

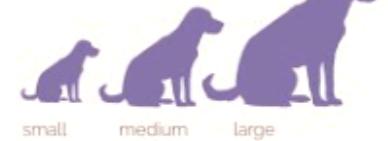
The Top 5 Most Popular Dog Breeds (2007-2017)

Ranking

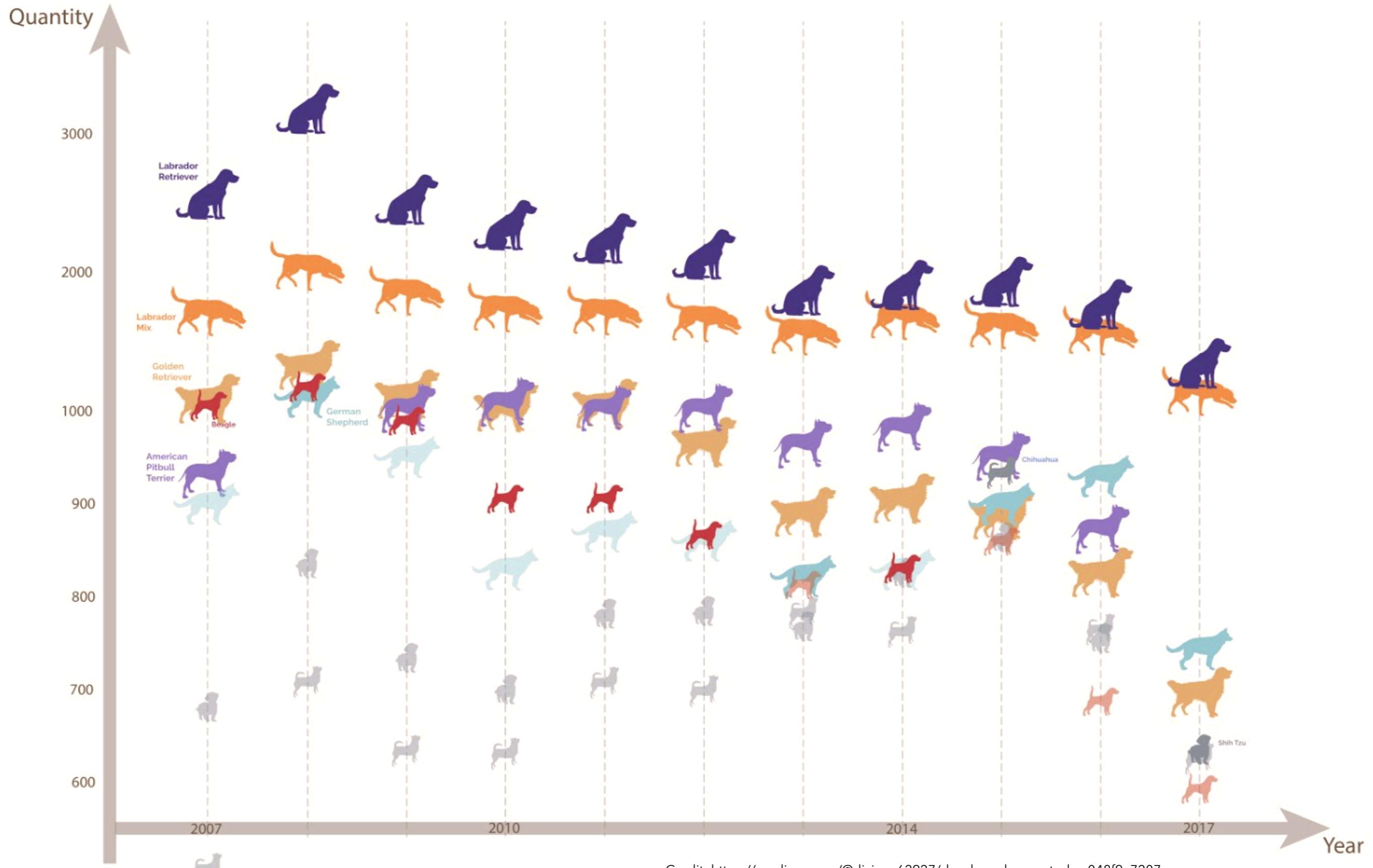


not in top 5

Size of Dog



small medium large



Credit: https://medium.com/@dixiao_62927/dog-breed-case-study-c048f9a7207e



Color

Jeff Rzeszotarski
Assistant Prof, InfoSci



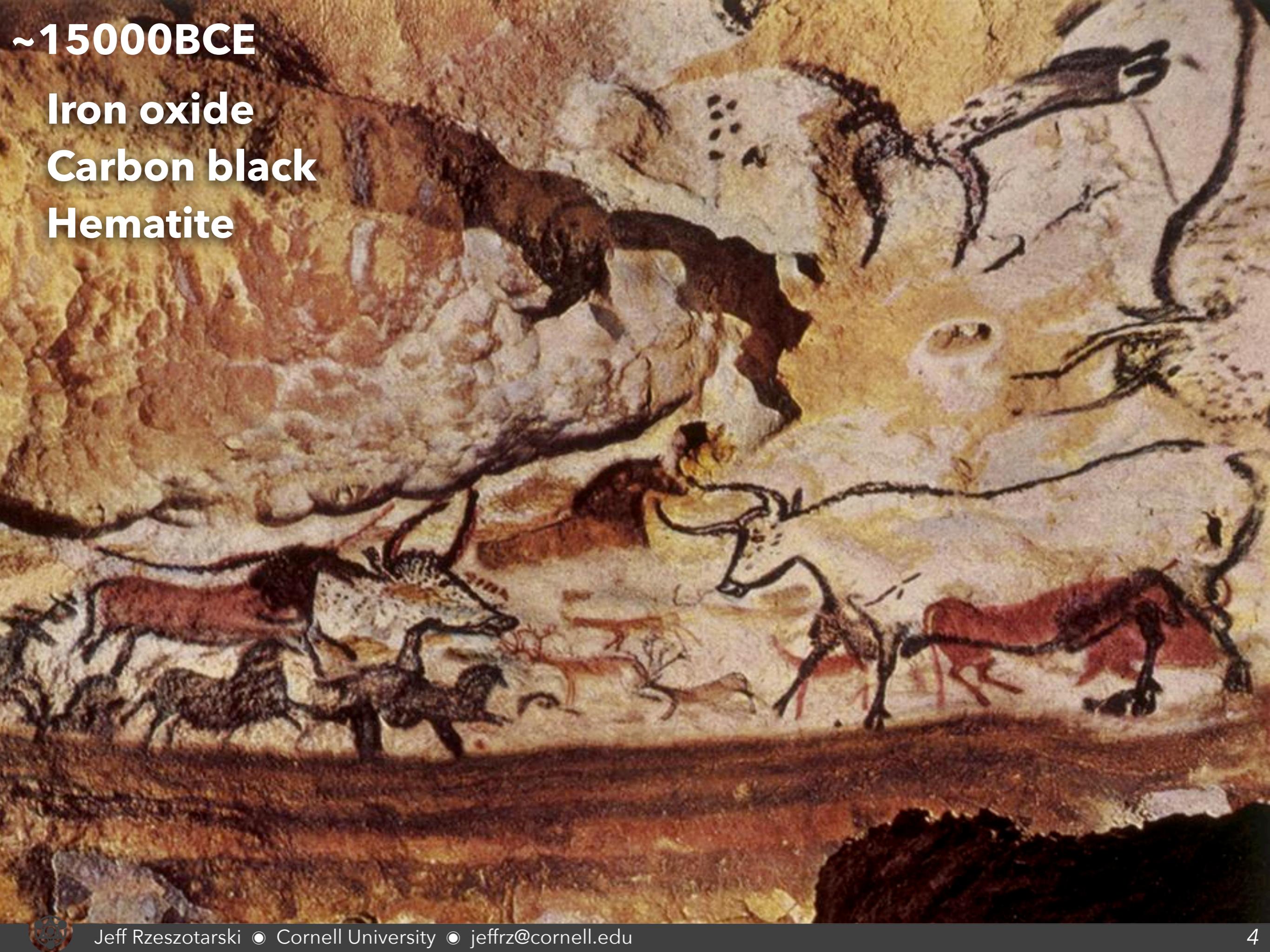


~15000BCE

Iron oxide

Carbon black

Hematite



~2000BCE

Indigo

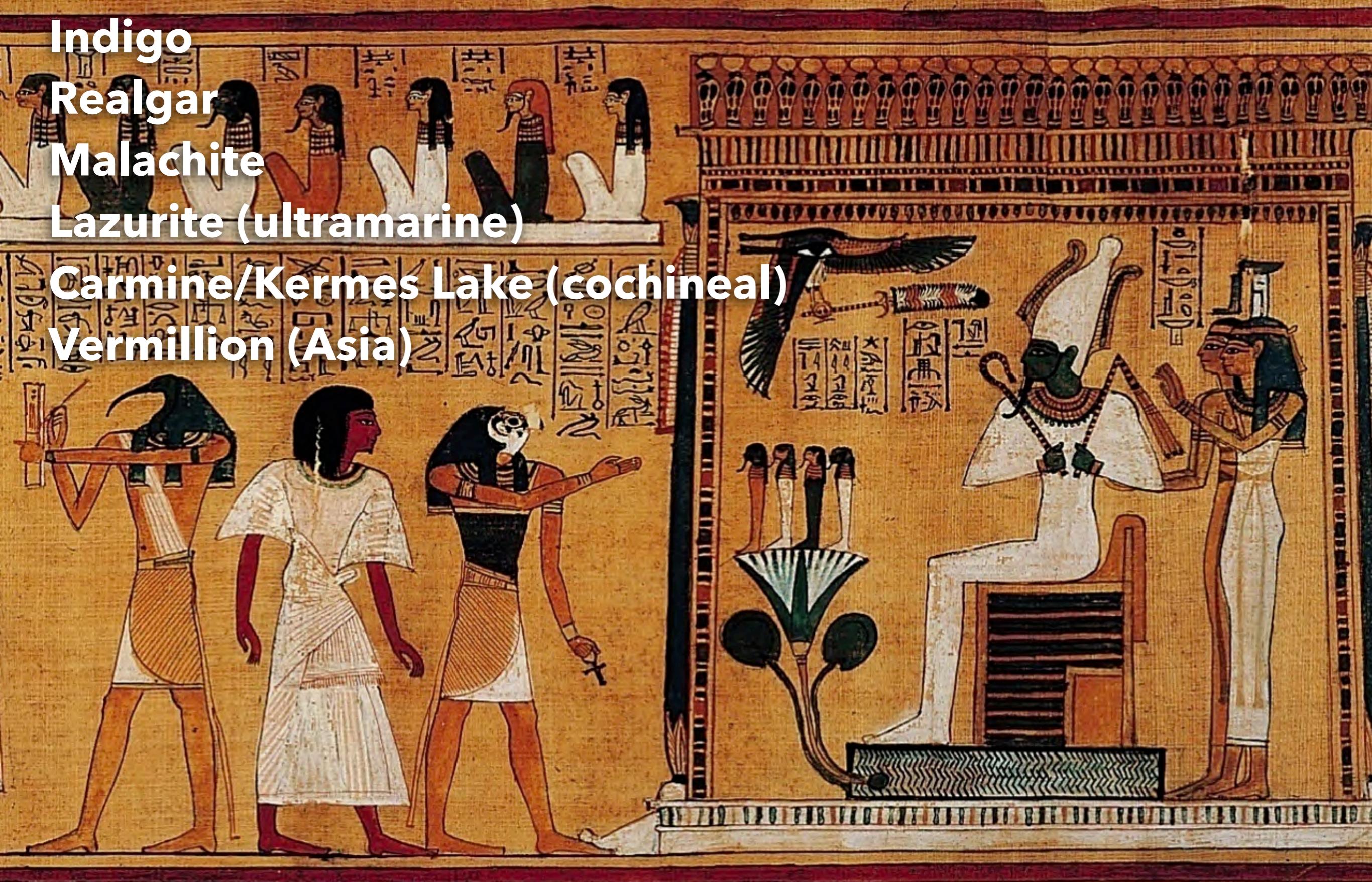
Realgar

Malachite

Lazurite (ultramarine)

Carmine/Kermes Lake (cochineal)

Vermillion (Asia)

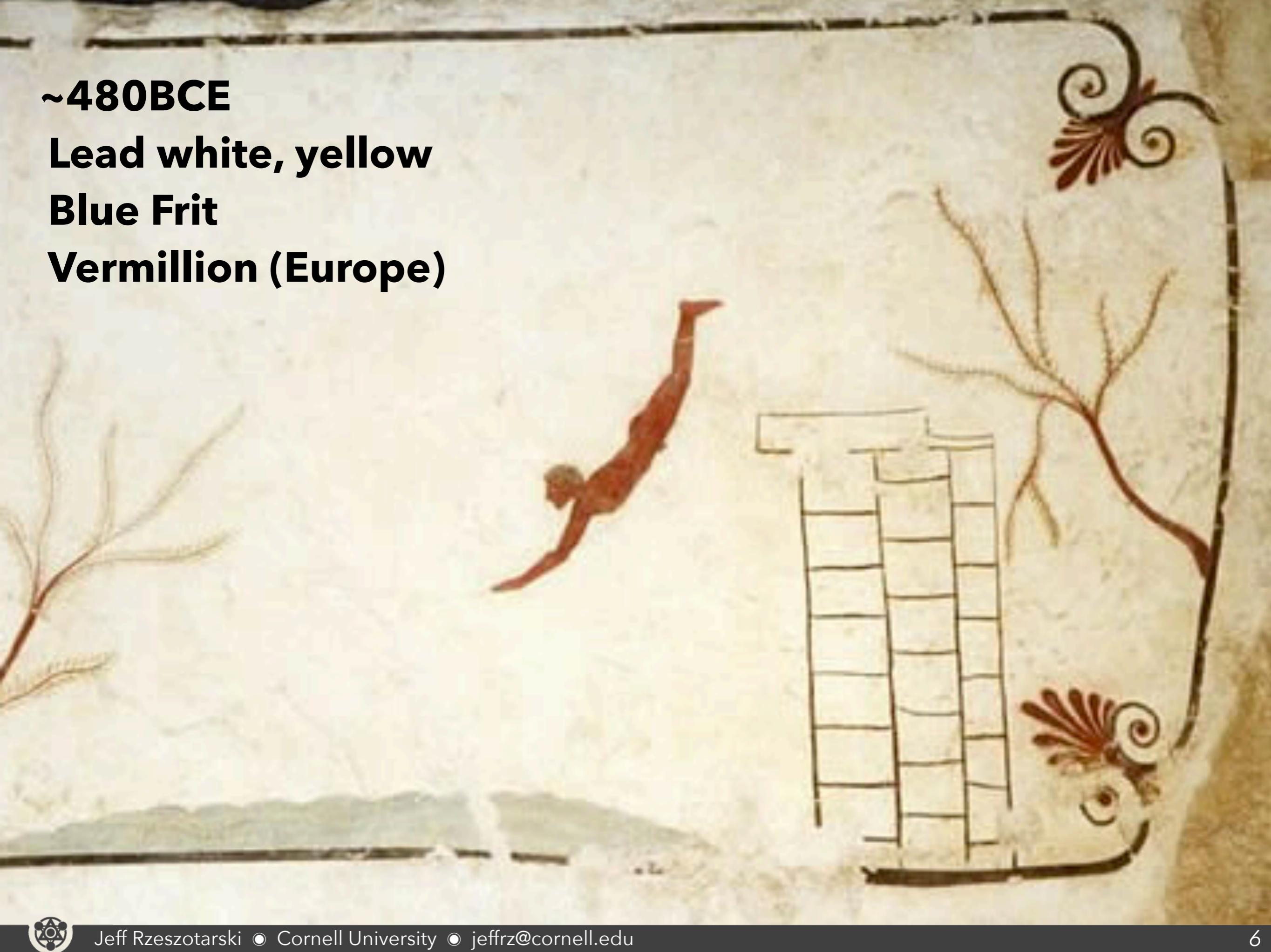


~480BCE

Lead white, yellow

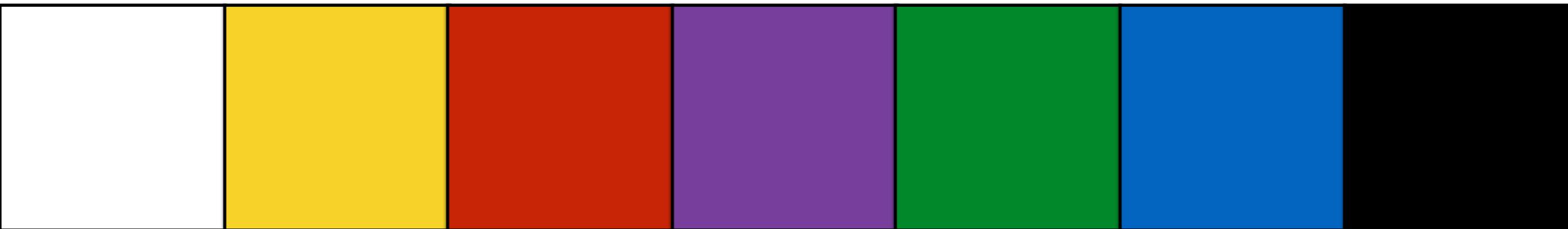
Blue Frit

Vermillion (Europe)



~350BCE

Aristotle



1541CE

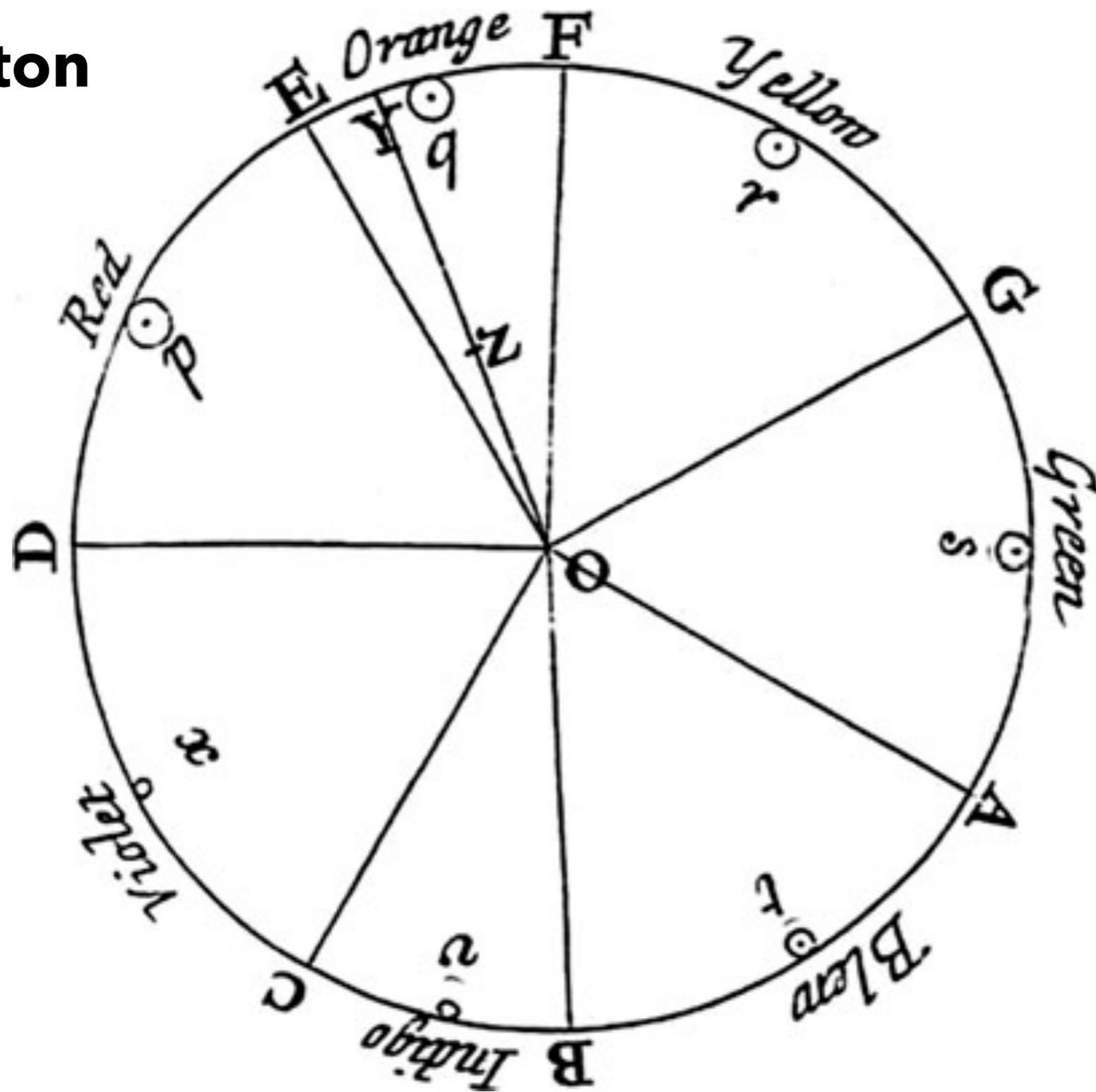
Mineral pigments



Michelangelo

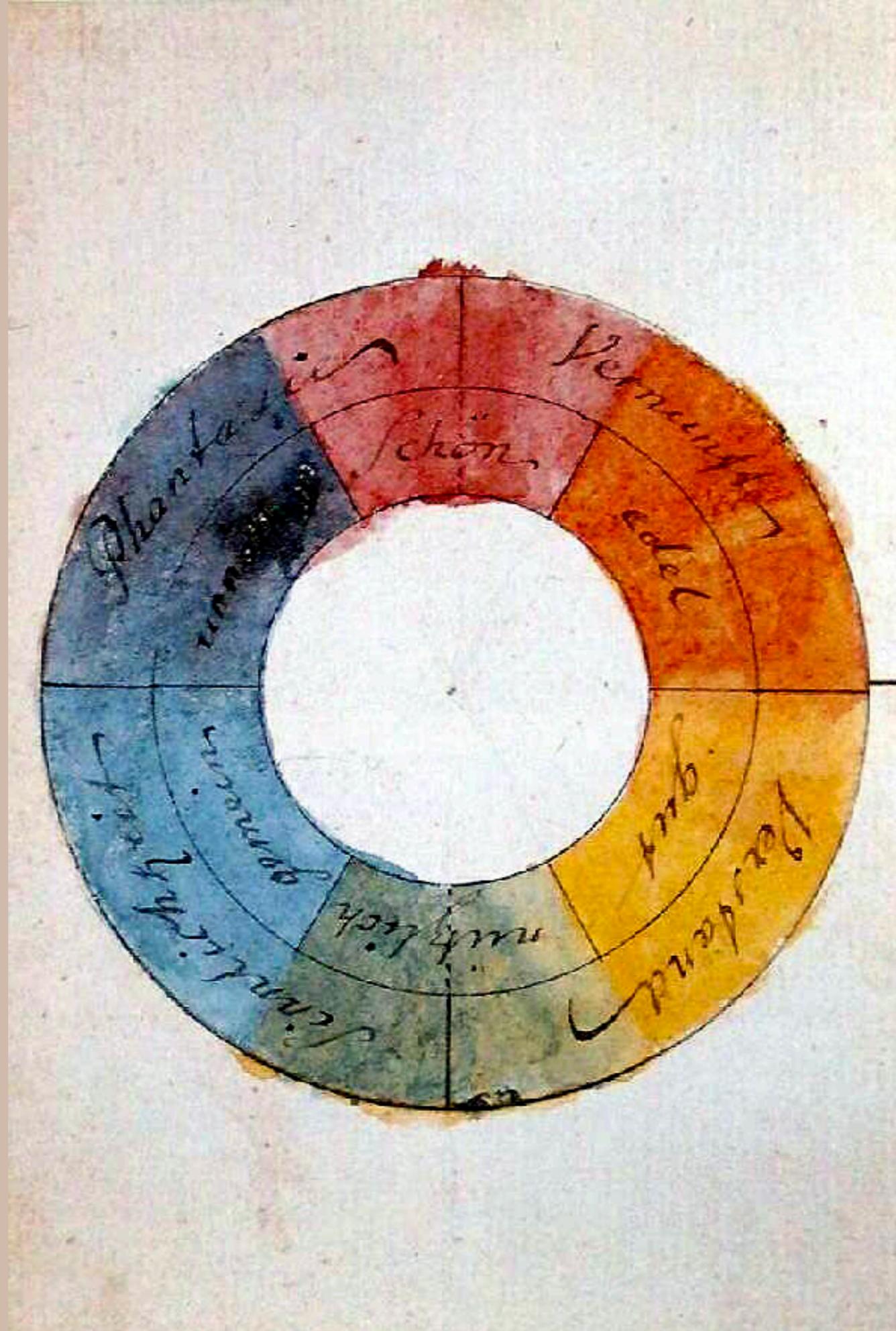
1665 CE

Isaac Newton



1801 CE

Goethe



1839 CE

Chevreul



1700s-1900s CE

Synthetic pigments



“Prussian blue”

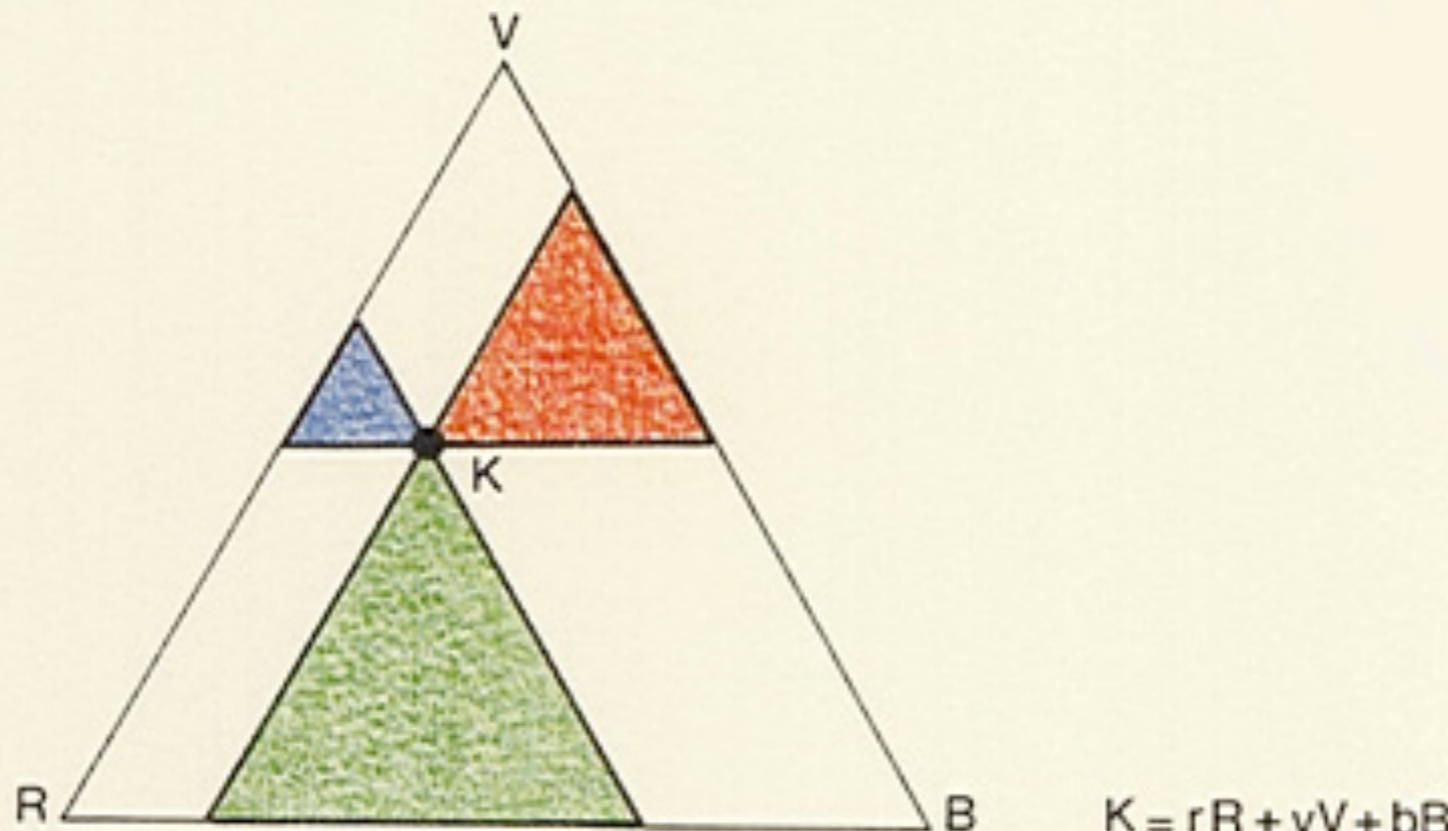


Claude Monet



~1860 CE
Maxwell

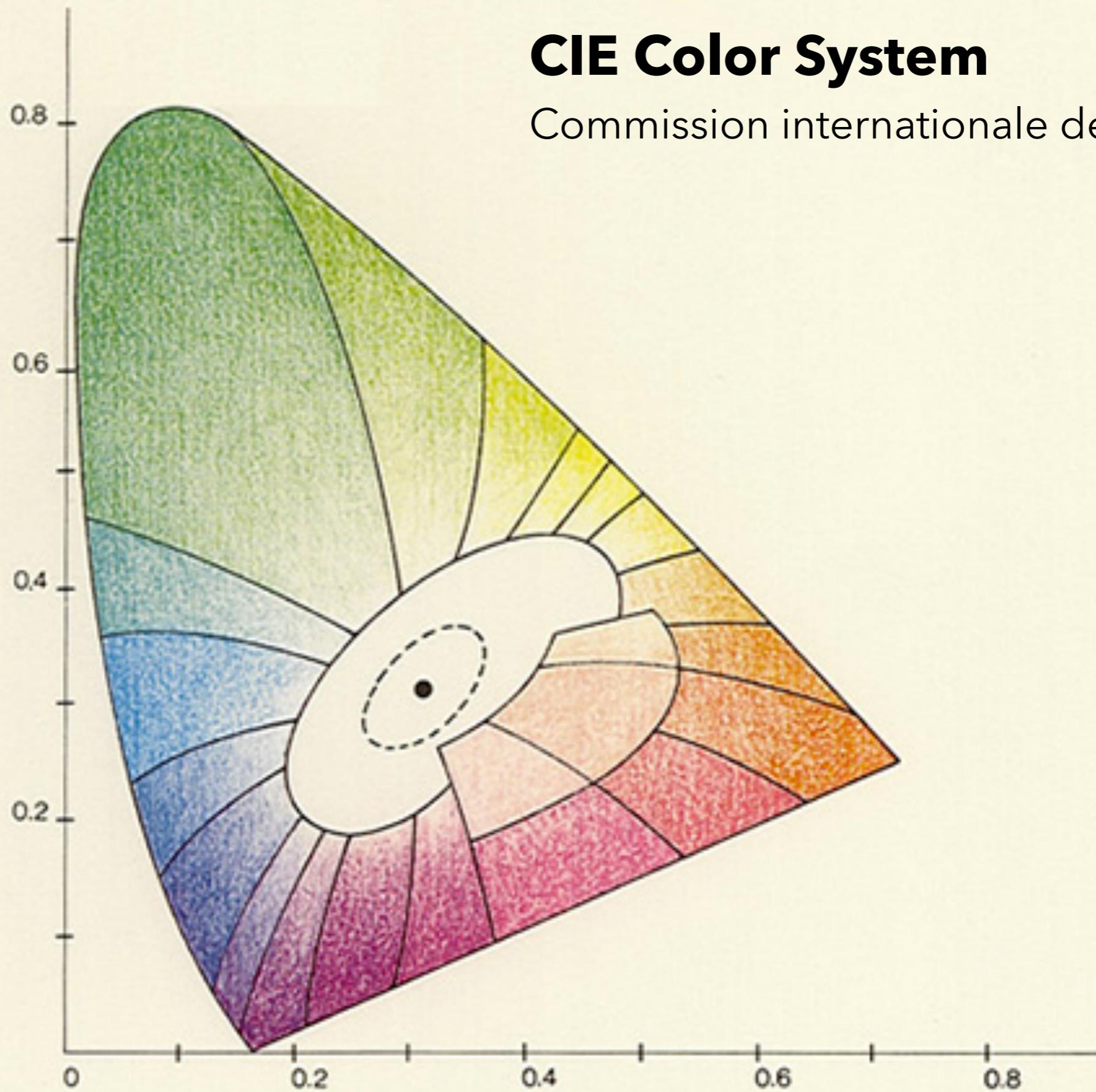
Trichromacy Theory & Colorimetry



1931 CE

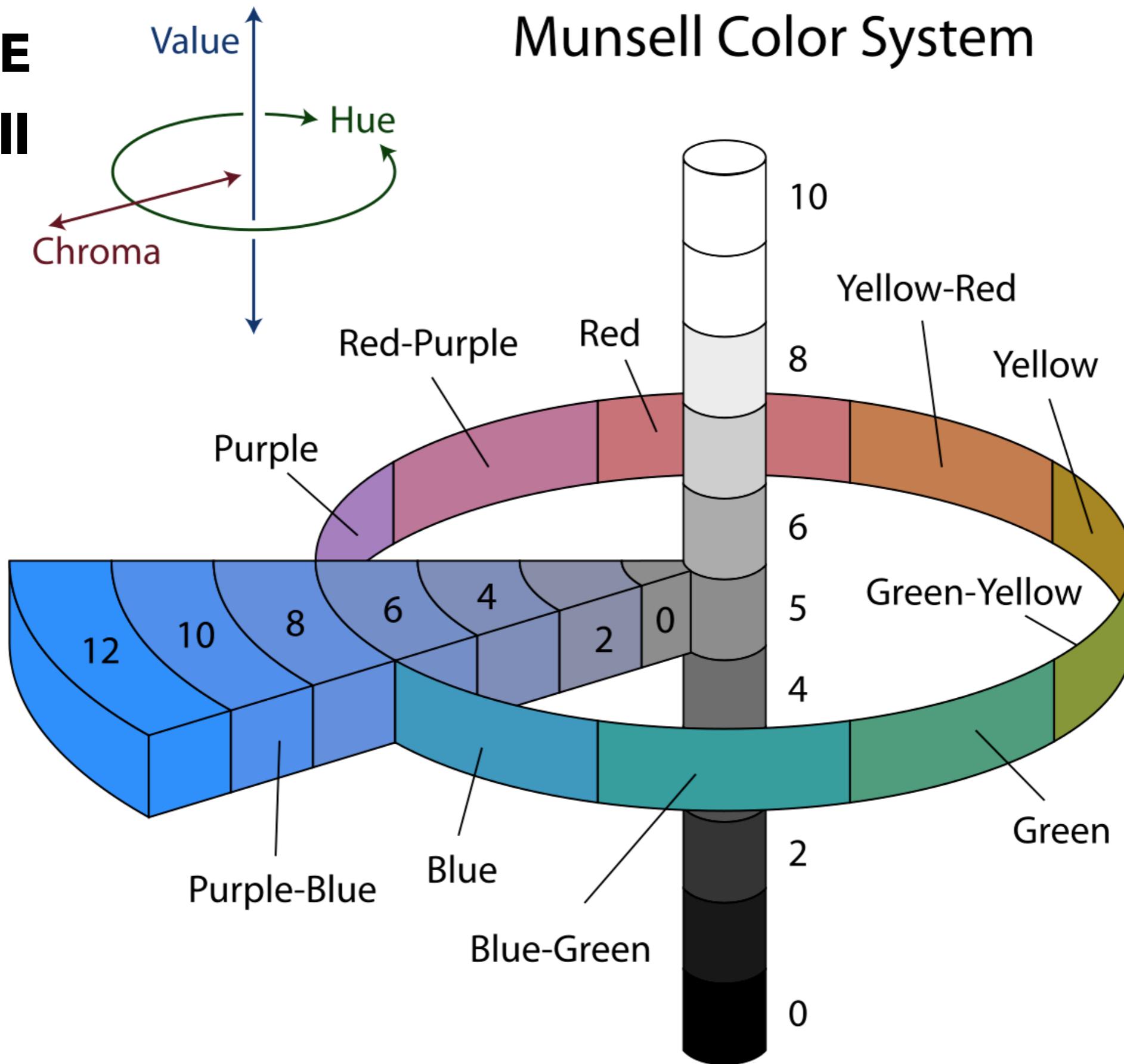
CIE Color System

Commission internationale de l'éclairage



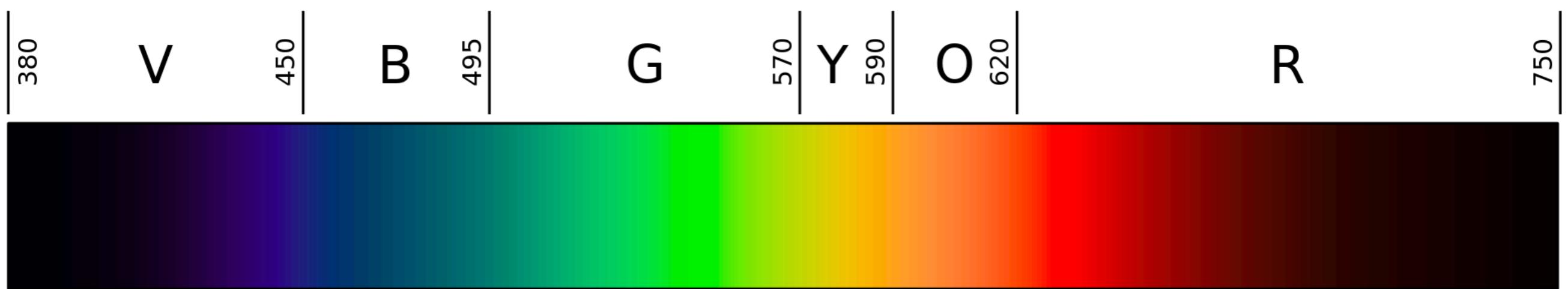
1943 CE

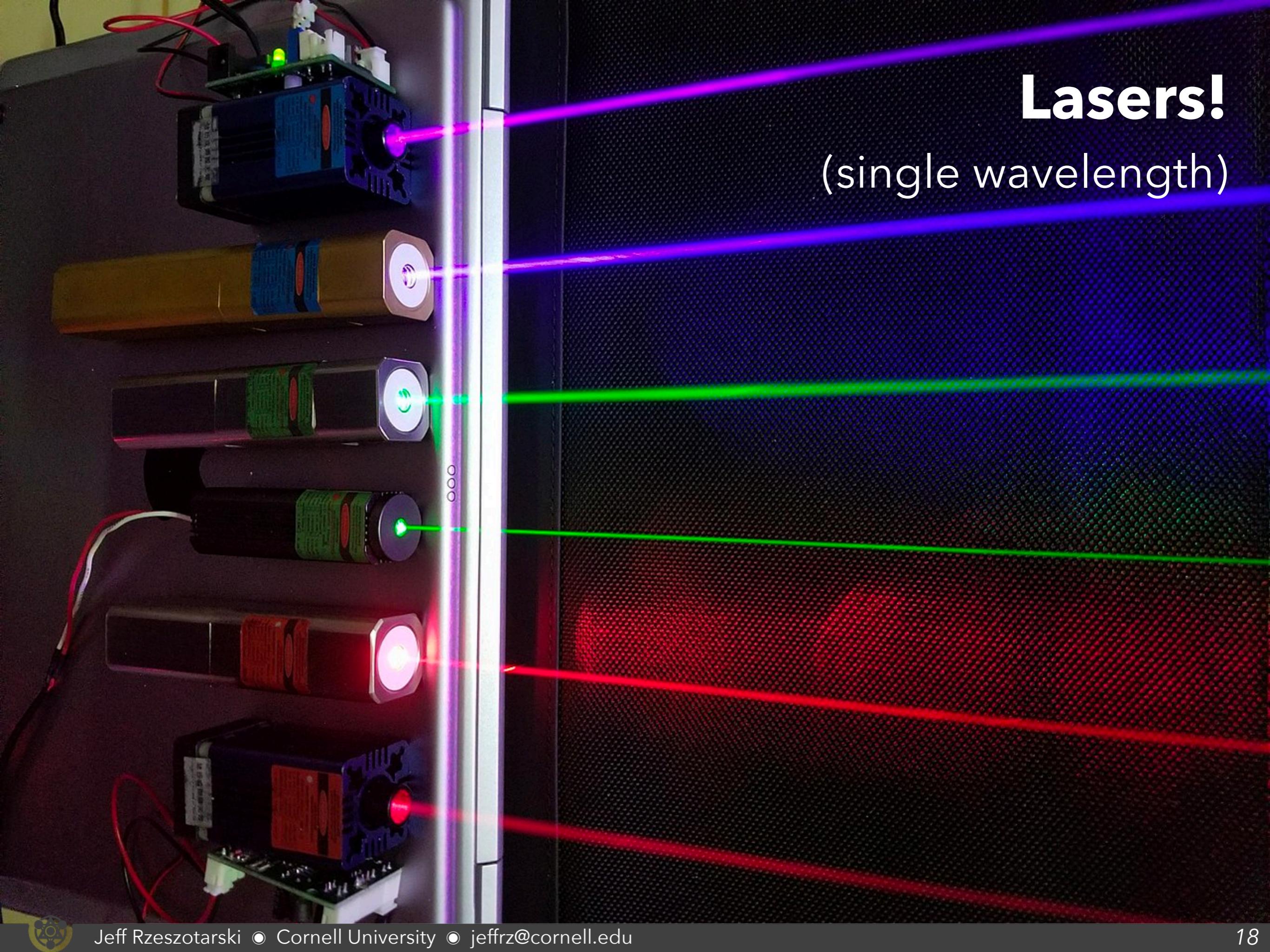
Munsell





Wavelength + Intensity



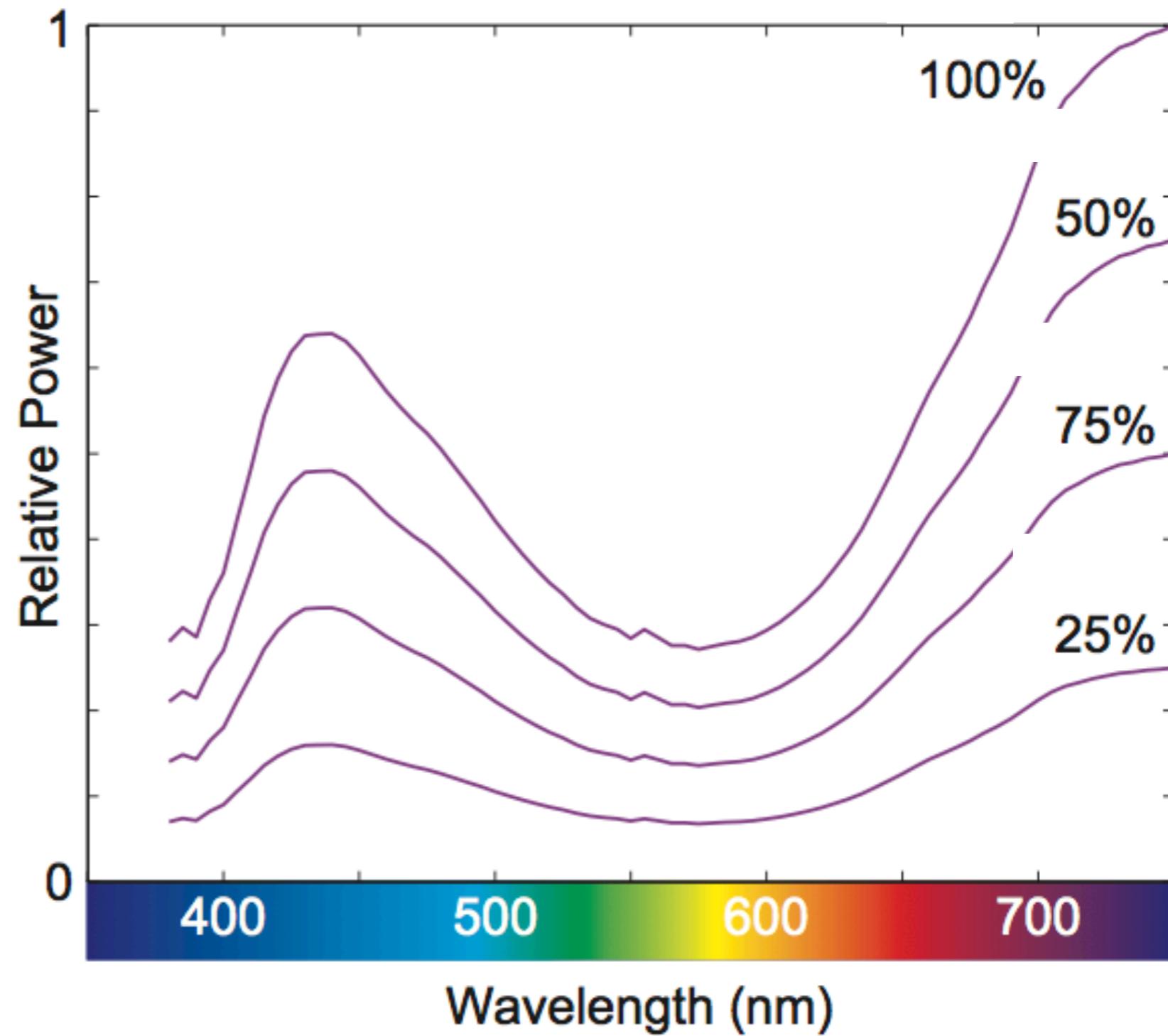


Lasers!

(single wavelength)

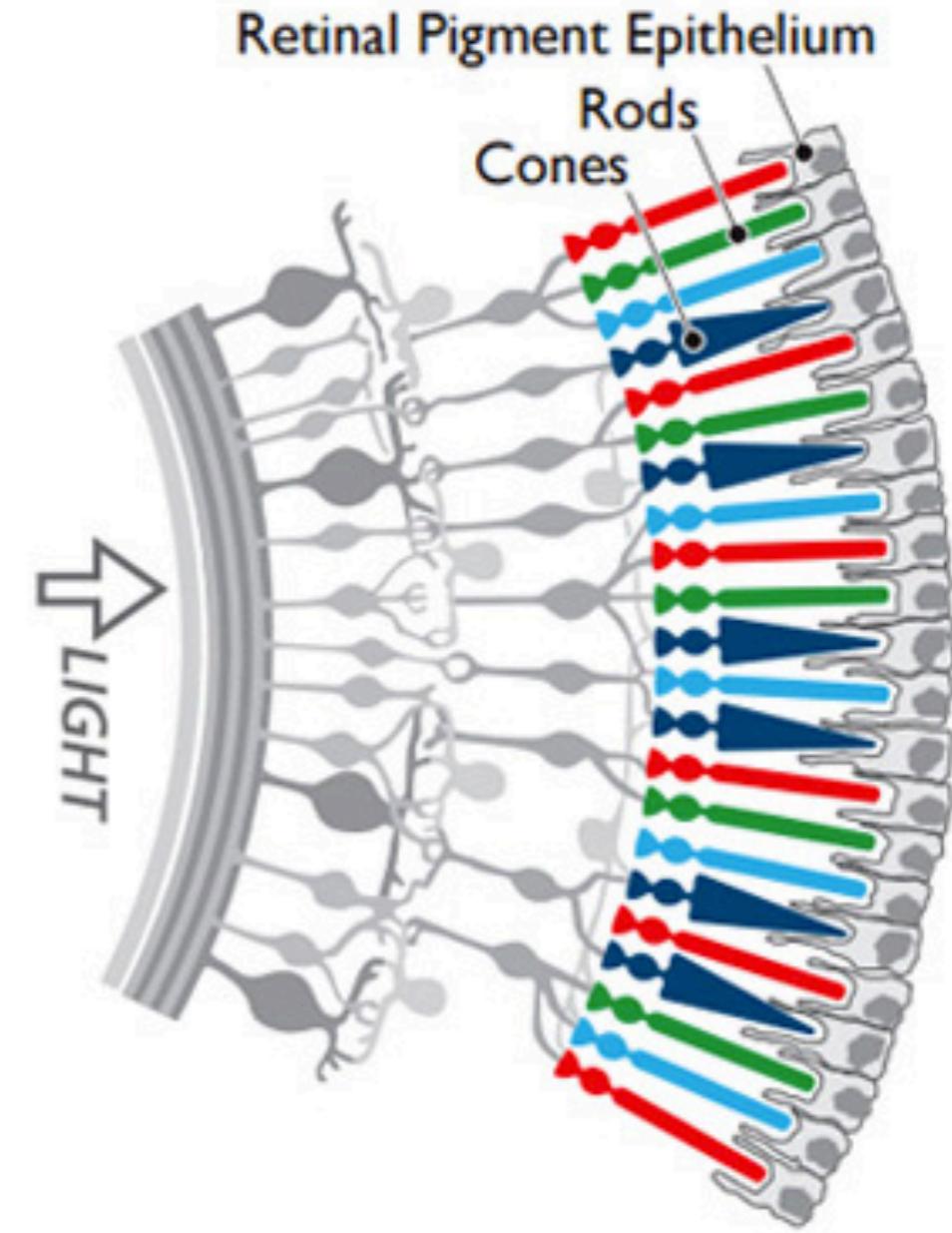
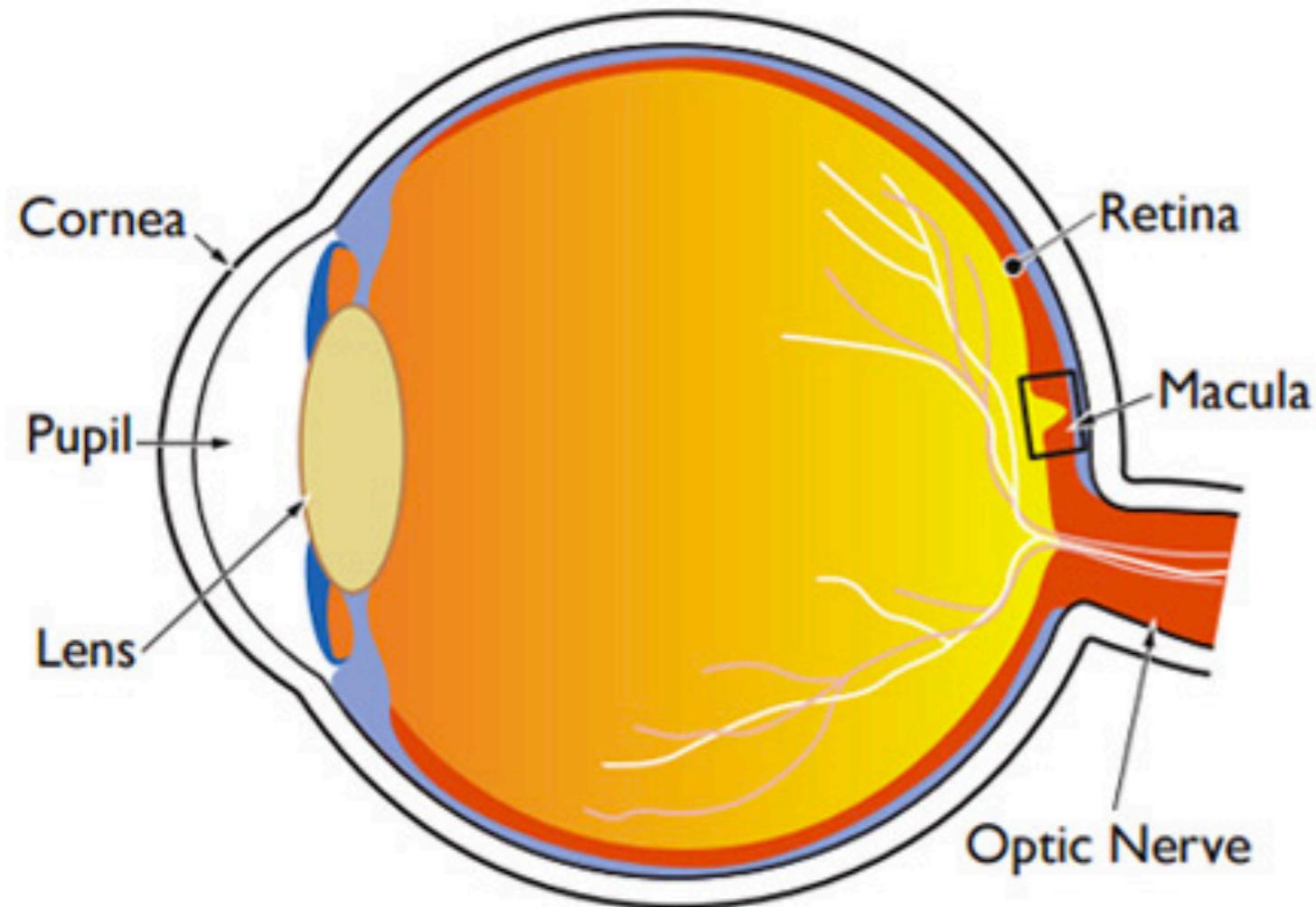


Most colors are mixtures of many wavelengths



Eyes have 3 kinds of color sensing elements

(this is an oversimplification!)

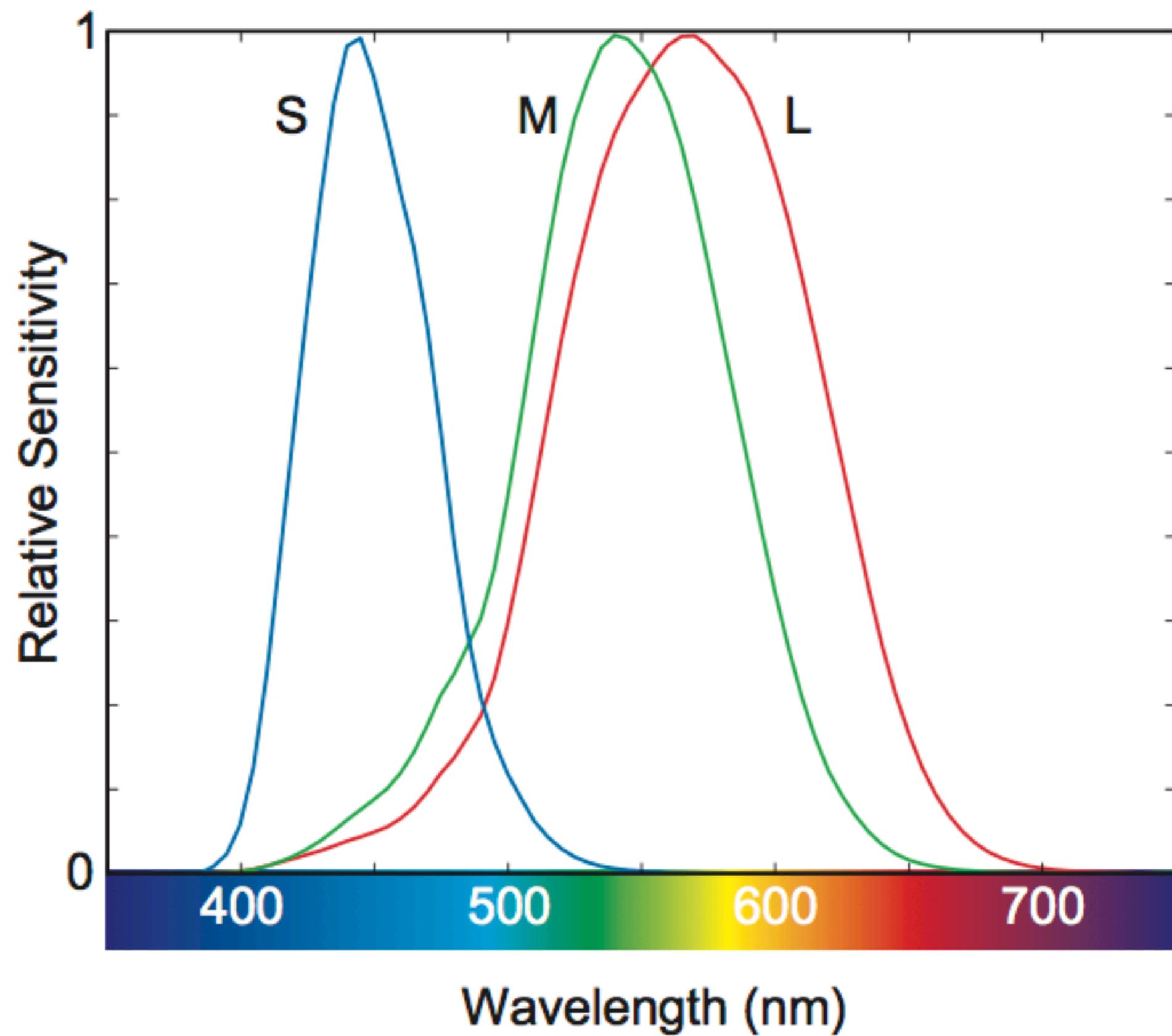


Cone Cells

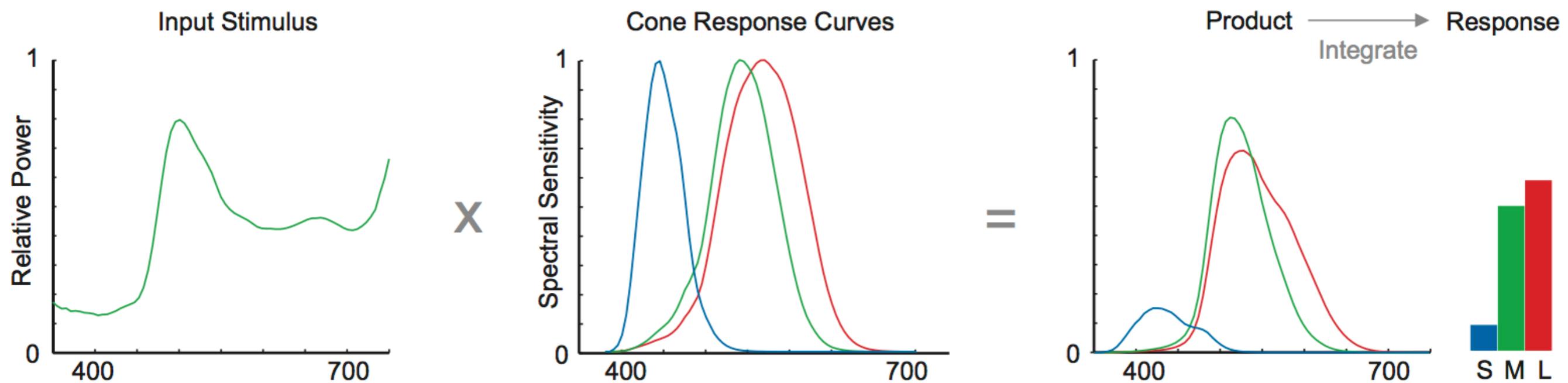
Short

Medium

Long



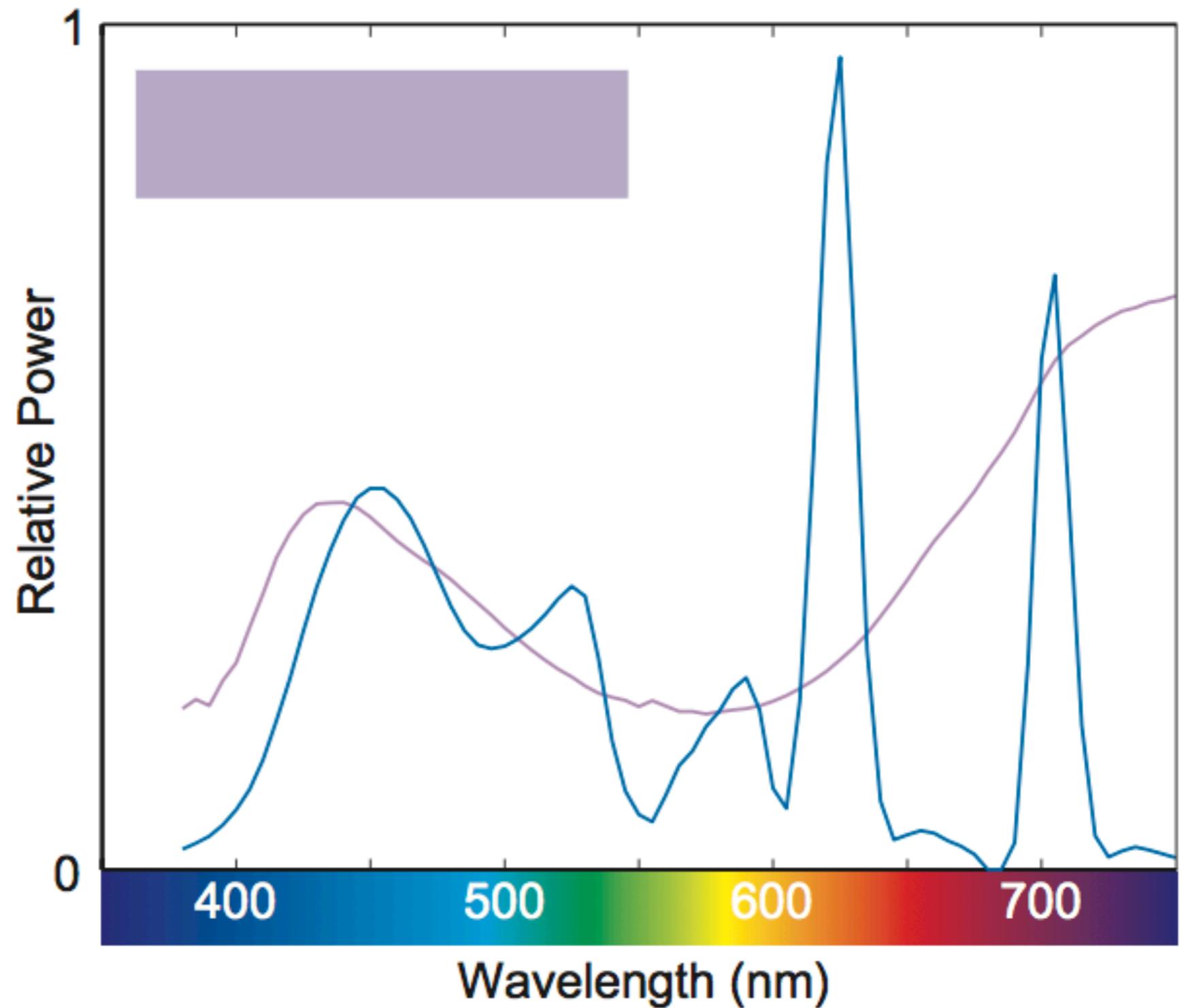
Cone response is integrated to produce response signal



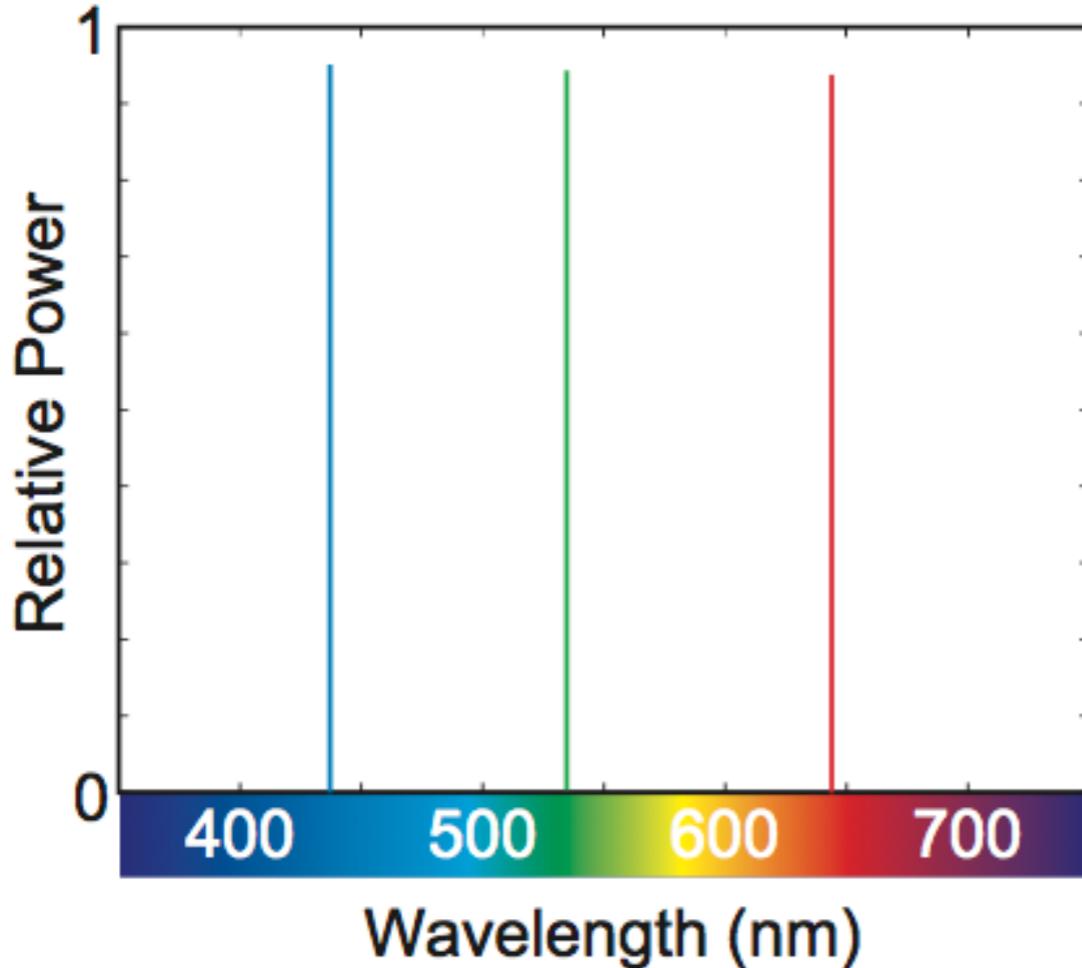
Metamerism

Many curves
produce same
signal due to
integration

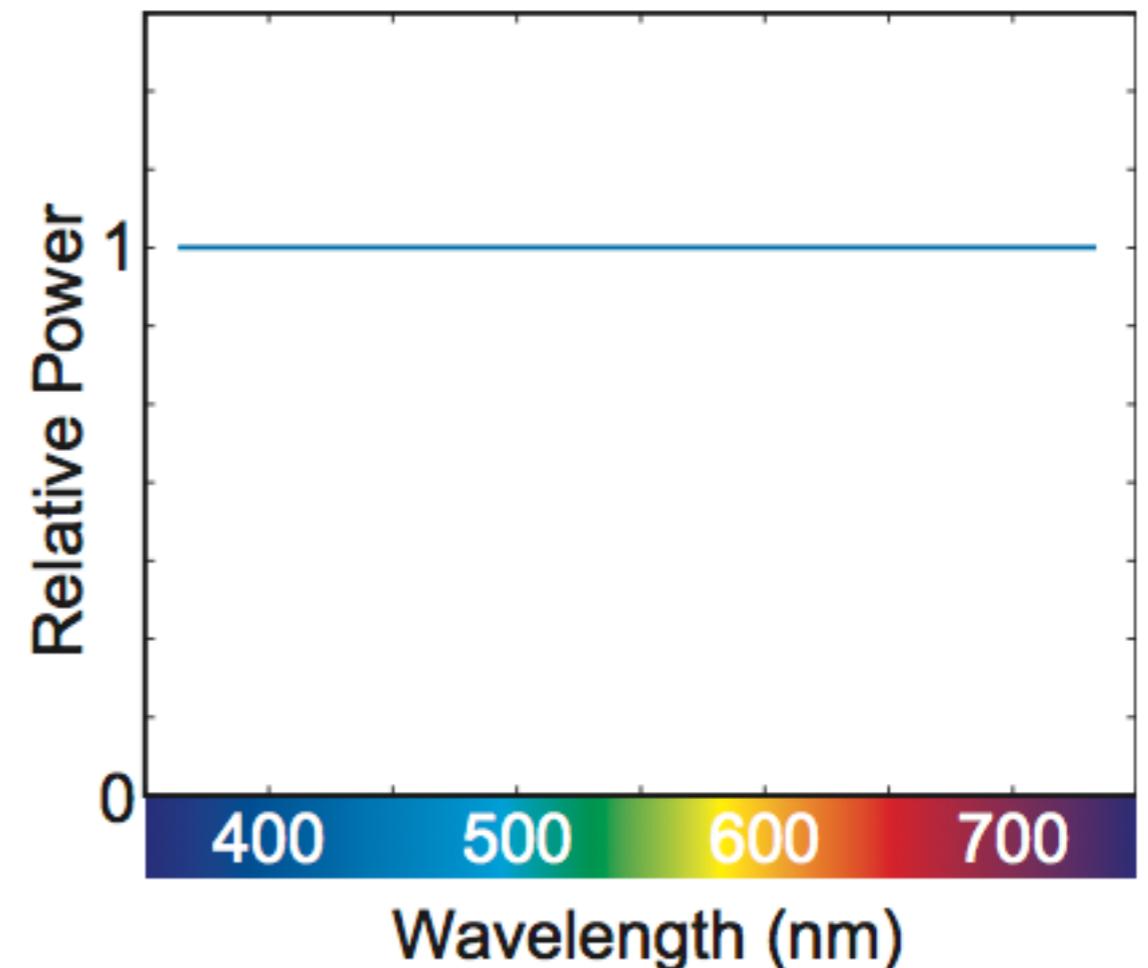
(called *metamers*)



White Light



White Light

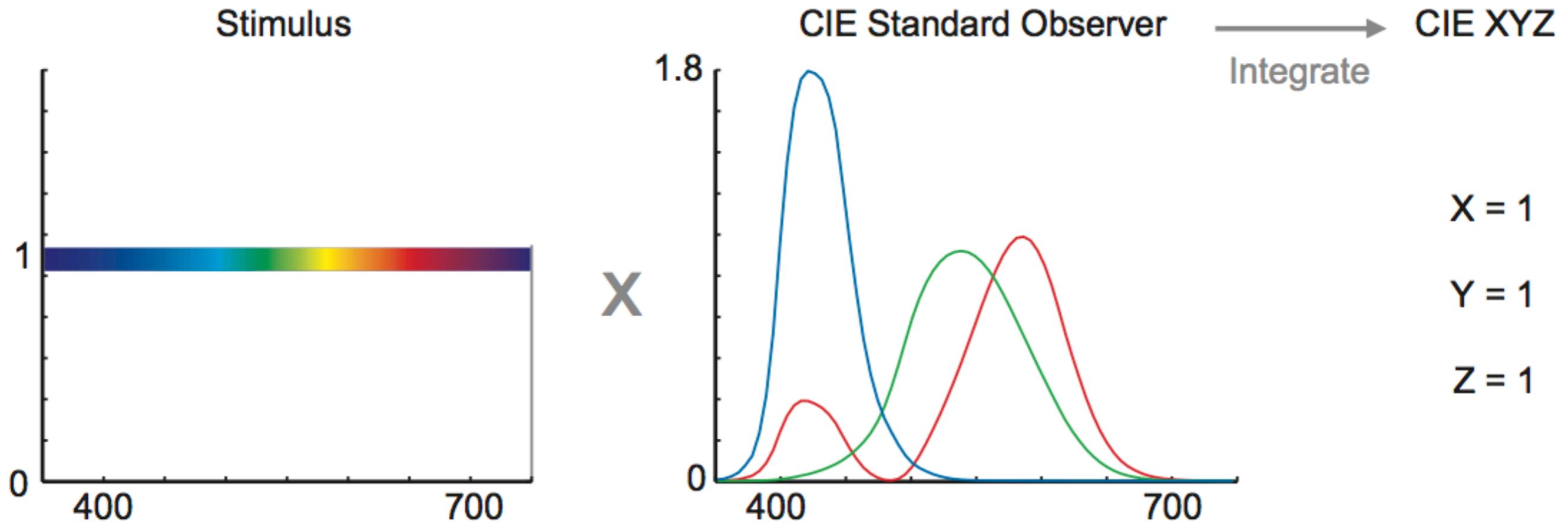


Tri-stimulus

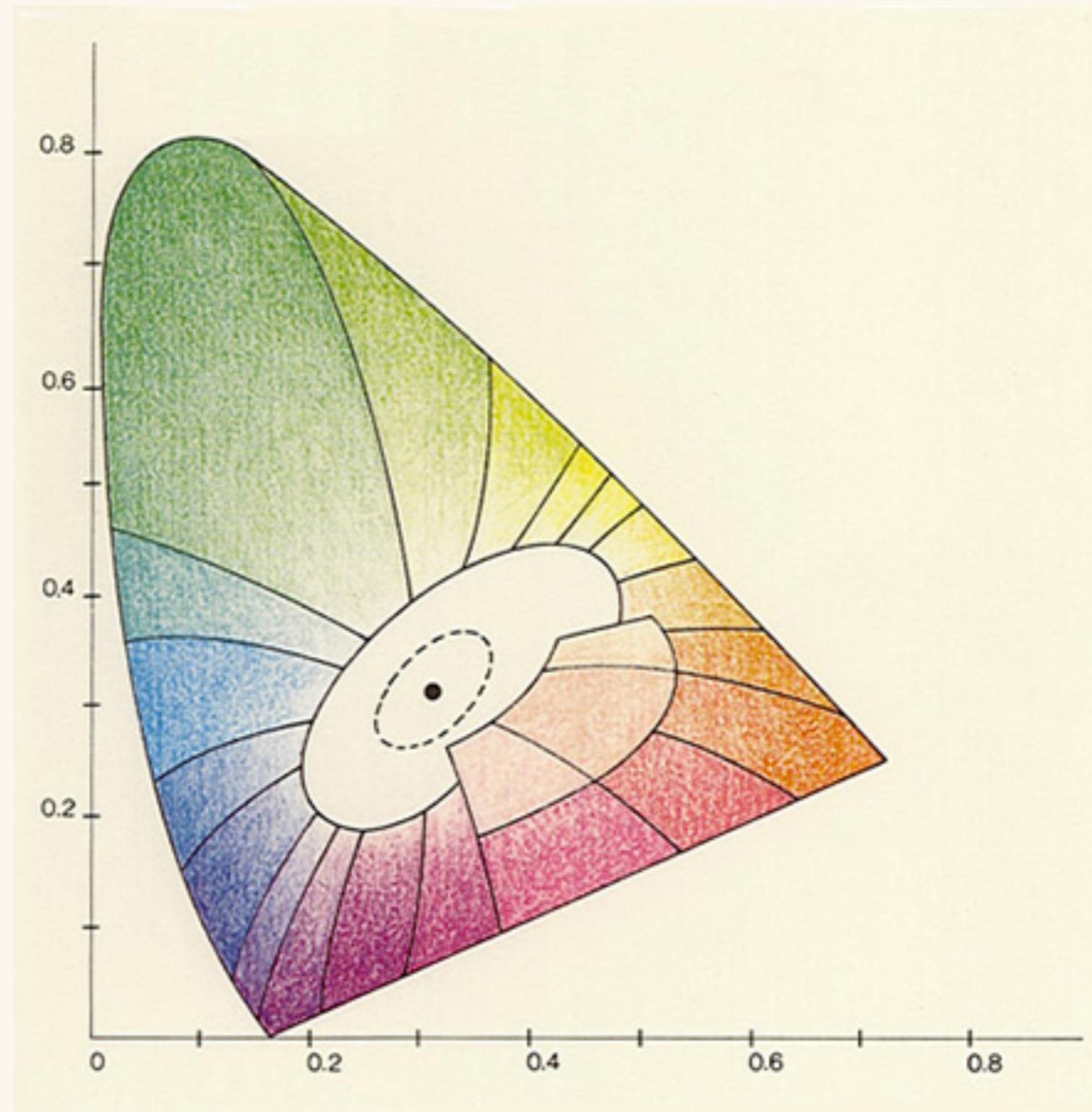


1931 effort to standardize tri-stimulus

X,Y,Z “standard observer” curves

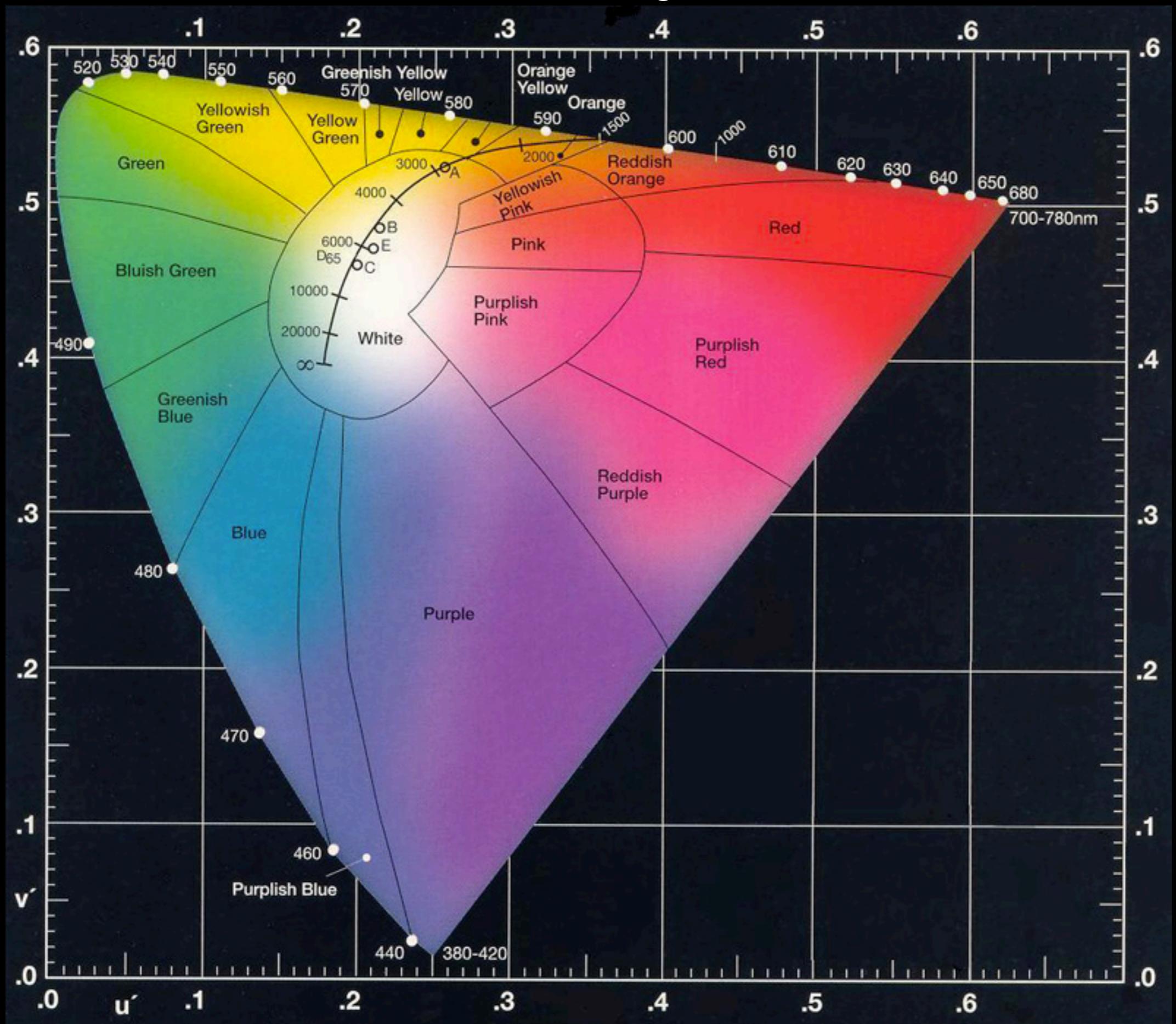


$\frac{Y}{X+Y+Z}$



$\frac{X}{X+Y+Z}$





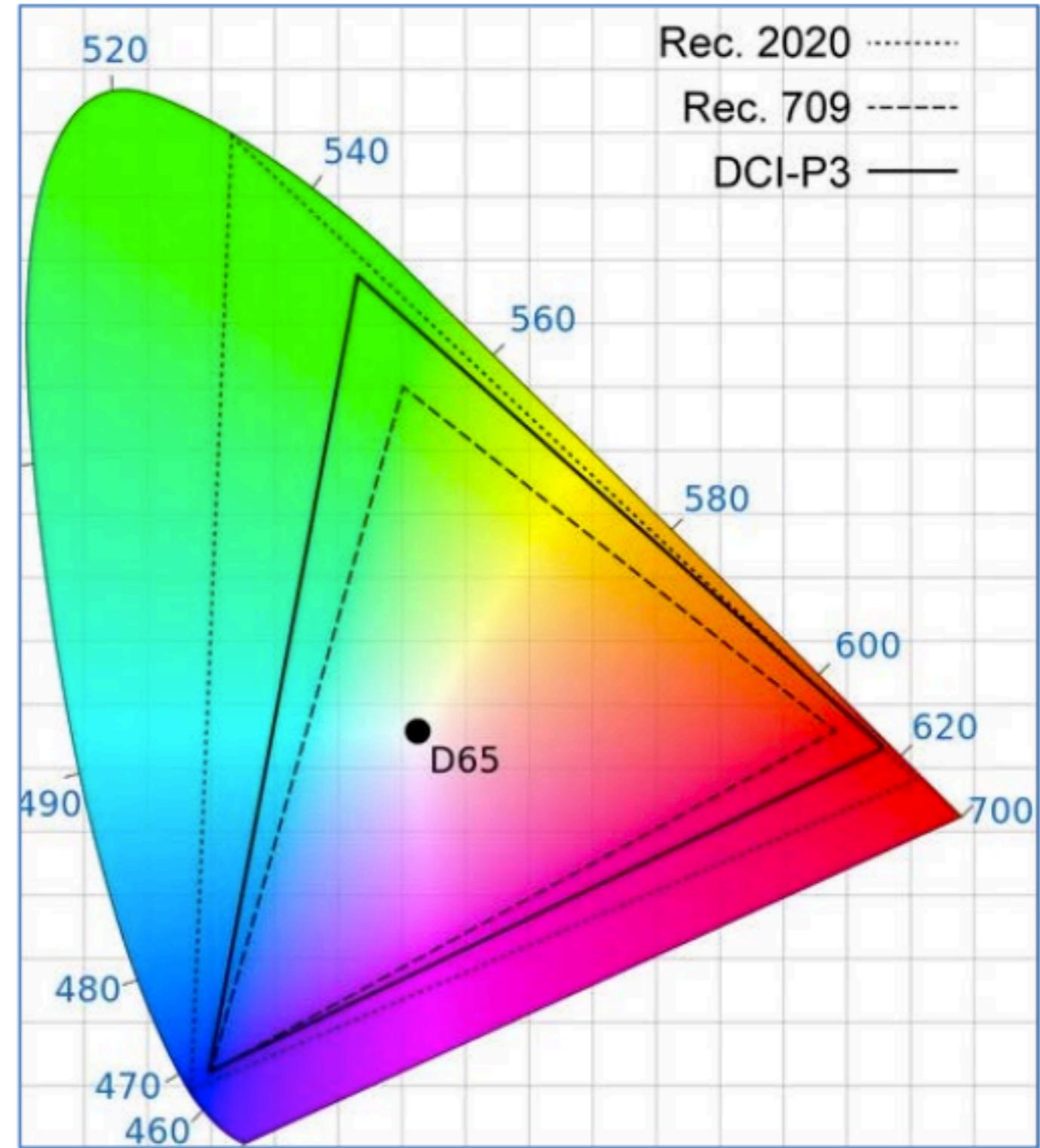
Gamut

Convex subset of colors

Device capabilities

“Colorants” in corners

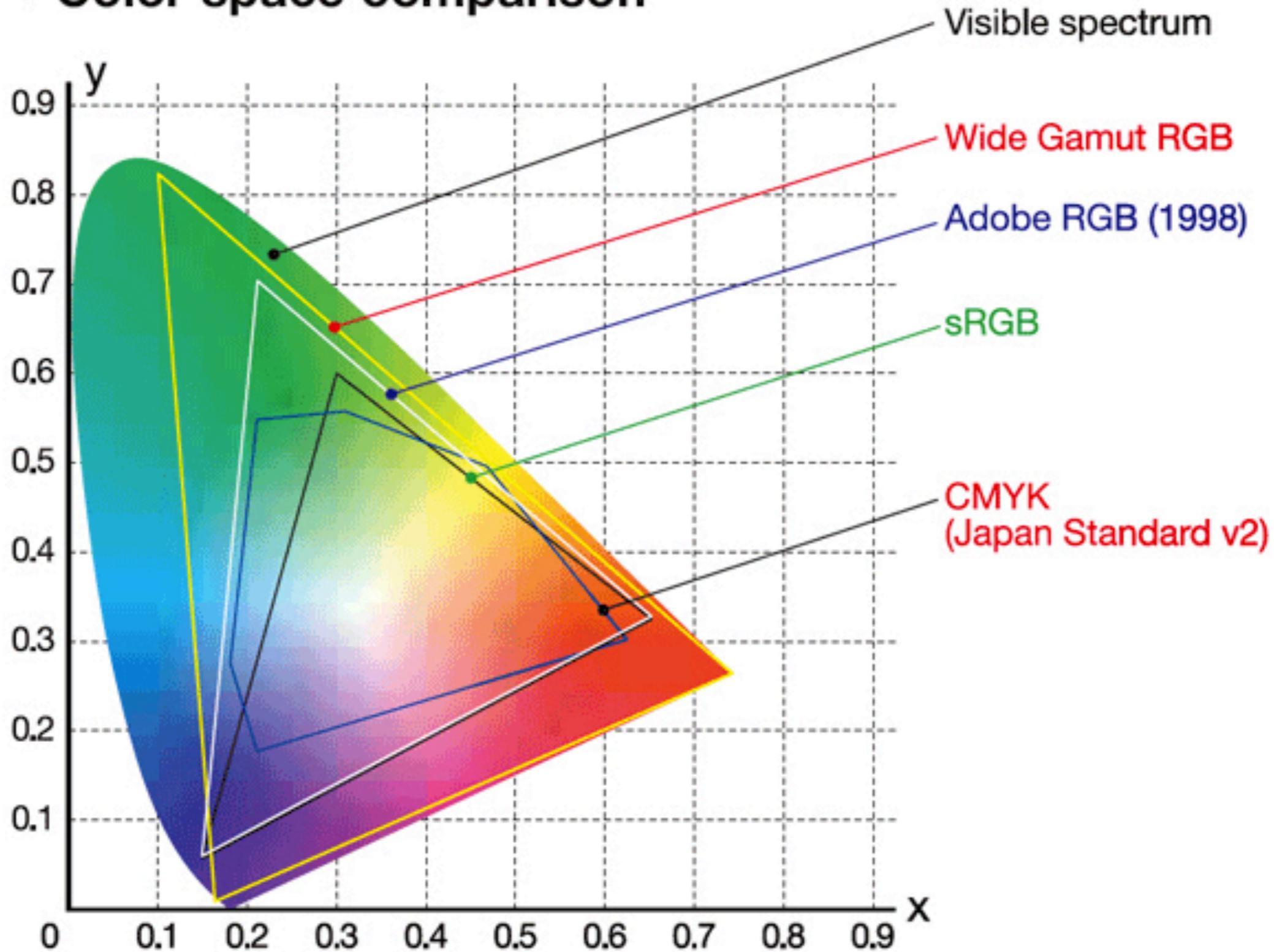
Color profiles



TV Broadcast Gamuts



- Color space comparison

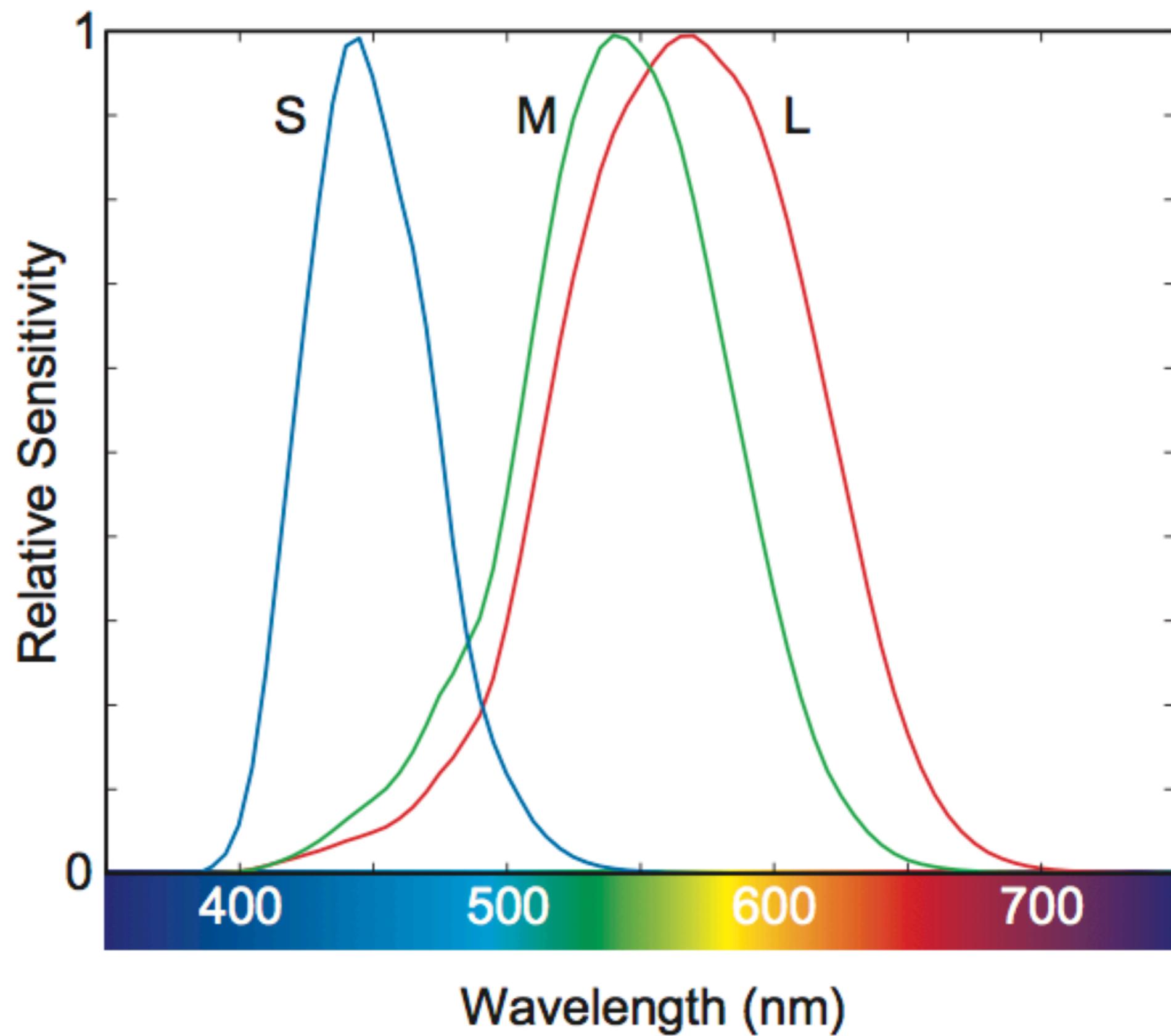


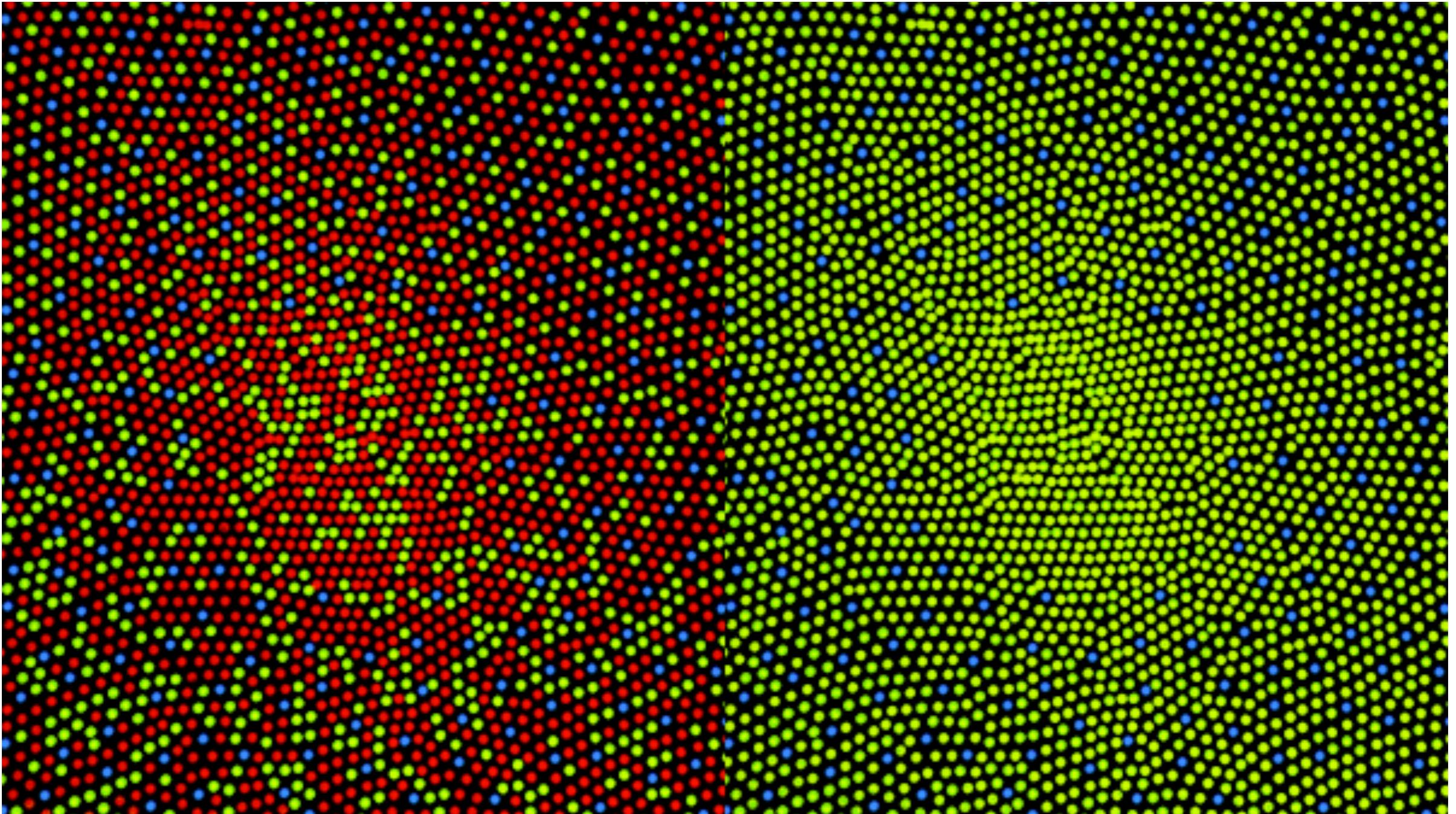
Cone Cells

Short

Medium

Long

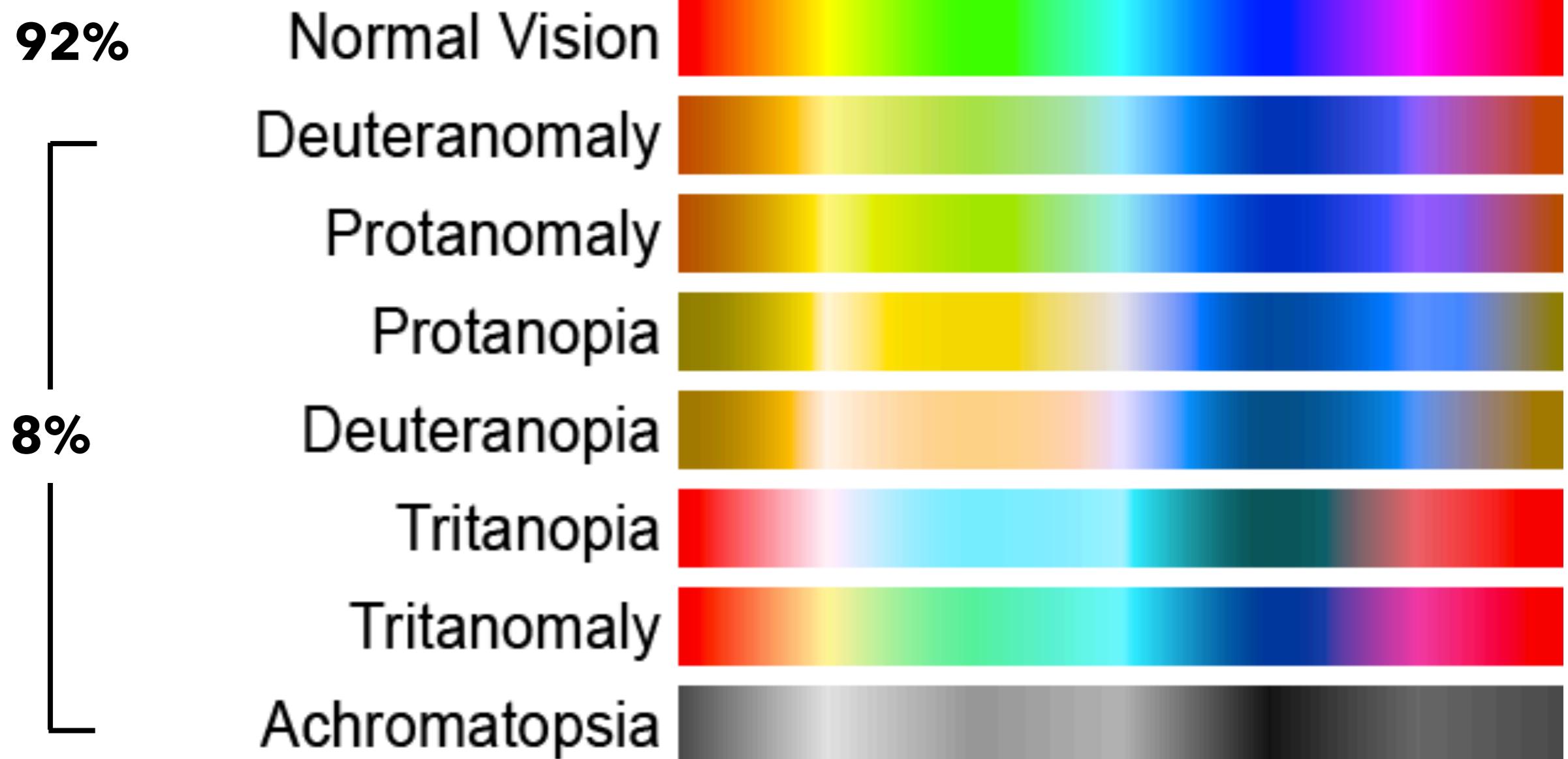




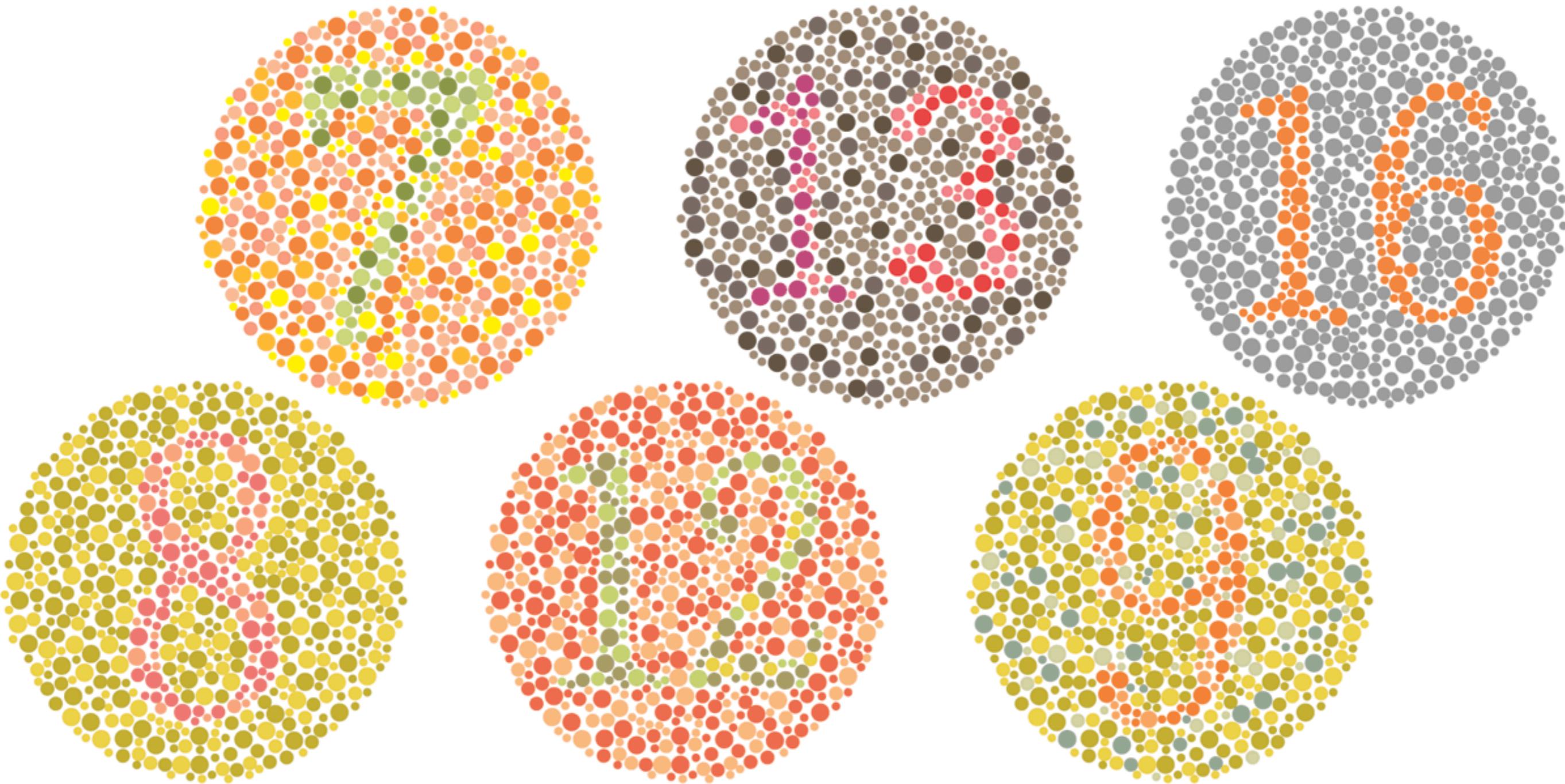
Typical

Protanopia

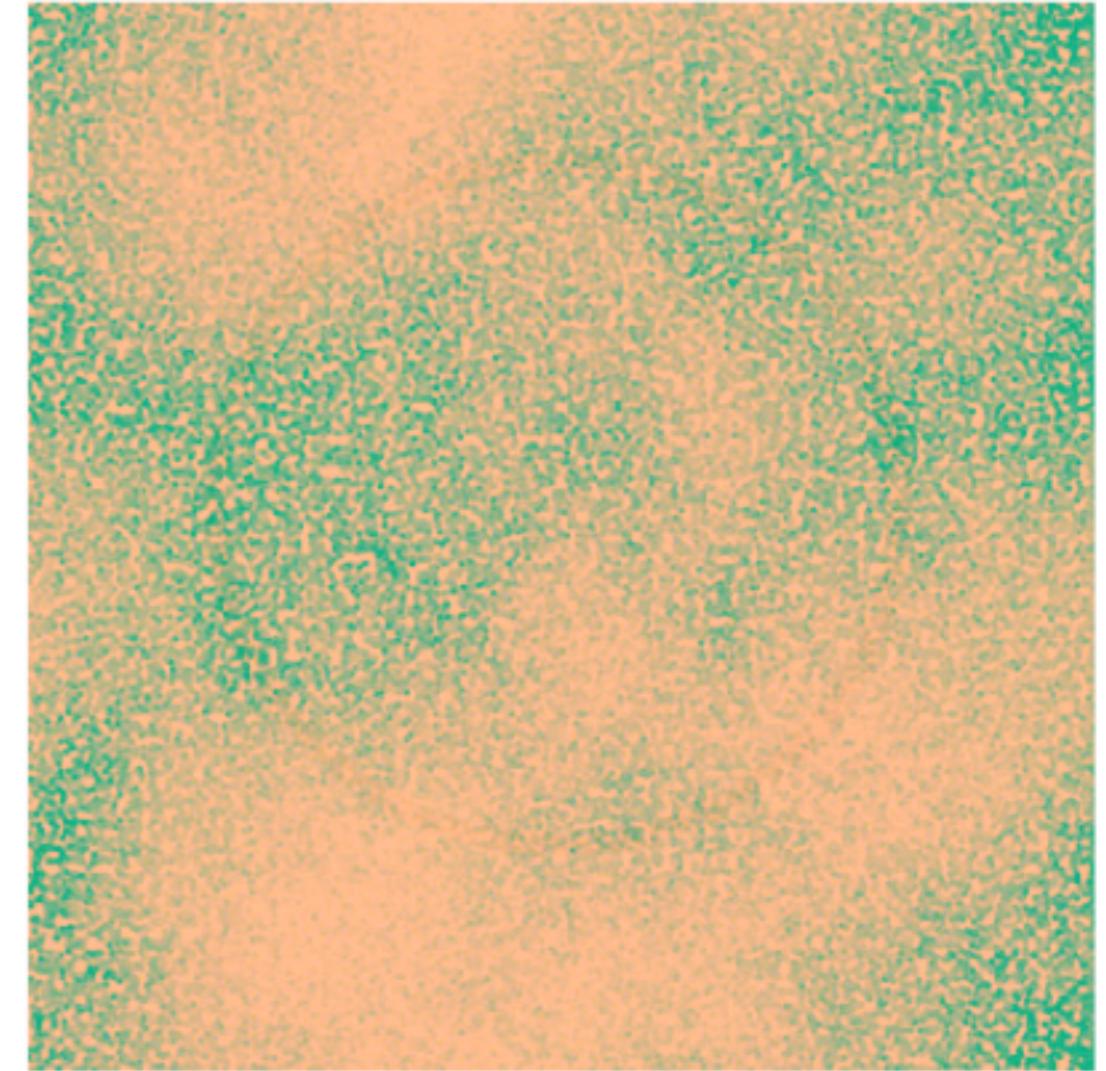
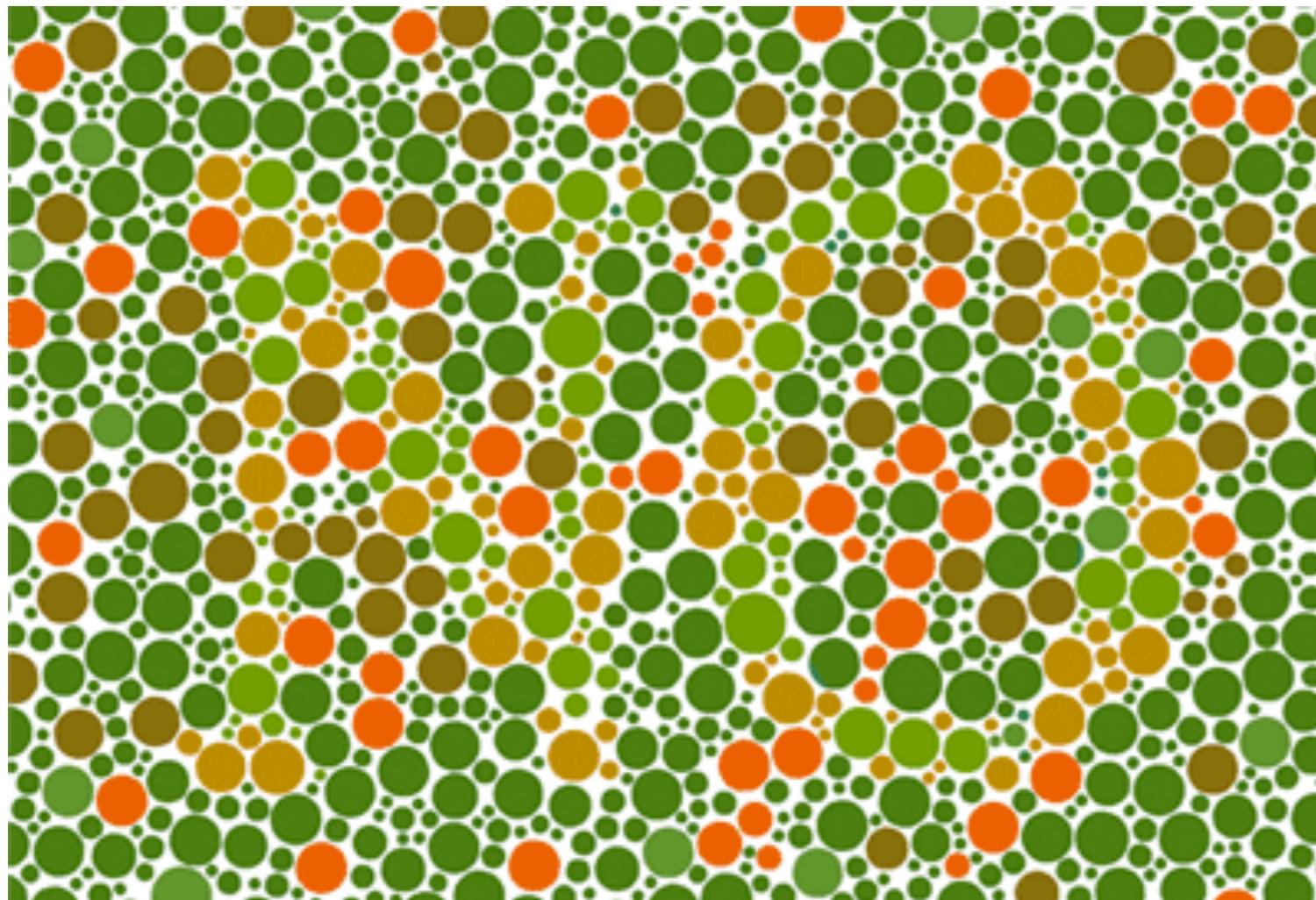
Color Blindness



Ishihara Tests

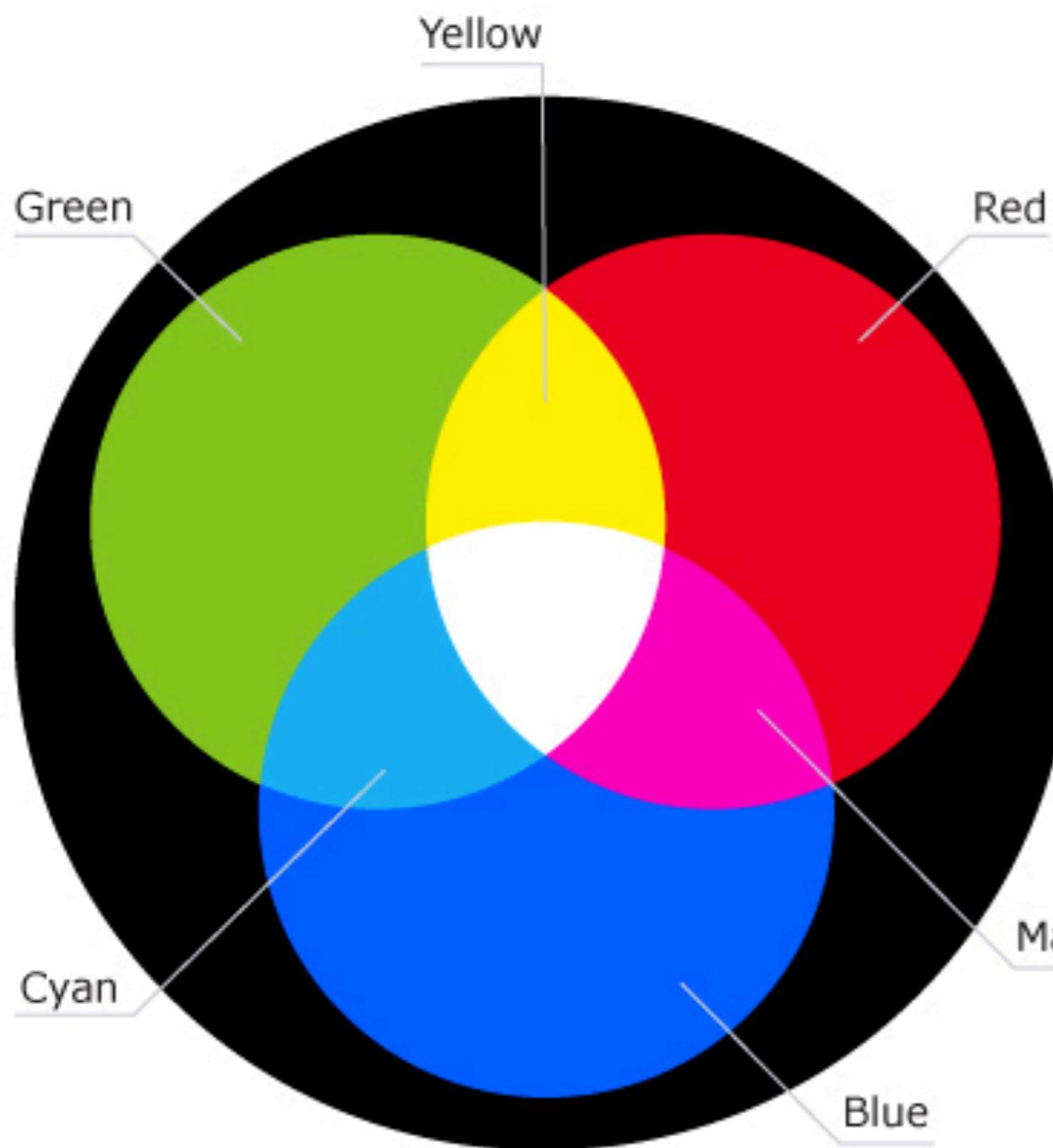


"Reverse Ishihara" Tests

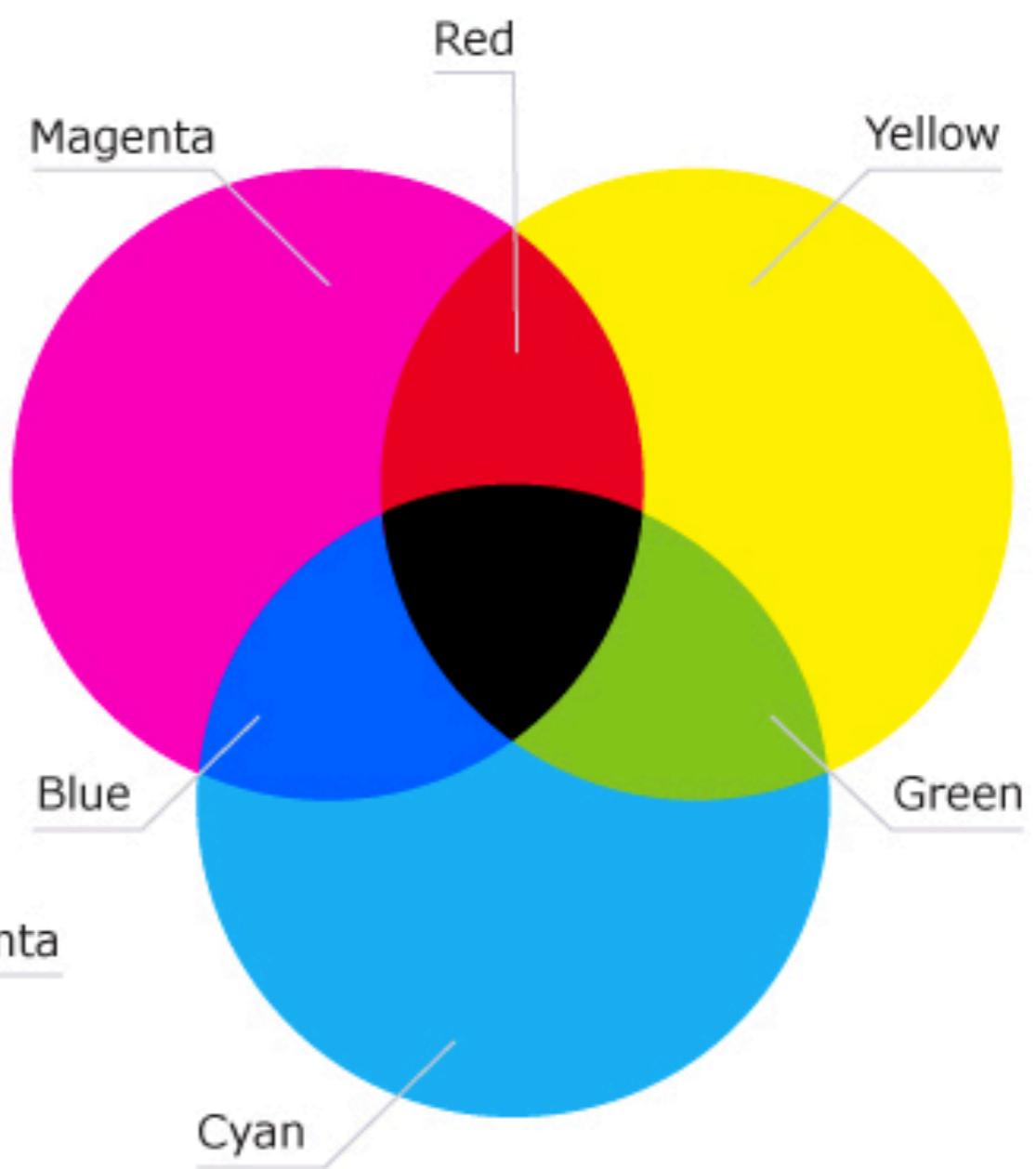


<https://www.cs.unm.edu/~aaron/creative/colorTest.htm>

Additive
(combining lights)

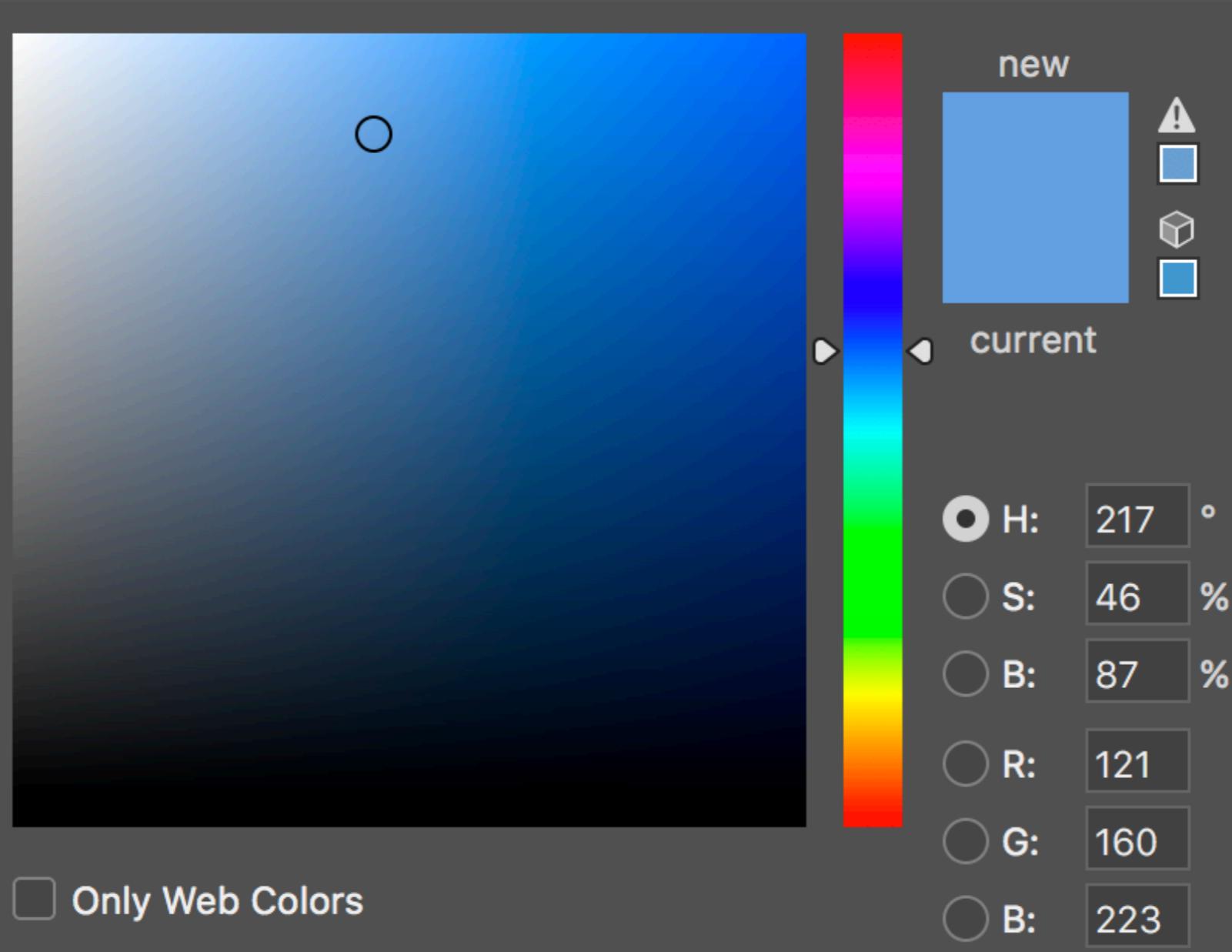


Subtractive
(mixing paints or inks)



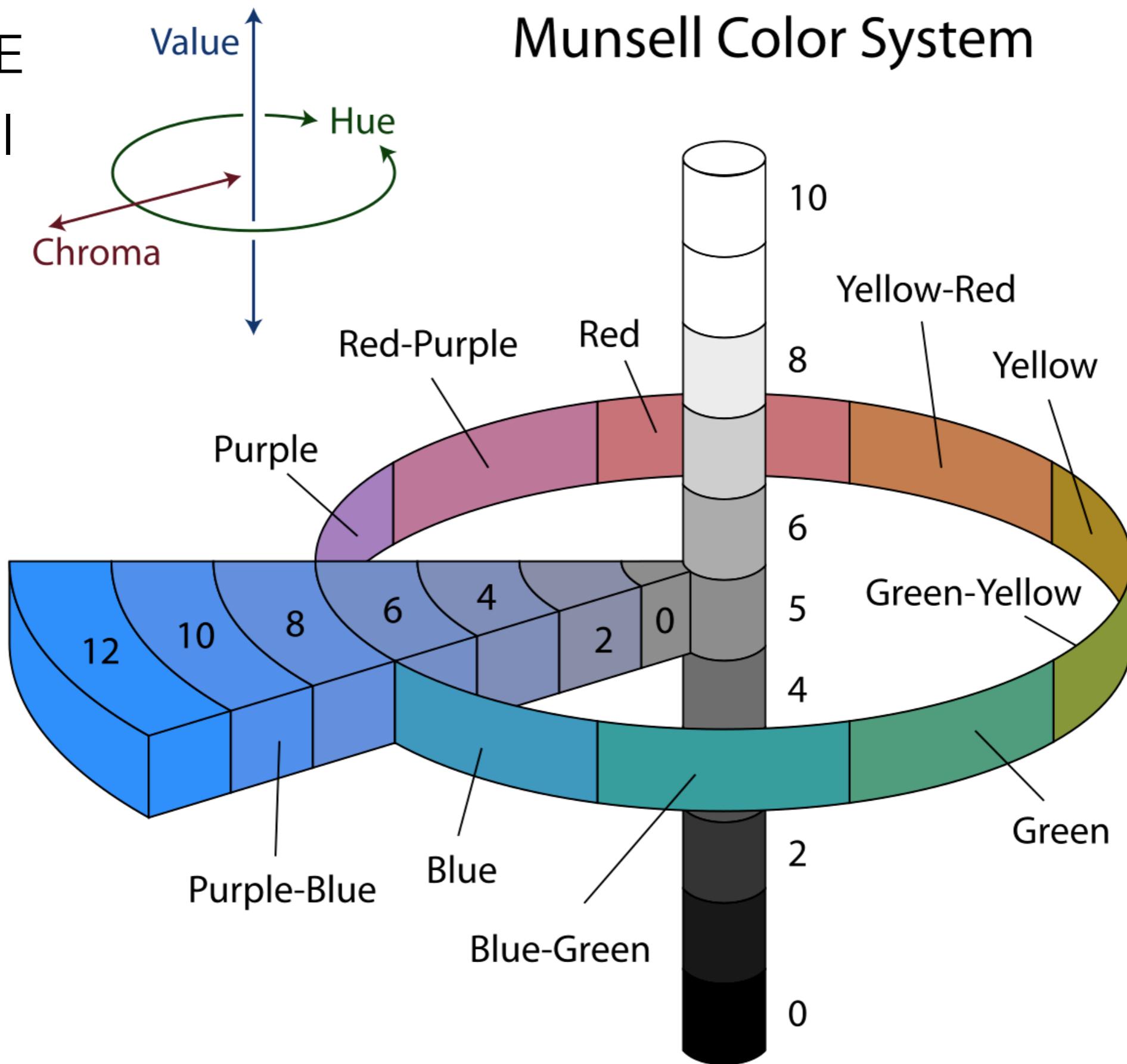
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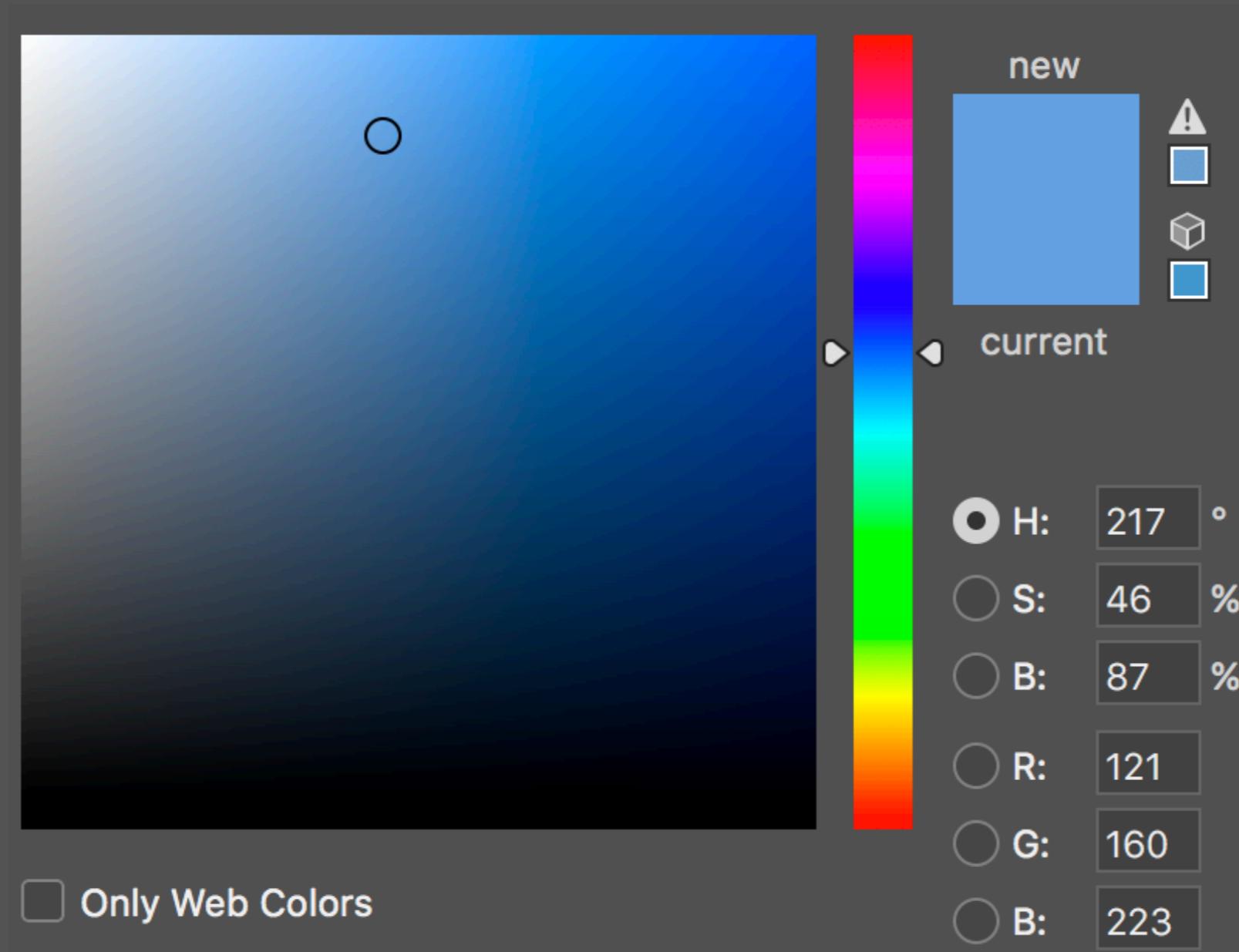
1943 CE

Munsell



HSV Color (aka HSB, HSL)

1970s graphics devs inspired by Munsell



HSV - hue shift



HSV - hue shift



HSV - V val



Luminance
(as perceived
by humans)



HSV - hue shift



HSV - V val



Luminance
(as perceived
by humans)



**This can impact how users perceive
differences in color scales!**

“Perceptually uniform” color spaces

d3.interpolateHsl(*a*, *b*) <[>](#)



d3.interpolateLab(*a*, *b*) <[>](#)



d3.interpolateHcl(*a*, *b*) <[>](#)



Data => Color

SANFORD AND SELNICK

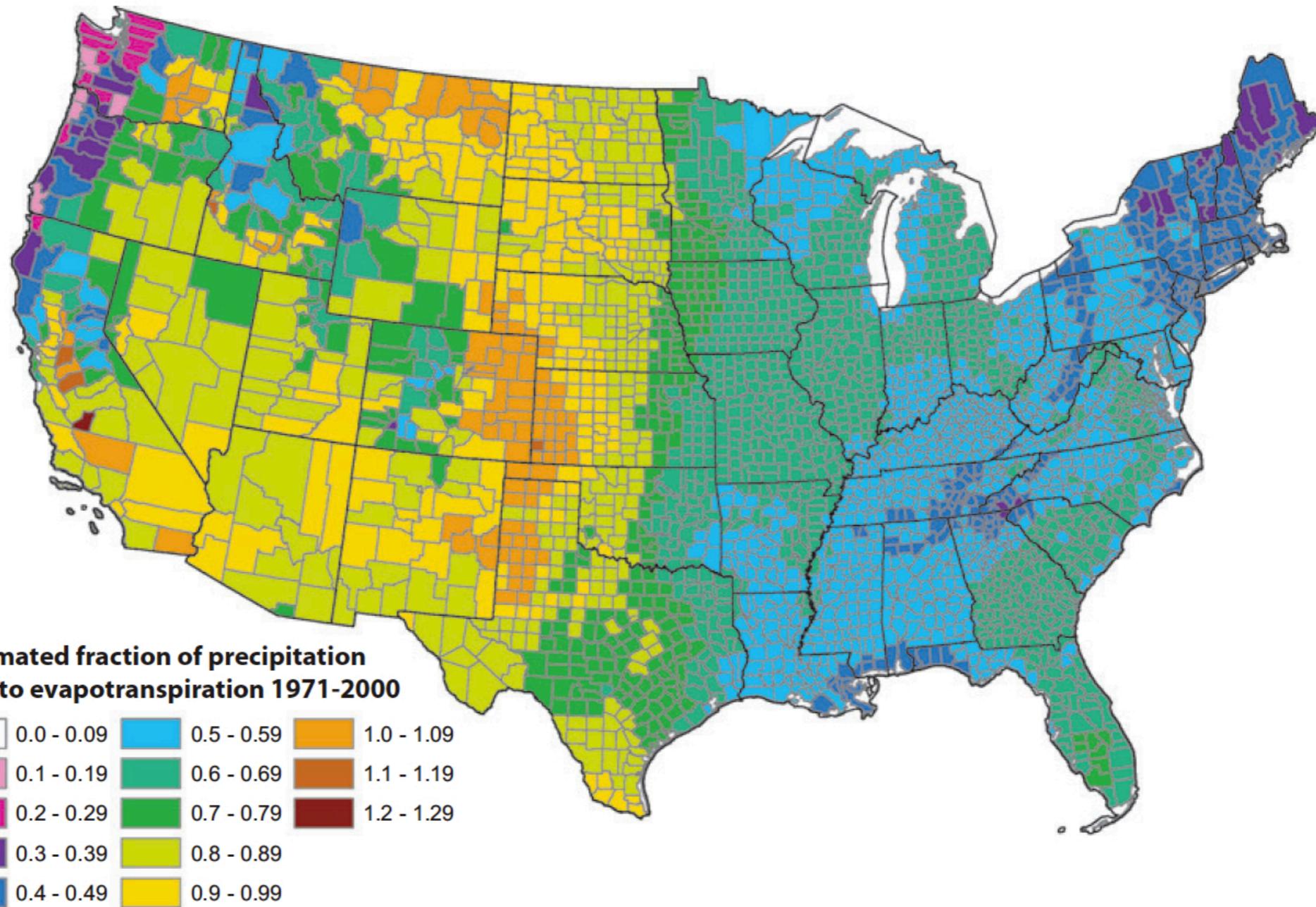


FIGURE 13. Estimated Mean Annual Ratio of Actual Evapotranspiration (ET) to Precipitation (P) for the Conterminous U.S. for the Period 1971-2000. Estimates are based on the regression equation in Table 1 that includes land cover. Calculations of ET/P were made first at the 800-m resolution of the PRISM climate data. The mean values for the counties (shown) were then calculated by averaging the 800-m values within each county. Areas with fractions >1 are agricultural counties that either import surface water or mine deep groundwater.



Kinds of Data

- **Nominal**
 - Dog breeds, party affiliation, cheese types
- **Ordinal**
 - Class grade, “size word”, stock class, “discretized” scales
- **Quantitative**
 - **Interval** – No fixed zero point
 - dates, temperature, geo-coords
 - **Ratio** – Fixed zero point
 - temperature, count



Color Channel - Nominal



Nominal (unordered) [hue works]



Nominal (unordered) [hue works]

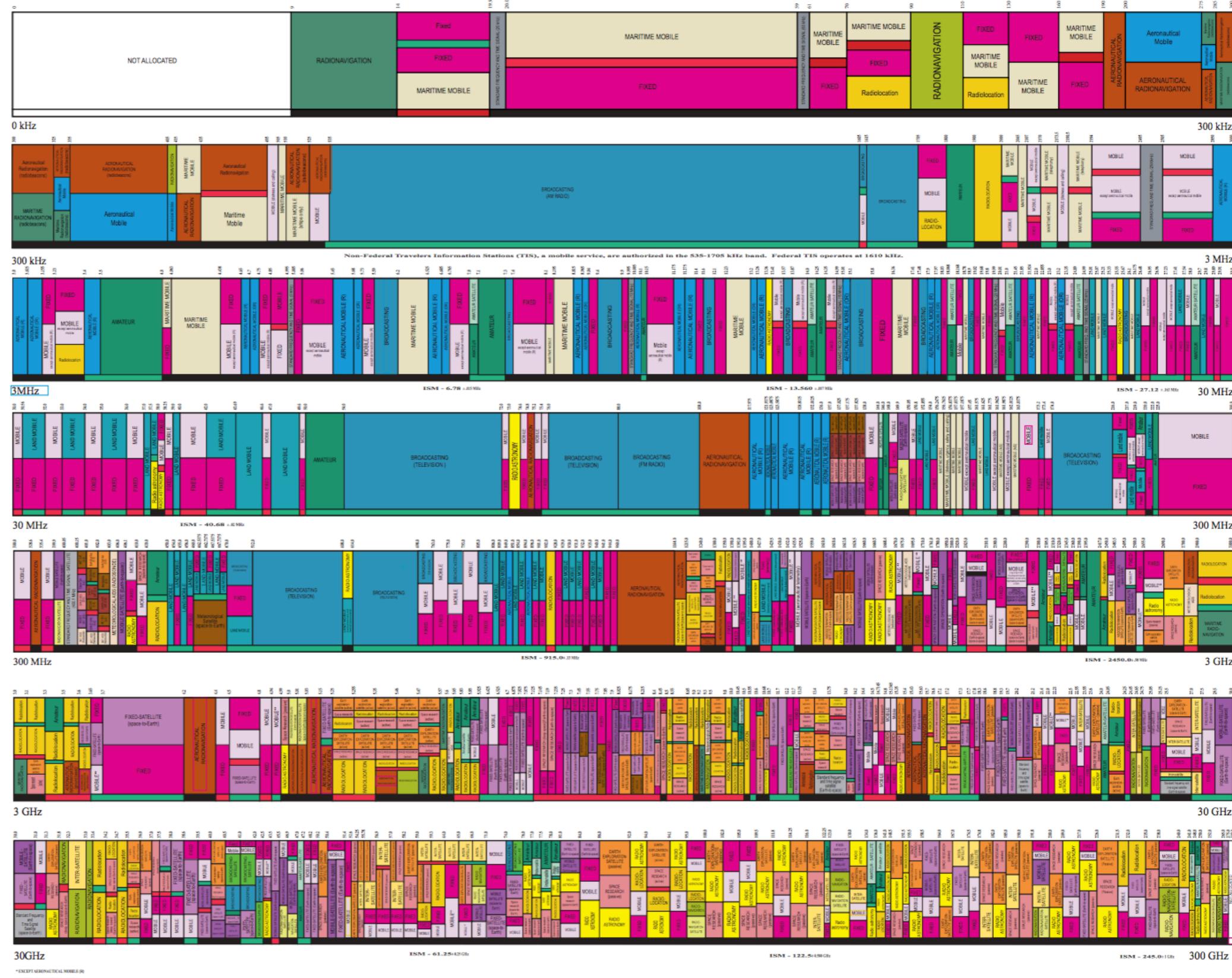


but choose carefully...

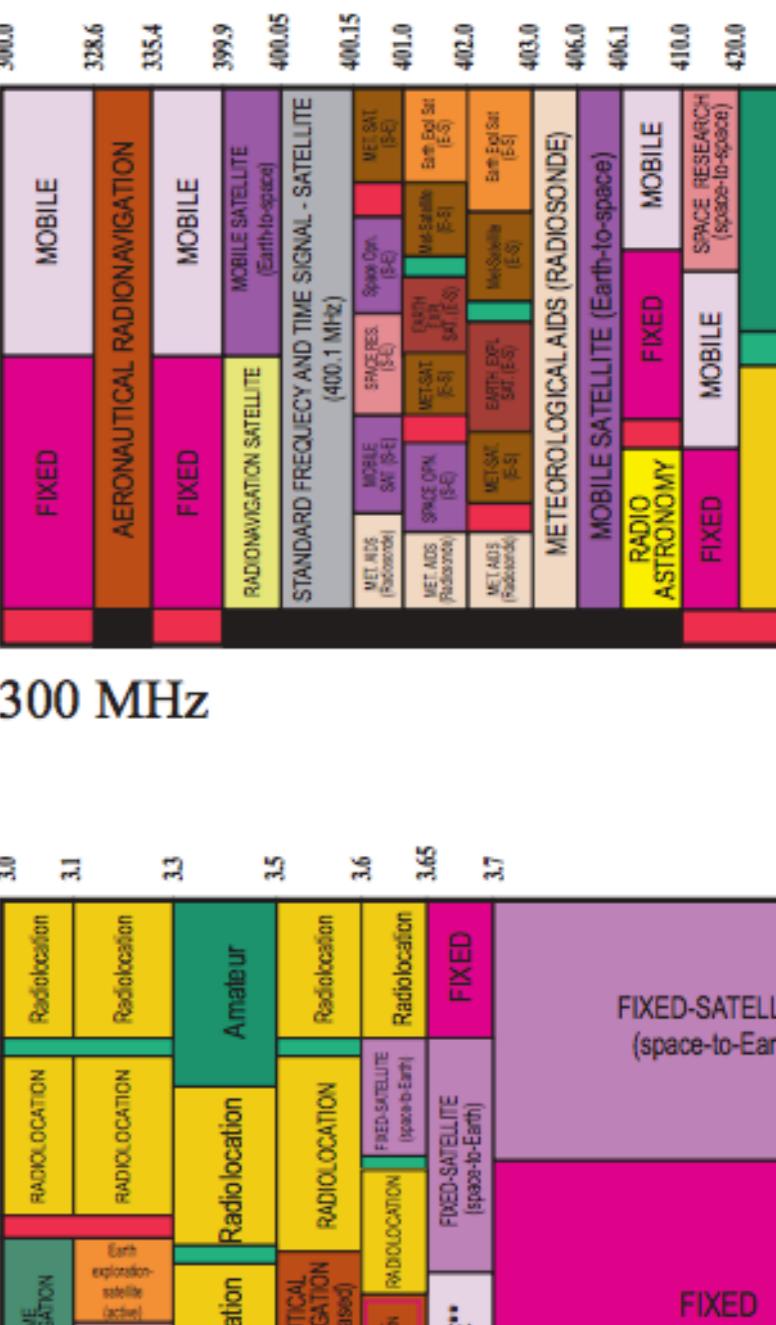
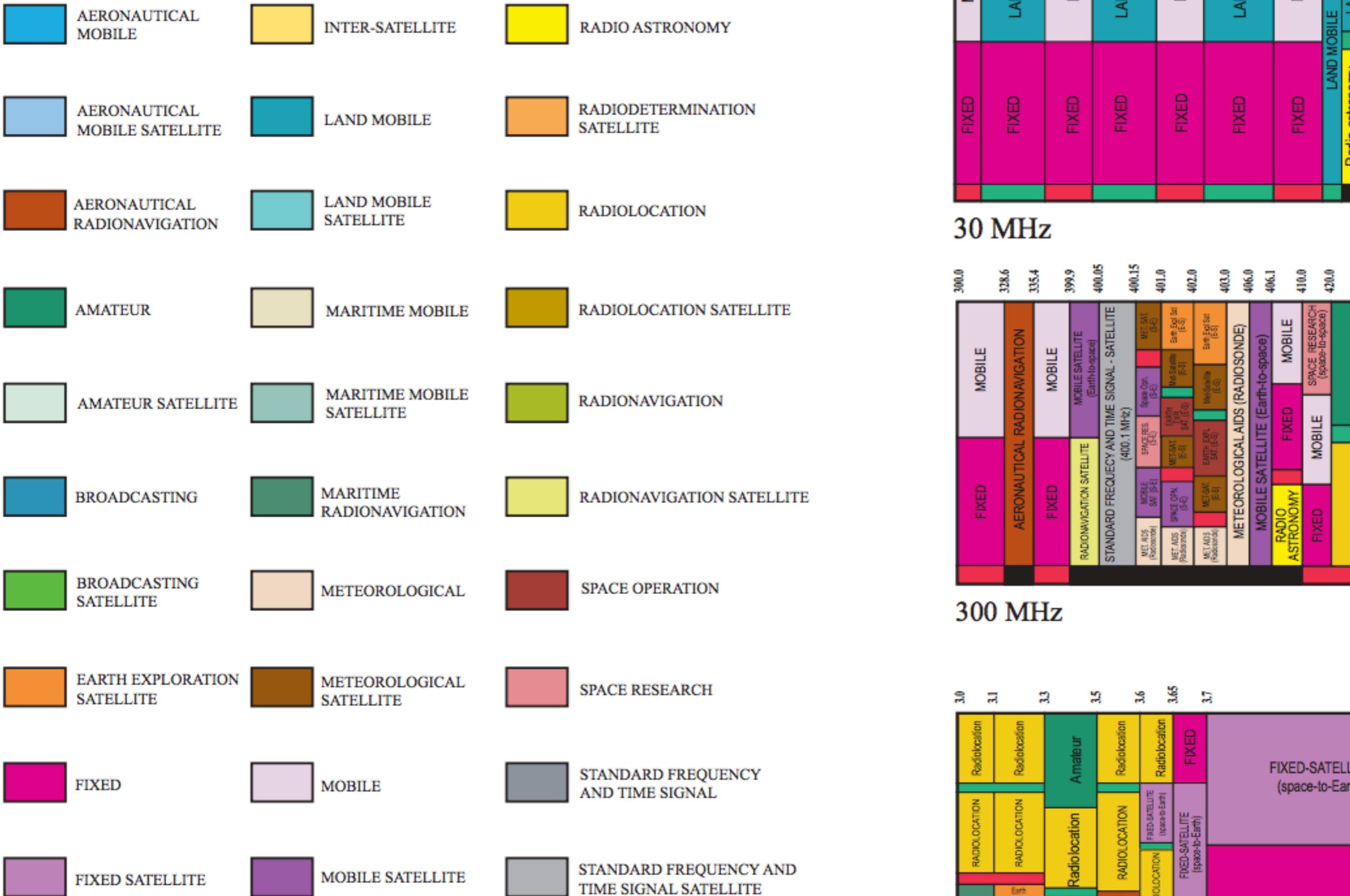


UNITED STATES FREQUENCY ALLOCATIONS

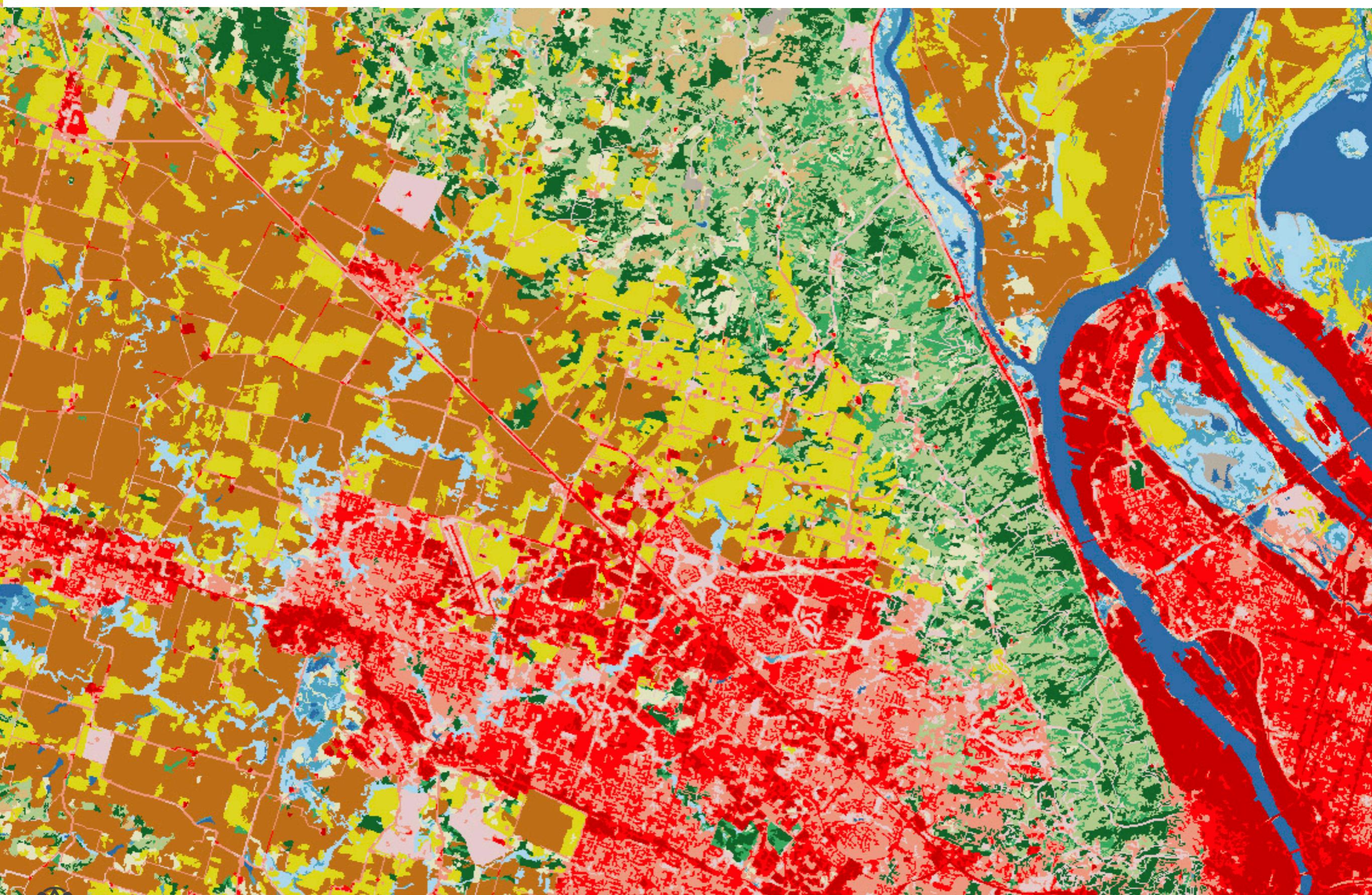
THE RADIO SPECTRUM



RADIO SERVICES COLOR LEGEND



Landsat Shows Land Use Around Portland, NASA



Number of data classes:

3

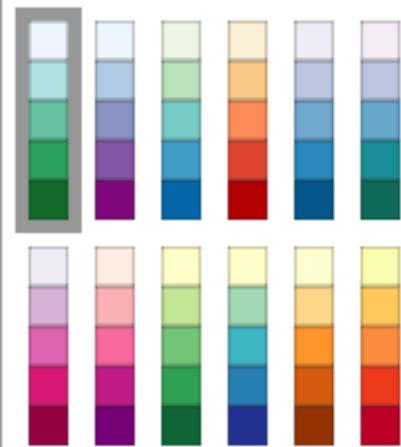


Nature of your data:

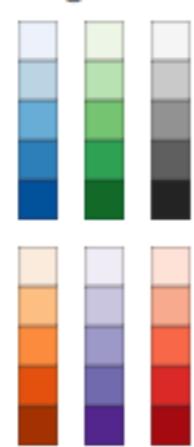
104

Pick a color scheme:

Multi-hue:



Single hue:



Only show:

3-class BuGn



HEX

#e5f5f9

#99d8c9

Context:

roads

cities

Background:

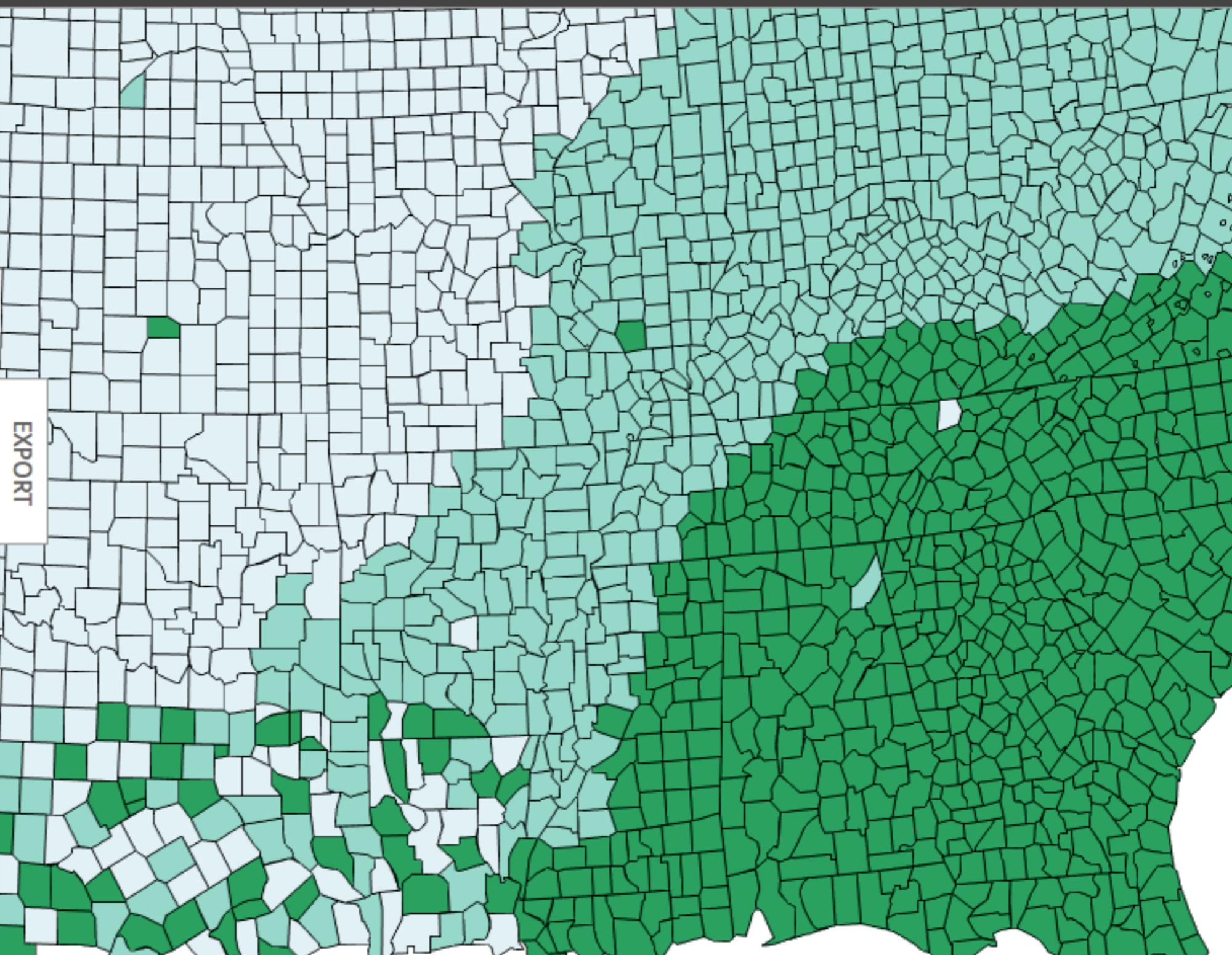
• solid color

terrain



1

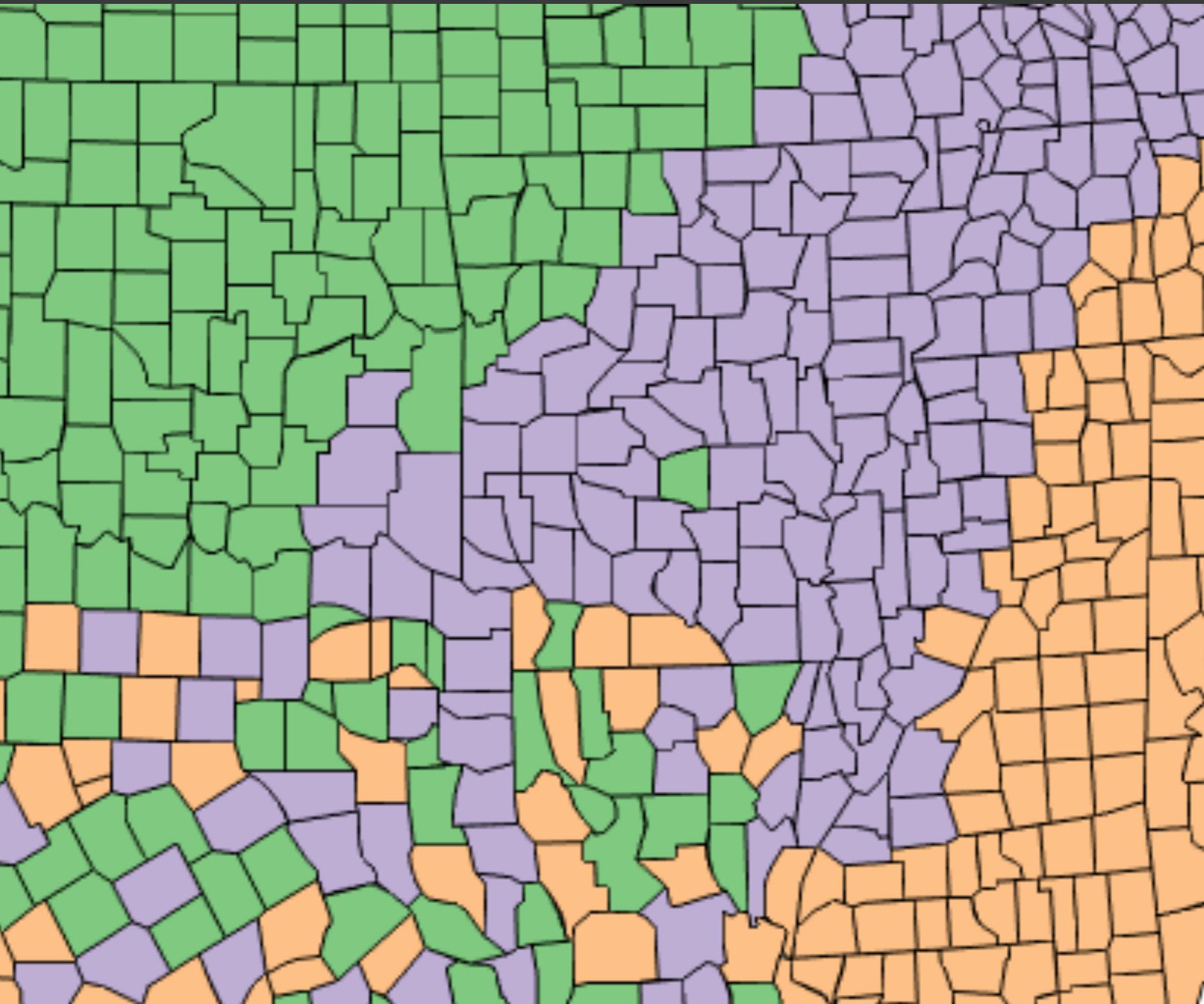
COLORBREWER 2.0
color advice for cartography



<http://colorbrewer2.org/>



Minimize unique colors (4-8) and maximize differences



Color Channel - Quant & Order



Varying hue

Ordinal (ordered)



1st

2nd

3rd

4th

5th

Varying hue

Quantitative (also “ordered”)



1, 2, 3, 4, 5, 6, 7, 8...



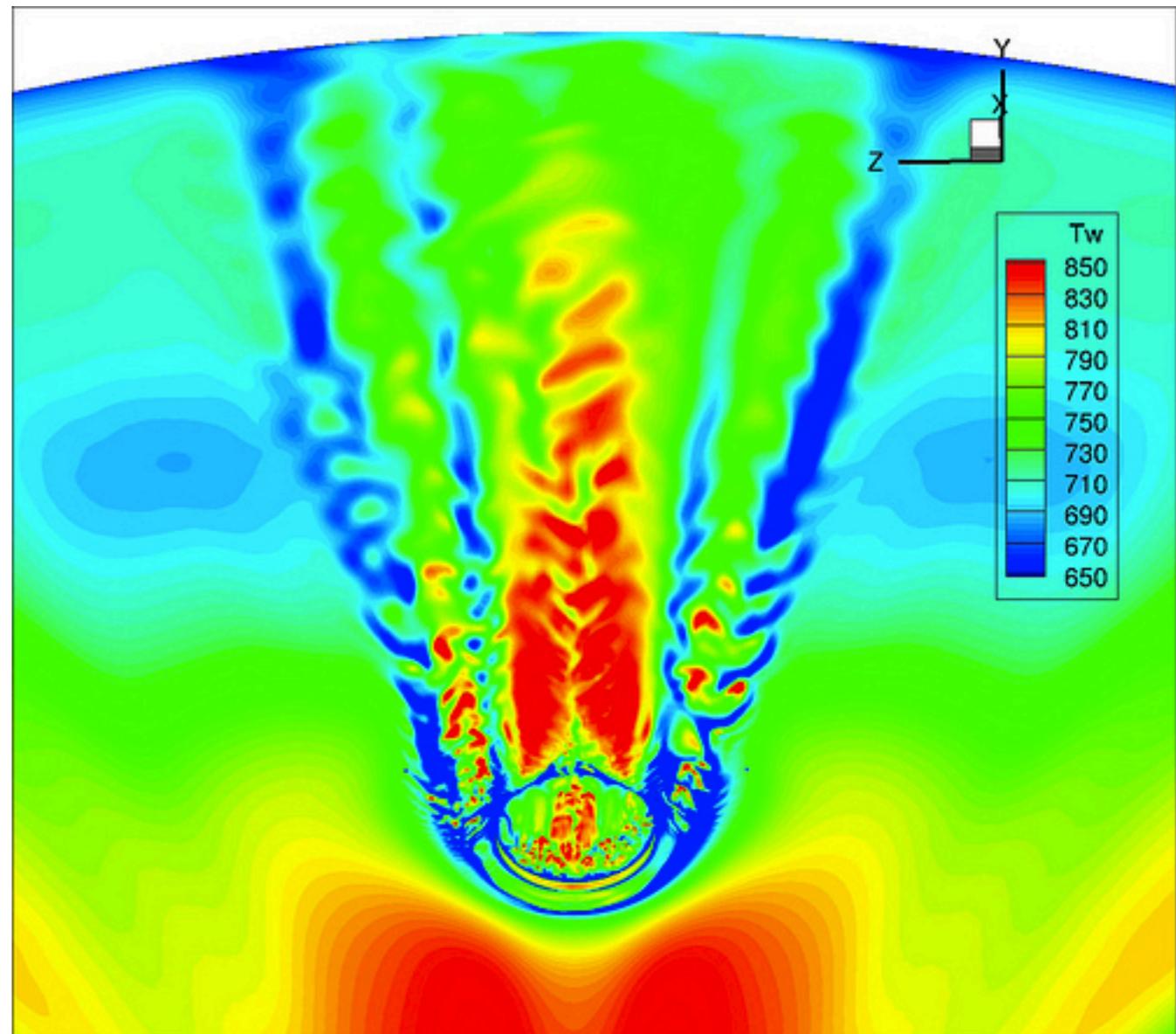
Caution: Rainbow Scales

Colors may have implicit categorizations

Unorderable – hard to judge place in scale

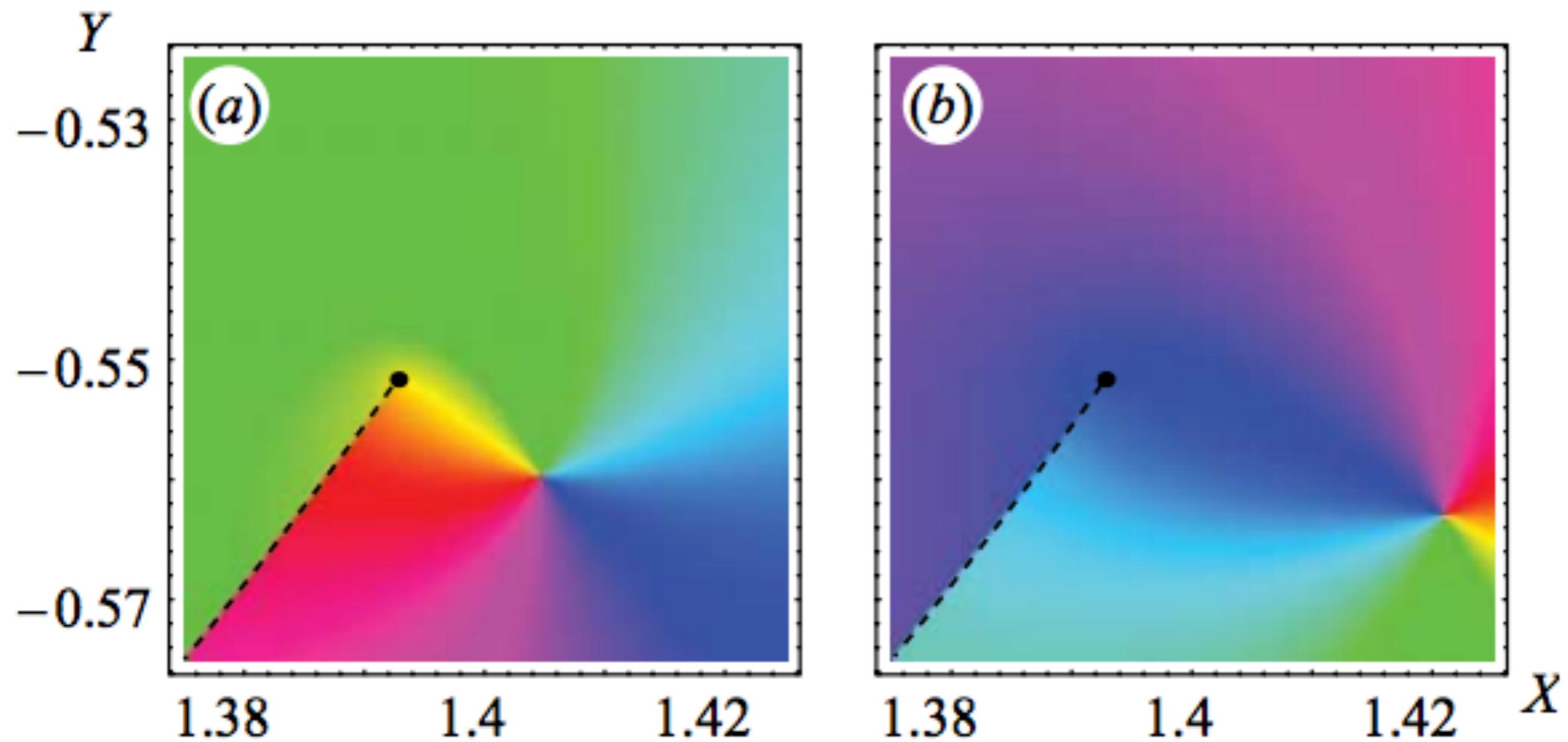
HSV vs LAB luminosity

Some colors have more “room” for detail than others



<http://www.flickr.com/photos/69612157@N06/7142993799/in/photostream/>







Varying hue

Quantitative (also “ordered”)



(What's wrong with this rainbow scale?)

Varying hue

Quantitative (also “ordered”)



Remember perceptual uniformity



PANTONE 19-1536
Red Pear
Deliciously deep red,
whose luscious depth
entices.



PANTONE 18-1549
Valiant Poppy
Brave and outgoing red
shade effusive in its allure.



PANTONE 18-4048
Nebulas Blue
Reminiscent of twilight, a
thoughtful, starry-eyed
blue.



PANTONE 15-0850
Ceylon Yellow
Savory and spicy yellow
adds an exotic touch.



PANTONE 18-0625
Martini Olive
Smooth, sophisticated and
urbane green adds depth
to the Fall/Winter 2018
palette.



PANTONE 16-1255
Russet Orange
This forest floor orange
speaks to earthen warmth.



PANTONE 18-3838
Ultra Violet
Inventive and imaginative
Ultra Violet lights the way
for what is yet to come.



PANTONE 15-3520
Crocus Petal
A cultivated and refined
hue adds a light and airy
spring-like feeling demand.



PANTONE 12-0740
Limelight
Animated and effervescent,
a pungent yellow-green
becomes the center of
attention.



PANTONE 18-5025
Quetzal Green
A deep elegant blue-green
hue suggestive of rich
plumage.



Red?



Orange?



Yellow?



People perceive small differences
between colors **more accurately** if they
use **different names** for them!



Varying hue

Ordinal (ordered) [no hue]



Quantitative (also “ordered”) [can work, but...]



Varying saturation & luminosity

Ordinal (ordered)



Quantitative (also “ordered”)



Varying saturation & luminosity

Ordinal (ordered)

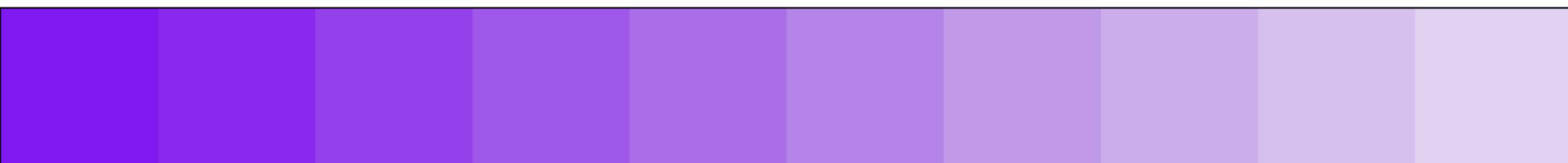


Quantitative (also “ordered”)



Varying saturation & luminosity

Ordinal (ordered) [pretty good for 4-8]



Quantitative (also “ordered”) [needs redundancy]



Kinds of Scales

Sequential

Use for most cases

Divergent

Use when your data has a “middle”



Sequential



Limited hue (ideally one)

Luminance, saturation, both

Higher values => darker colors

“Discretize” your scale!

Sequential



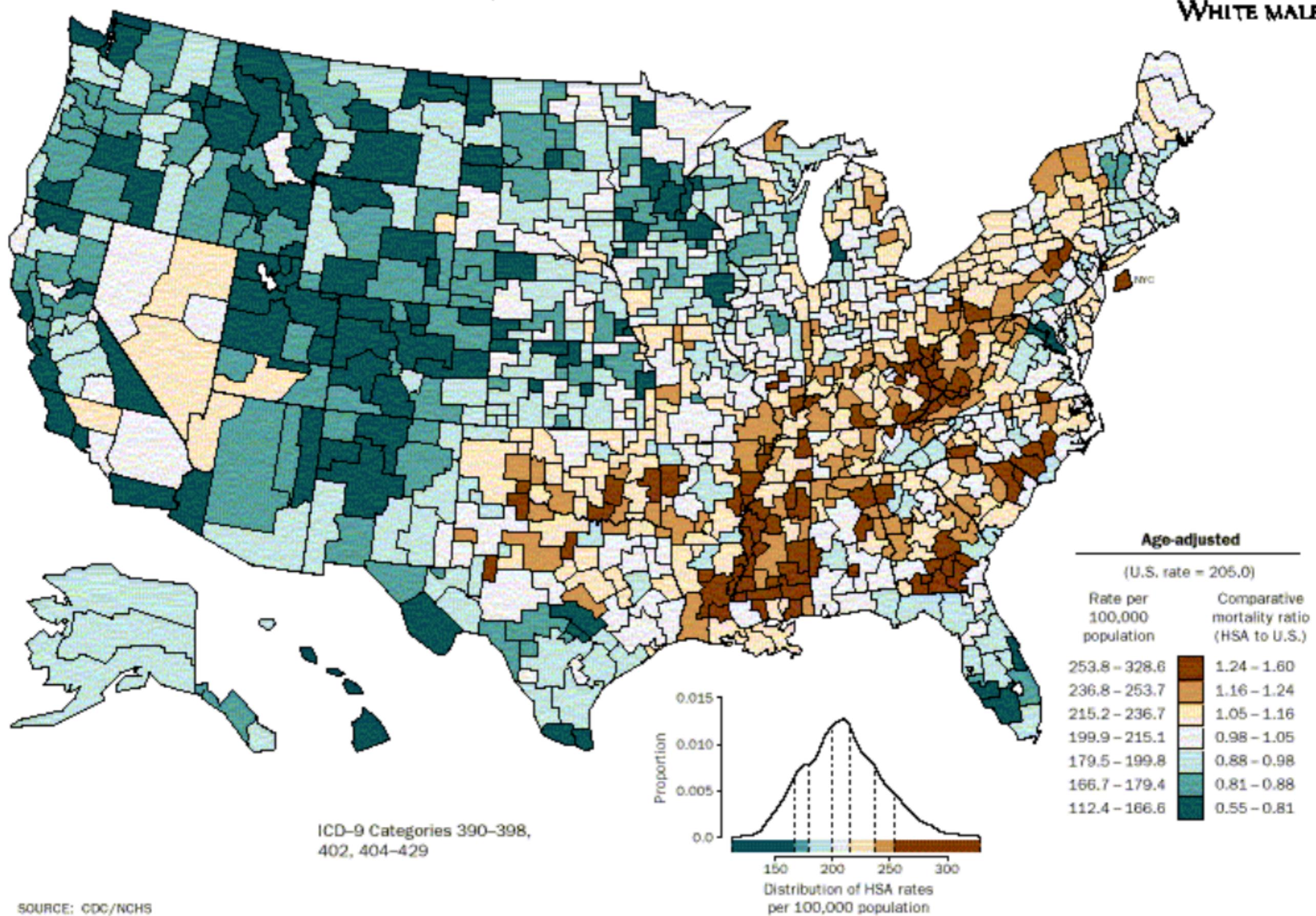
Hue variation is possible

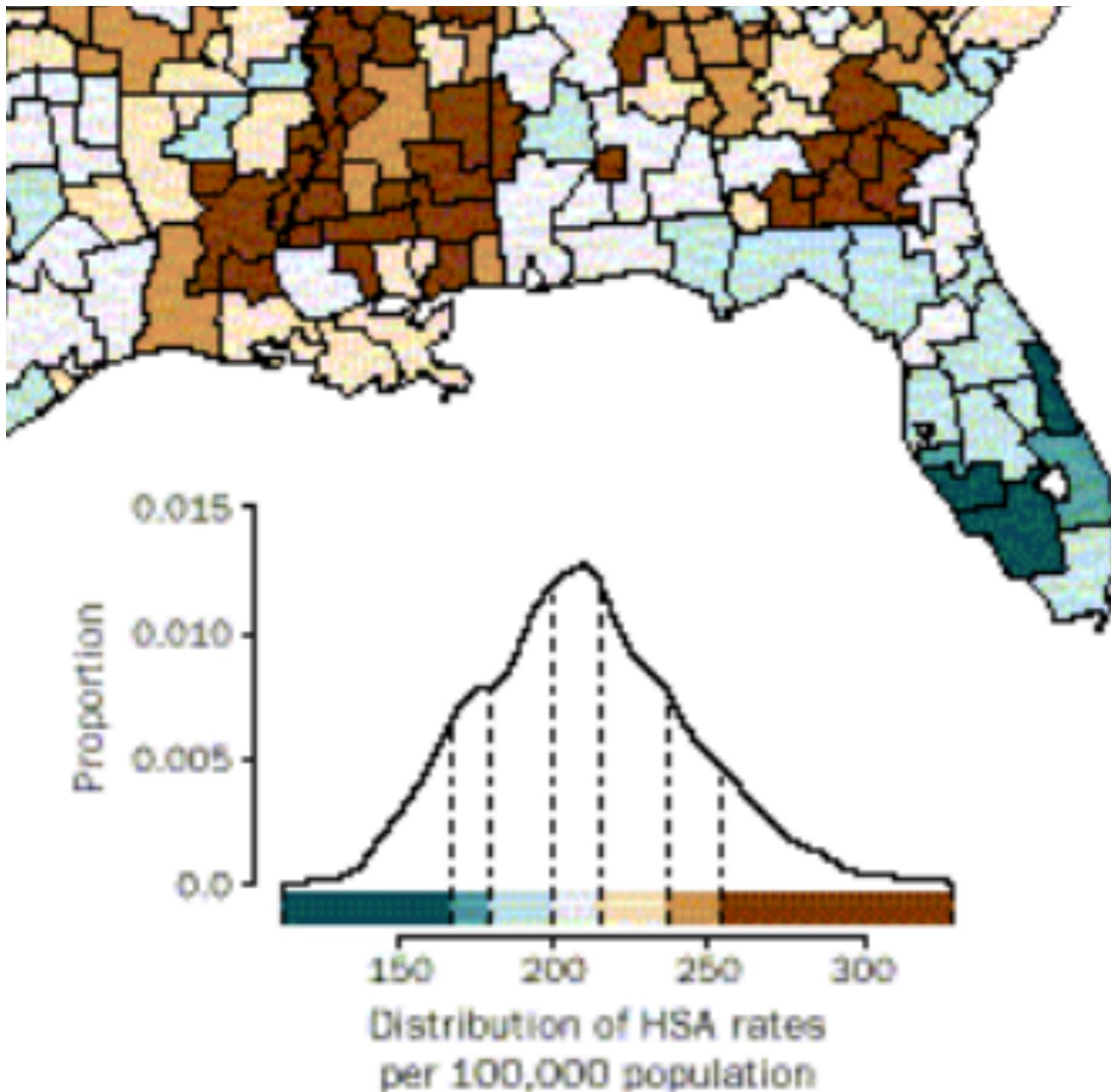
Choose neighbors

Incorporate luminosity

Use hue variation *very thoughtfully*

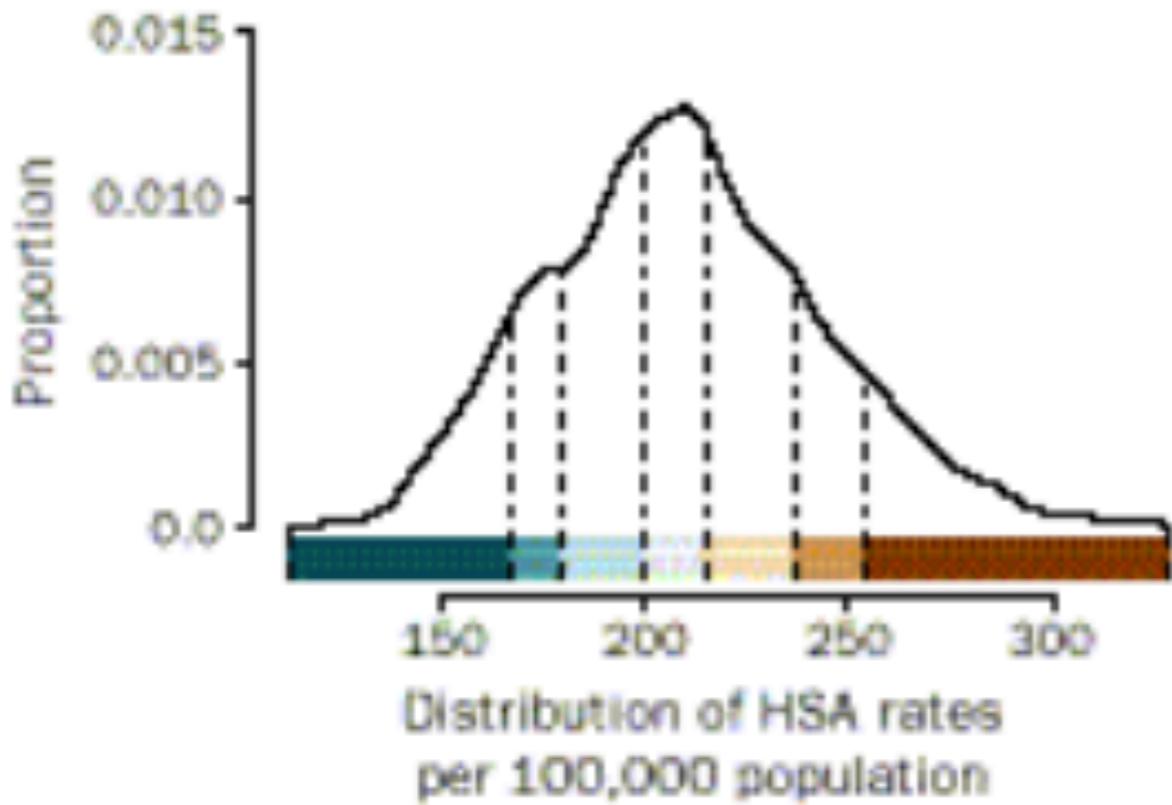
32 AGE-ADJUSTED DEATH RATES BY HSA, 1988-92

HEART DISEASE
WHITE MALE



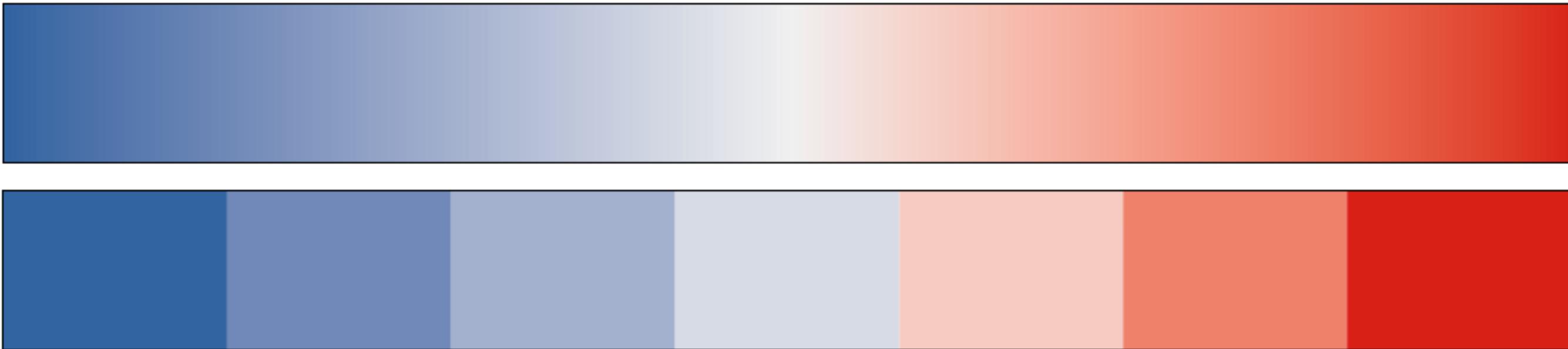
“Discretized” – data systematically put into “bins”

Discretizing data for scales



- Fixed, equal intervals
- Quantiles (3, 4, 5, 7)
- Std. deviation
- Clustering (conservative)

Diverging



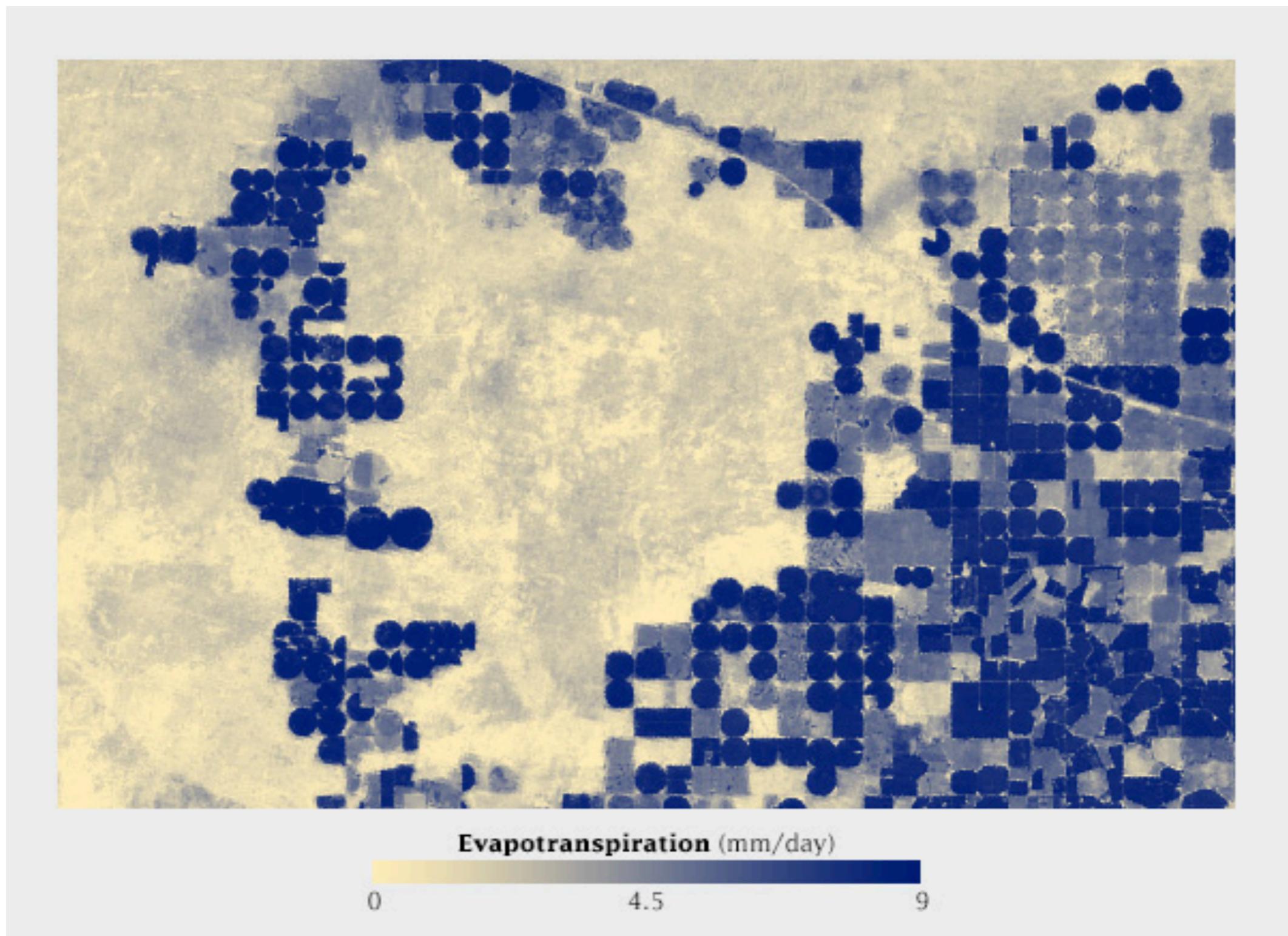
Does data have a “midpoint”?

“Sequential on either side”

Neutral middle, saturated ends

Endpoints should only differ in one channel

Be naturalistic

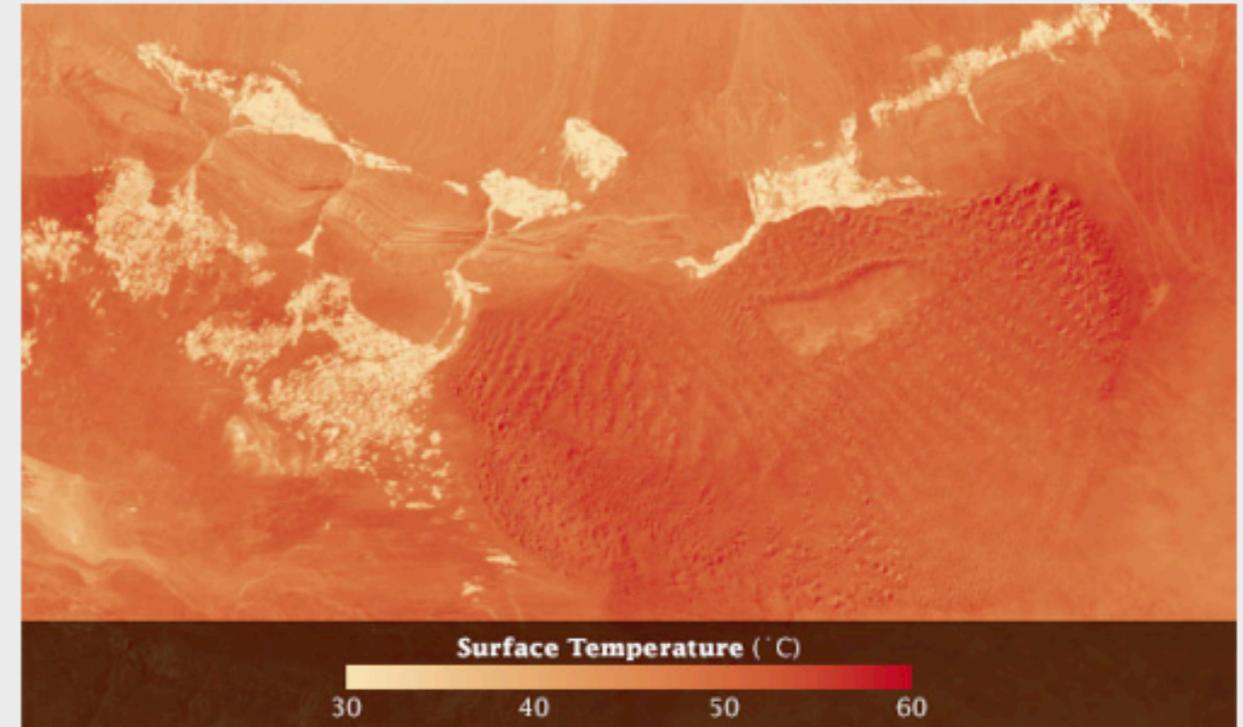
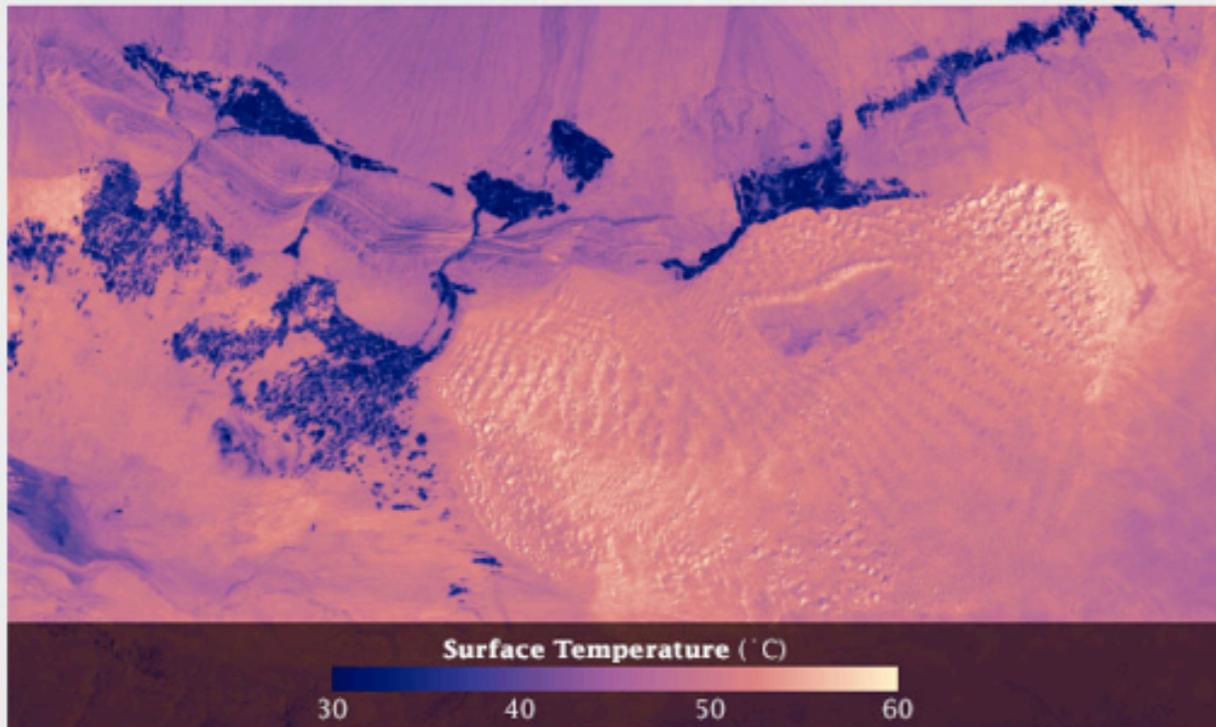


Robert Simmon, Subtleties of Color, go.nasa.gov/2jQHzAX



Evoke implicit signals and symbolism

(but also be aware of culture)



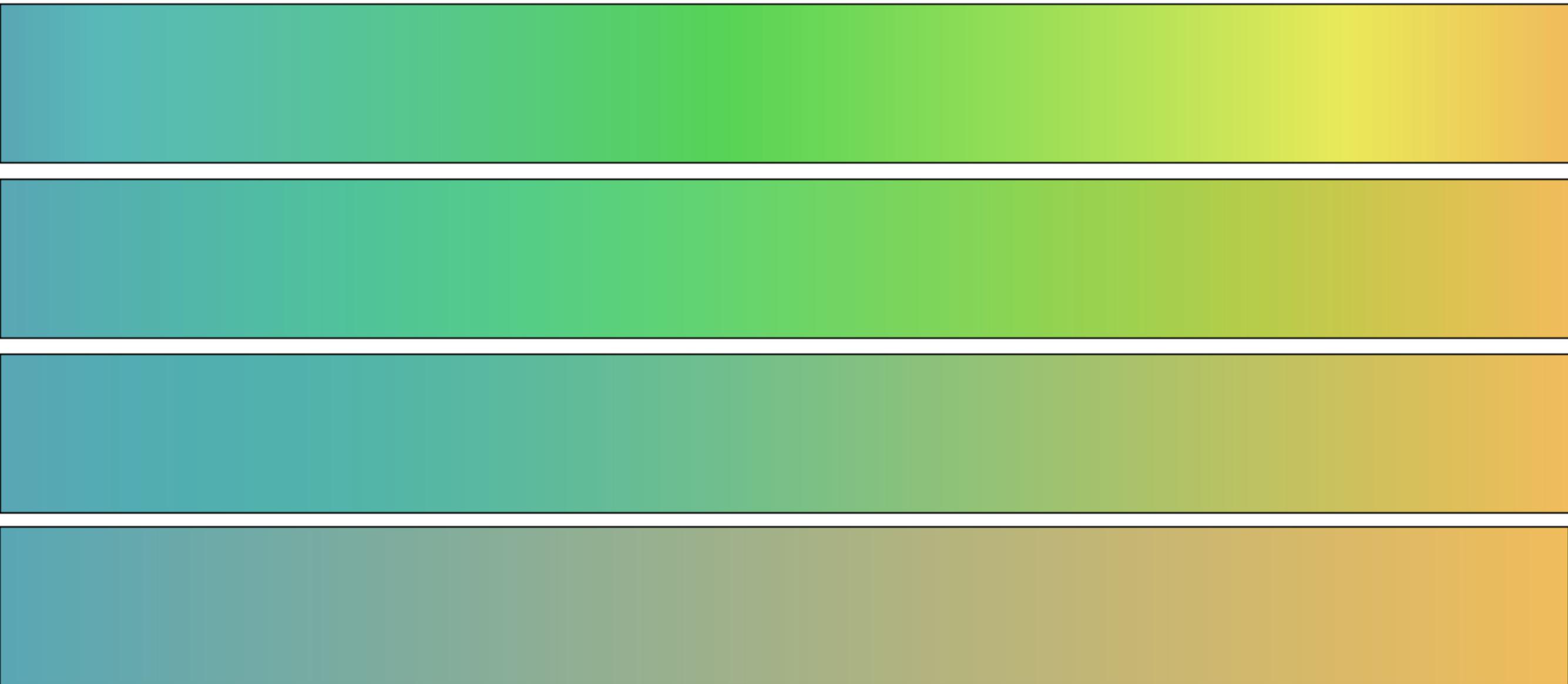
Robert Simmon, Subtleties of Color, go.nasa.gov/2jQHzAX



Be aware of accessibility



Use LAB, HCL, and perceptual spaces



Don't forget about print

