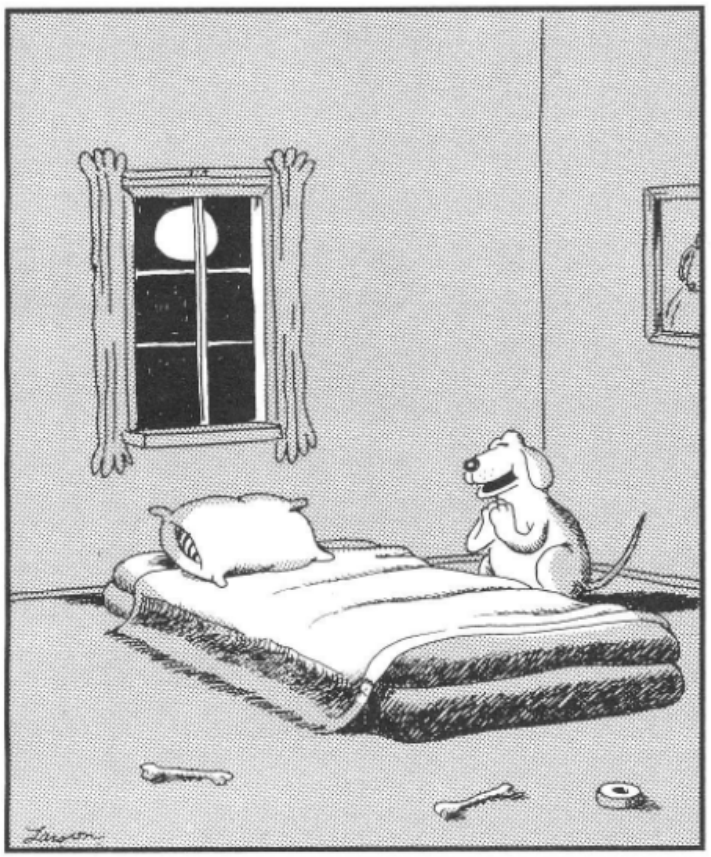
# FUNDAMENTALS OF DATA VISUALIZATION

Color



"… and please let Mom, Dad, Rex, Ginger, Tucker, me and all the rest of the family see color."

The Far Side, Gary Larson

# COLOR IS THE NEW BLACK

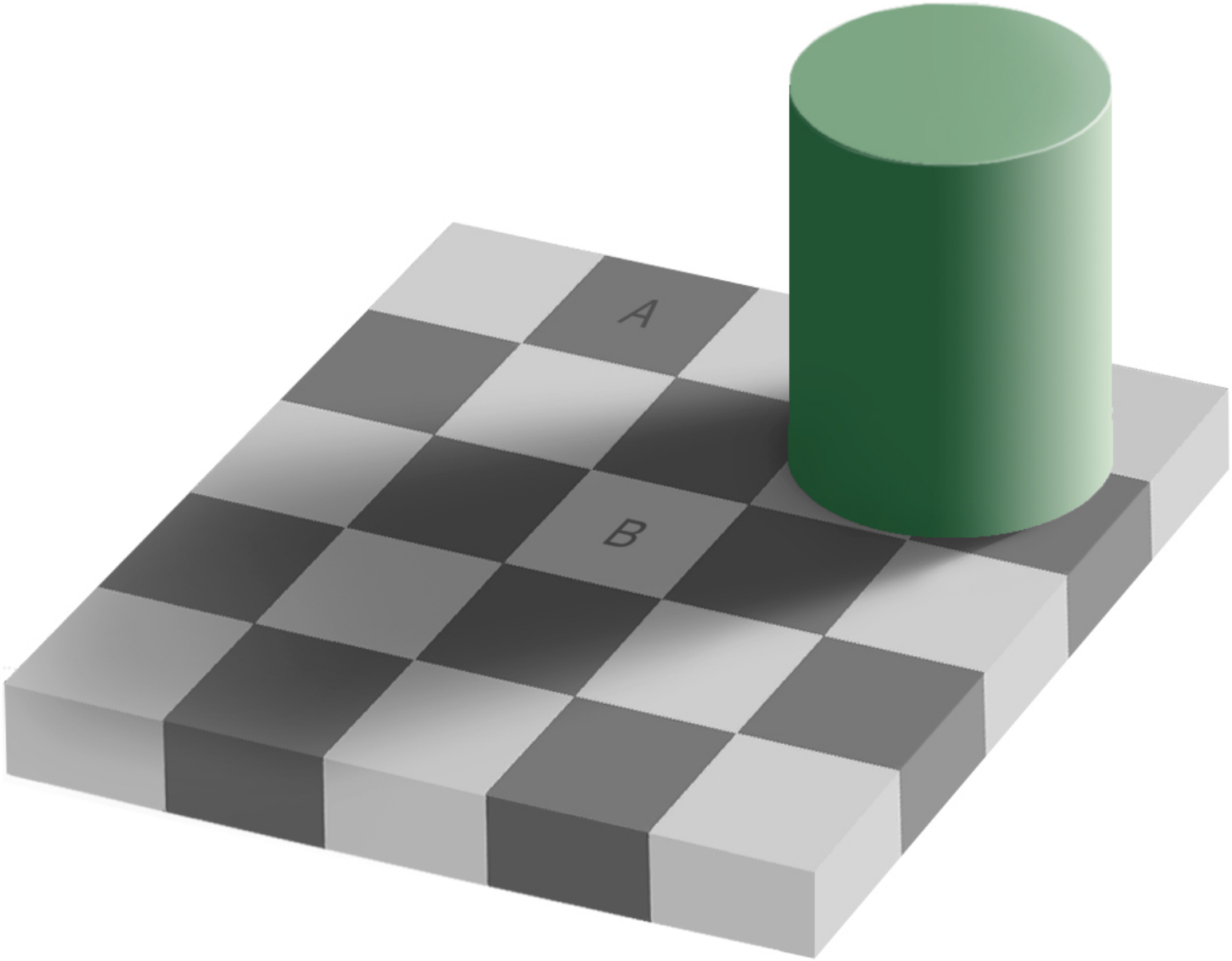



Image from Adelson, MIT

# POP QUIZ, HOTSHOT

1) A IS LIGHTER THAN B
2) B IS LIGHTER THAN A
3) A AND B ARE THE SAME
4) JUST TELL ME, ALLRIGHT?

Image from Colin Ware

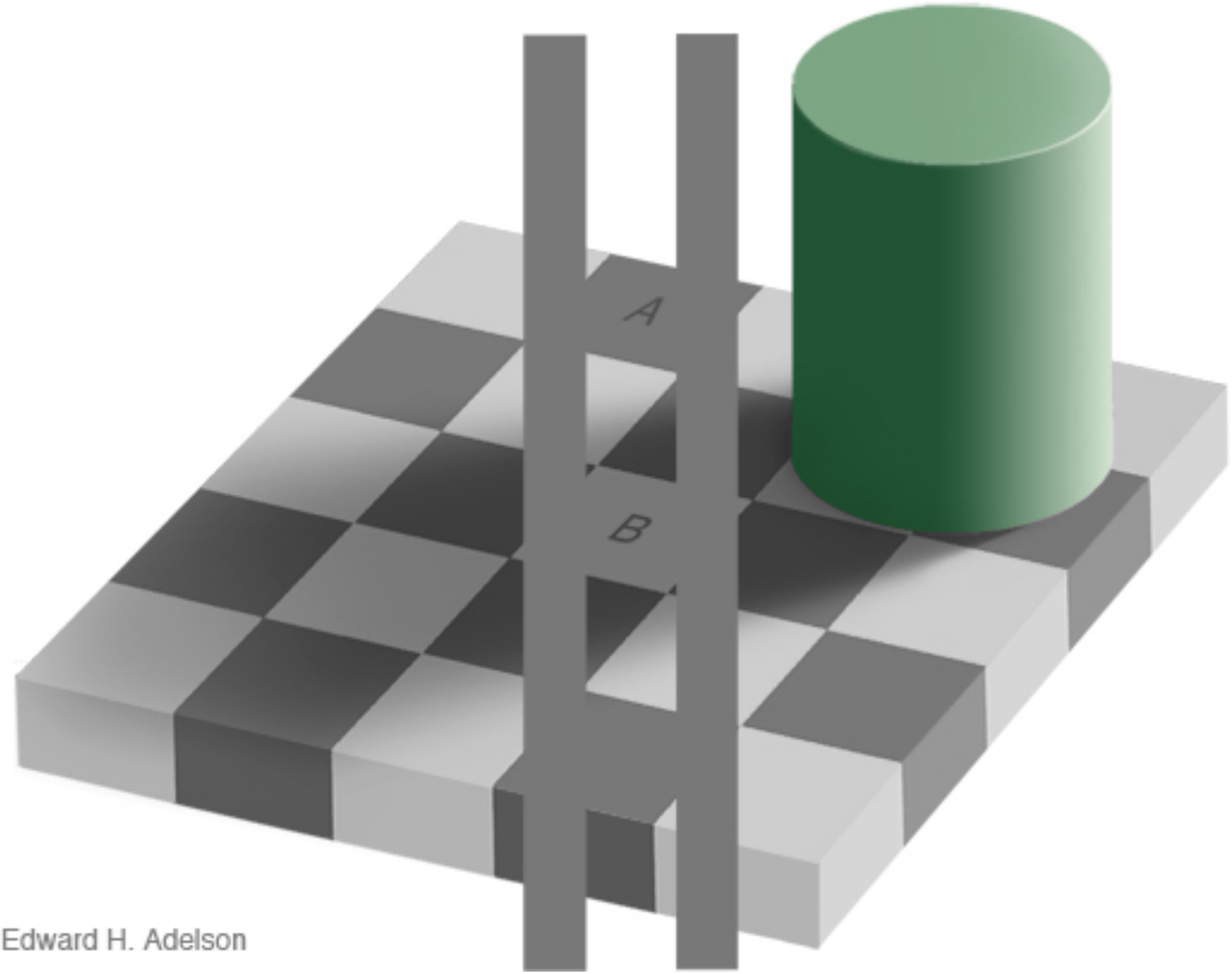
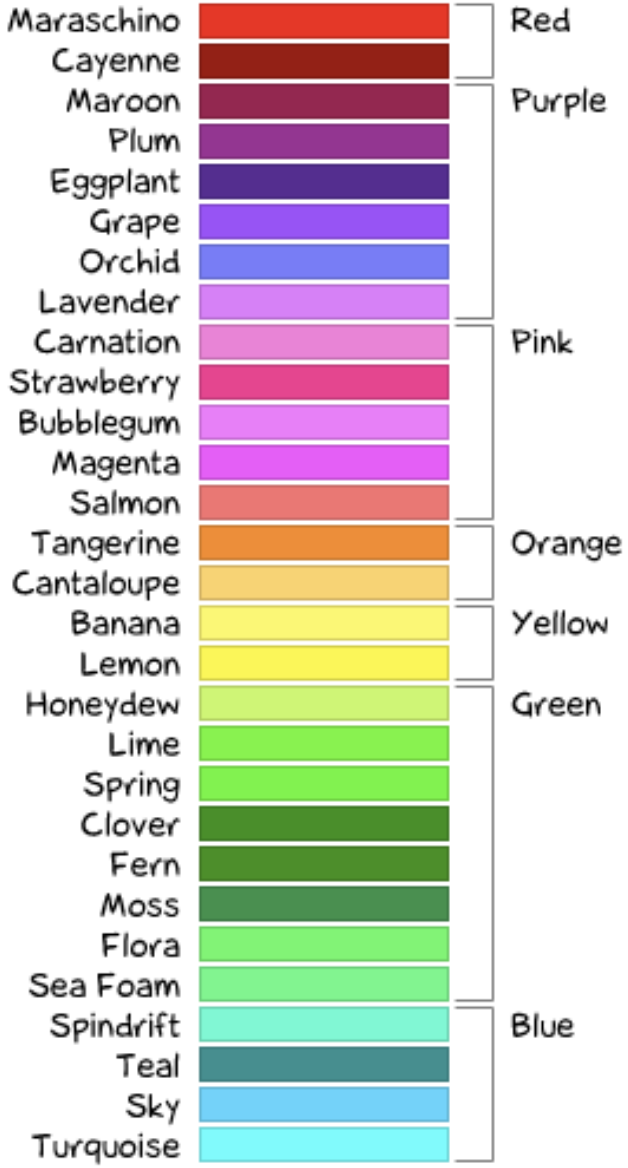



Image from Adelson, MIT

Color names if you're a girl...




Color names if you're a guy...

Doghouse Diaries
"We take no as an answer."


Image from the most excellent xkcd.com

# WHAT IS COLOR?

| Physics | Biology | Visual System | Mental Models |
|---|---|---|---|
| Light Energy | Cone Response | Opponent Encoding | Perceptual Models |
| Wavelength | L, M, S | L, R-G, Y-B | Color perception |

# THE HUMAN EYE

SMALL FREQUENCY RANGE

HUGE LUMINANCE RANGE

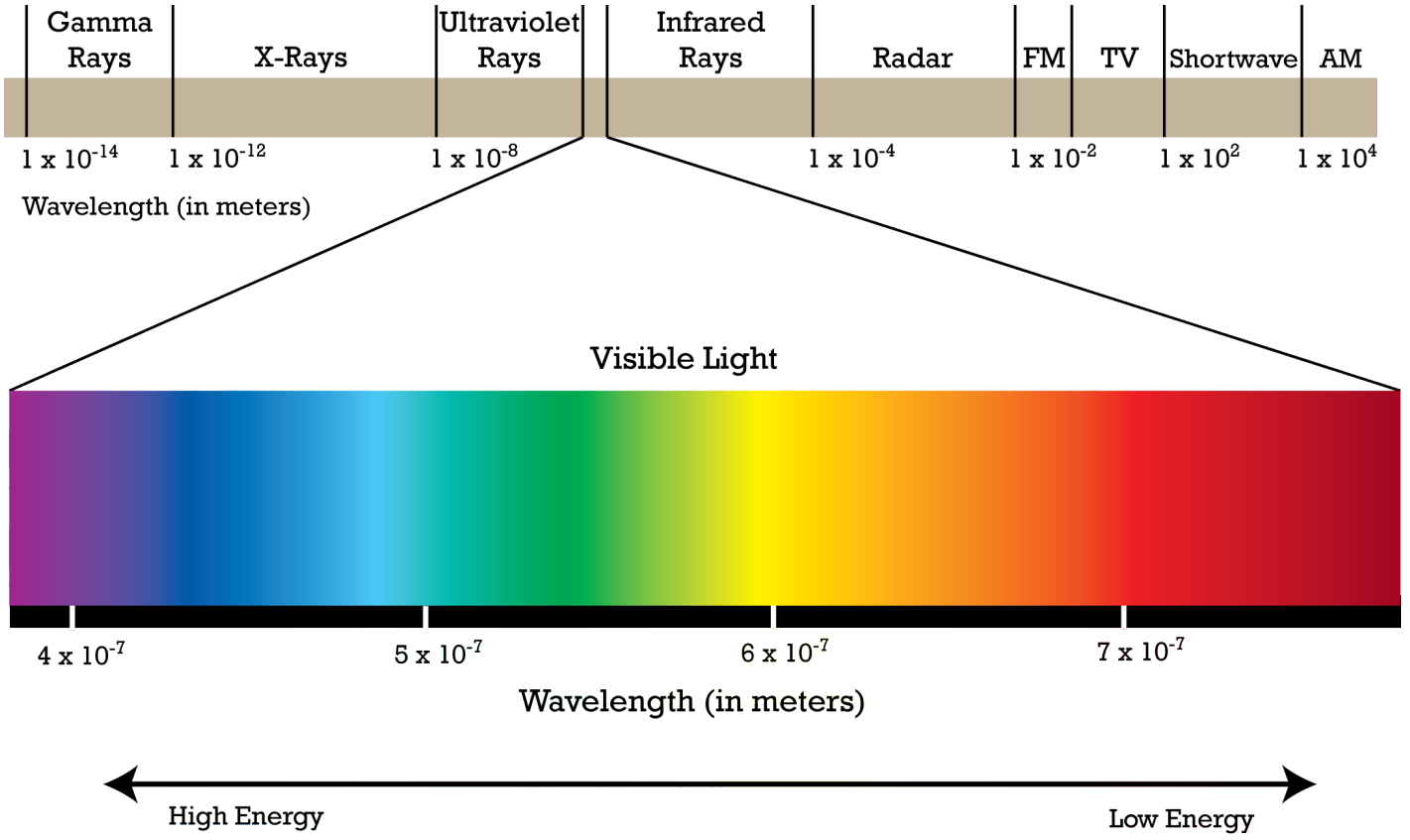



Image from where else? Wikipedia!

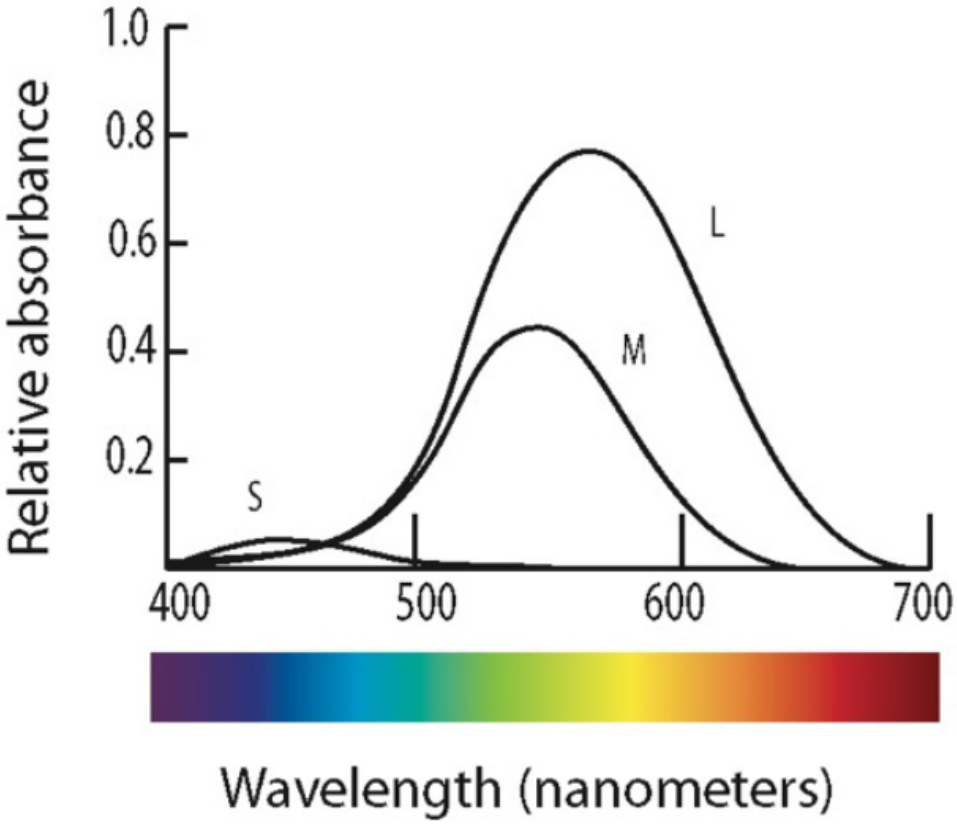



Image from Colin Ware

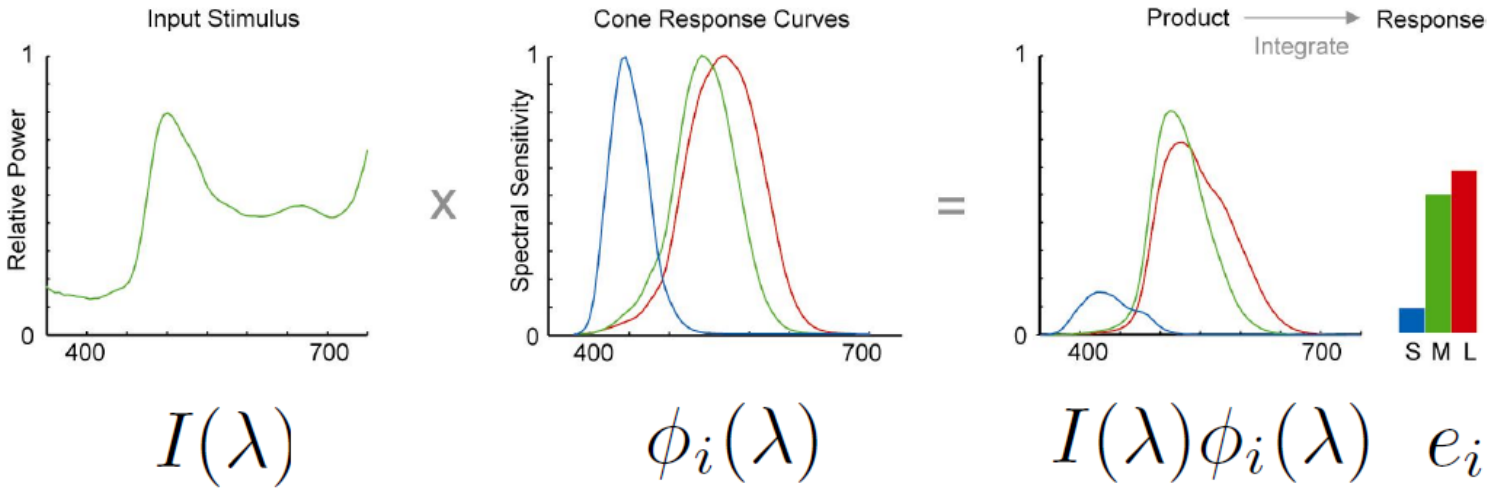



Image from Stone: A Guide to Digital Color

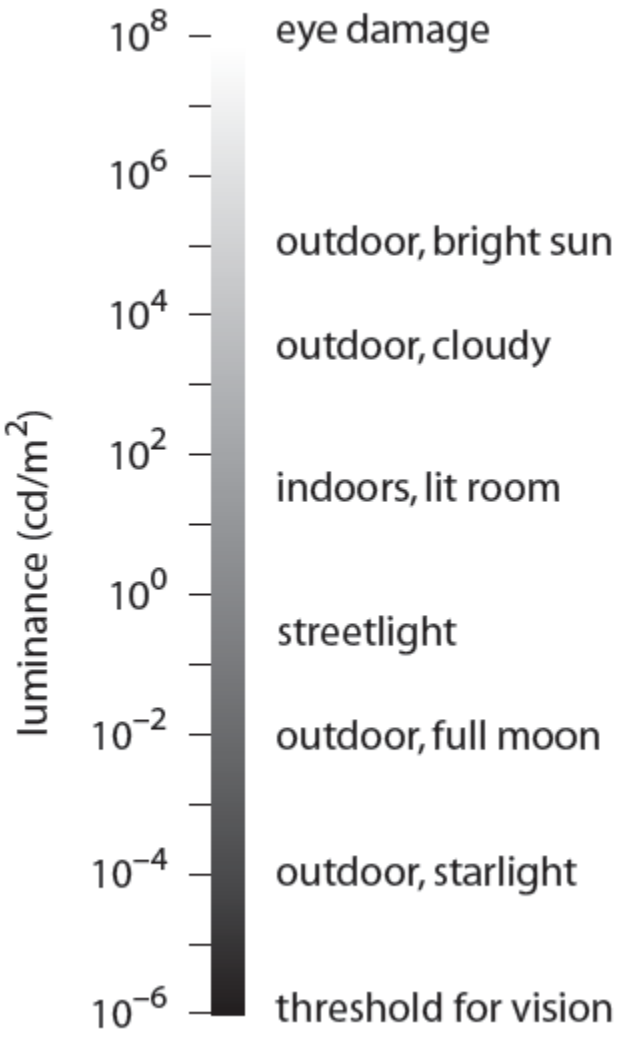



Image from Mazur

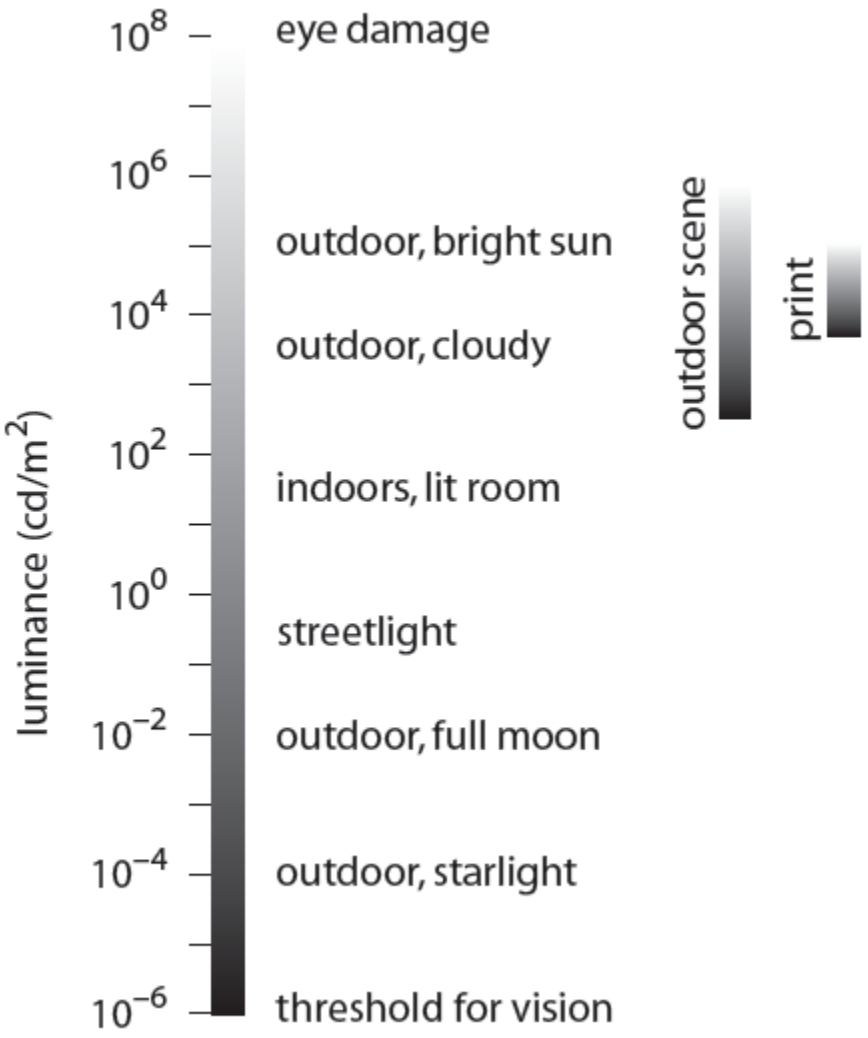
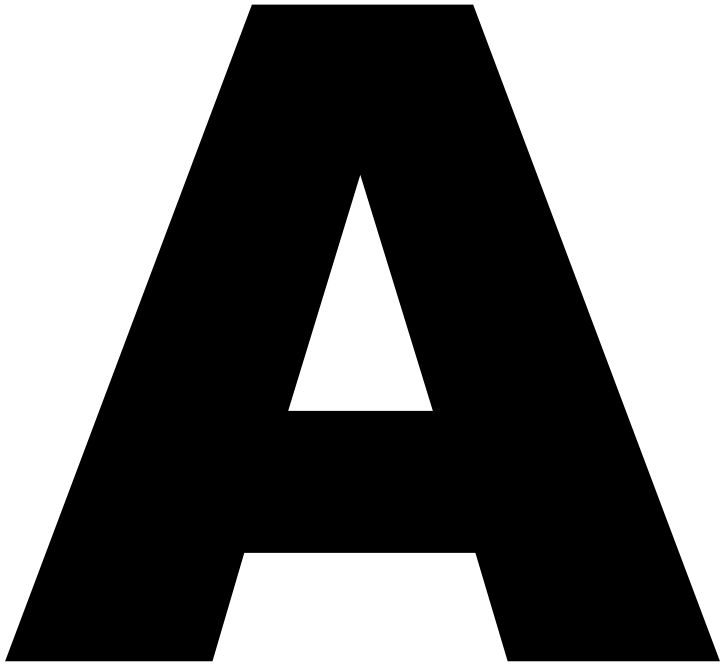



Image from Mazur


A

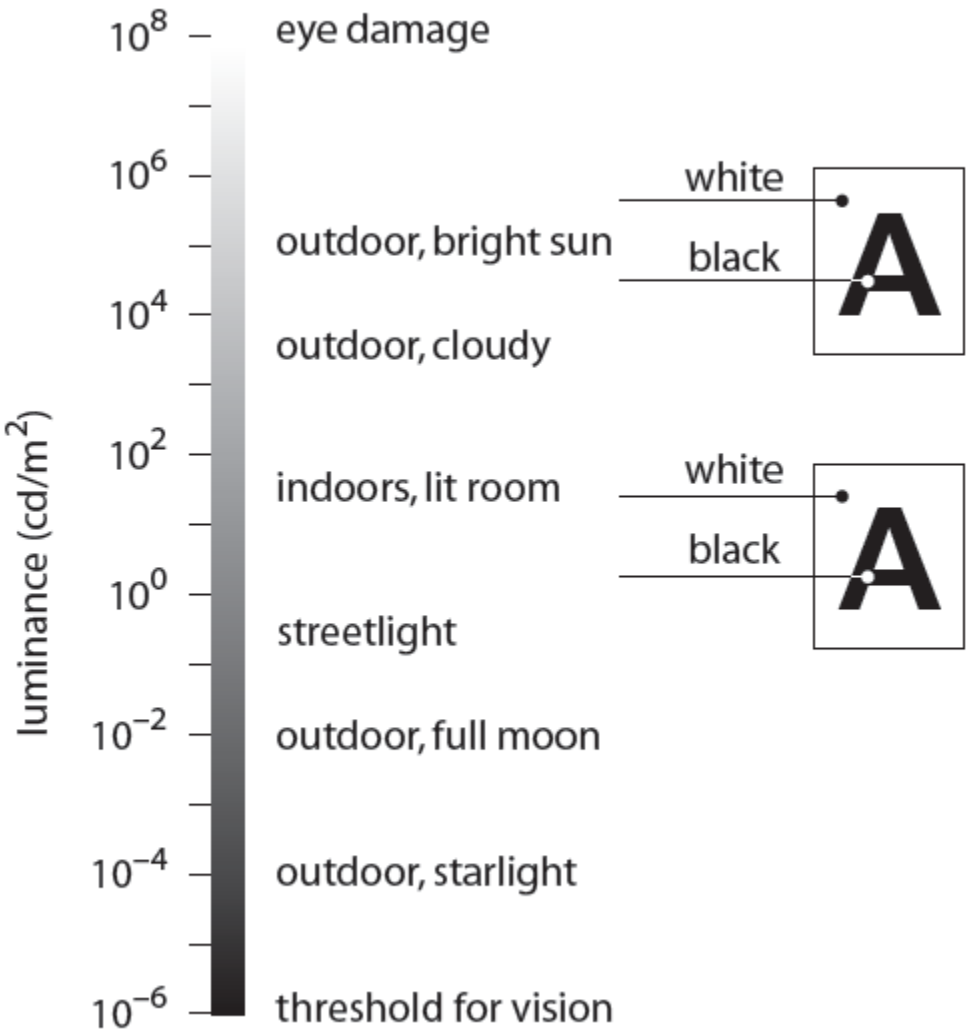
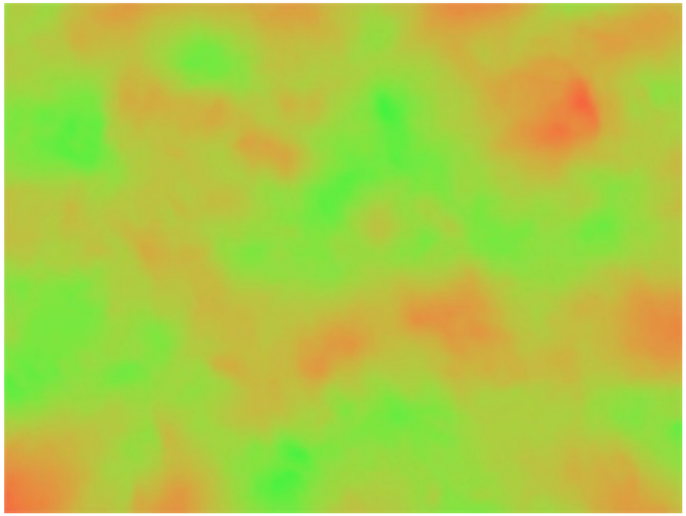
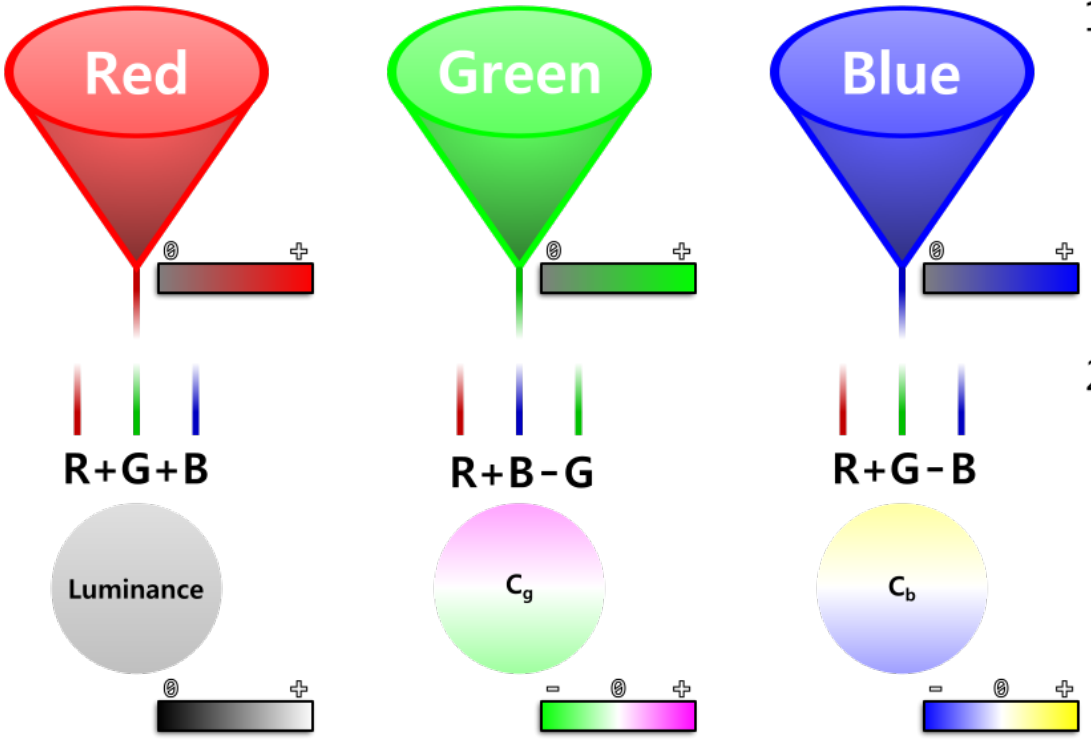



Image from Mazur

Image from http://ideas.etublogs.usj.edu.lb/



Colin Ware




## 1. Trichromatic Stage

Trichromatic cone cells respond positively to one of three frequencies exhibited by photons arriving on their surface.

## 2. Opponent Process Stage

The three color channels are discovered by nearby opponent cells.

Opponent cells tuned to luminosity are excited by the red, green, and blue color signals.

Cg cells are excited by red and blue and inhibited by green. Cb cells are excited by red and green and inhibited by blue.

Image from Wikipedia

- Luminance (L): Sum of Red and Green
- Red - Green: Difference between Red and Green
- Yellow - Blue: Difference between L and Blue

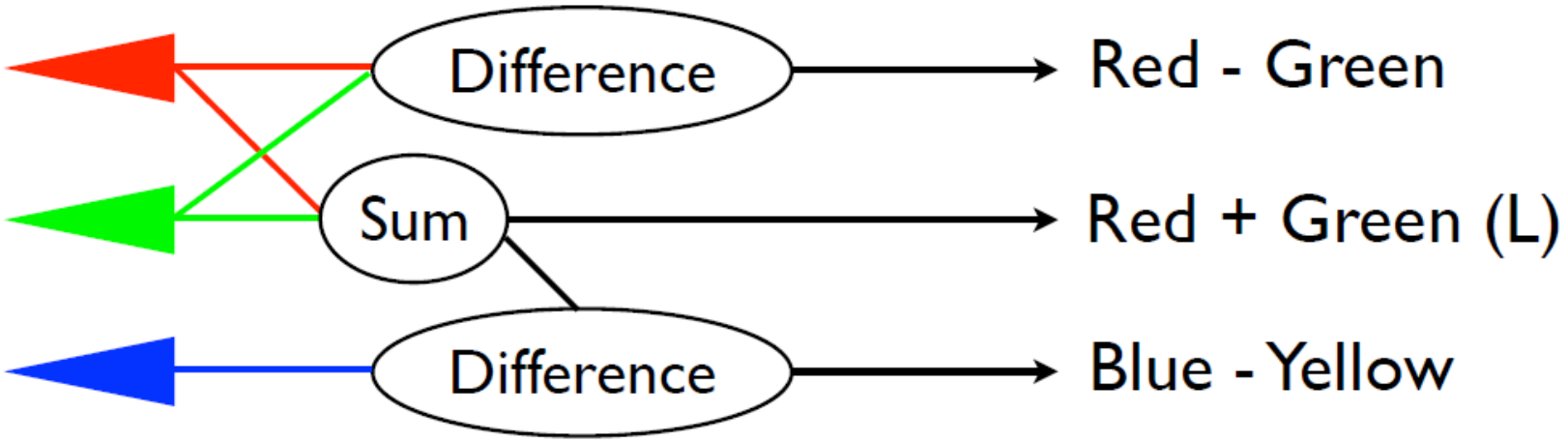



Image from Wikipedia

# THE RETINA & COLOR

1) SPATIAL COMPRESSION
2) ADJUST LUMINANCE RANGE TO NERVE S/N
3) EXTRACT REFLECTANCE (COLOR)

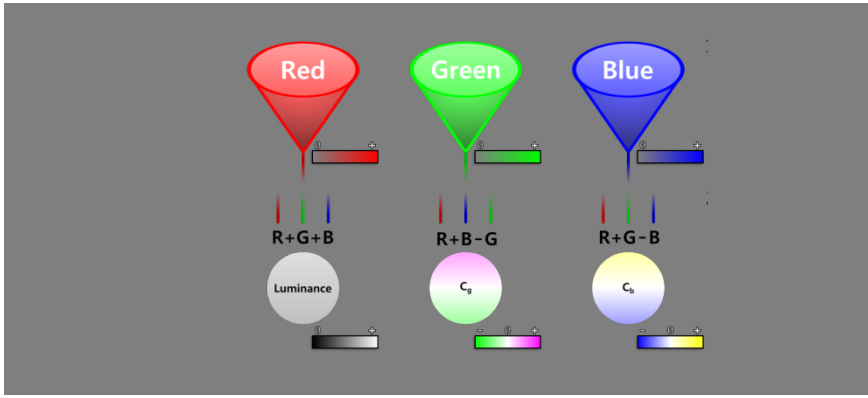



Image from Colin Ware

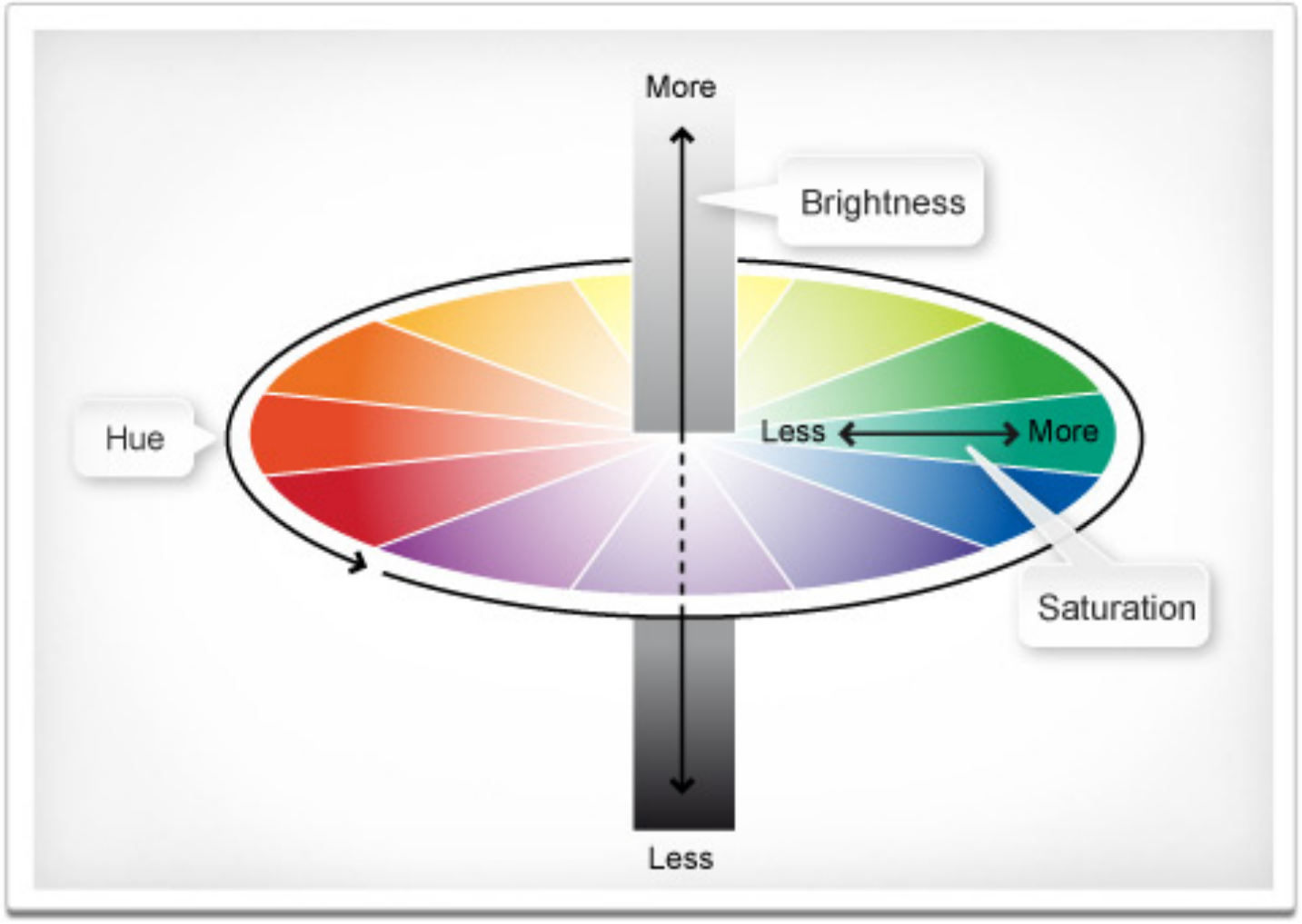



Image surprisingly from Commonwealth of Australia

Who in the rainbow can draw the line where the violet tint ends and the orange tint begins? Distinctly we see the difference of the colors, but where exactly does the one first blendingly enter into the other? So with sanity and insanity.

—***Herman Melville,*** **Billy Budd**

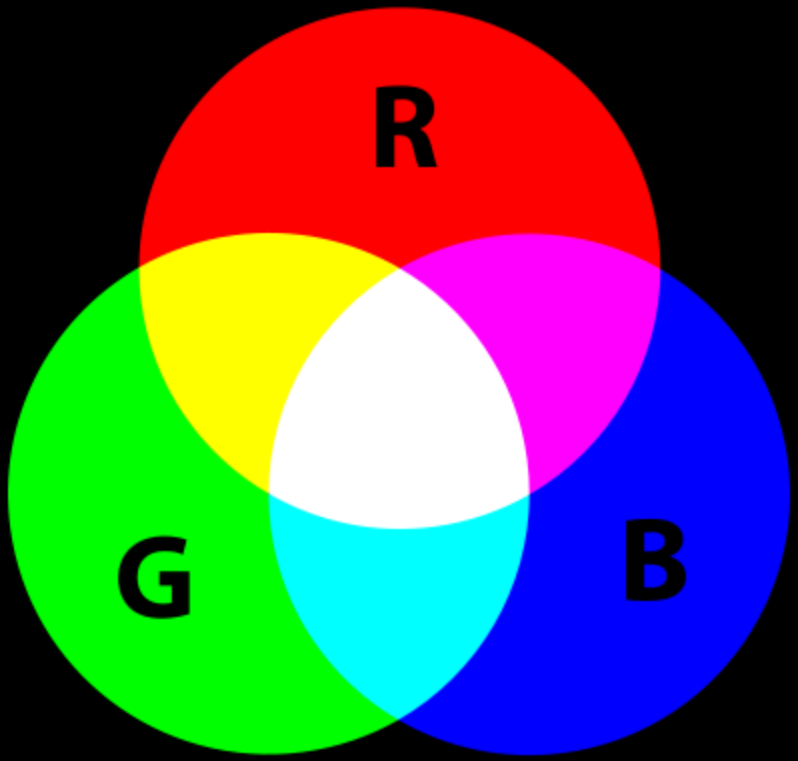



Image from Wikipedia

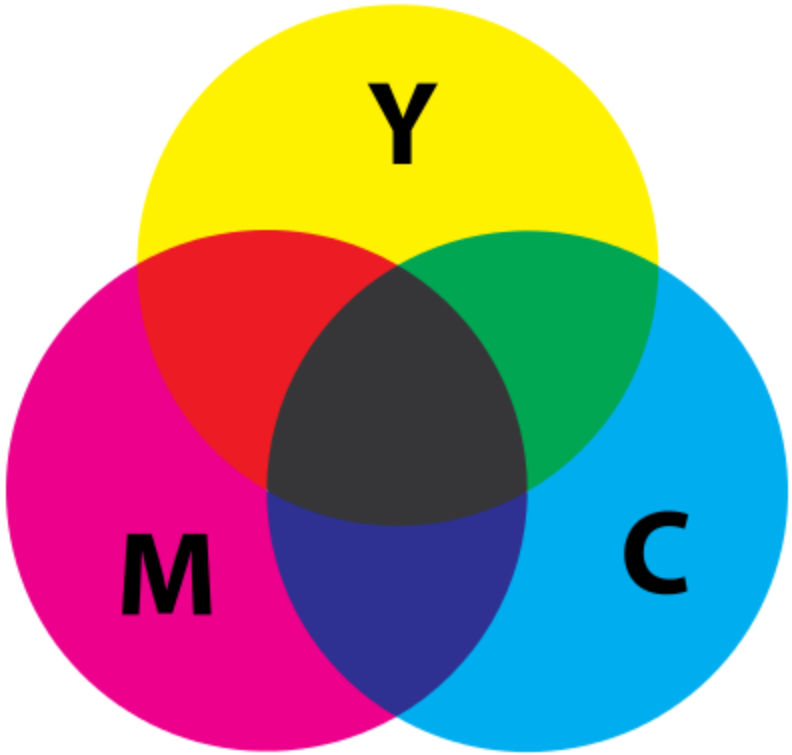



Image from Wikipedia

GOOGLE THIS IS NOT YELLOW

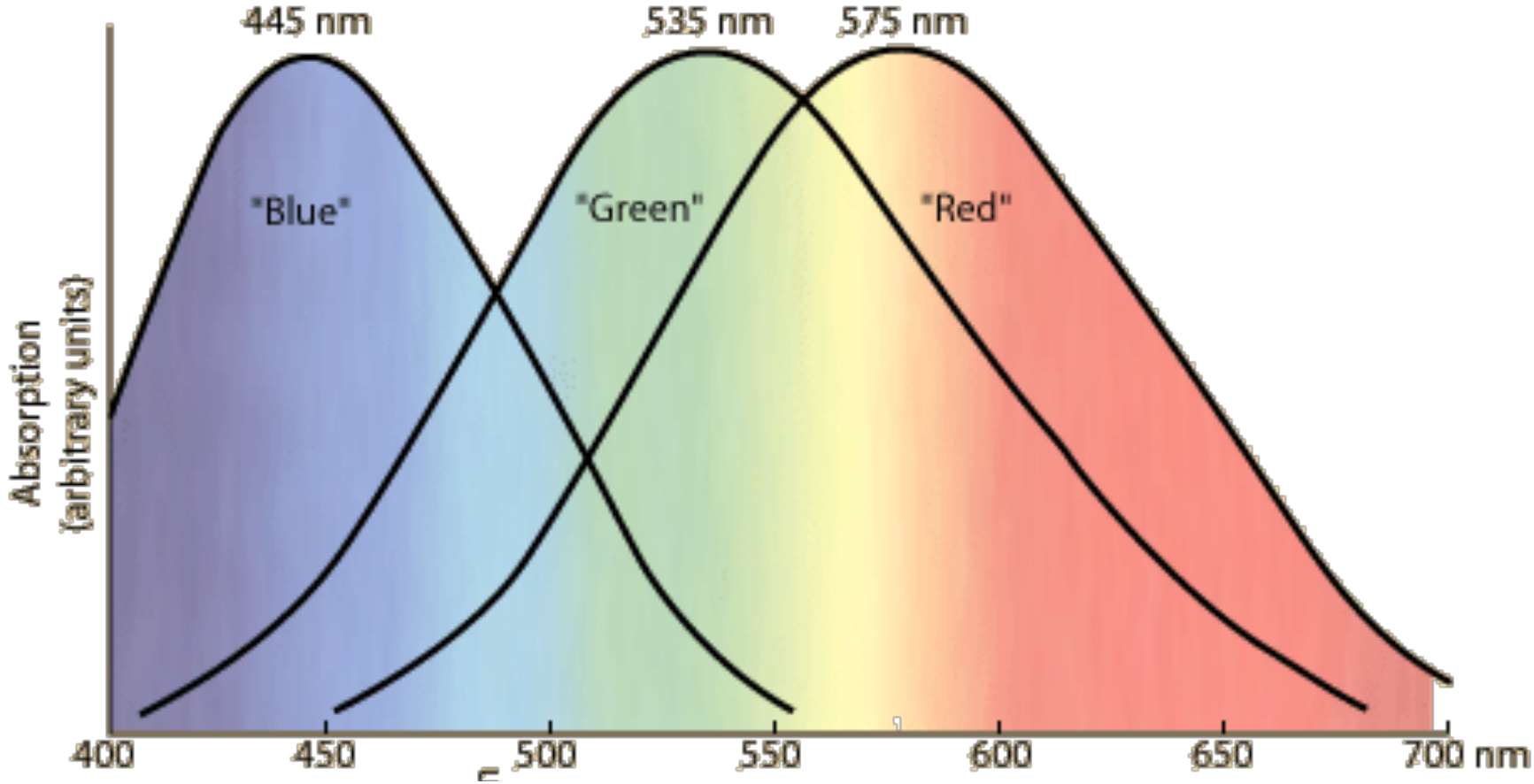



Image from hyperphysics.com

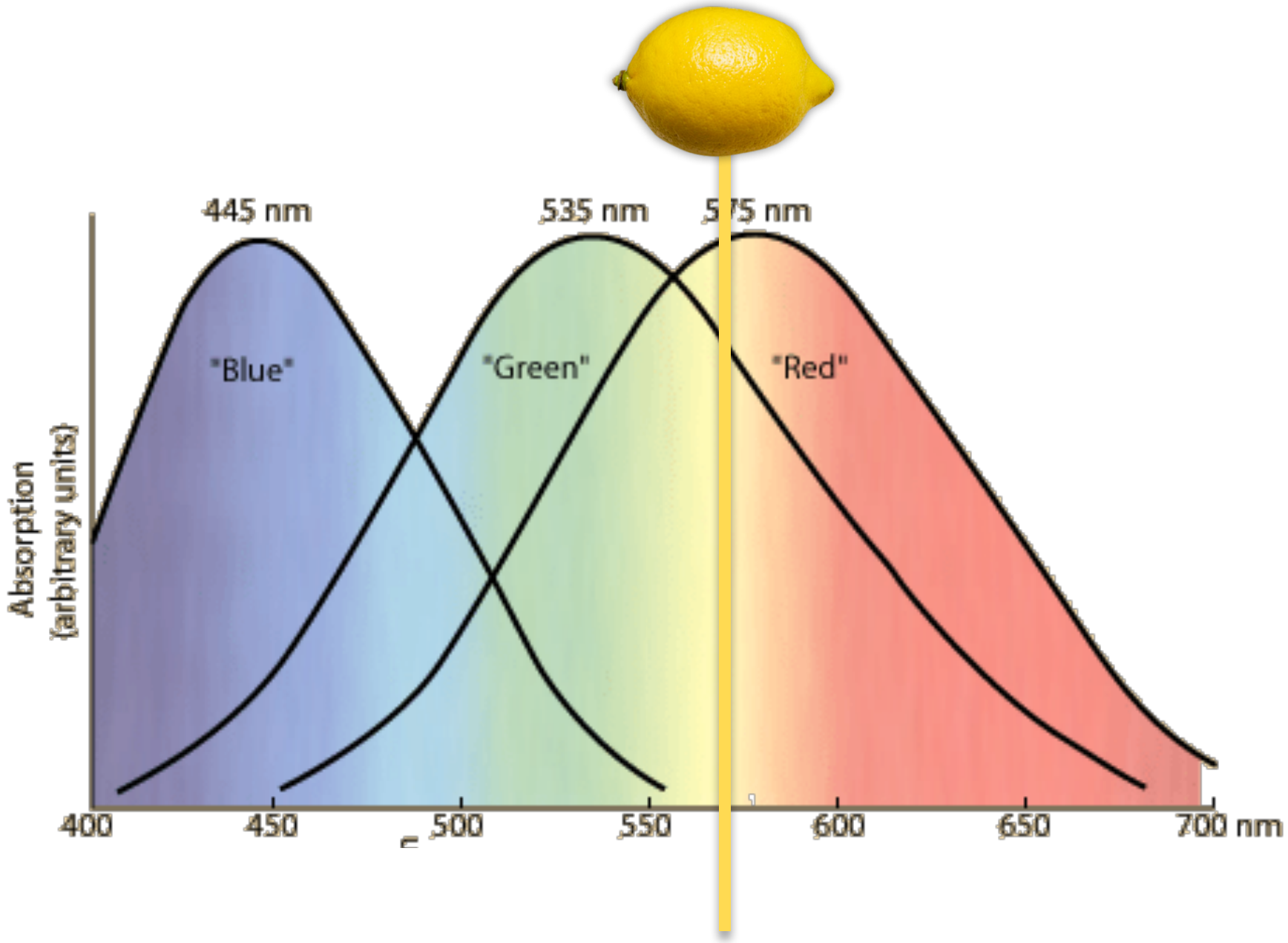



Image from hyperphysics.com

# WHAT IS YELLOW?

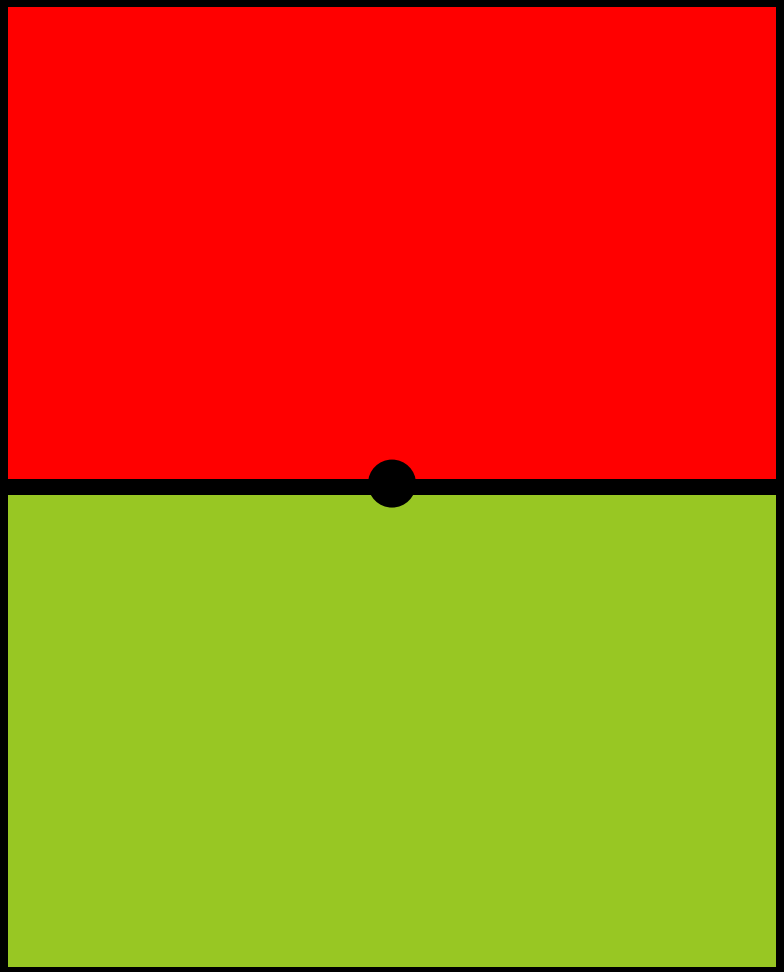
REAL WORLD: 570 NM

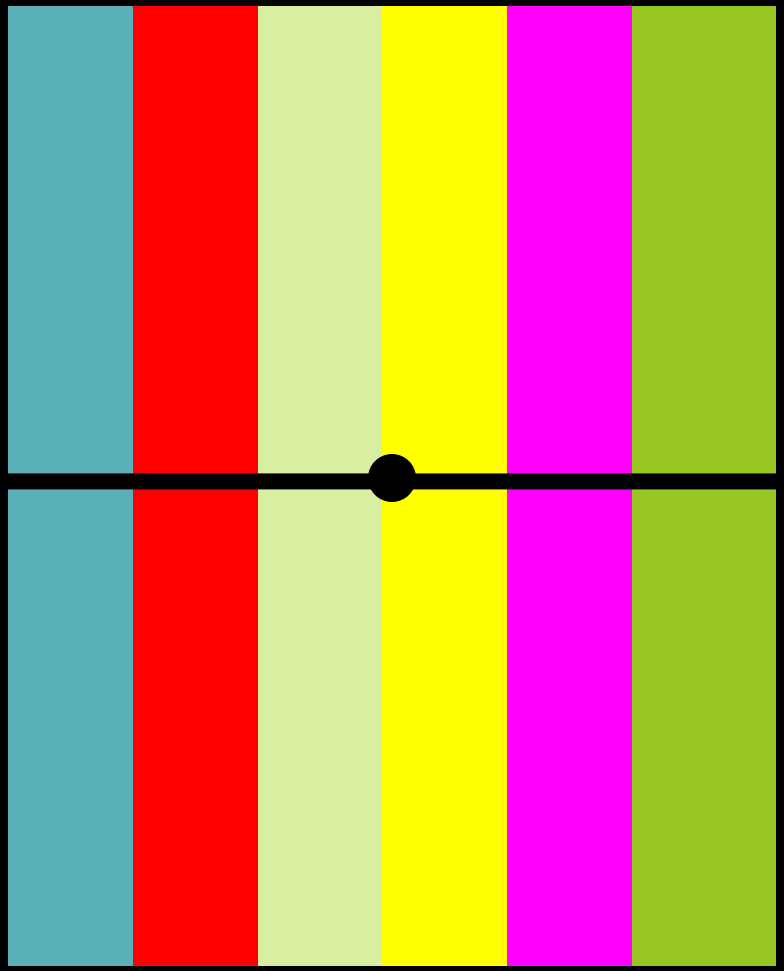
SCREEN: ADDITIVE (R+G)

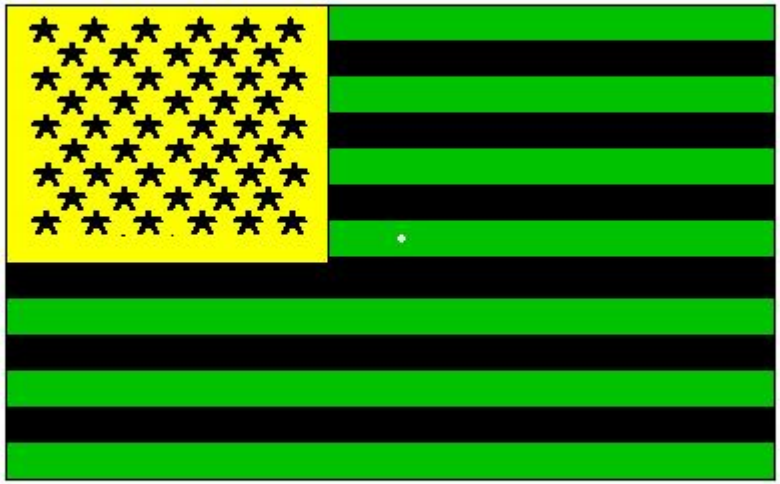
PRINT: SUBTRACTIVE

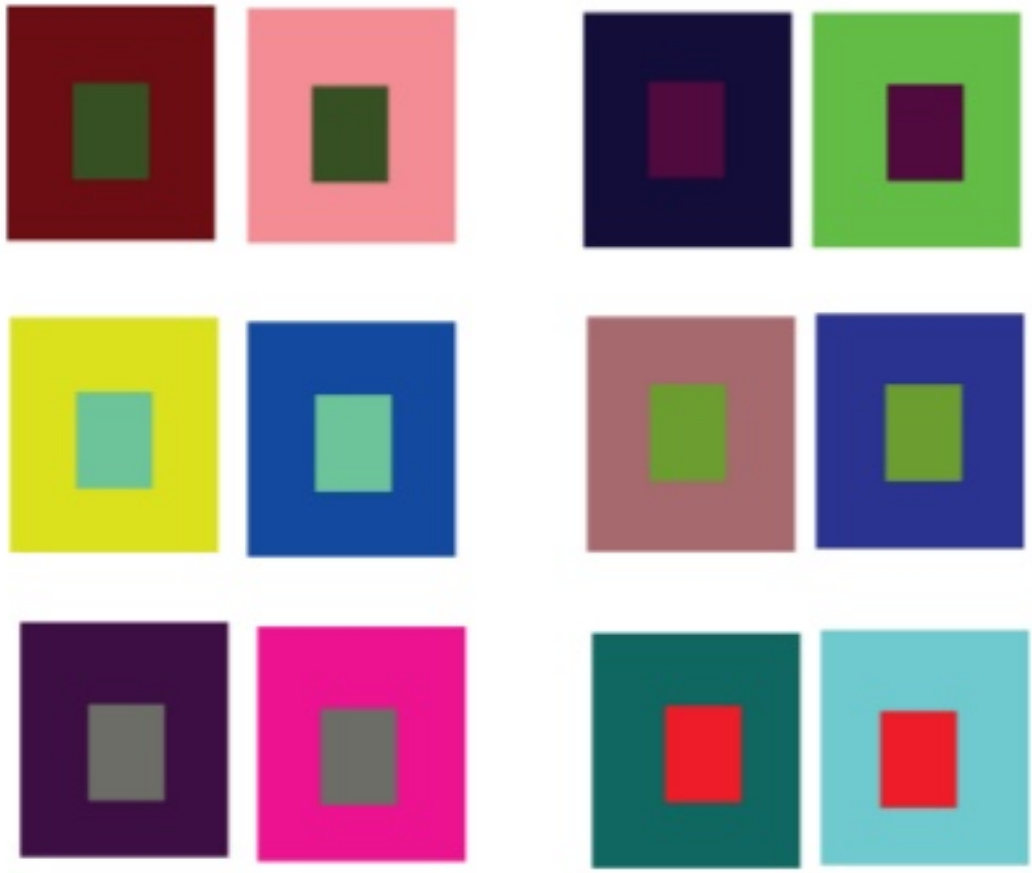

Photo: Andrew Bain

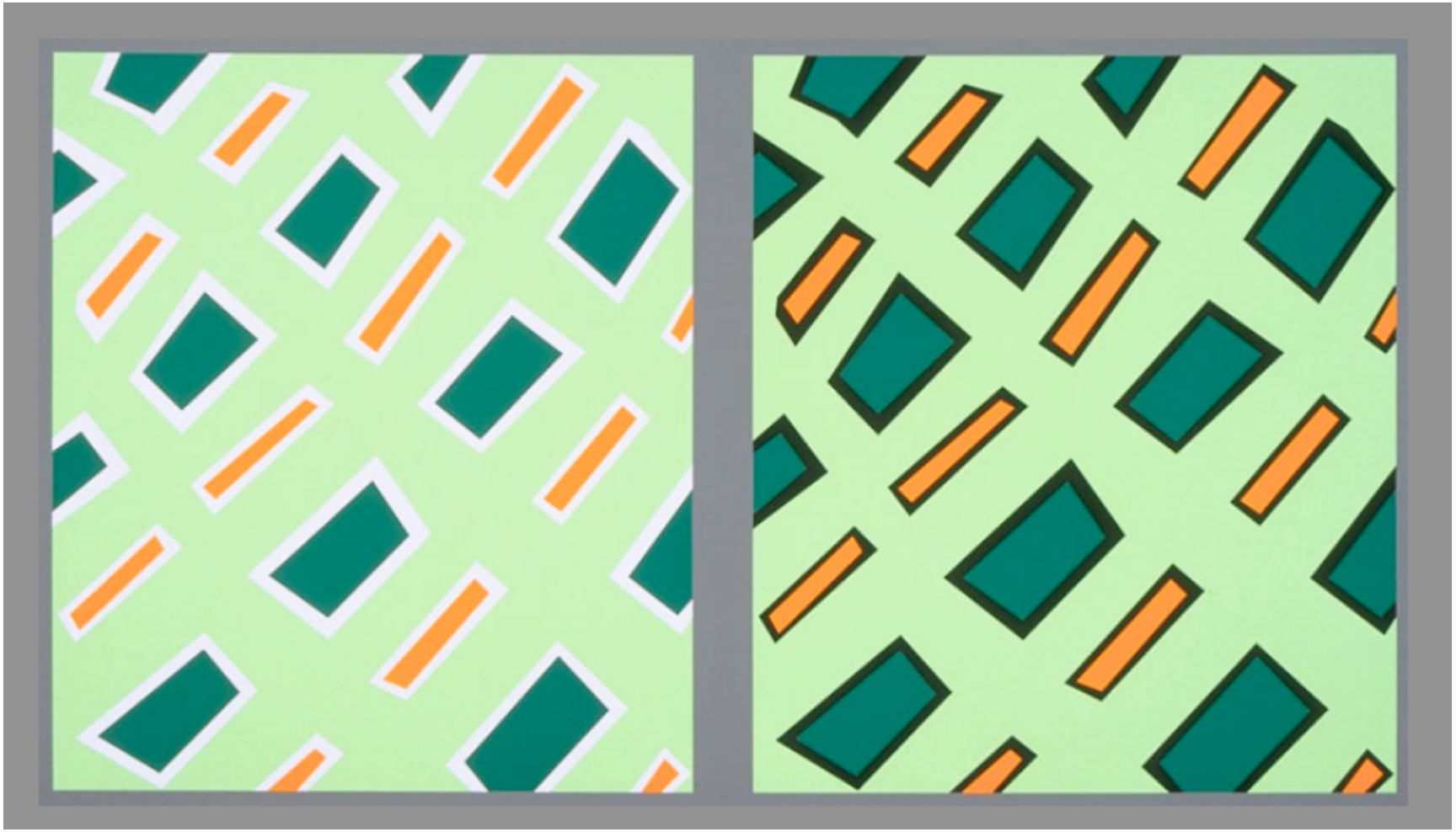
# SOME COLOR ODDITIES












http://visual.ly/color-emotion-guide

# RULE OF THUMB

COLOR: FORM & FUNCTION
QUALITATIVE

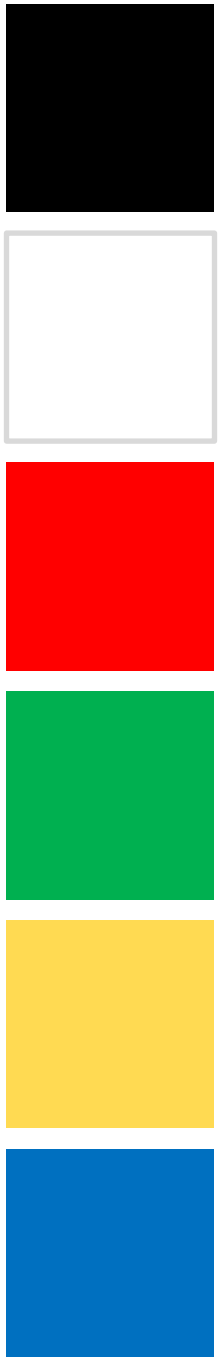
LUMINESCENCE: DEPTH
SLIGHTLY QUANTITATIVE

Image from the most excellent exck.com

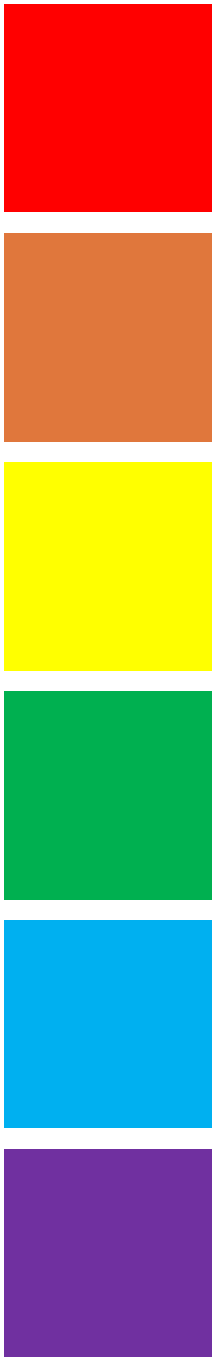
# USING COLOR

Image from the most excellent exck.com

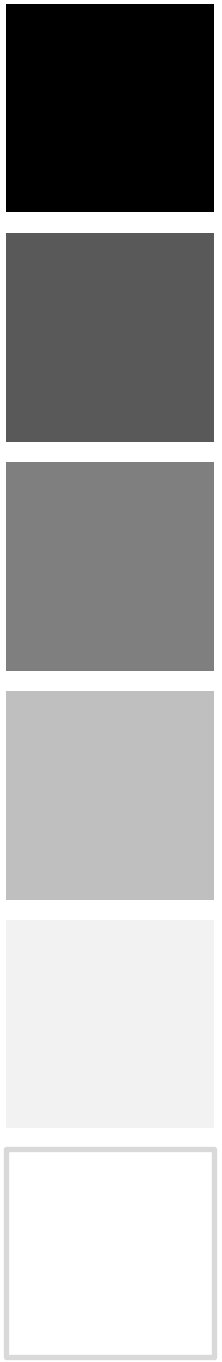
# NOMINAL



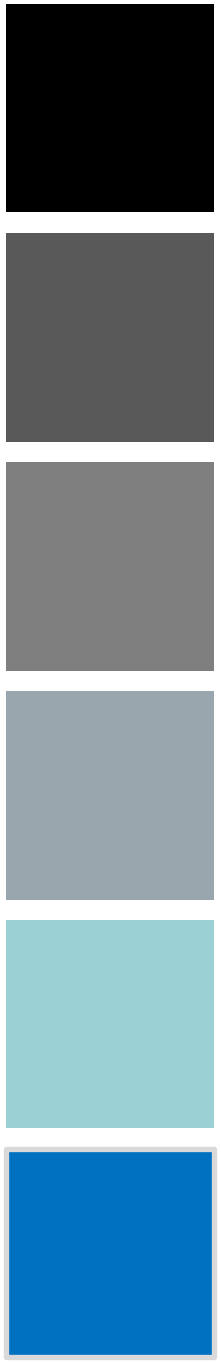
# ORDINAL



# ORDINAL / SEQUENTIAL



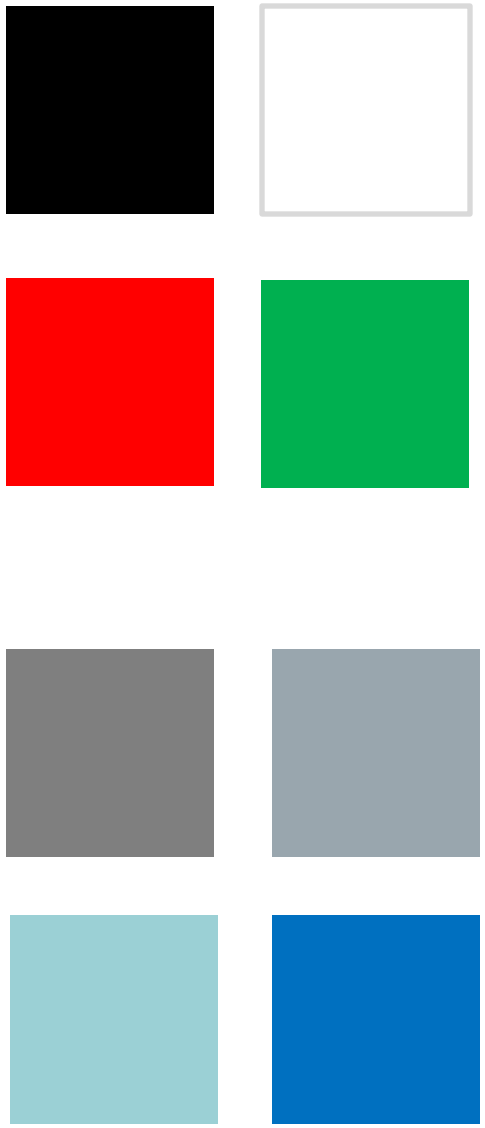
# DIVERGENT



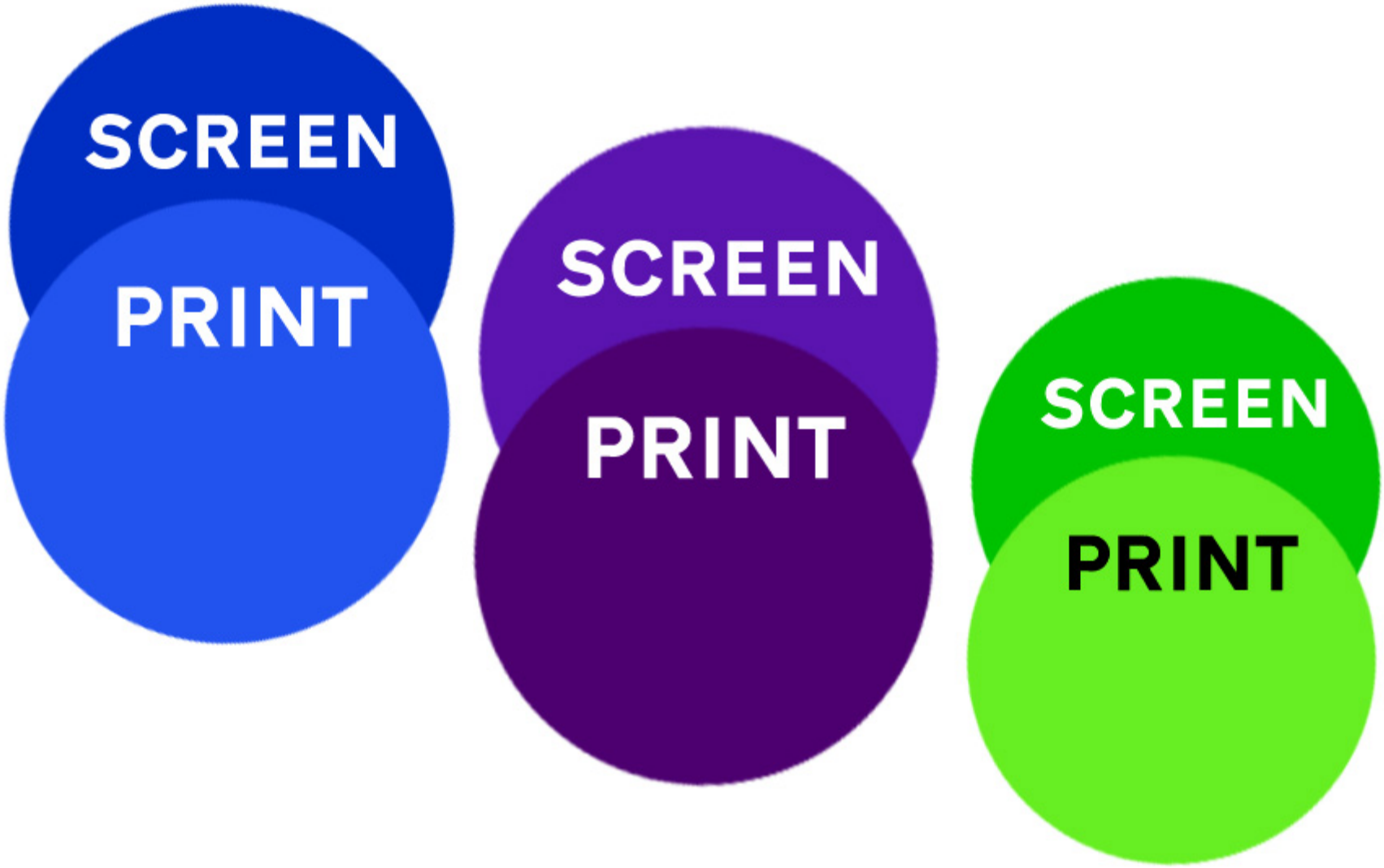
# SEQUENTIAL

Zeilis et al 2009

# SEPARABLE INTEGRAL



Zeilis et al 2009


SCREEN
PRINT
SCREEN
PRINT
SCREEN
PRINT

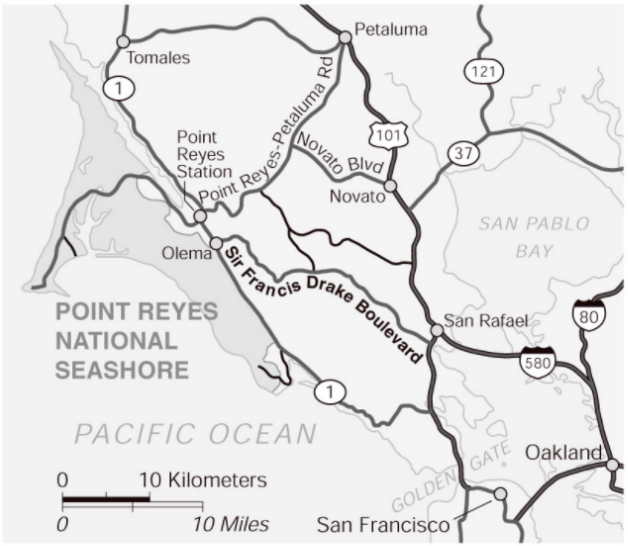
# DON'T DO THIS!

- Avoid loud, garish colors...dark text on light background or vice versa is best.
- Avoid text colors that fade into background, i.e. blue and black
- Avoid color-blind combinations:
  - Red and green
  - Blue and yellow


CHECK LUMINANCE & COLOR IN GRAYSCALE

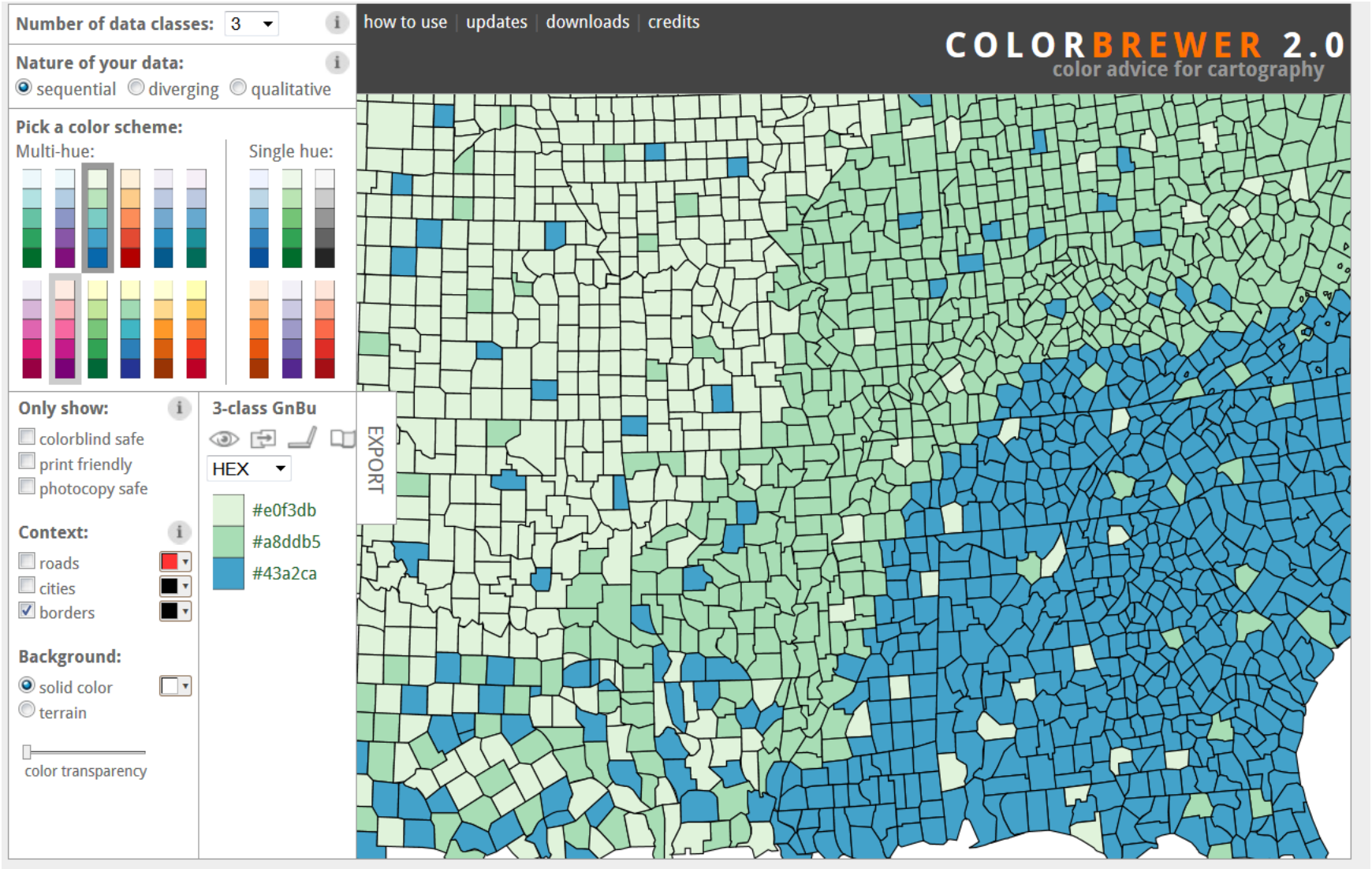
# “Get It Right in Black and White”

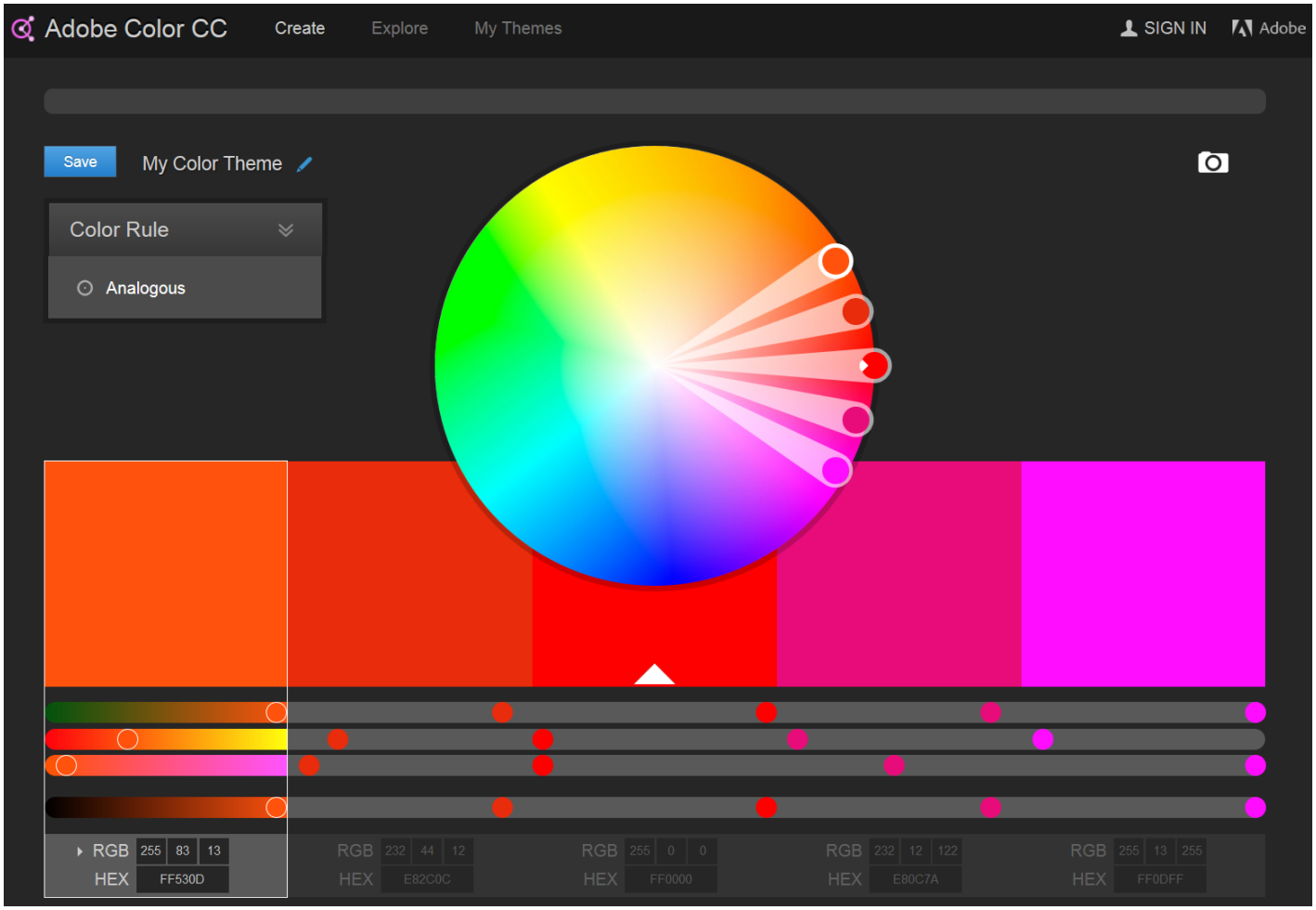
M. Stone

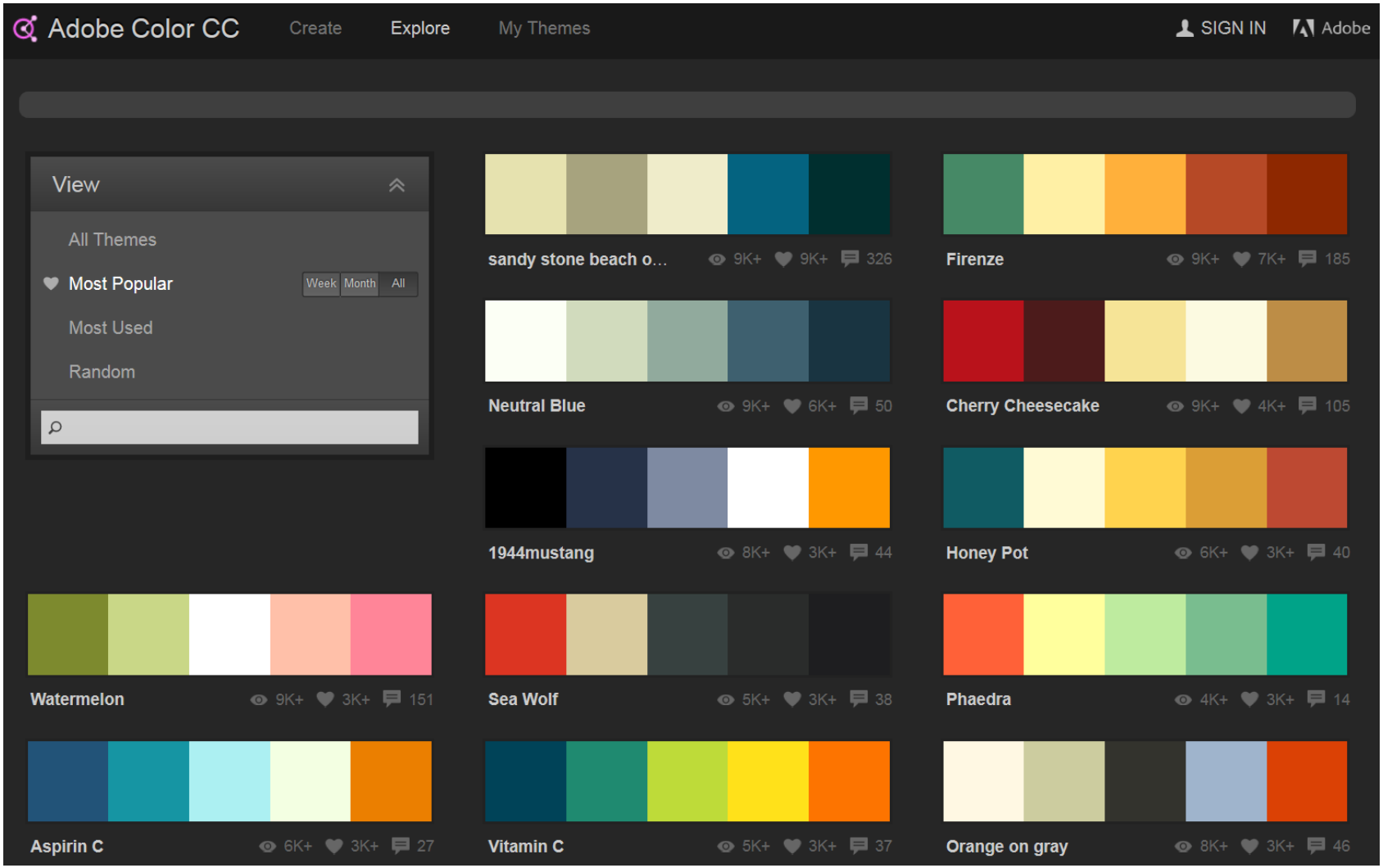

Hanspeter Pfister, quoting Stone

Colin Ware – Maps in B&W Beware! Fig 3.8


how to use | updates | downloads | credits
COLORBREWER 2.0
color advice for cartography
Number of data classes: 3
Nature of your data:
sequential diverging qualitative
Pick a color scheme:
Multi-hue:
Single hue:
Only show:
colorblind safe
print friendly
photocopy safe
Context:
roads
cities
borders
Background:
solid color
terrain
color transparency
3-class GnBu
HEX
#e0f3db
#a8ddb5
#43a2ca
EXPORT




https://color.adobe.com/create/color-wheel/




https://color.adobe.com/create/color-wheel/

# RESOURCES

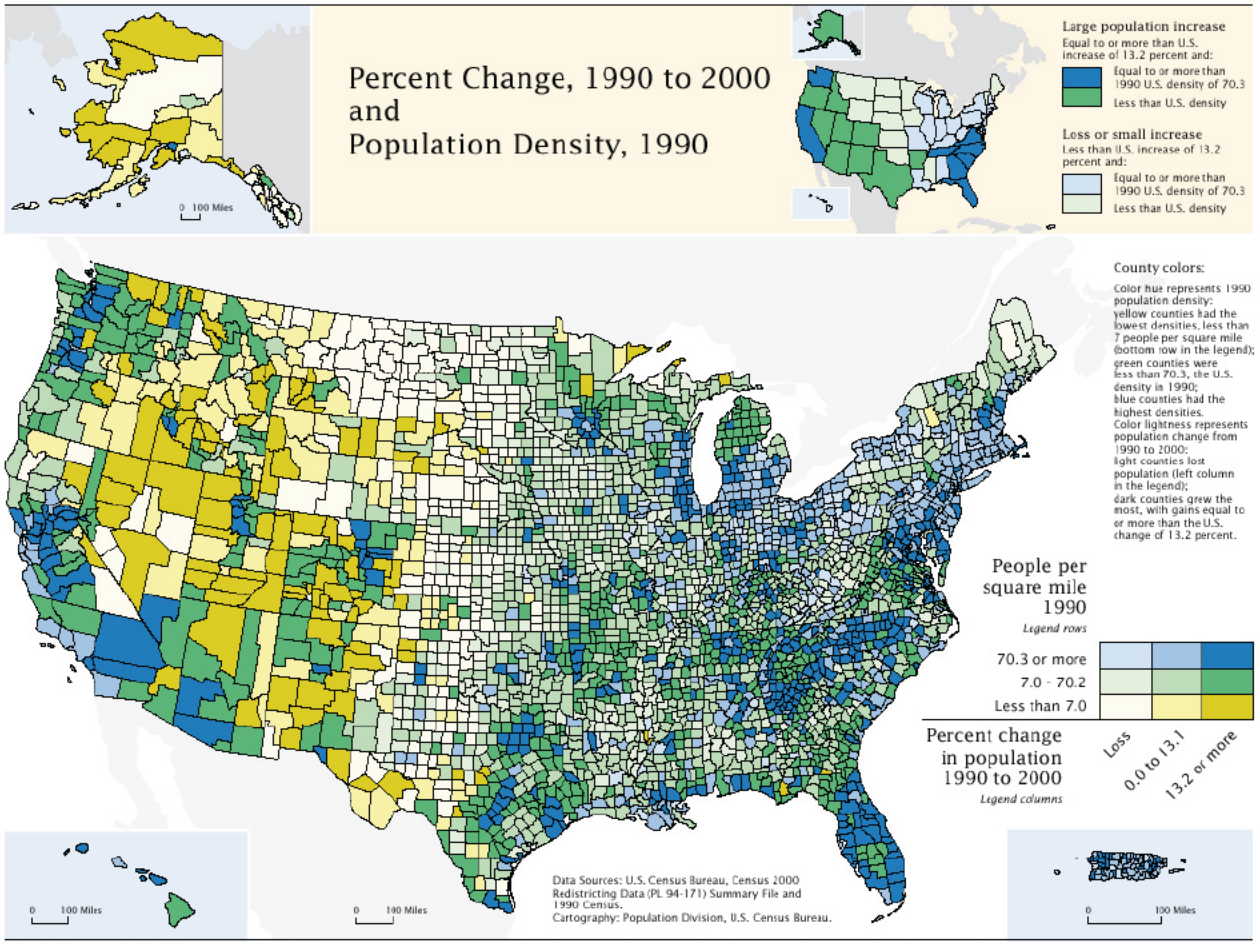
HTTP://WWW.COLOR-BLINDNESS.COM

HTTP://WWW.VISCHECK.COM/

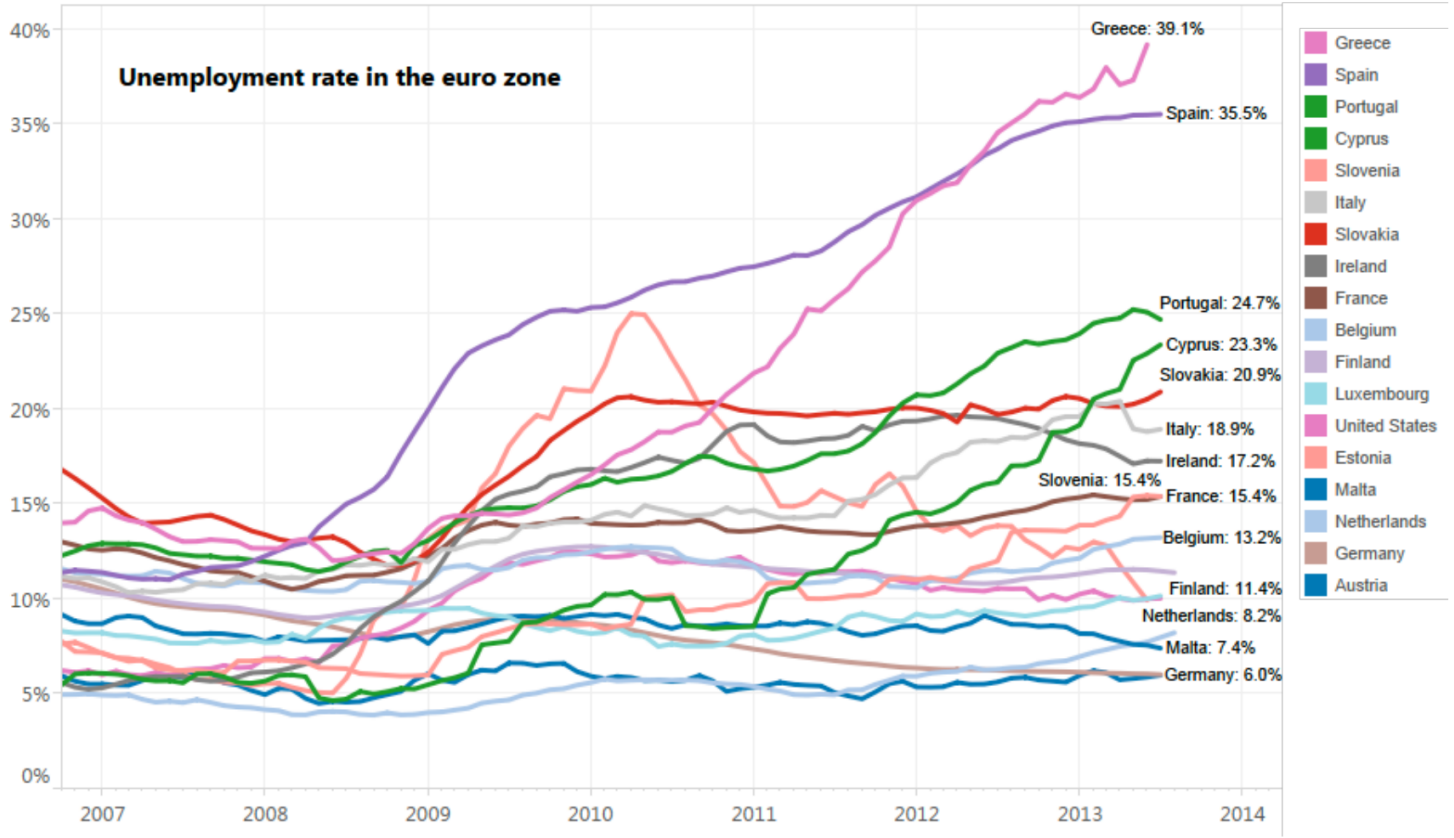
HTTP://COLOR.ADOBE.COM

# COLOR ABUSE

Image from Colin Ware




From the 1st lecture!



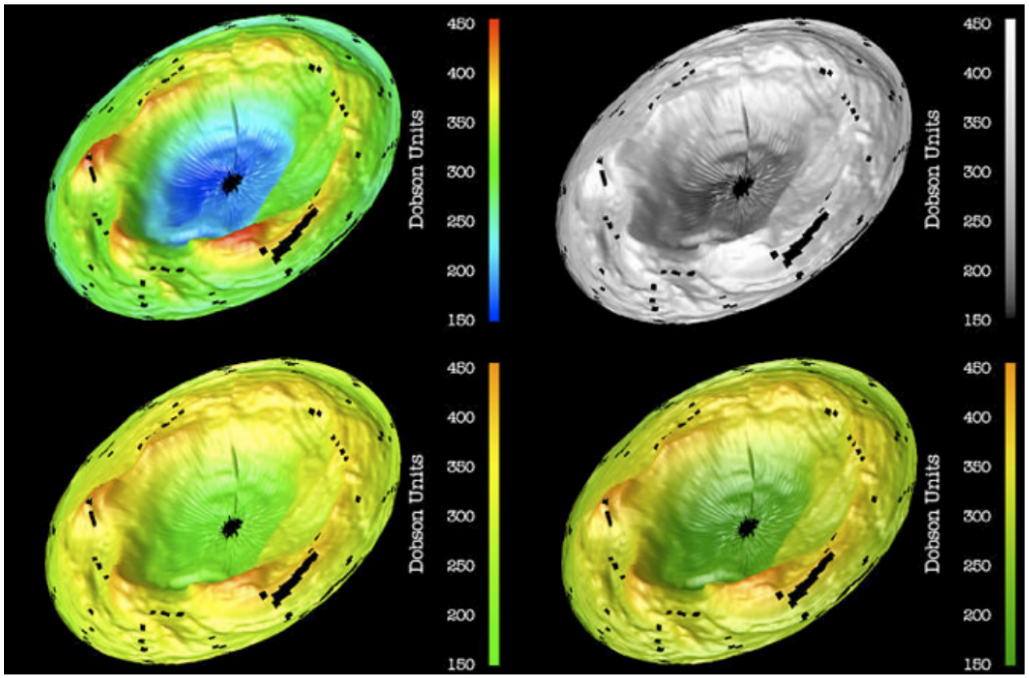

Jim Wahl, 2014

# COLOR USE: QUASI QUANT

Image from Colin Ware

HUE:
SKITTLES

HUE:
BIVARIANT



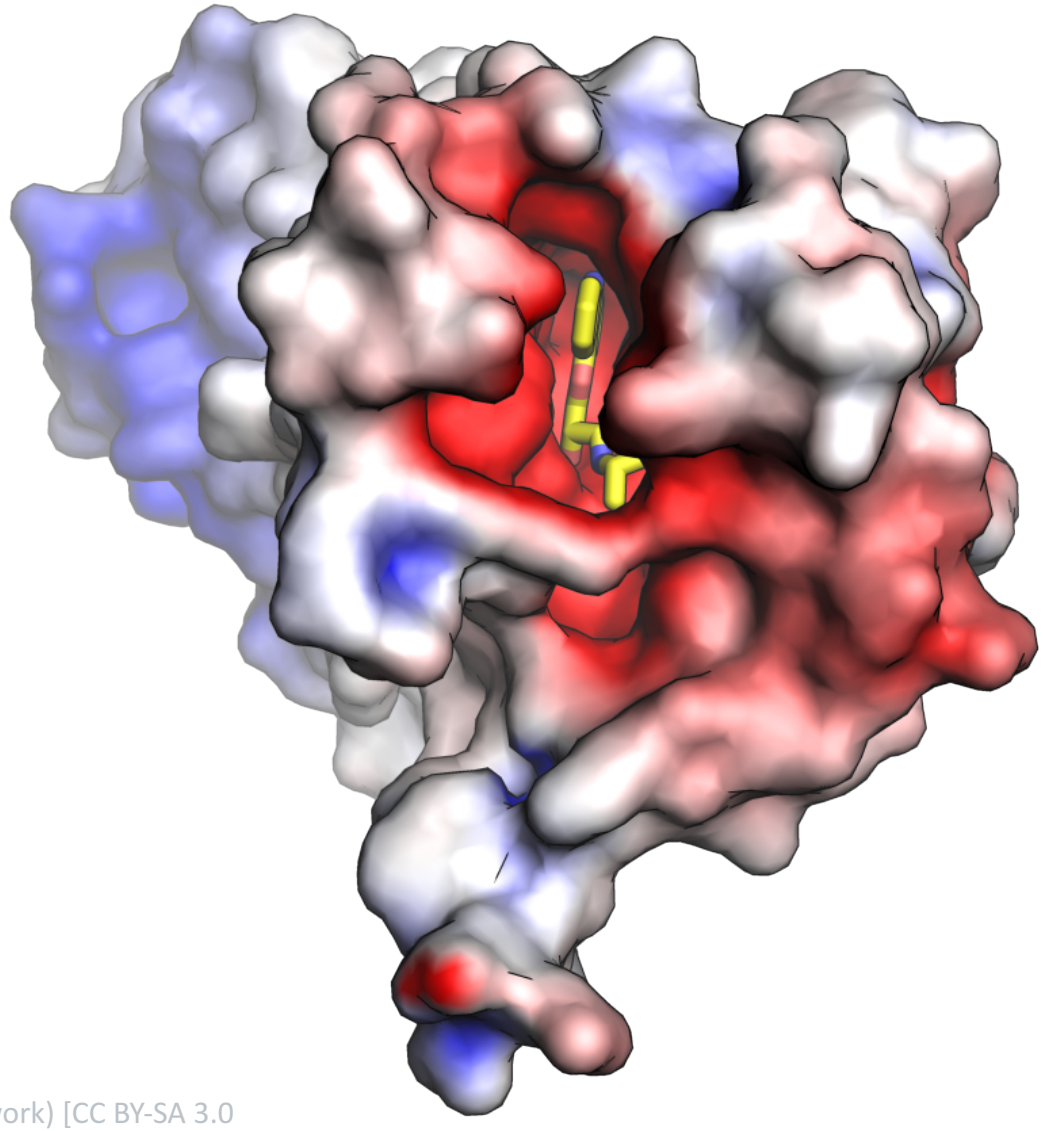

LUMINESCENCE

HUE +
LUMINESCENCE

Rogowitz and Treinish, Why should engineers and scientists be worried about color?

# COLOR USE: FIELD NORMS

Image from Colin Ware



What’s your field norm?

What’s your field norm?

"AVOIDING CATASTROPHE BECOMES THE FIRST PRINCIPLE IN BRINGING COLOR TO INFORMATION: ABOVE ALL, DO NO HARM."

Tufte, Envisioning Information