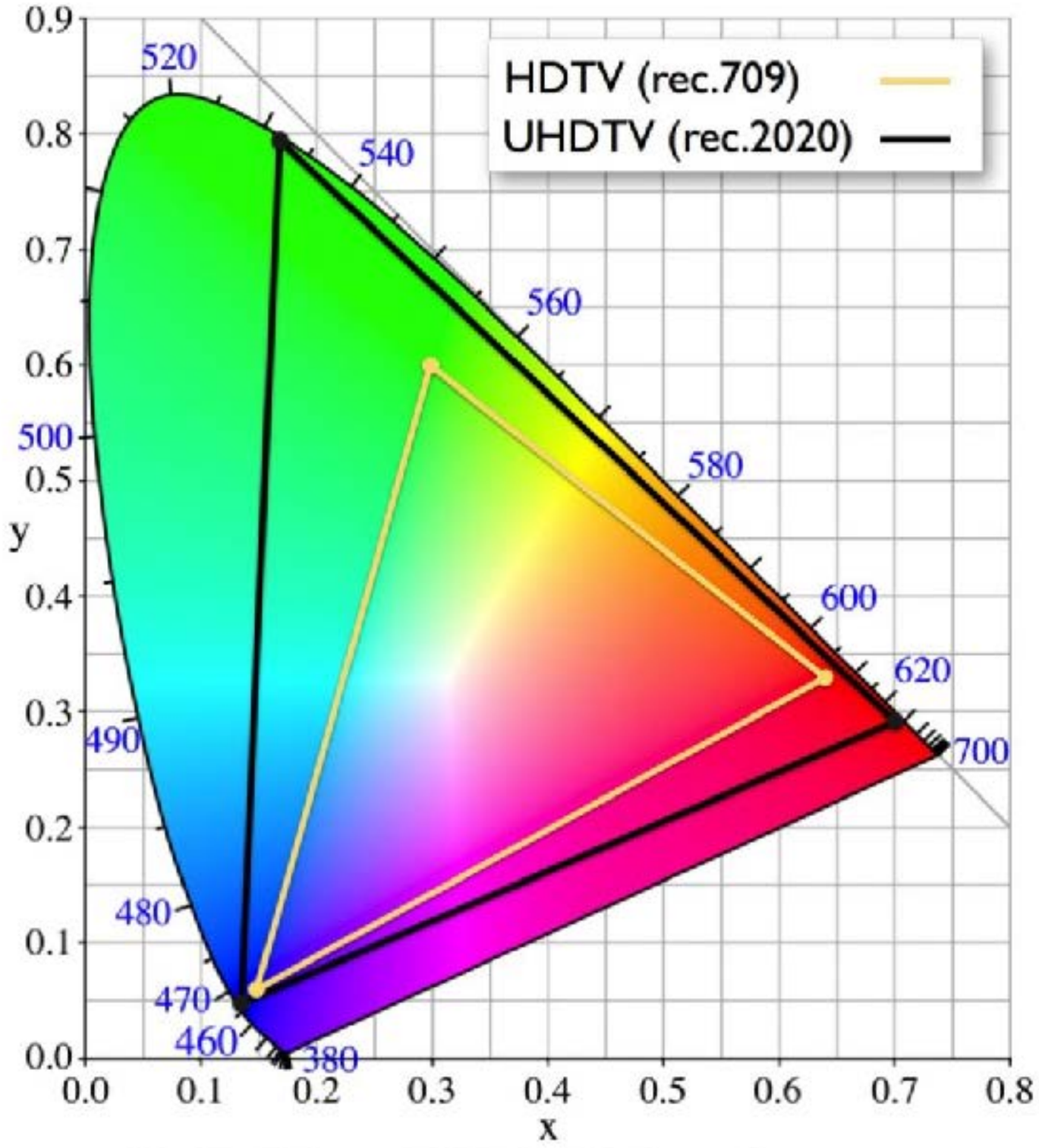
RGB Primaries Specified
Tone Transfer Specified
XYZ-to-RGB Defined



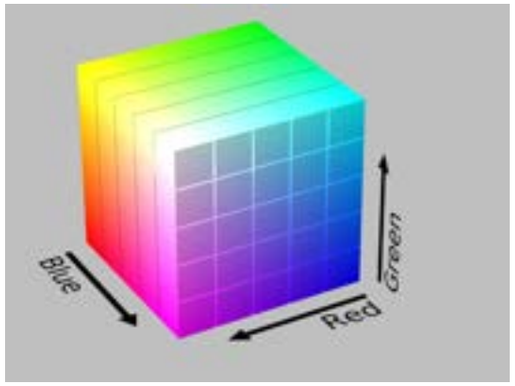


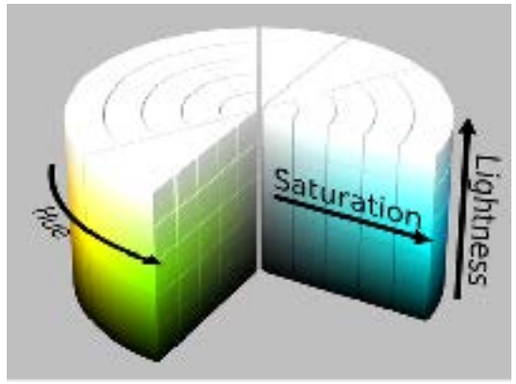


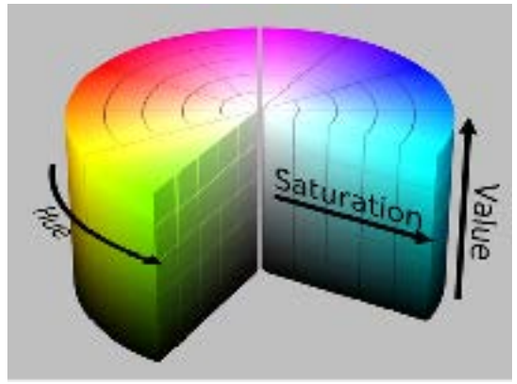
Rec.709, Rec.2020

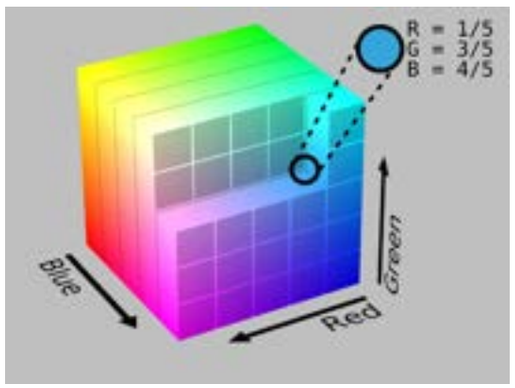


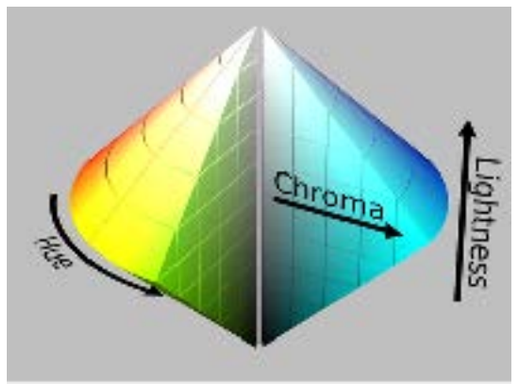
RGB, HSL, HSV, CMYK

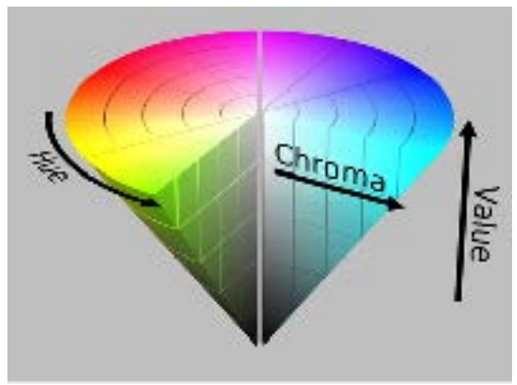












Device Dependent Spaces
RGB/CMYK Not Defined

Categories of Systems

(1) Systems Related to Colorimetry (e.g., XYZ) or Not

(2) Systems Based on Color Appearance or Not

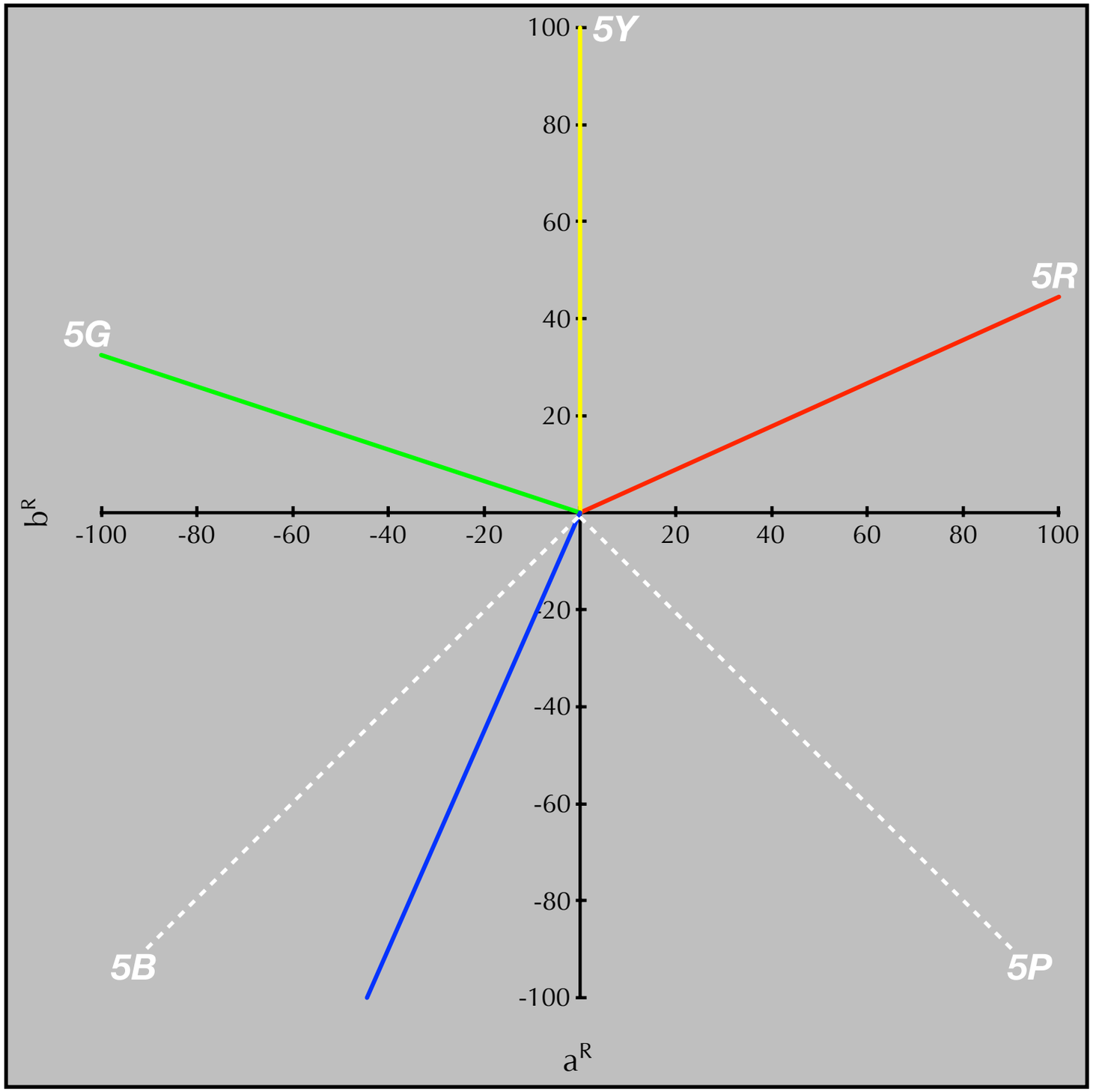
Munsell & NCS: (1) Yes (2) Yes
sRGB & Rec.2020: (1) Yes (2) No
Pantone, RAL, Paints: (1) No (2) No**

***Proprietary*

Principal/Unique Hues

Munsell :
5 Principal Hues :
Based on Thresholds/Differences

NCS :
4 Unique Hues :
Based on Appearance



Individual Differences

Individual Differences

Angelica Dass

Causes

Genetics

- *Different Pigments (Color Blind in Extreme)*
- *Different Pigment Density*
- *Cone Morphology*
- *Eye “Color”*

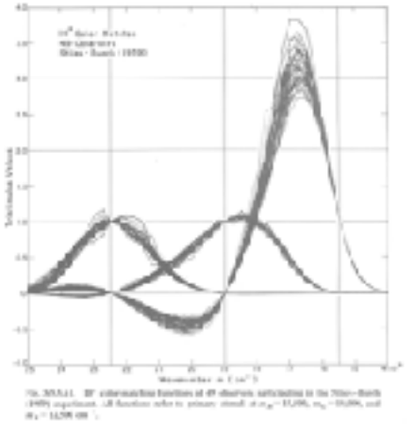
Diet, Lifestyle, Environment, Age

- *Macular Pigment Density*
- *Lens Density*

Psychology, Cognition

- *Knowledge of Conditions*
- *“Set” of Judgments*
- *Available Vocabulary*

CIE 2006 + INDIVIDUALS



- Stiles & Burch 49 Observers

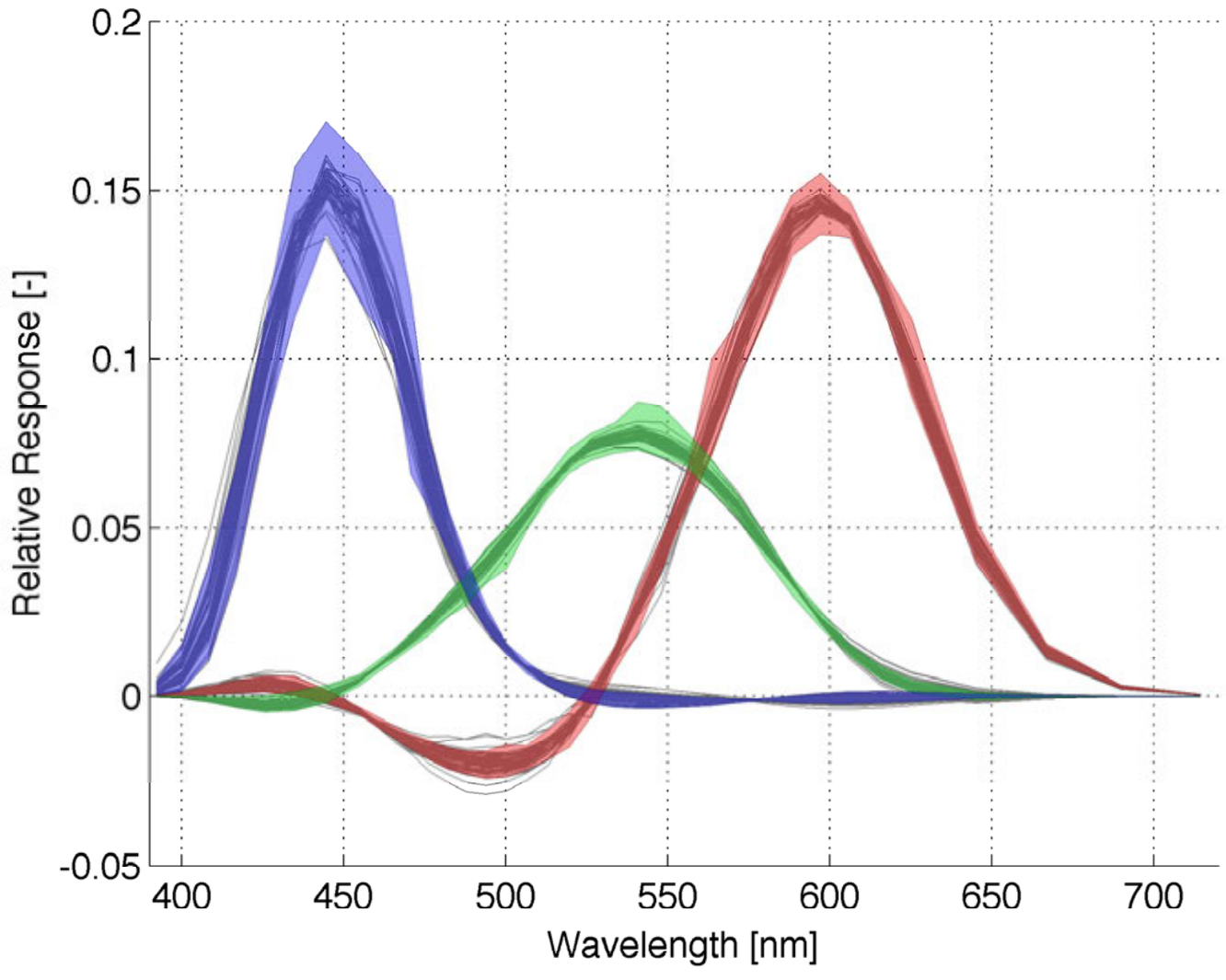
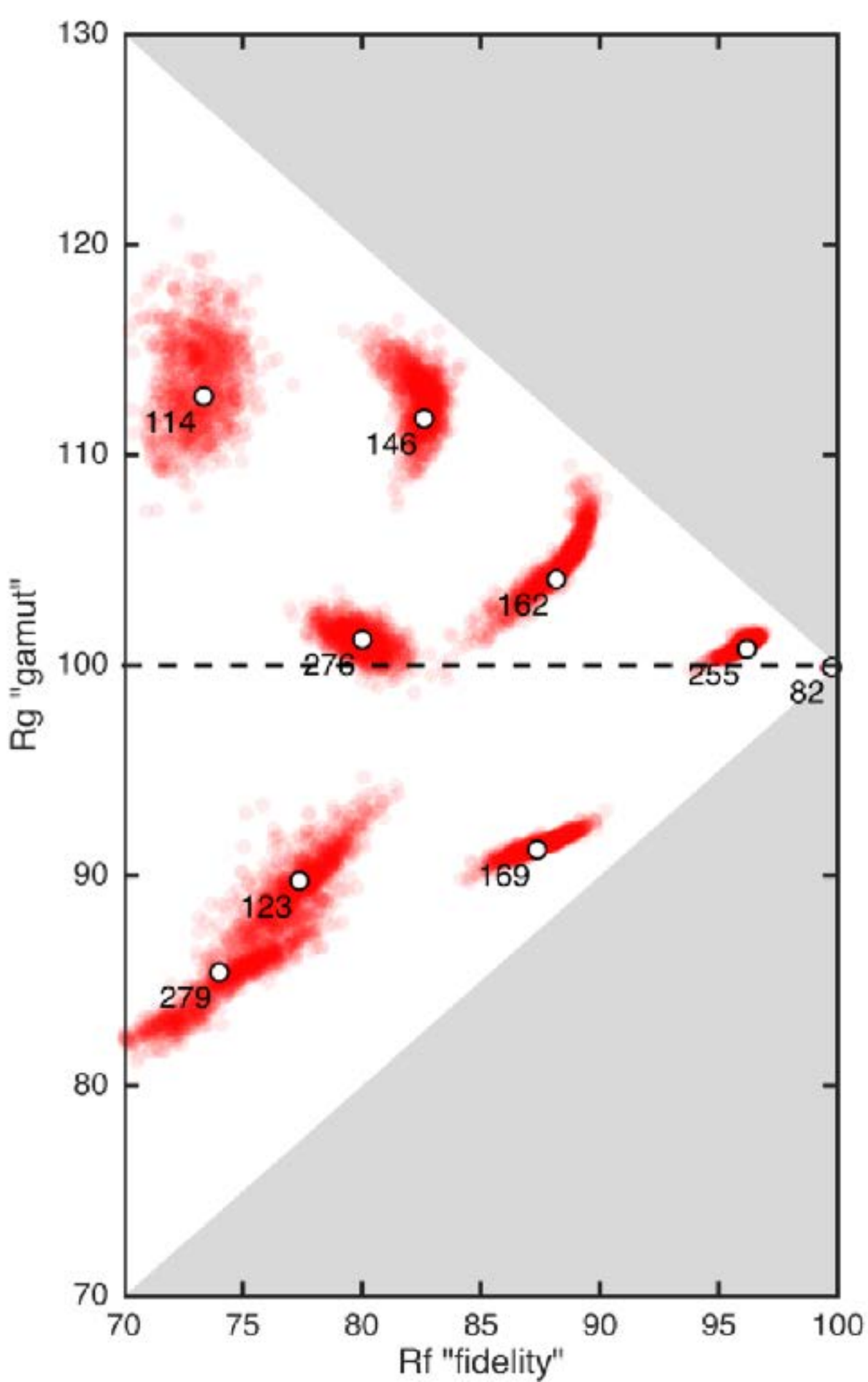


Fig. 3.12 – 49 sets of rgb-CMFs generated by the proposed observer model (gray lines) aiming to predict the Stiles and Burch's experiment results. The maxima and minima of 49 sets of CMFs for the Stiles and Burch's experiment participants are superimposed as color-shaded areas. All the CMFs are normalized to equal area.

Color Rendering



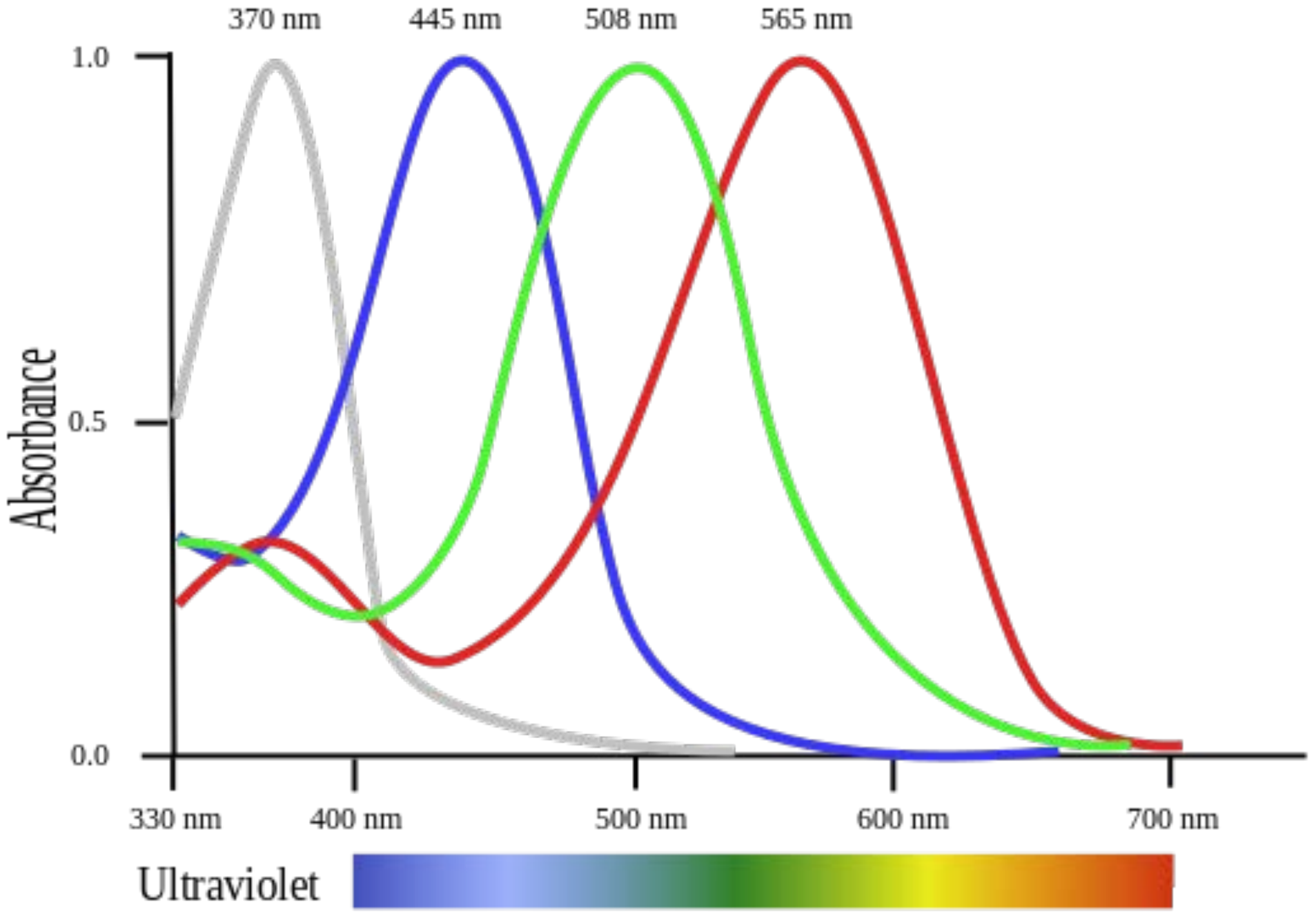
Animal Vision

Animal Vision

Birds

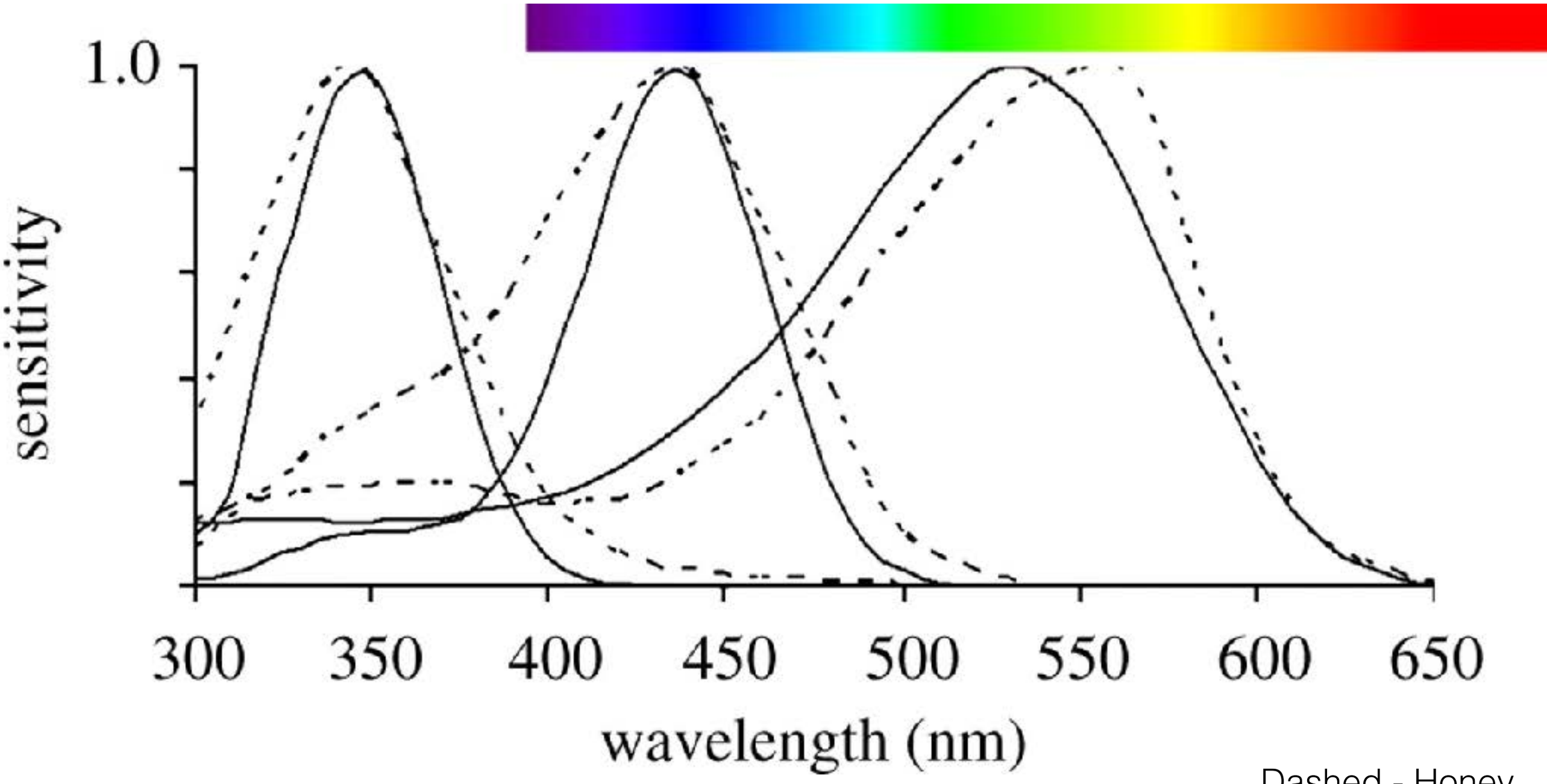
Kestrel

Bird Vision


370 nm
445 nm
508 nm
565 nm
1.0
0.5
0.0
Absorbance
330 nm
400 nm
500 nm
600 nm
700 nm
Ultraviolet

Bees

Bee Color Vision



Dashed - Honey
Solid - Bumble

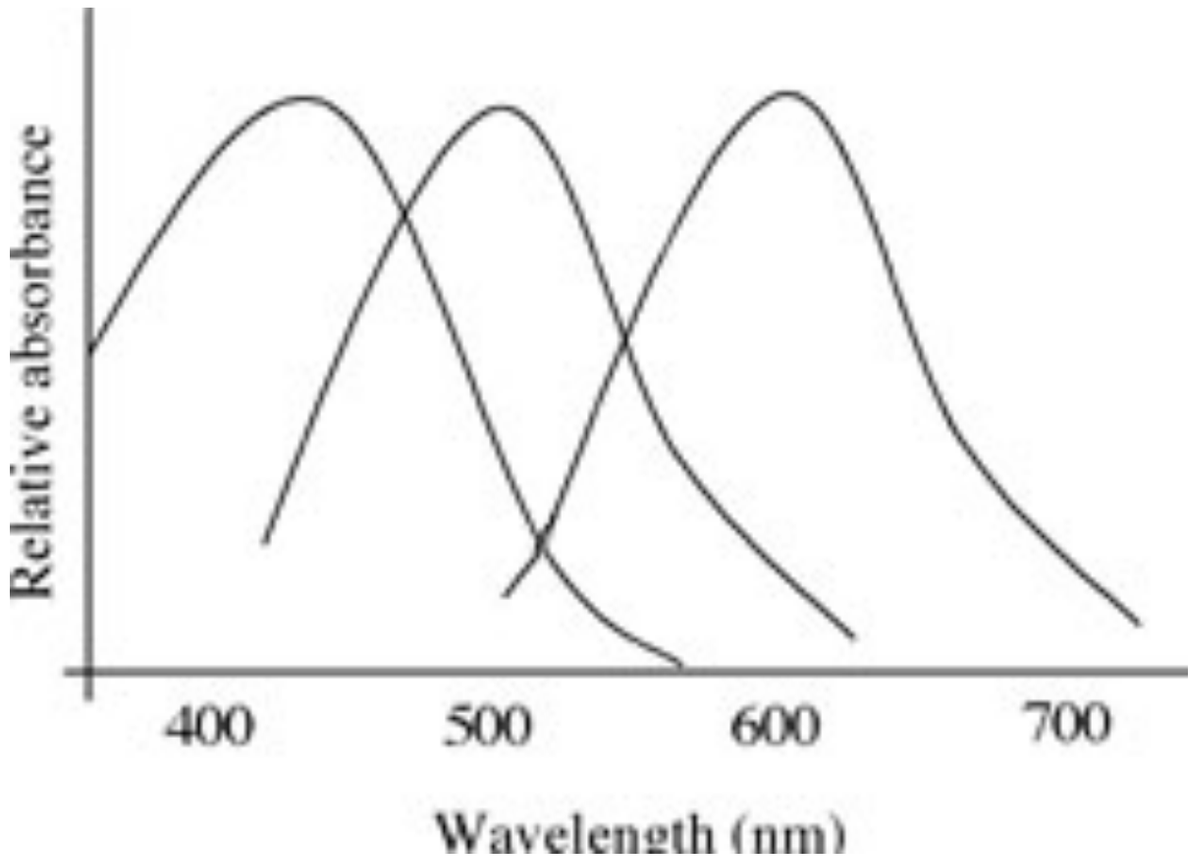
Bee Color Vision

Humans

Honey Bees

Goldfish

Goldfish Color Vision

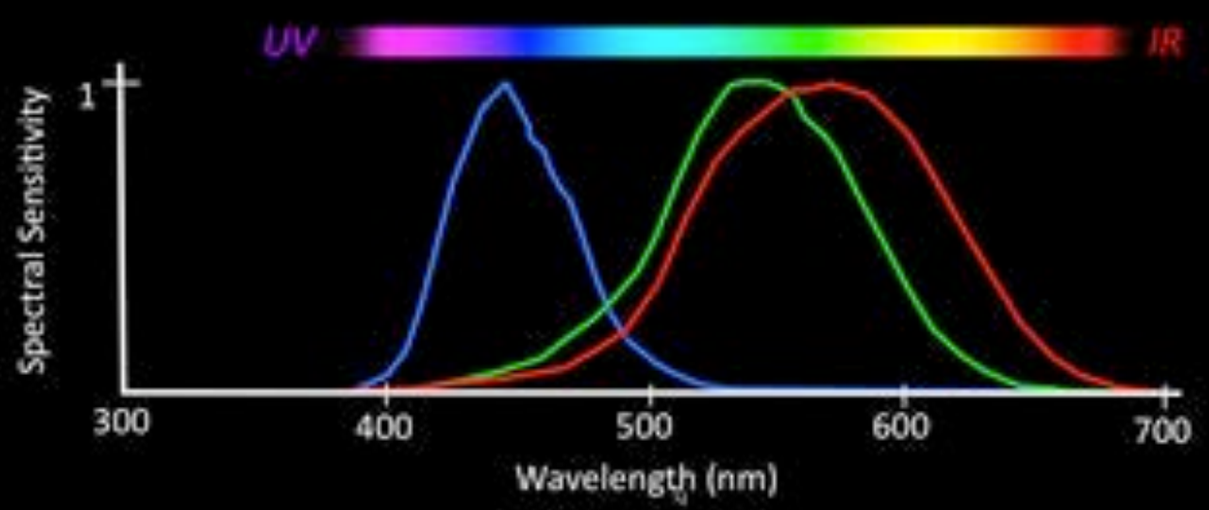


Mantis Shrimp

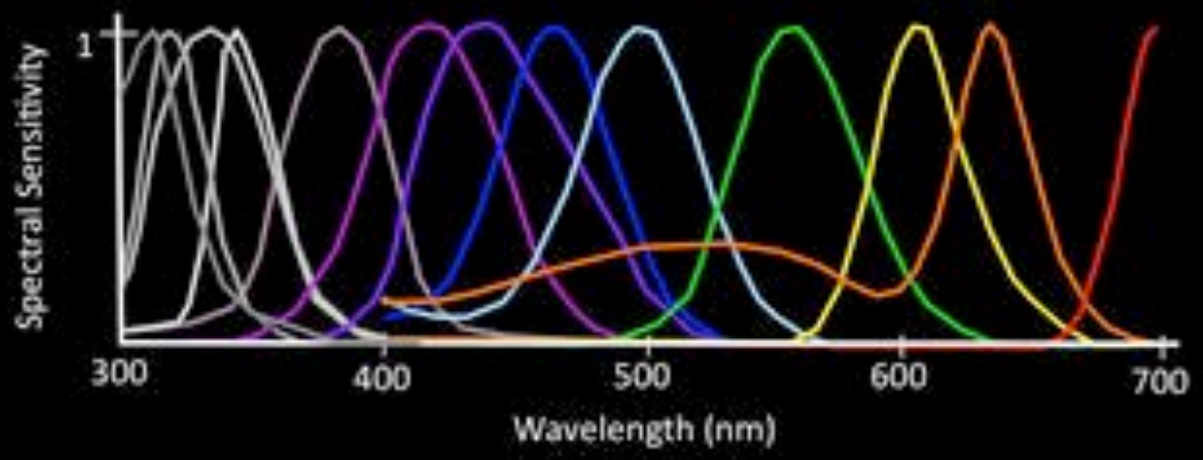
Complexity

Mantis Shrimp: Extraordinary Eyes

Homo sapiens



Neogonodactylus oestedii



Marshall *et al.*, 2007; Marshall and Oberwinkler, 1999

Final Thoughts …

Dimensions

Lightness - Chroma - Hue

Brightness - Colorfulness - Hue

(Saturation instead of Chroma & Colorfulness??)

Brilliance - Saturation - Hue

(Need at least 5 total, which can be defined by 4.)

Colorimetry

CIE XYZ

CIELAB

CIECAM02

(Remember individual variation.)

Color Specification

Pantone, RAL, etc.

sRGB, Rec.709, Rec.2020, Dolby ICtCp

(All could be replaced by colorimetry, but they are convenient and helpful.)

Color Order

Munsell

NCS

(Perhaps could be replaced by a CAM one day.)

Questions