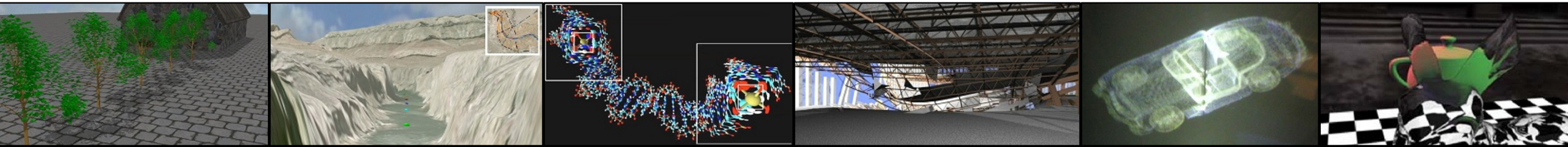
CIS 4930/6930-002
DATA VISUALIZATION

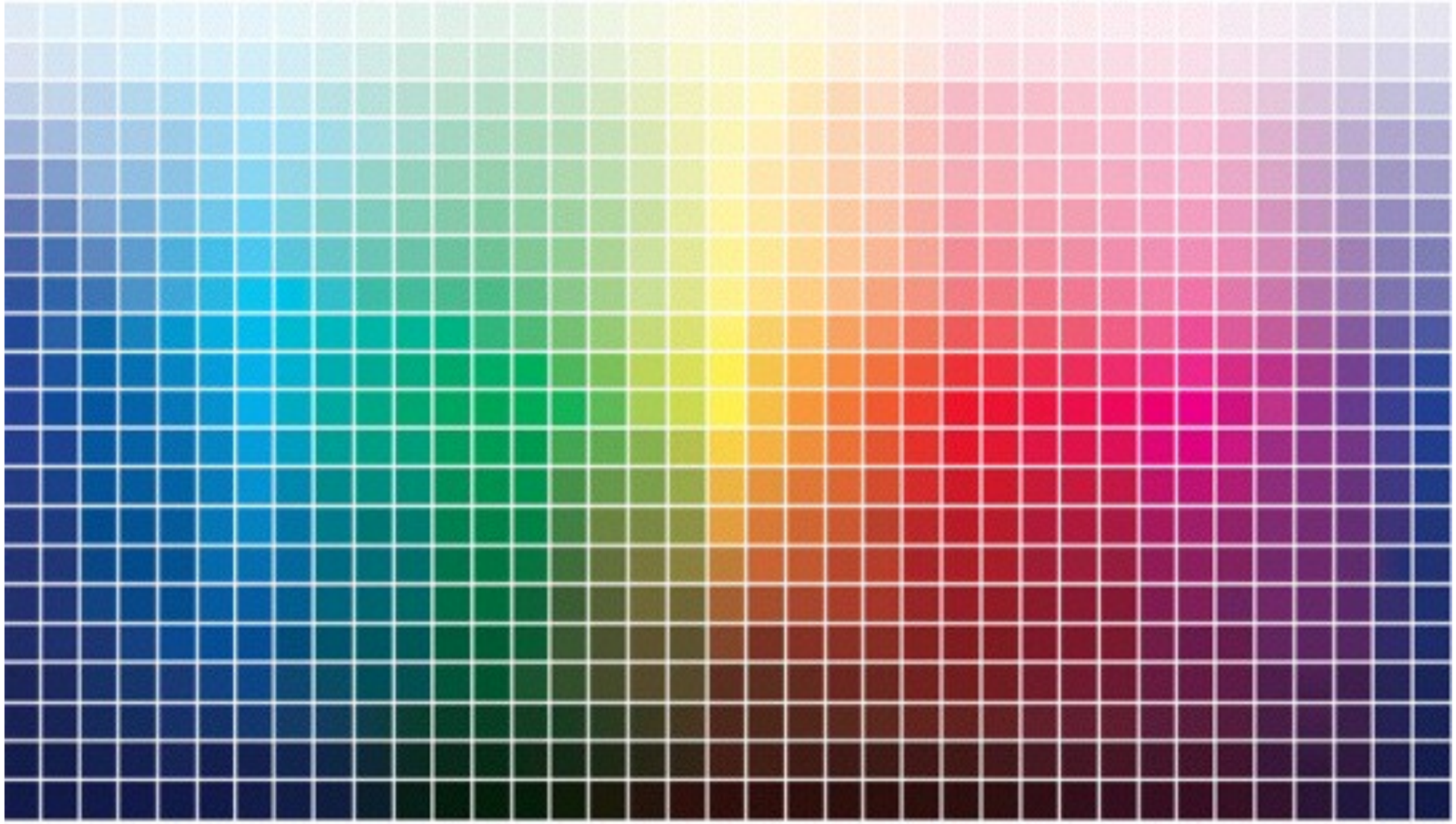
COLOR

Paul Rosen
Assistant Professor
University of South Florida

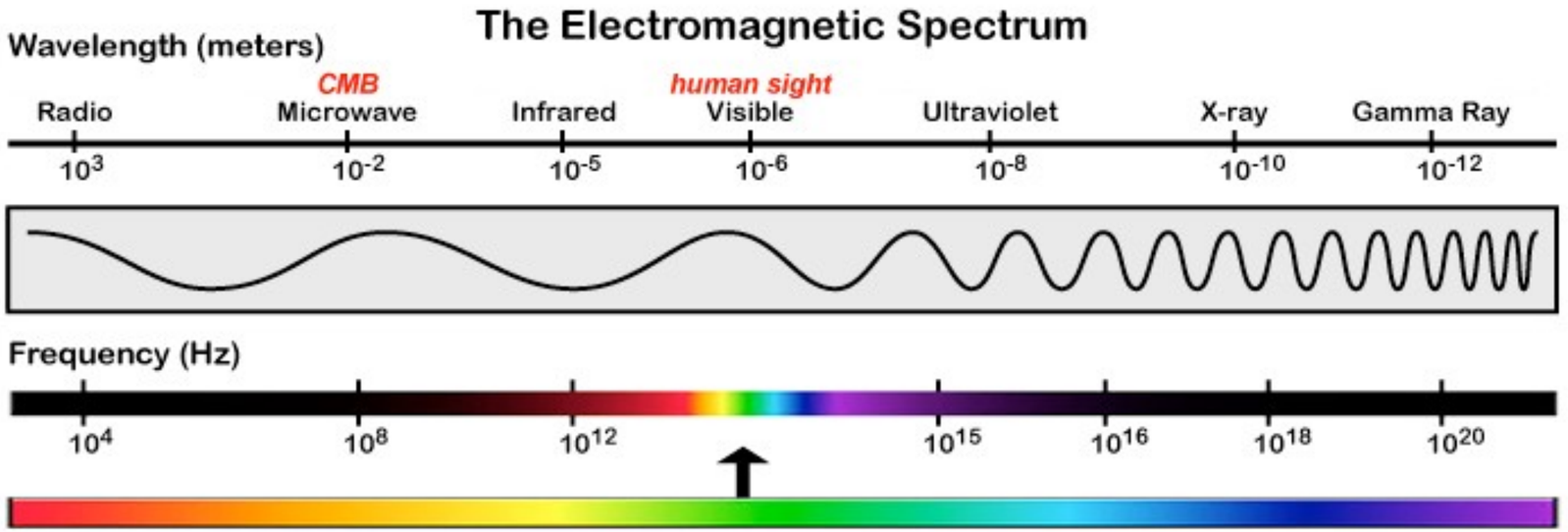
slides credits Chris Johnson (U of Utah), Hanspeter Pfister (Harvard), BangWong (Broad Institute), Miriah Meyer (U of Utah)



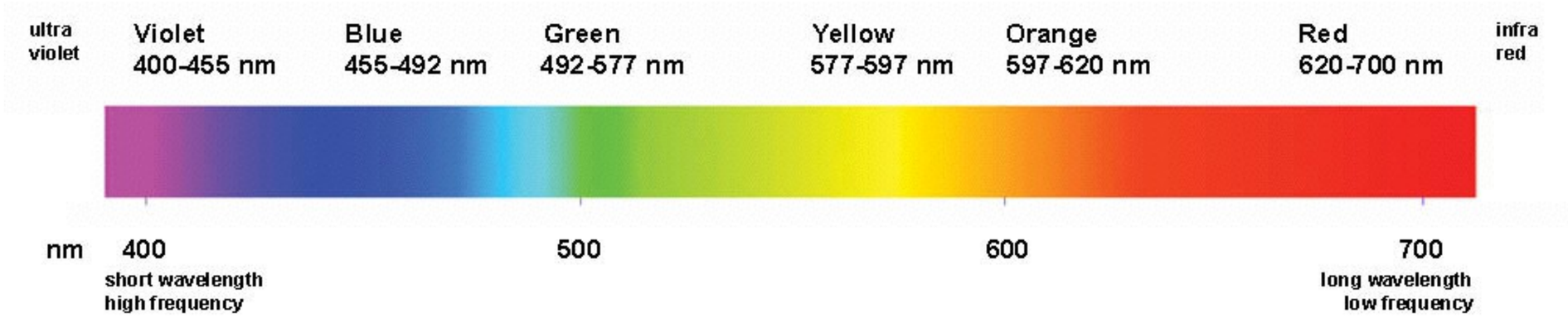
Color



LIGHT

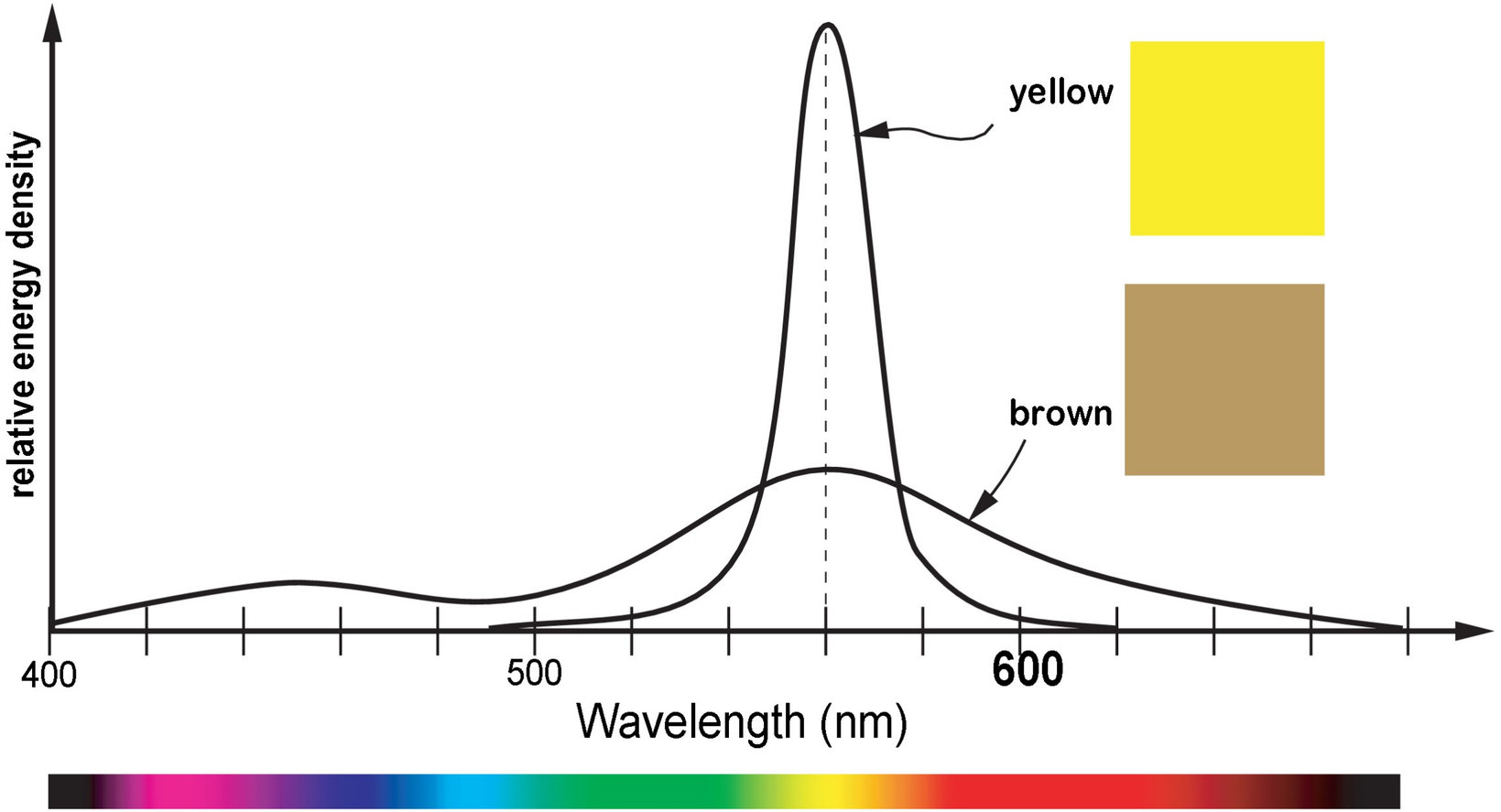

The Electromagnetic Spectrum
Wavelength (meters)
CMB
human sight
Radio
Microwave
Infrared
Visible
Ultraviolet
X-ray
Gamma Ray
10^{3}
10^{-2}
10^{-5}
10^{-6}
10^{-8}
10^{-10}
10^{-12}
Frequency (Hz)
10^{4}
10^{8}
10^{12}
10^{15}
10^{16}
10^{18}
10^{20}

(HUMAN) VISIBLE LIGHT

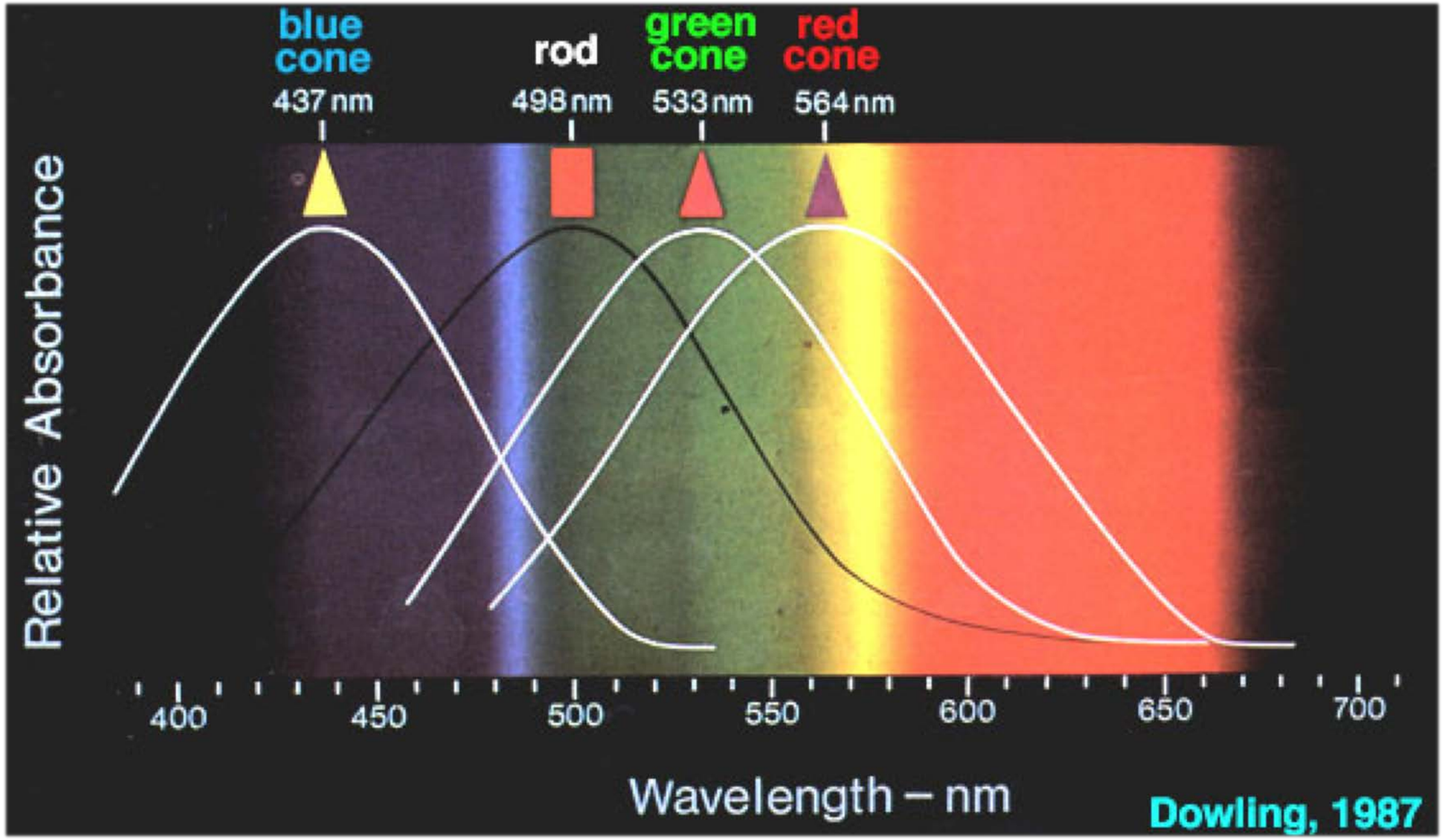


COLOR != WAVELENGTH

but rather, a combination of wavelengths and energy



Cone Response



RADIOLAB
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Rippin' the Rainbow a New One

« Back to Episode

00:30 / 19:37

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(jared/flickr/CC-BY-2.0)

We tear into this show with a dark scene from 1665. A young Isaac Newton, hoping to ride out the plague by heading to the country to puzzle over the deep mysteries of the universe, finds himself wondering about light. And vision. He wants to get to the bottom of where color comes from--is it a physical property in the outside world, or something created back inside your eyeball somewhere? **James Gleick** explains how Newton unlocked the mystery of the rainbow. And, as **Victoria Finlay** tells us, sucked the poetry out of the heavens.

Jonah Lehrer restores some of the lost magic by way of Goethe--who turned a simple observation into a deep thought; even though color starts in the

PODCAST SUPPORT

Latest Comments

What a fascinating story! I found it interesting as some aspects of it reminded me of the conflict in Gaza ...

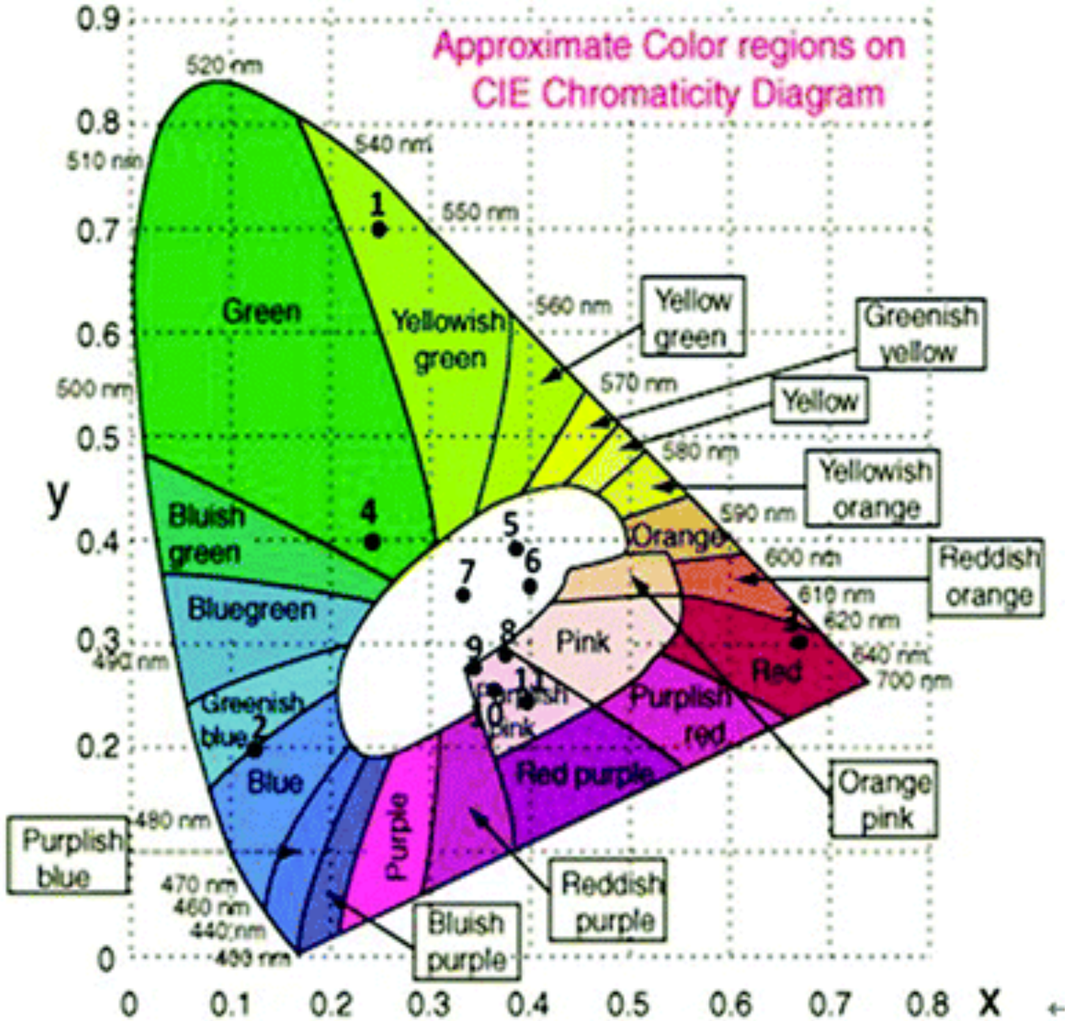
Benny
on Fu-Go

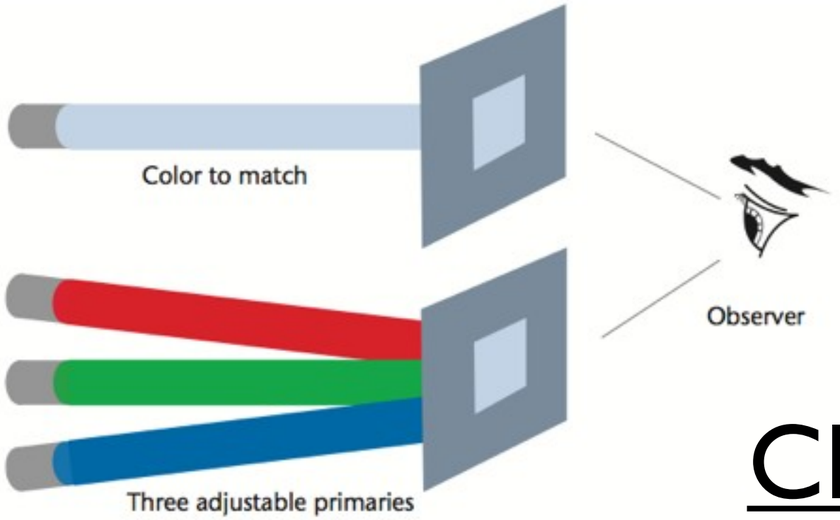
The Most

Viewed | Listened | Commented

COLOR ABSTRACTION, REPRESENTATION

SPACE OF HUMAN COLOR





CIE COLOR SPACE

CIE (International Commission on Illumination)

standardized a set of color-matching functions that form the basis for most color measurement instruments

experiments done in the 1920's and 1930's

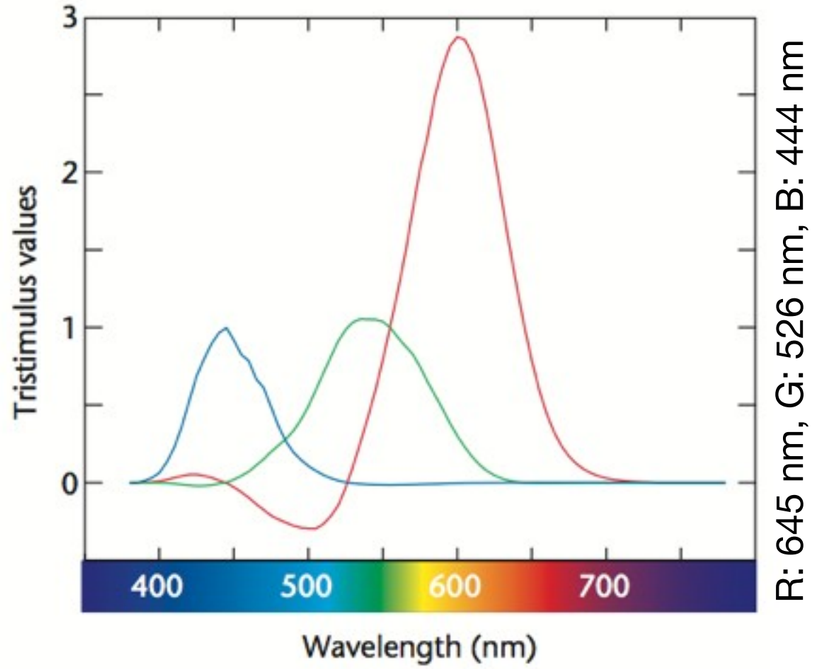
humans can mimic any pure (visible) light by addition and subtraction of three primary lights

CIE COLOR SPACE

with RGB, addition and subtraction were required to get all visible wavelengths

in nature, light adds (but does not subtract)

any three primaries (additive) can produce only a subset of all visible colors

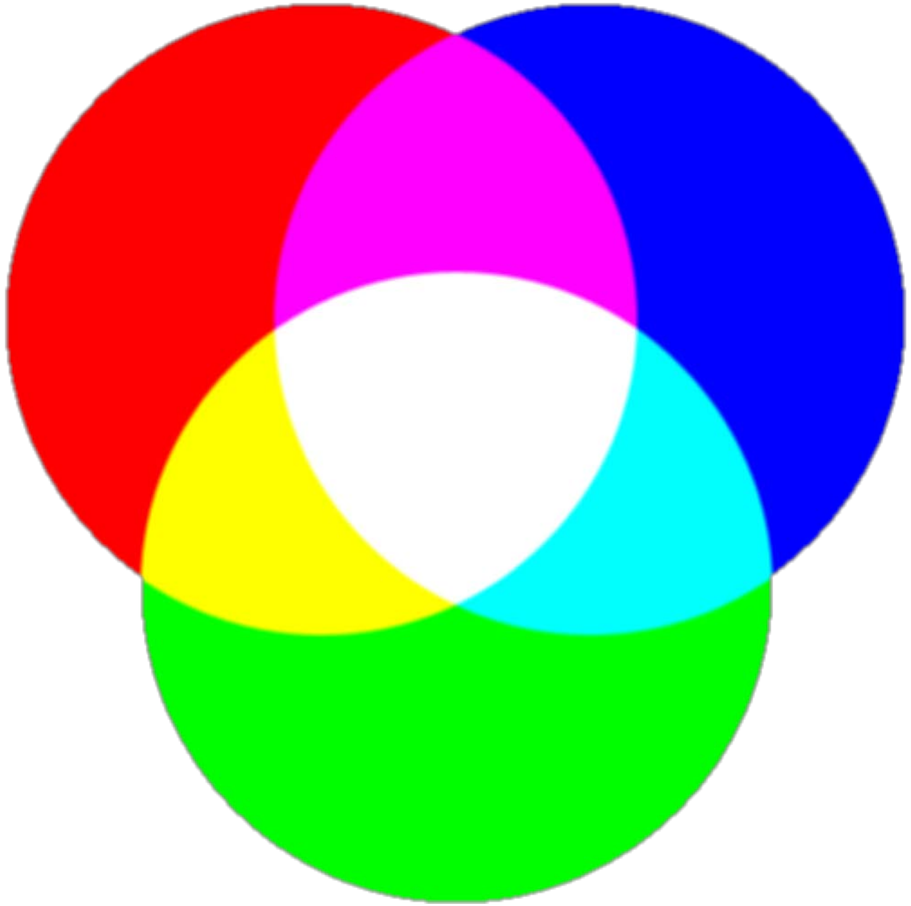


ADDITIVE COLOR

(like we see in light)

primary: RGB

secondary: CMY

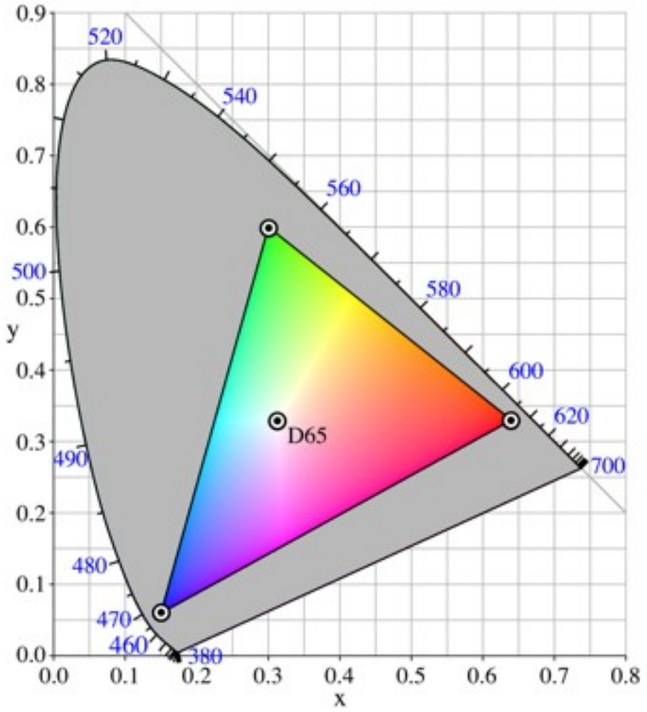


RGB COLOR SPACE

very common color space

not perceptually uniform

actual color is device-dependent

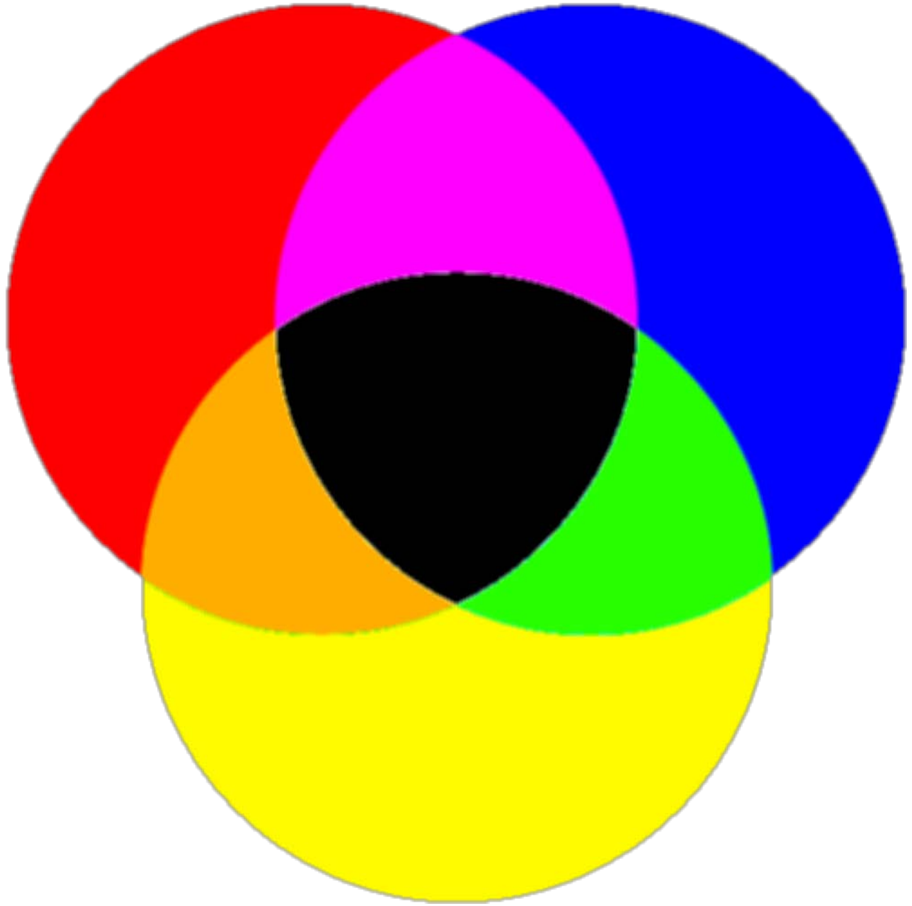


SUBTRACTIVE COLOR

(used in painting)

primary: RYB

secondary: OGV



SUBTRACTIVE COLOR

(used in print ink)

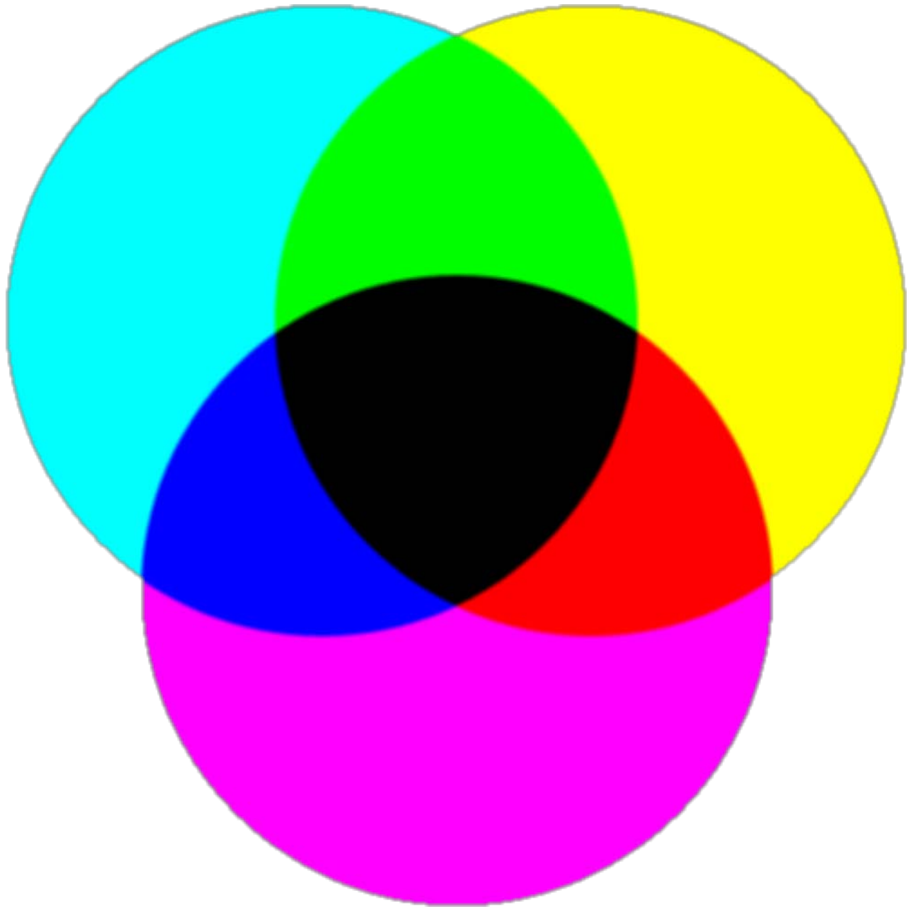
primary: CMY

secondary: RGB

approx black = C+M+Y

true black = C+M+Y+K

actual color is device-dependent



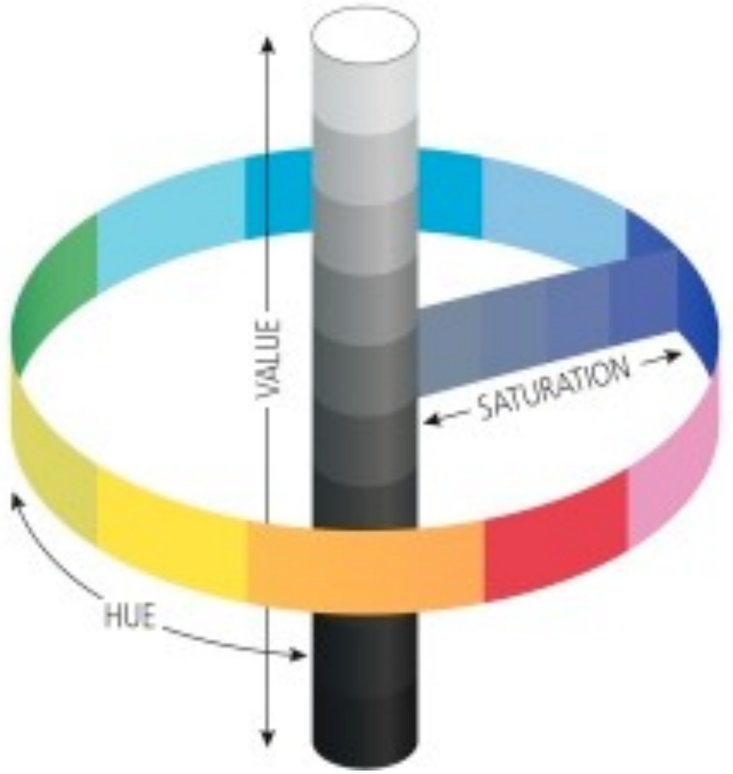
HSV [B, L, I] (ADDITIVE)

Hue, Saturation, [Value, Brightness, Lightness, Intensity]

polar coordinate representations of RGB space

conical or cylindrical shaped space

more intuitive than RGB for color tuning



HSV [B, L, I] (ADDITIVE)

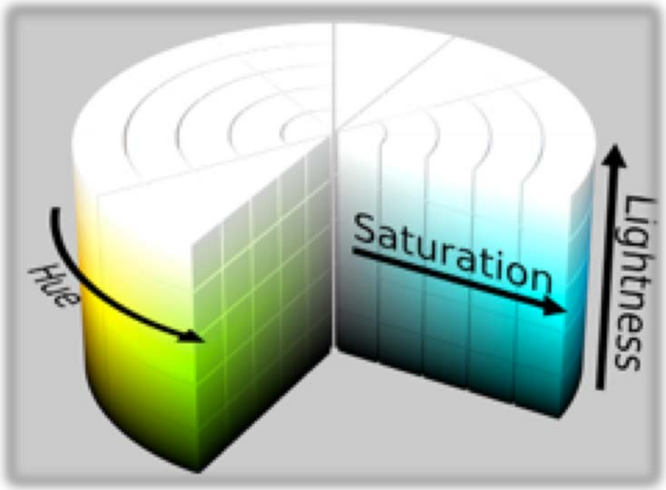
hue: what people think of as color

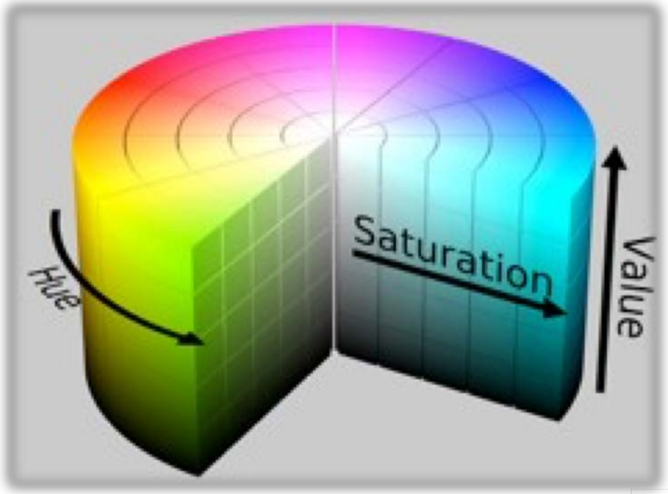
saturation: amount of white mixed in

luminance: amount of black mixed in

lightness vs value (or brightness)

intensity, in computer vision applications





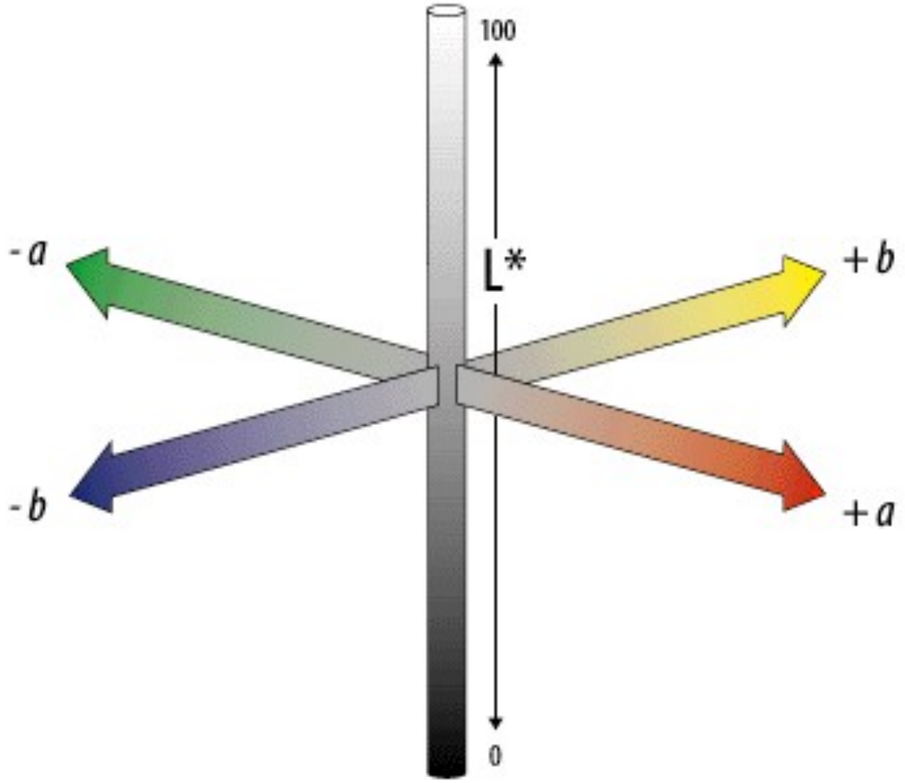
CIE LAB/LUV

mathematically defined & perceptually based to include all perceivable colors

a: red to green

b: yellow to blue

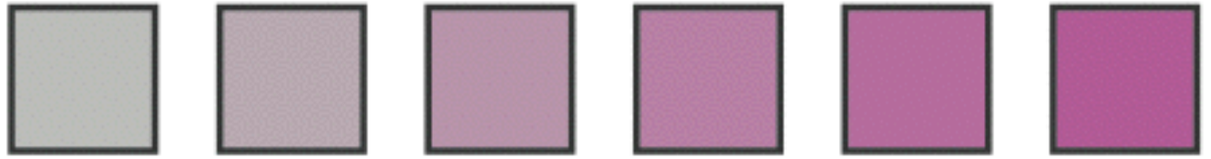
L*: lightness (black to white)



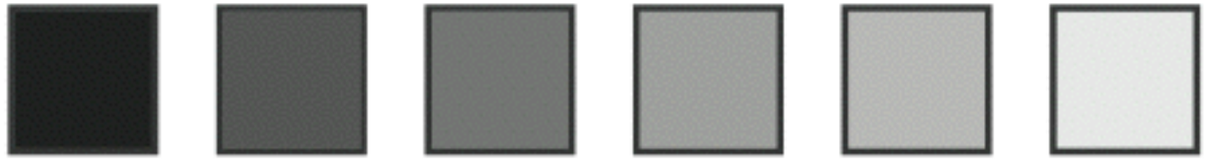
IN THIS CLASS…

hue

saturation



luminance



COLOR DEFICIENCIES & LIMITATIONS

COLOR BLINDNESS

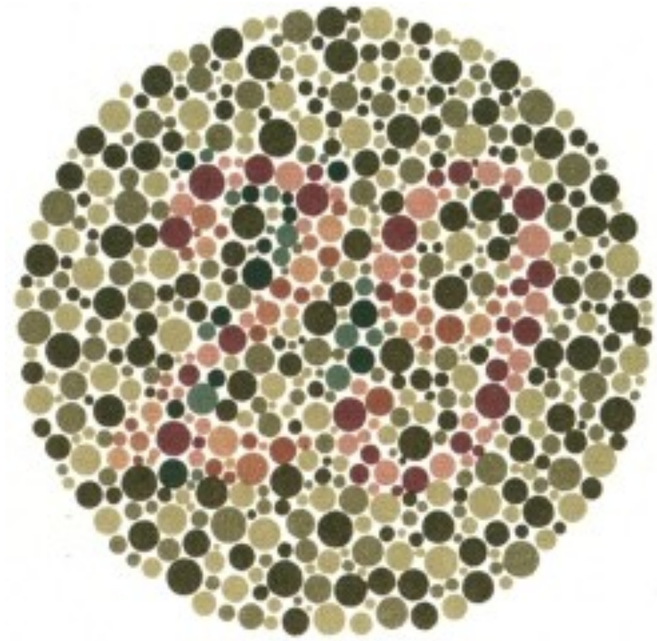
deficiency in color vision

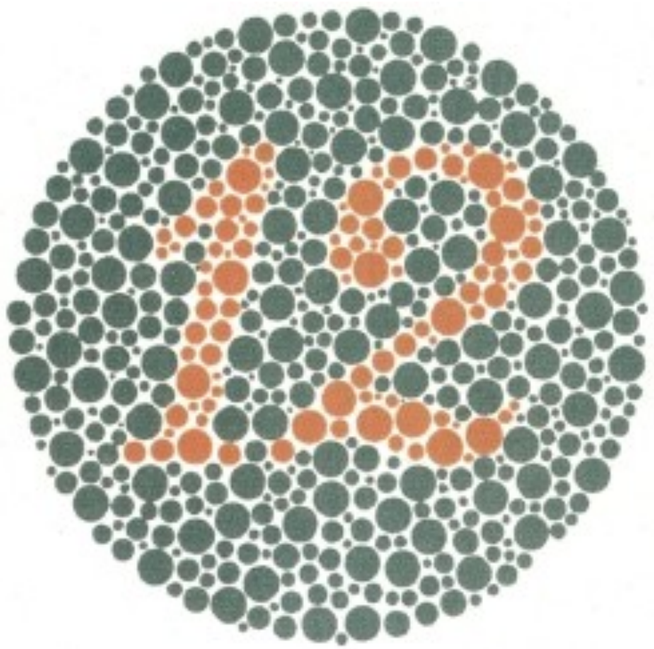
typically caused by faulty cone development

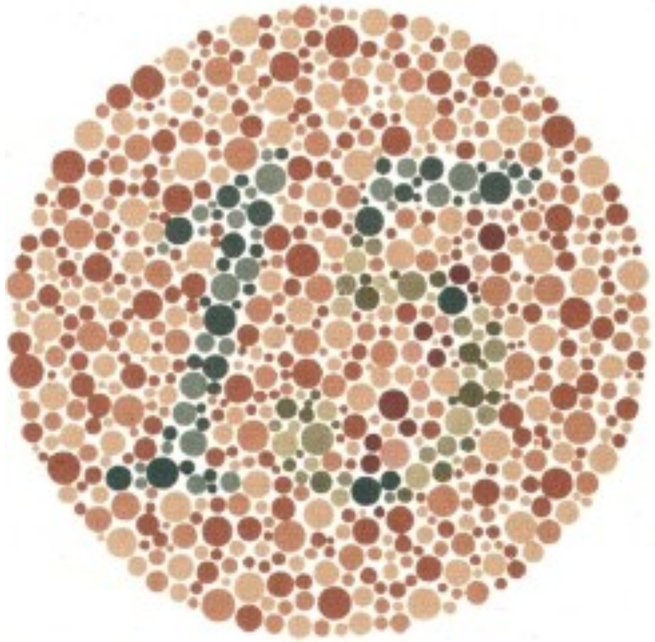
found more in men than women

photopigment genes carried in x-chromosome

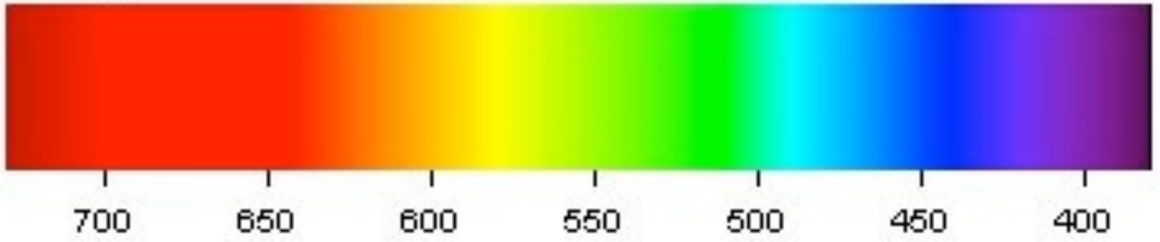
5-8% of men and 0.5% of women



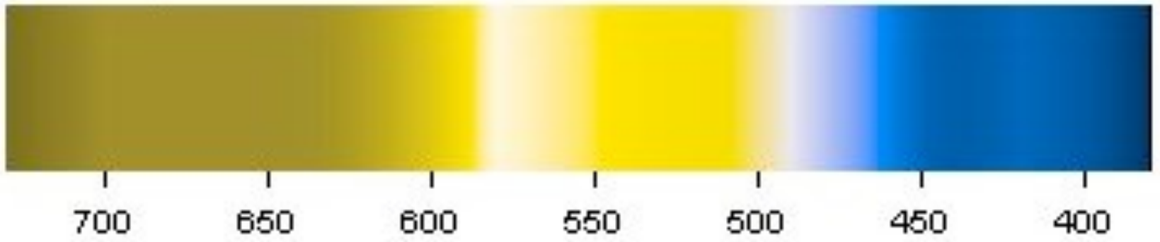




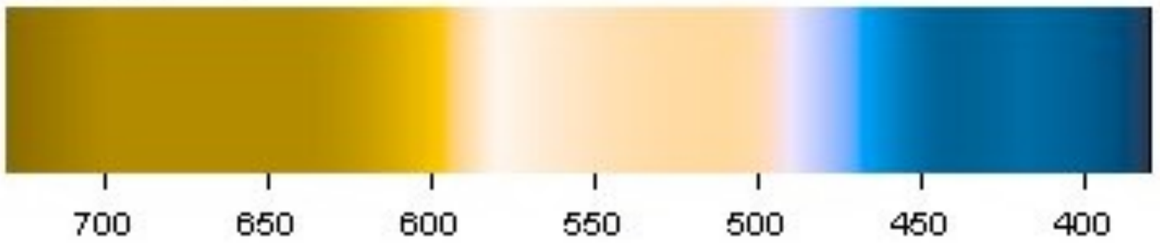
Normal



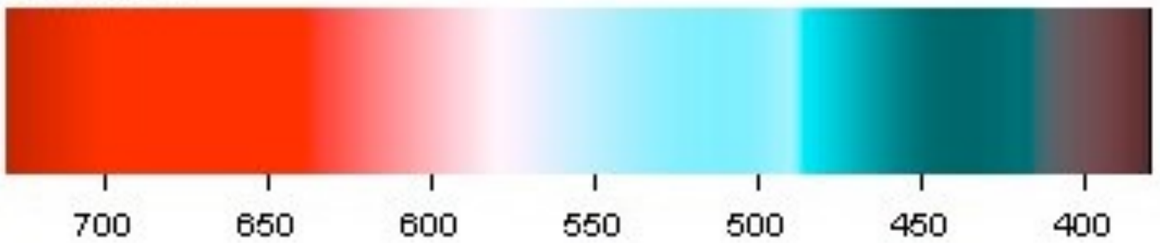
Protanopia

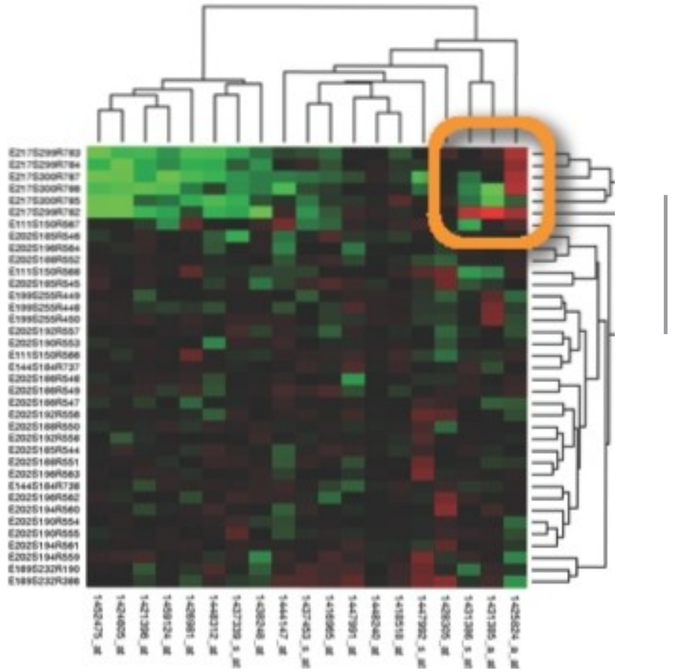


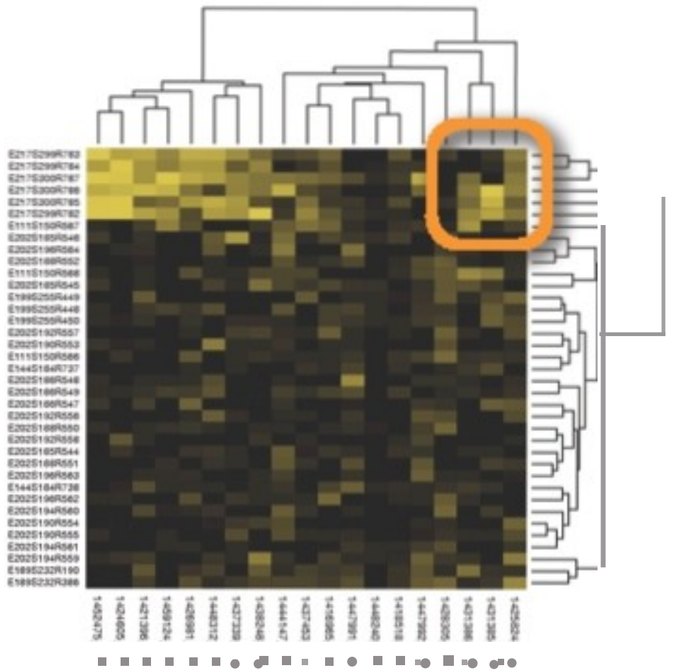
Deuteranopia



Tritanopia







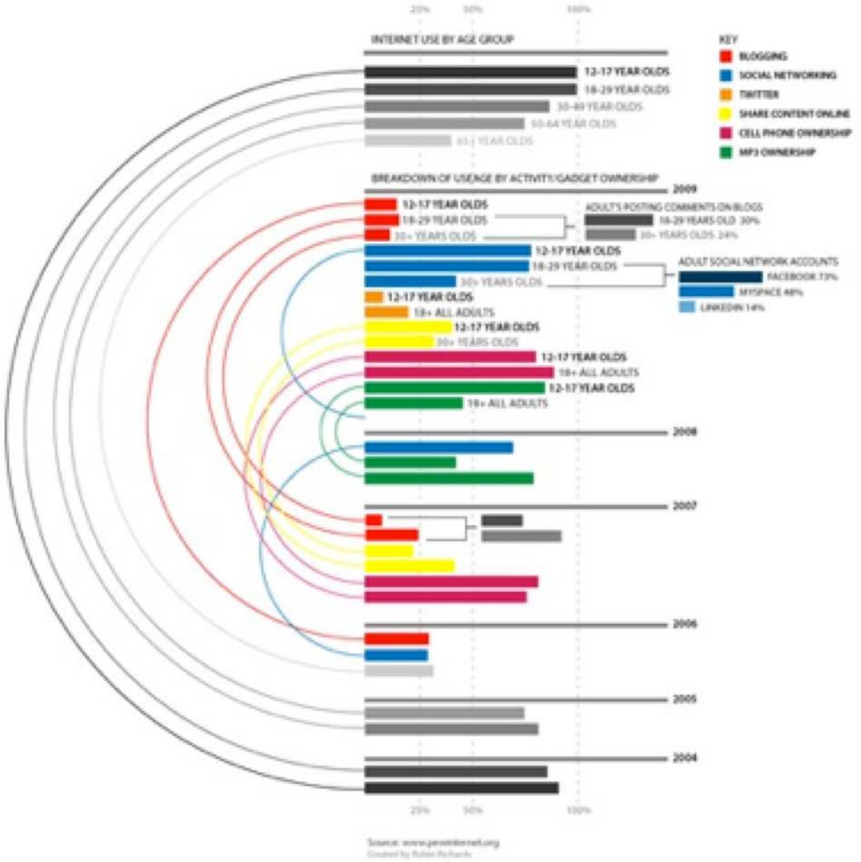
NG

www.ngonlinenews.com

How different age groups are using the internet

With the growth of social media networks such as Facebook and Twitter, traditional blogging has been usurped by micro-blogging quick and short 140 character updates instead of lengthy, in-depth (and sometimes still equally pointless) articles.

However, while teens and young adults seem to be shunning blogging, it is still strong among the over 30s...



Source: www.pewinternet.org

Created by Robin Richards

NG

www.ngonlinenews.com

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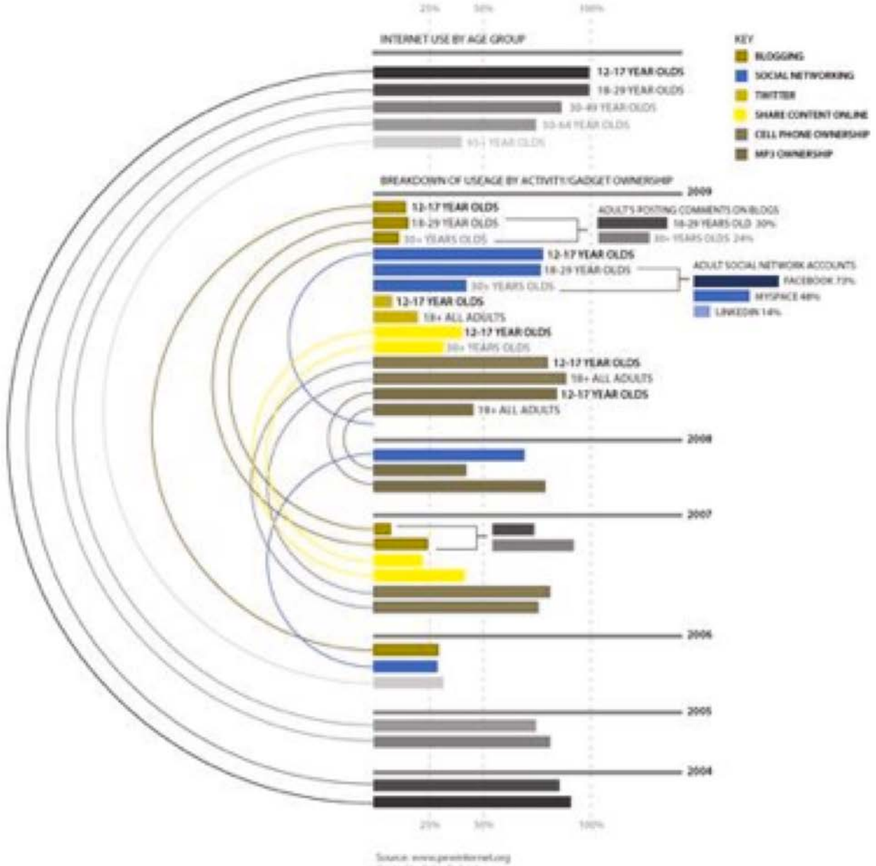


Source: www.pewinternet.org

Created by Robin Richards

MONOCHROMACY

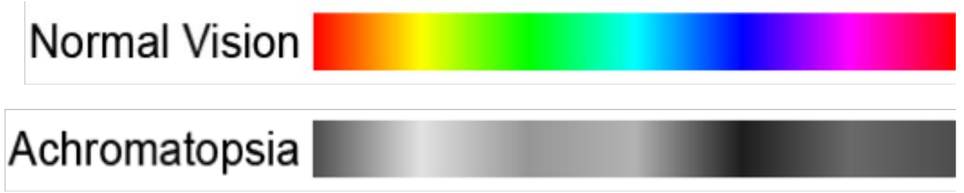
total color blindness, very rare

1 dimensional color vision

2 or 3 cone pigments are missing

rod monochromacy: non-functioning or missing cones (achromatopsia)

cone monochromacy: multiple deficient cones



DICHROMACY

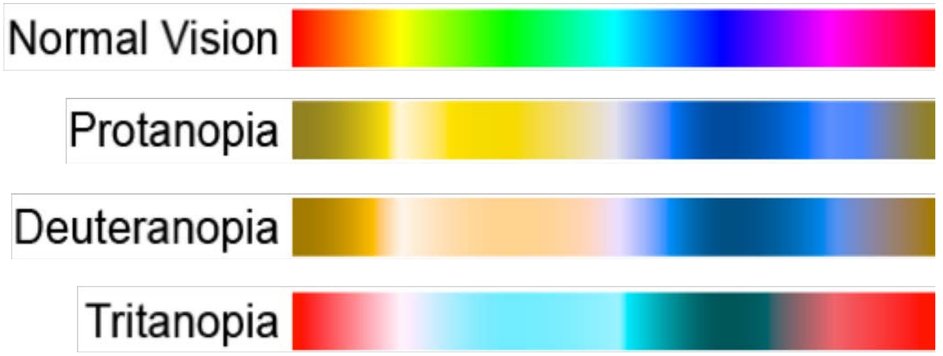
2 dimensional color vision

1 cone pigment is missing

protanopia: absence of red receptors

deuteranopia: absence of green receptors

tritanopia: absence of blue receptors



TYPES: TRICHOMACY

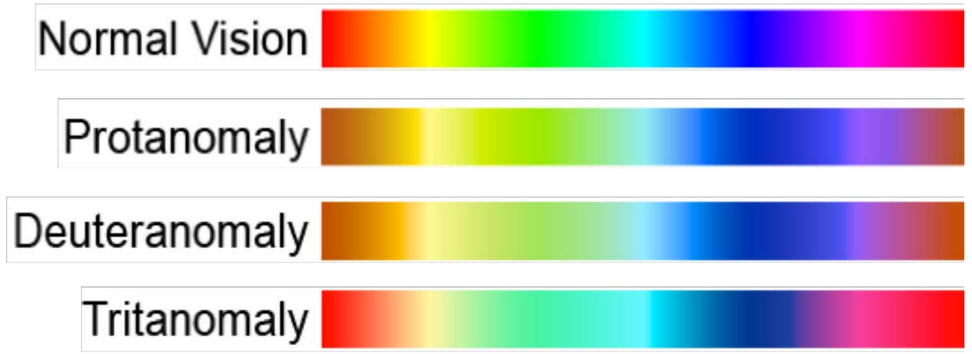
3 dimensional color vision

1 cone is altered in spectral sensitivity—impairment rather than loss

protanomaly: shift in red, poor red-green discrimination

deuteranomaly: shift in green, poor red-green discrimination (most common form of color deficiency)

tritanomaly: poor blue-yellow discrimination



The X-Rite Color Challenge and Hue Test

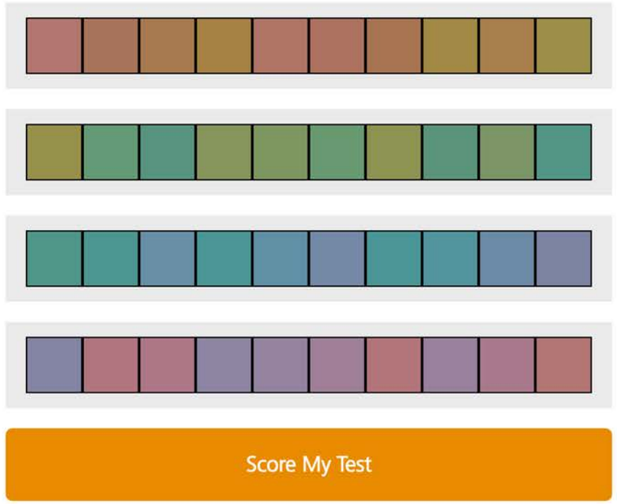
Are you among the 1 in 255 women and 1 in 12 men who have some form of color vision deficiency? If you work in a field where color is important, or you're just curious about your color IQ, take our online challenge to find out. Based on the Farnsworth Munsell 100 Hue Test, this online challenge is a fun, quick way to better understand your color vision acuity.

Just remember, this is not a replacement for the full test!

Directions:

1. The first and last color chips are fixed.
2. Drag and drop the colors in each row to arrange them by hue color.
3. Complete all four color tests.
4. Click 'Score My Test' to review results.

What's My Color IQ?

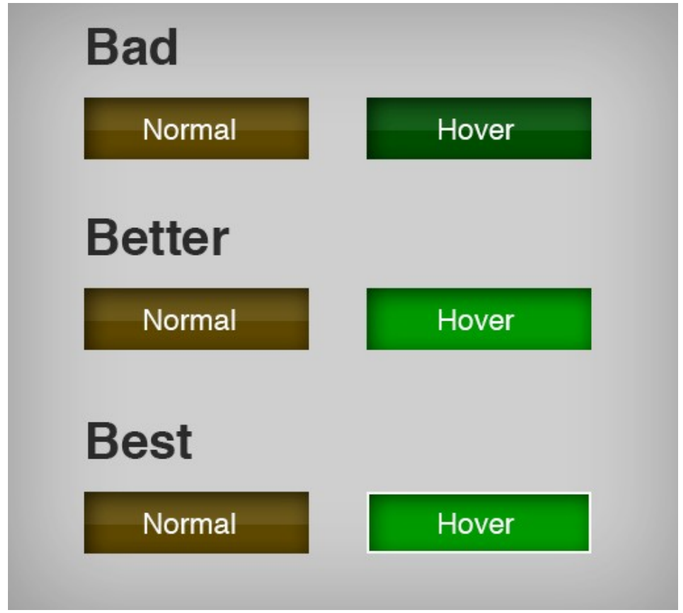


TAKEAWAY

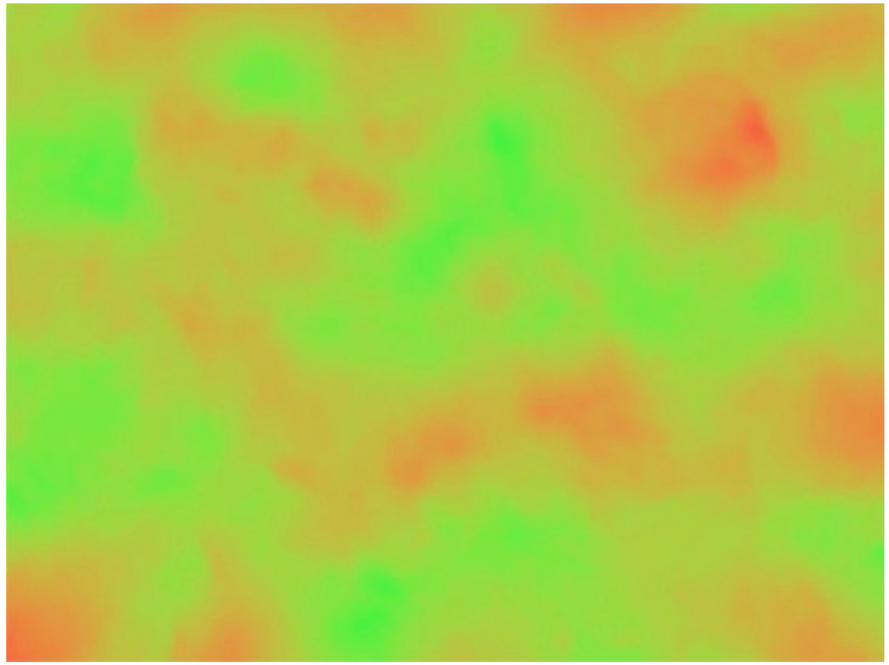
Even if you aren't colorblind, someone you're working with could be.

Be sure to design with colorblindness in mind by:

varying hue, saturation, brightness
using monochrome color schemes
using cues besides/in addition to color
software solution, vischeck (http://www.vischeck.com)

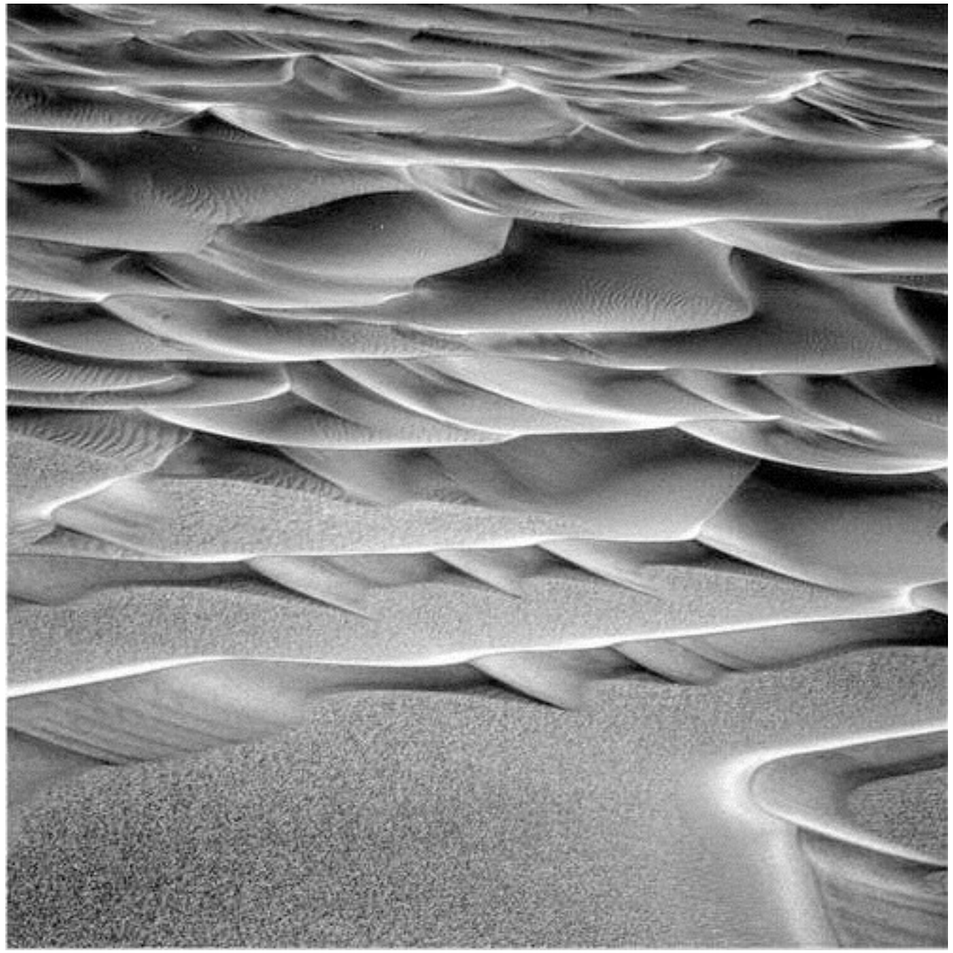


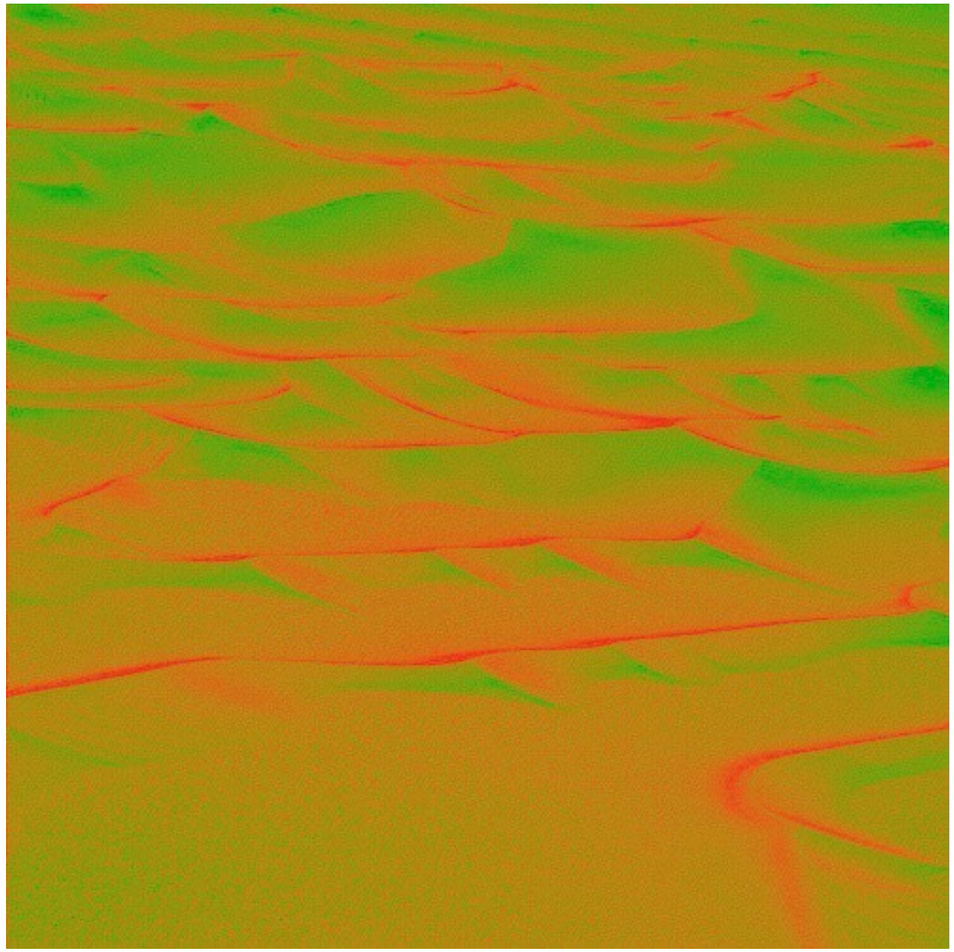
Contrast Sensitivity



C. Ware, "Visual Thinking for Design"

Contrast Sensitivity



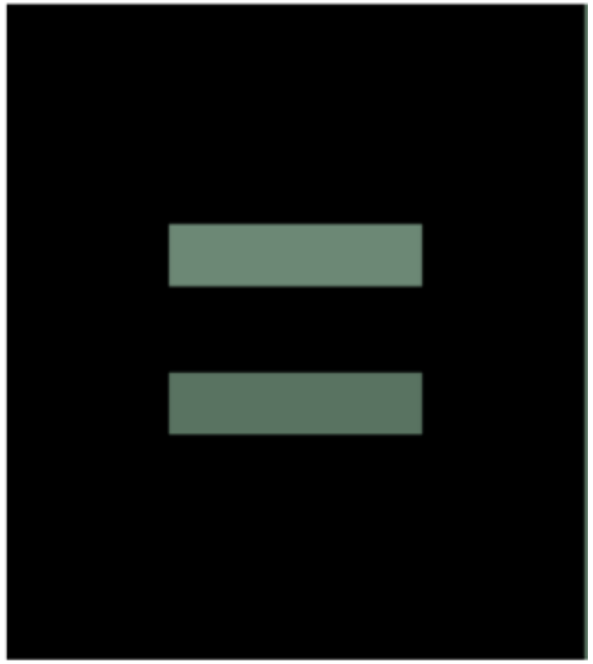


C. Ware, "Visual Thinking for Design"

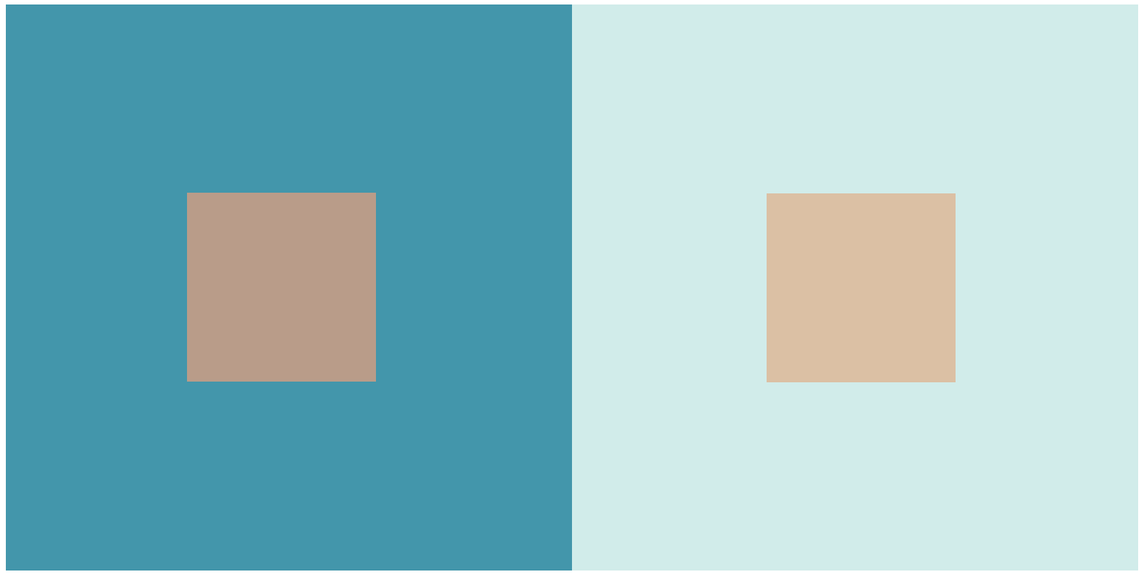
TAKEAWAY

We have higher contrast sensitivity in the luminance than in the chrominance channel. Show preference to luminance for encoding detail.

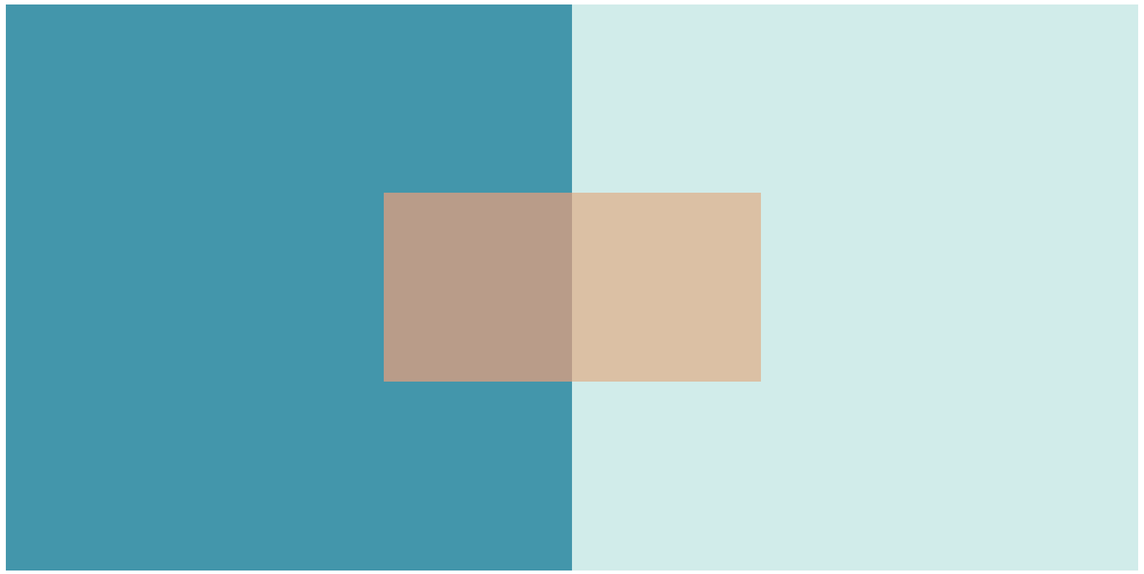
Color Relativity



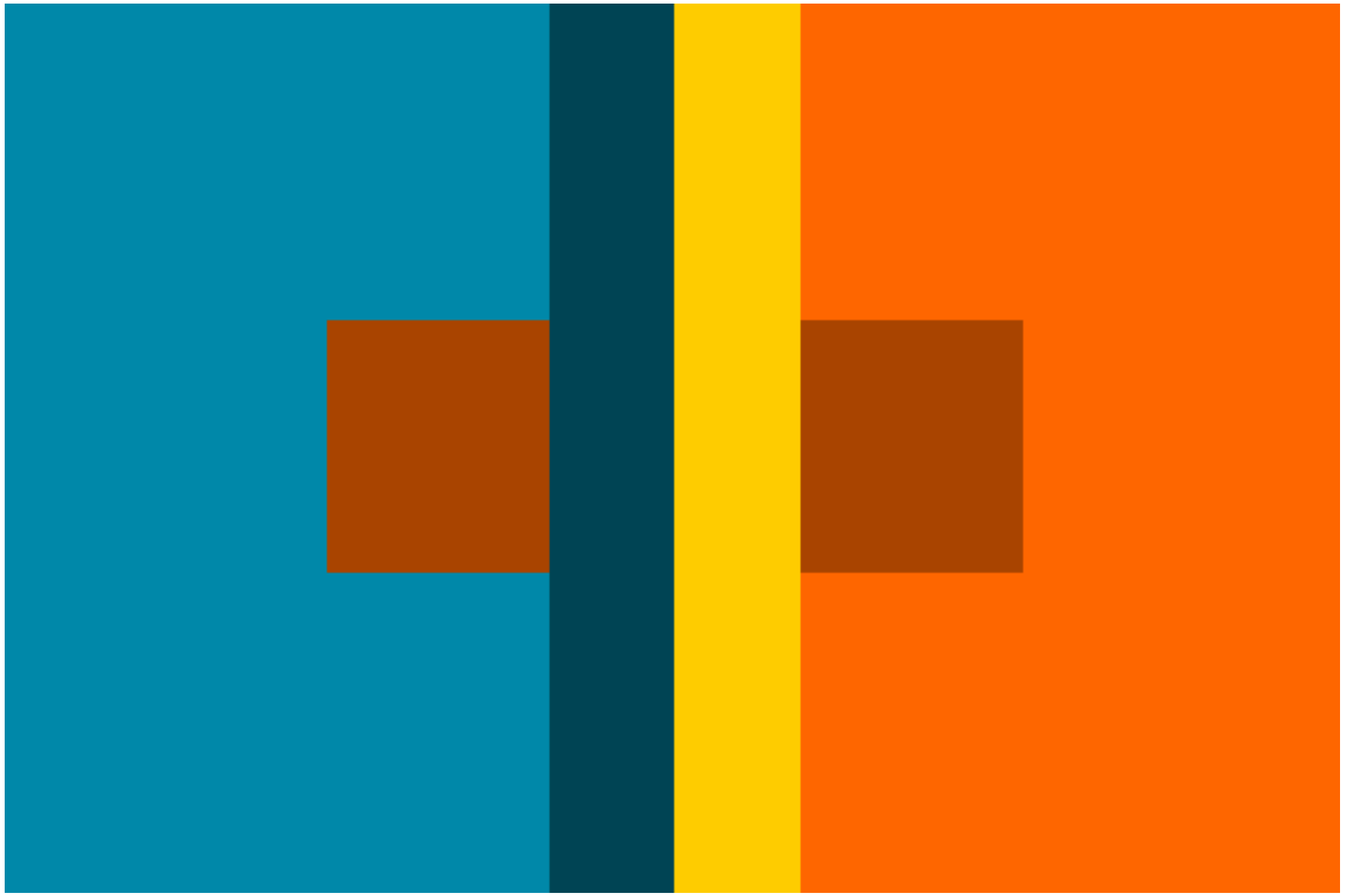
Color Relativity



Color Relativity



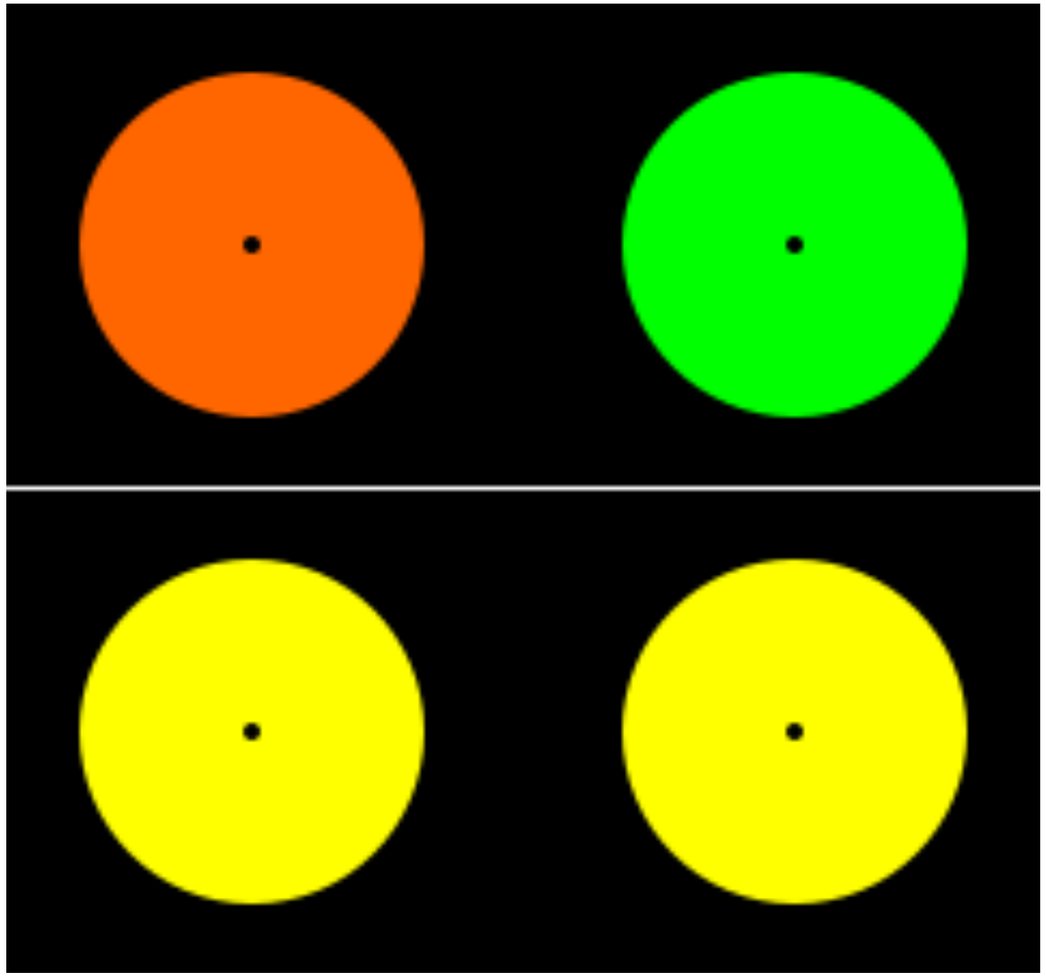
Color Relativity



Color Relativity

Color Relativity

SUCCESSIVE CONTRAST



look at a dot

then look at a dot

LUMINANCE CONTRAST

Showing small blue text on a black background is a bad idea.
There is insufficient luminance contrast.

Showing small blue text on a black background is a bad idea.
There is insufficient luminance contrast.

Showing small yellow text on a white background is a bad idea.
There is insufficient luminance contrast.

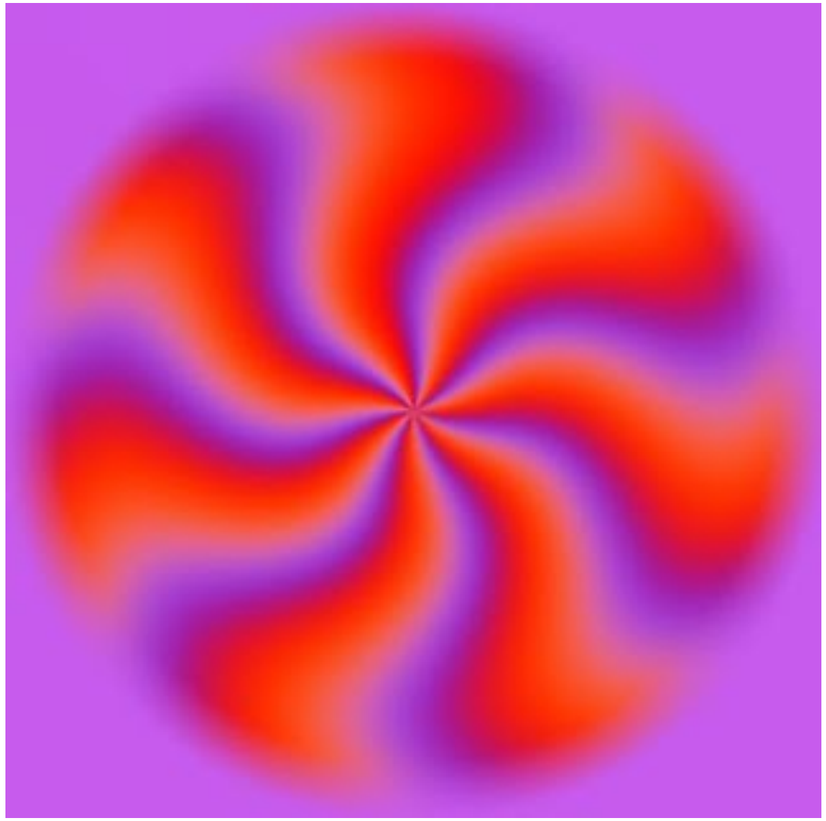
Showing small yellow text on a white background is a bad idea.
There is insufficient luminance contrast.

EQUILUMINANT COLORS

strong contrast: shapes seen by color sensitive cells

equiluminance: hides positions from light sensitive cells

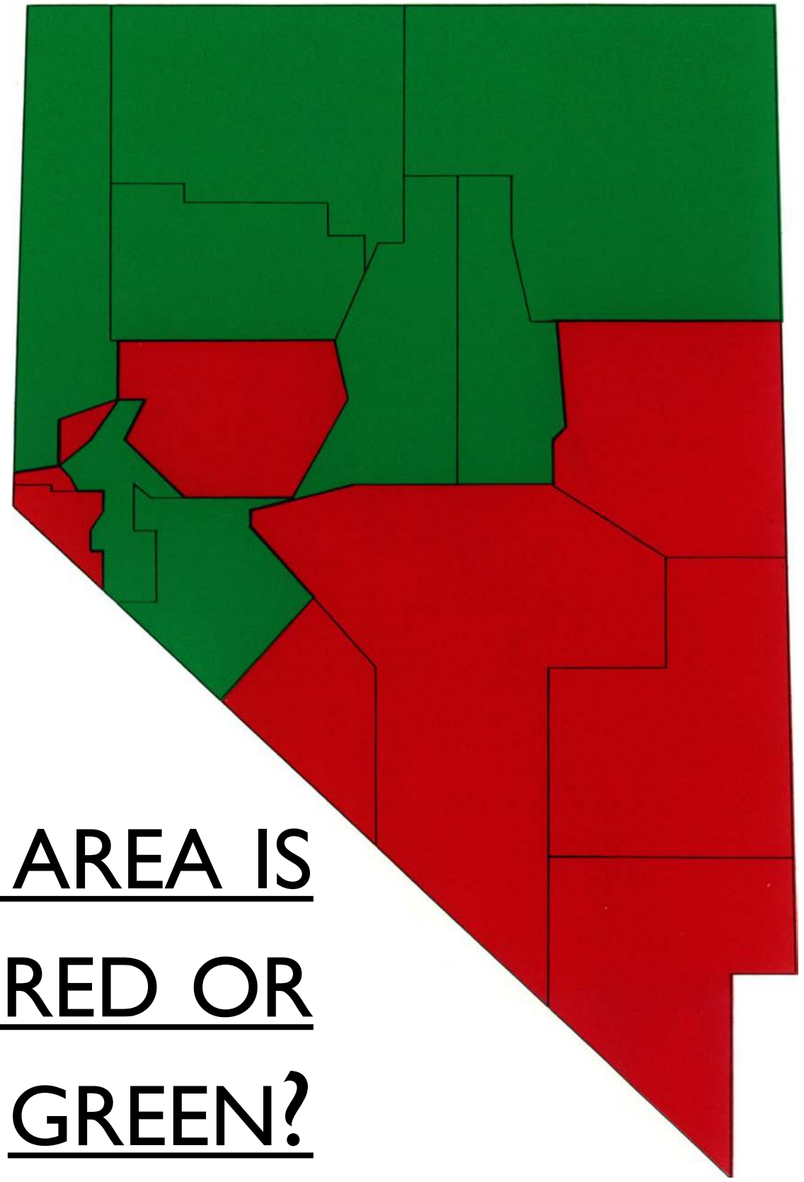
flickering/movement caused by this disconnect



SIZE & COLOR

"the smaller the mark, the less distinguishable are the colors"

-Jacques Bertin



WHICH AREA IS LARGER, RED OR GREEN?

Figure 1. Stimulus From the High-Saturation Group

TAKEAWAY

We have a strong propensity to assume our judgments of color are absolute, when in fact they are extremely relativistic.

Do your best to not place data in difficult contexts. Use color sparingly.

GUIDELINES

color is a relative medium—if encoding ordinal data with color, place marks on solid, neutral background

because of contrast effects, it is difficult to perceive absolute luminance of noncontiguous regions

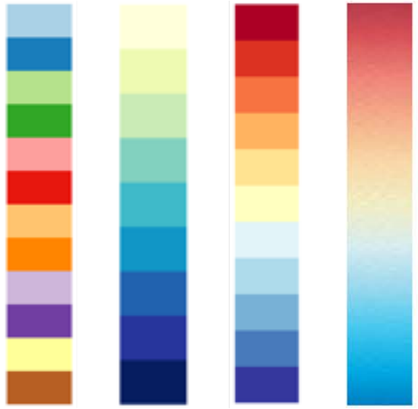
for text, ideally use 10:1 ratio, 3:1 minimum

GUIDELINES

in small regions use bright, highly saturated colors

for points and lines use just two saturation levels

use low saturation pastel colors for large regions and backgrounds



WHAT IS A COLORMAP?

specifies a mapping between color and values
also called a transfer function

categorical vs ordered
sequential vs diverging
segmented vs continuous
univariate vs bivariate

EXPRESSIVENESS: MATCH COLORMAP TO ATTRIBUTE TYPE CHARACTERISTICS!

GUIDELINES

categorical colors are easier to remember if they are nameable

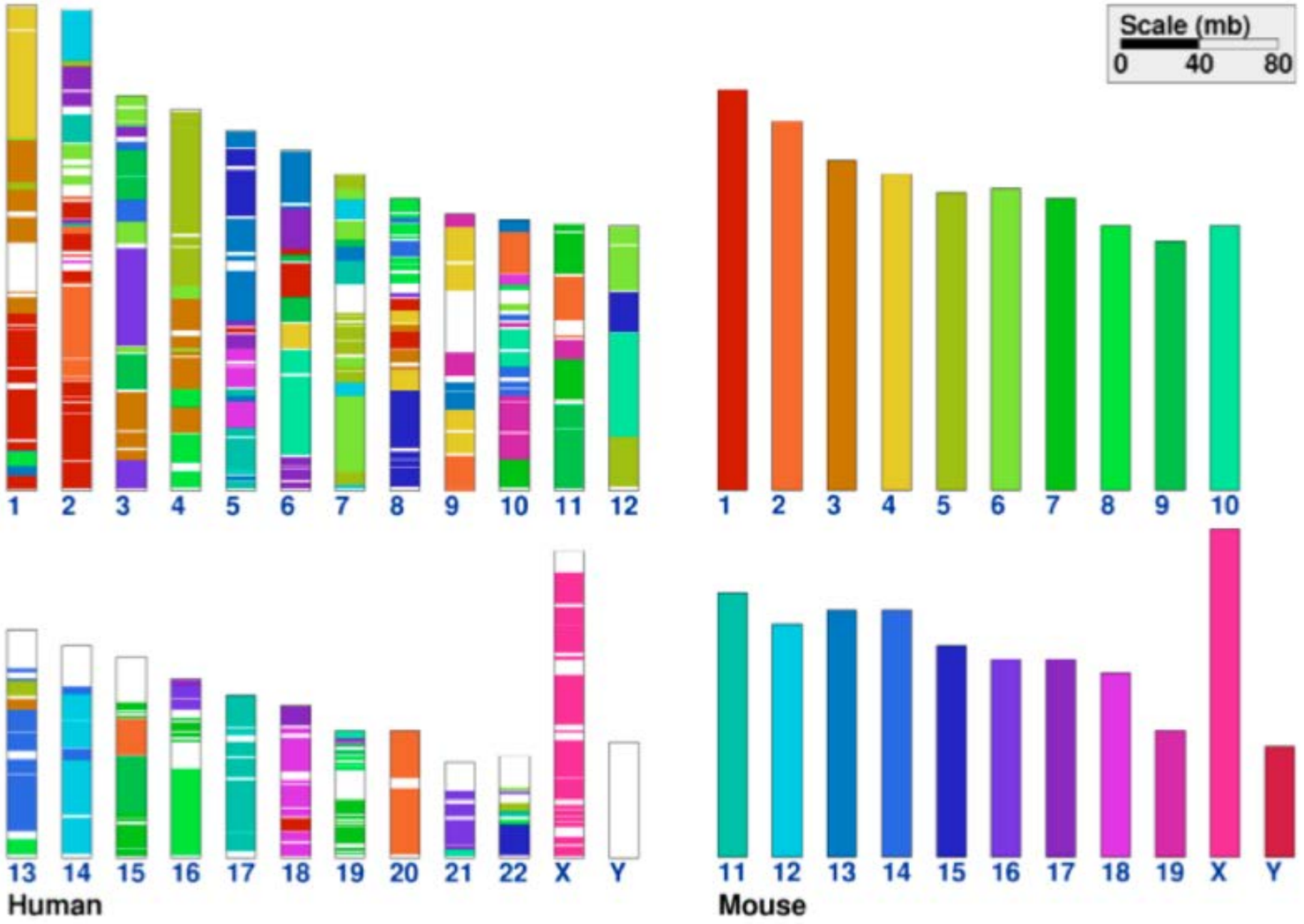
ordered colormaps should vary along saturation or luminance

bivariate colormaps are difficult to interpret if at least one variable is not binary

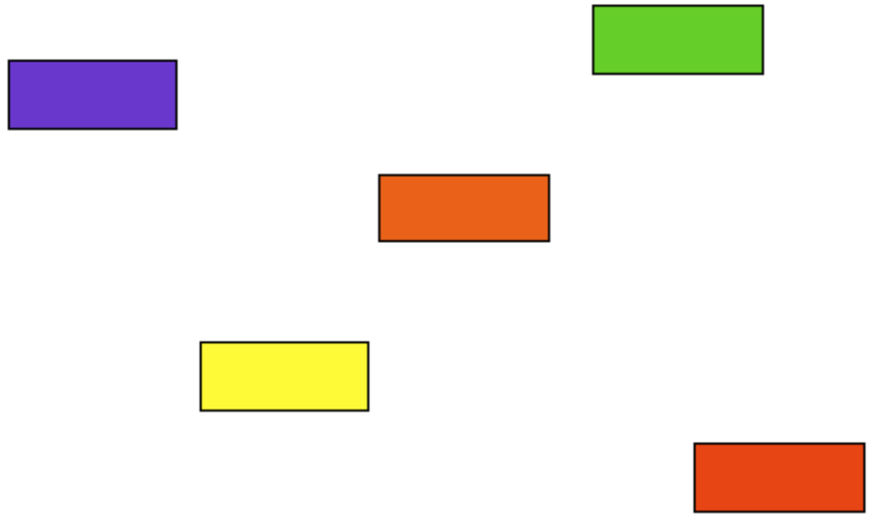
HUES FOR CATEGORIES

DISTINGUISHABILITY

only good at distinguishing 6-12 simultaneous colors

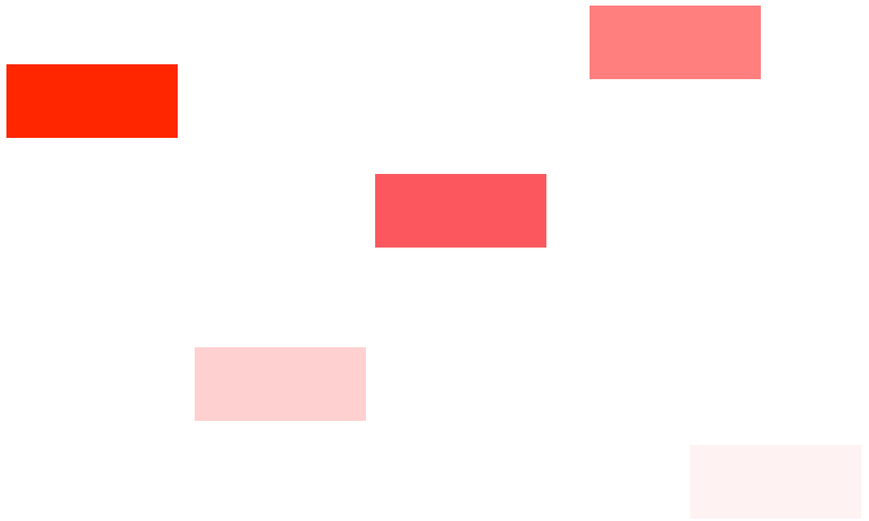


ORDER THESE COLORS…



ORDER THESE COLORS…

ORDER THESE COLORS…



GUIDELINES

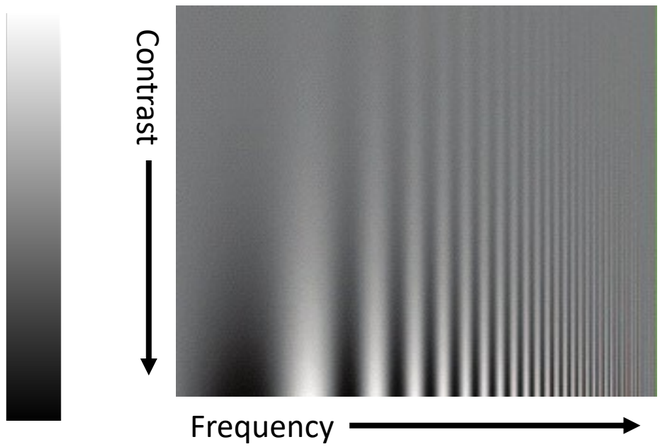
luminance and saturation are most effective for ordinal data because they have an inherent ordering

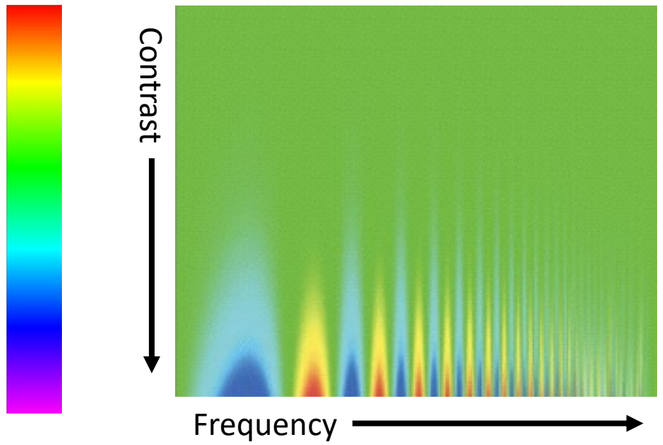
hue is great for categorical data because there is no inherent ordering

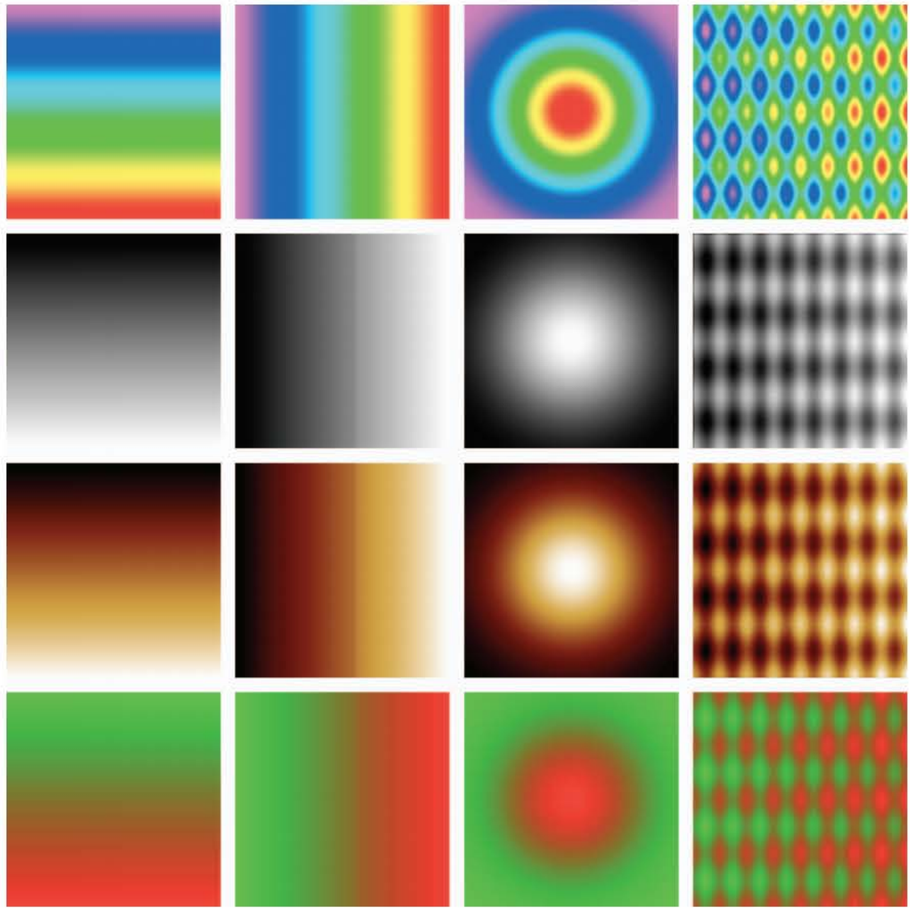
but limit number of hues to 6-12 for distinguishability

number of hues and distribution on the colormap should be related to which and how many structures in the data to emphasize

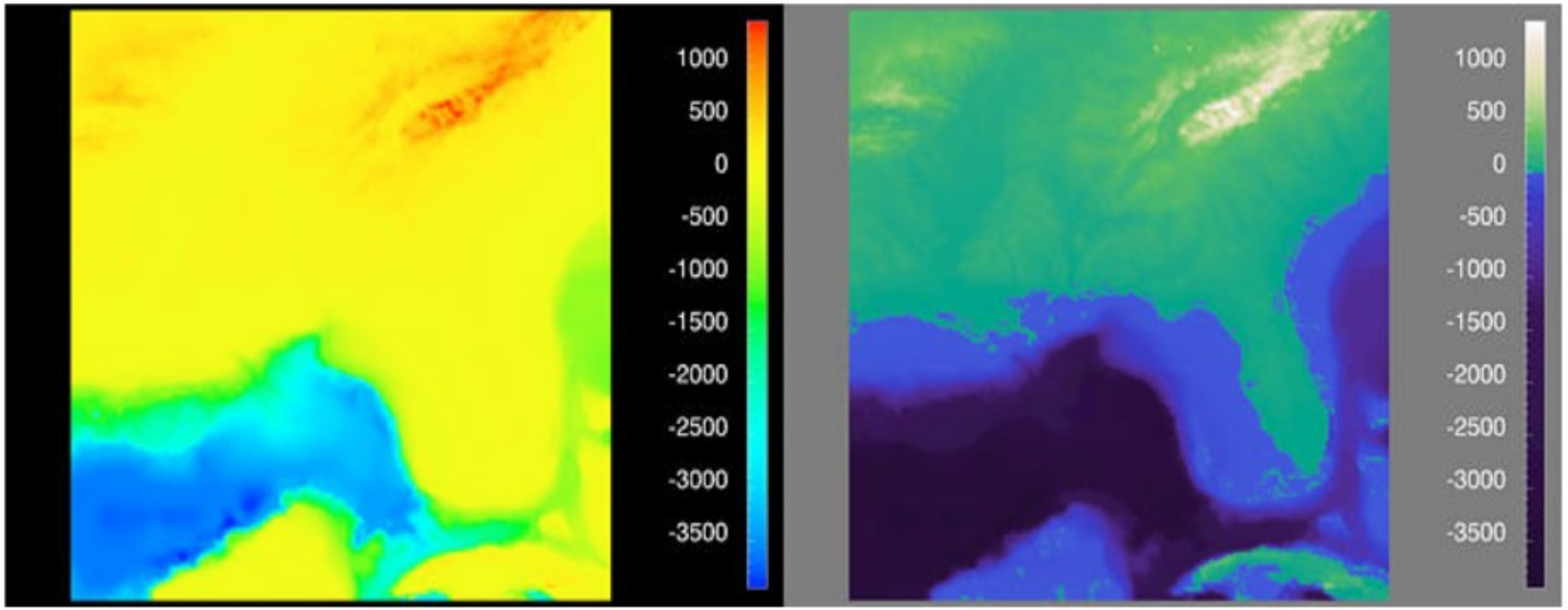
RAINBOW COLORMAPS: CHALLENGES





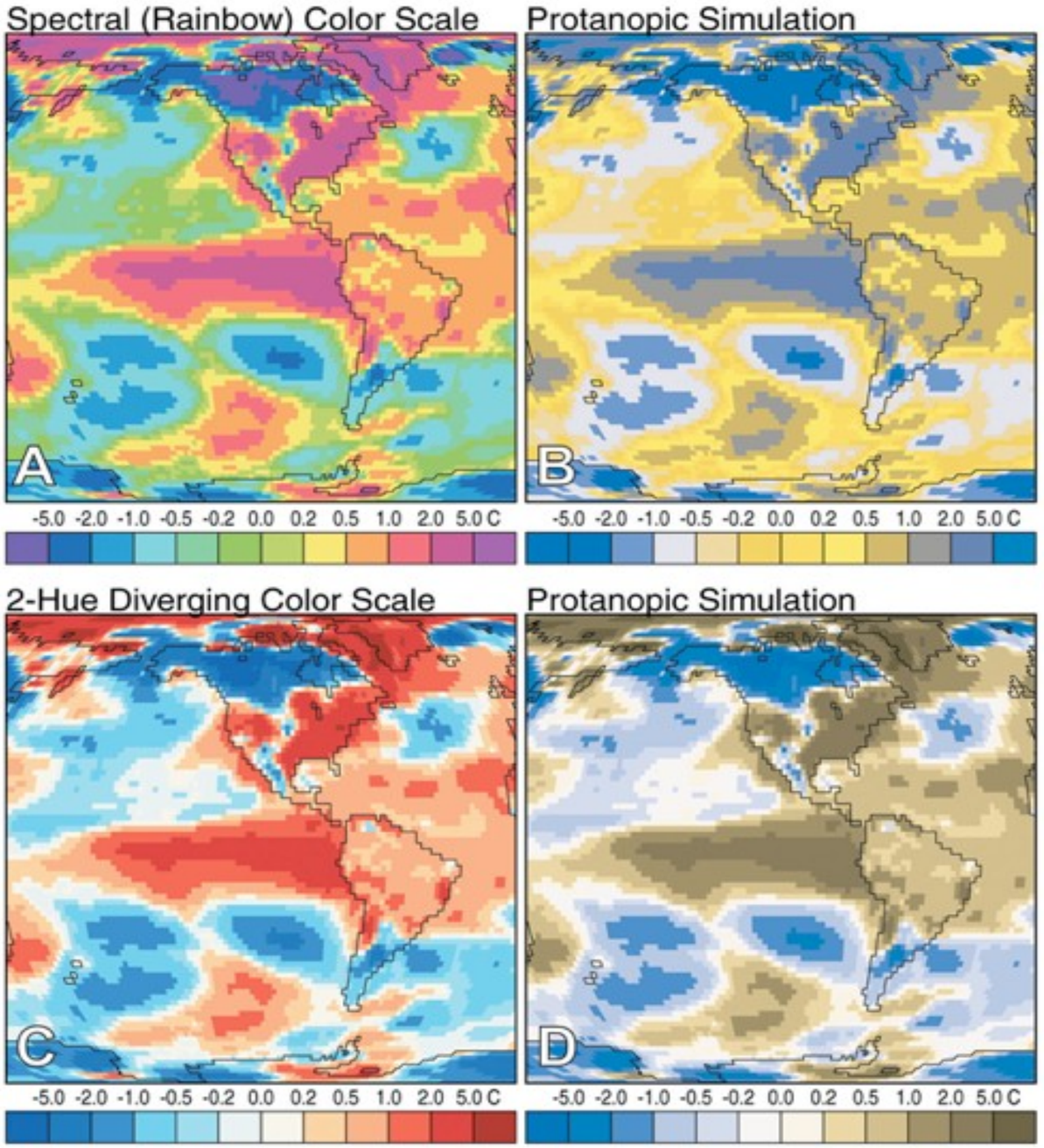


RAINBOW COLORMAPS: CHALLENGES



zero crossing not explicit

RAINBOW COLORMAPS: CHALLENGES



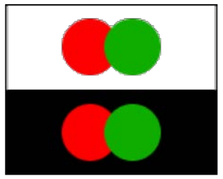
Color section Guidelines

RAINBOW GUIDELINES

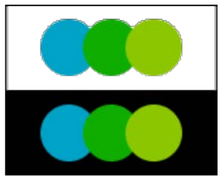
poor

better

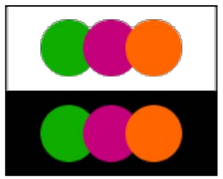
Color Harmonies

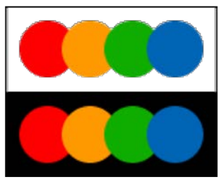
Complementary—high contrast creates a vibrant look

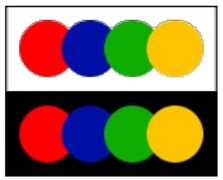
Analogous—often found in nature and are harmonious and pleasing to the eye

Triad—vibrant, even if you use pale or unsaturated versions of your hues

Split-complementary—same strong contrast as the complementary but less tension

Rectangle—rich color scheme offers plenty of possibilities for variation

HTTP://WWW.TIGERCOLOR.COM/COLOR-LAB/COLOR-THEORY/COLOR-HARMONIES.HTM

LOOK TO NATURE

SIMPLICITY

choose one color to be used in larger amounts

be selective about the base color

use other colors to add interest

AVOIDANCE OF COLOR

use neutrals (work with any scheme)

black, white, grey

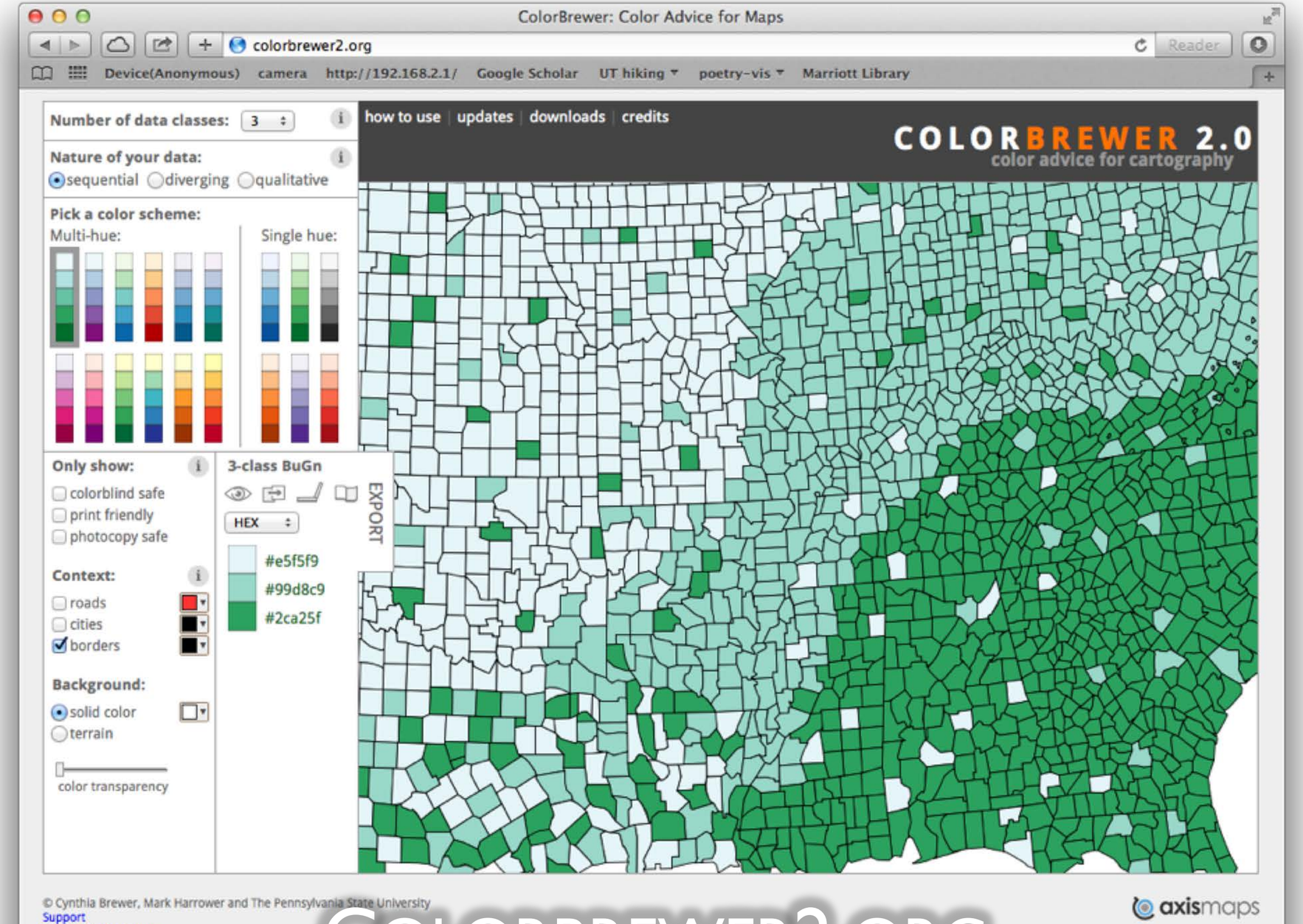
use diagrammatic marks (may be better encoding channels)

size, shape, texture, length, width, orientation, curvature and intensity

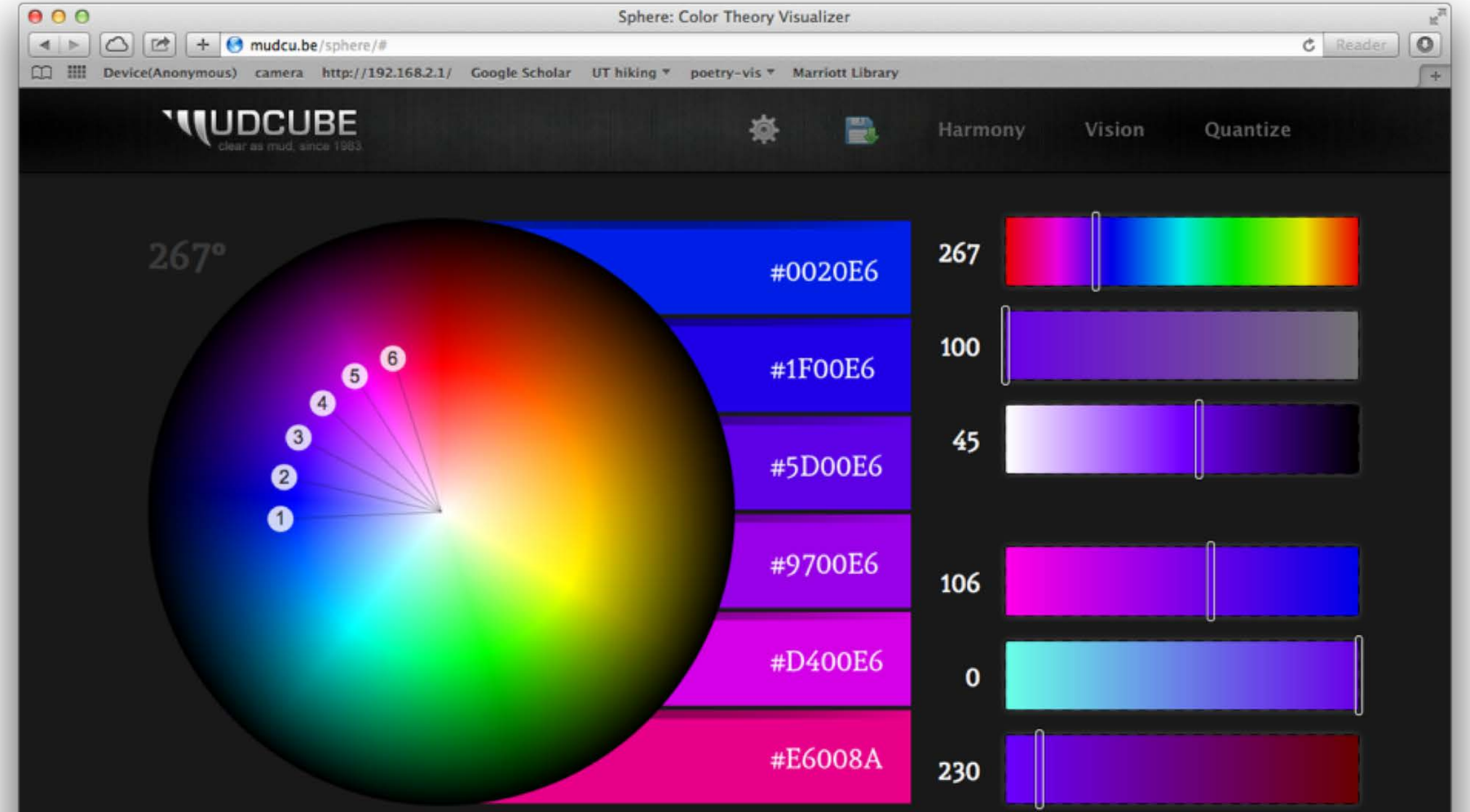
GET IT RIGHT IN BLACK AND WHITE.

Maureen Stone

TOOLS FOR COLOR



COLORBREWER2.ORG



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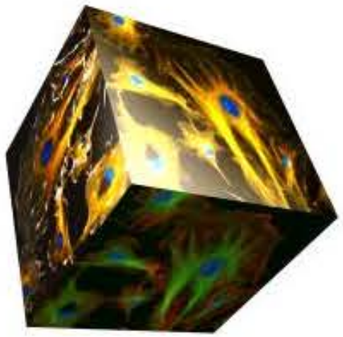

How do babies see the world? Visit TinyEyes.

Passive monitoring of cognitive health: Mindstrong Health.

Recommended Reading

Visualization Analysis & Design: Chapter 10 (pp. 218-241)