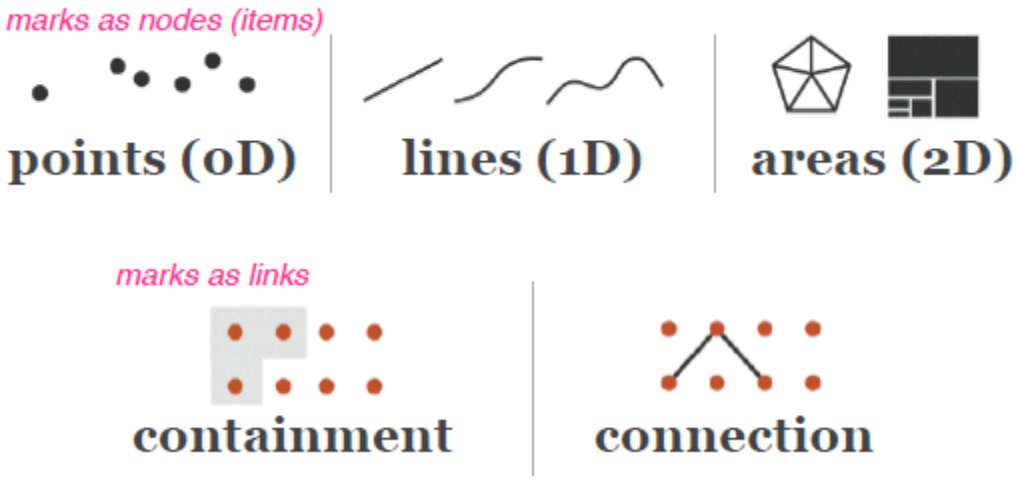
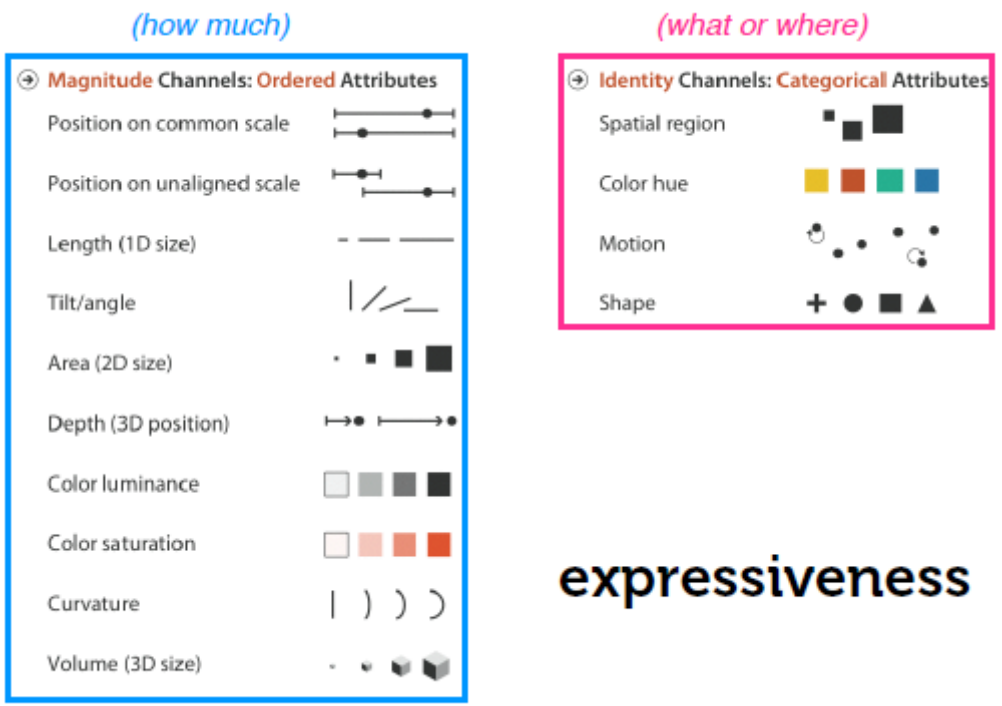
Chapter 10
Colors

11/3/20

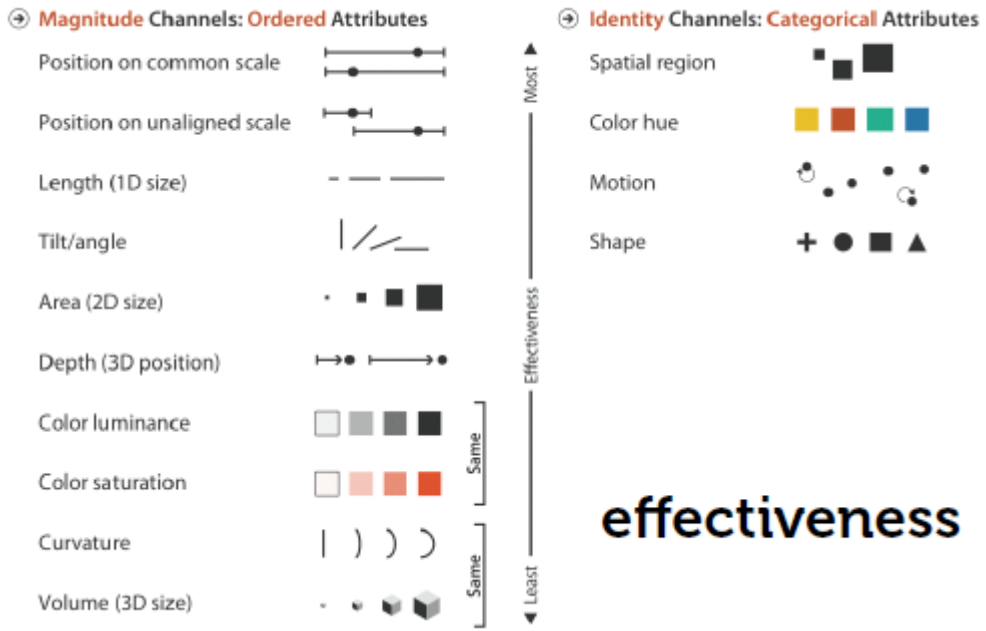
Mark Types


marks as nodes (items)
points (0D)
lines (1D)
areas (2D)
marks as links
containment
connection

Channels - Expressiveness



Channels - Effectiveness

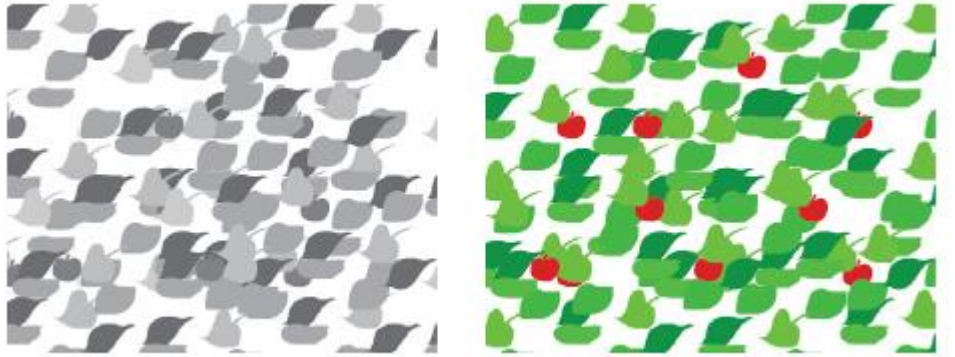


Limited Cognition

- Easy to compare views by moving eyes
- Hard to compare view to memory of what you saw

Get it Right in Black and White

- Functions of Color
  - Identify
  - Group
  - Layer
  - Highlight

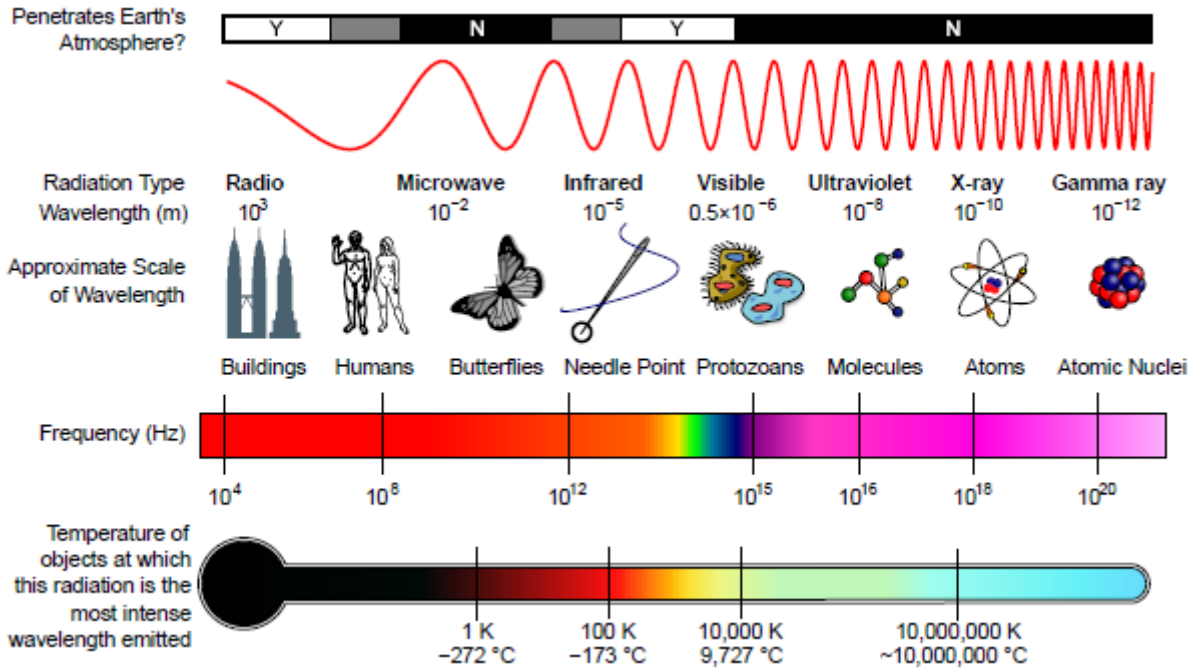


Colin Ware, Information Visualization: Perception for Design

Color and Light

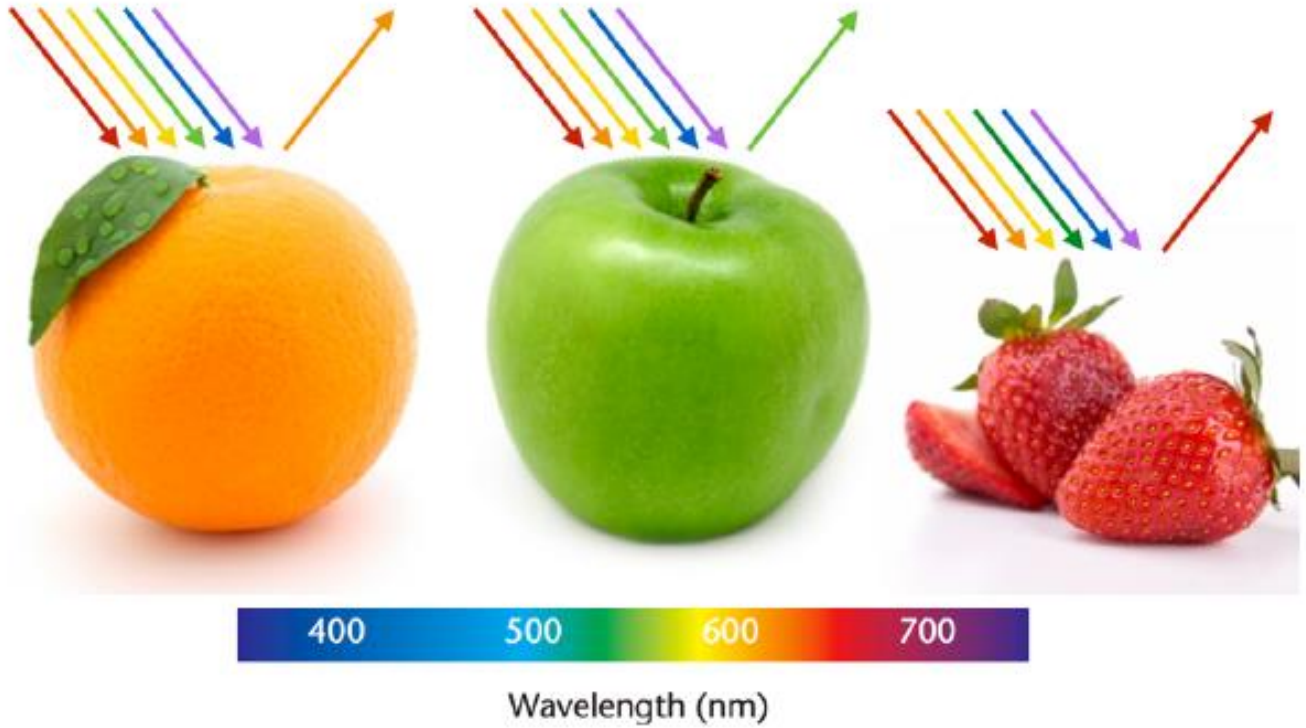
- Color is a perceptive property, depending on the eyes and brain
- Electromagnetic spectrum
  - Composed of waves at various frequencies (wavelengths), all traveling at the speed of light
  - Small portion of this is visible light

Electromagnetic Spectrum



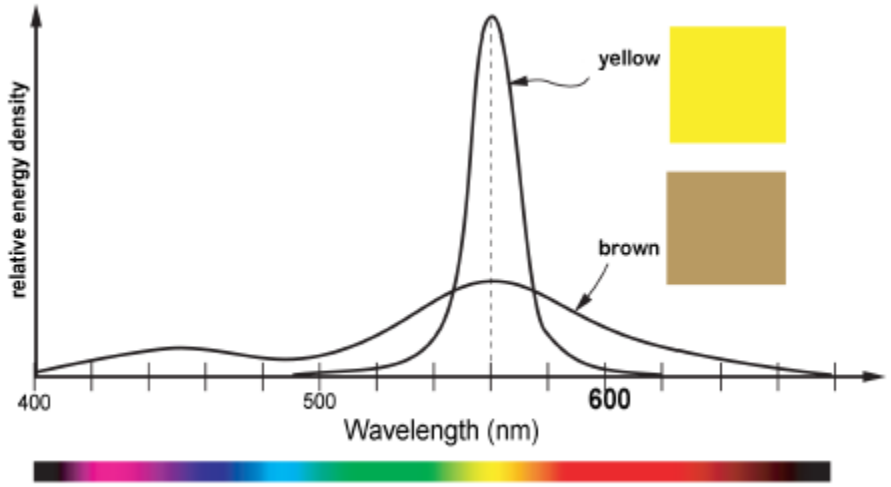
https://commons.wikimedia.org/wiki/File:EM_Spectrum_Properties_edit.svg

Light Reflection and Absorption



Color ! = Wavelength

- Instead, color is a combination of wavelengths and energy



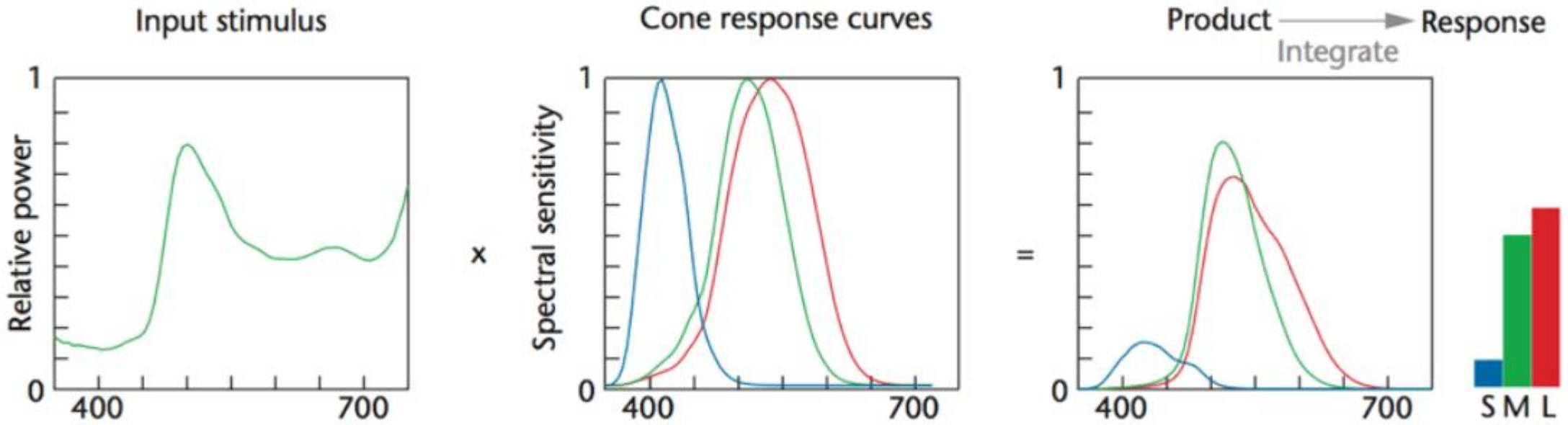
Human Color Perception

- Individual wavelengths of light are not detected by humans
- Rods and Cones detect light
  - Rods – intensity
  - Cones - color

Human Color Perception - Trichromacy

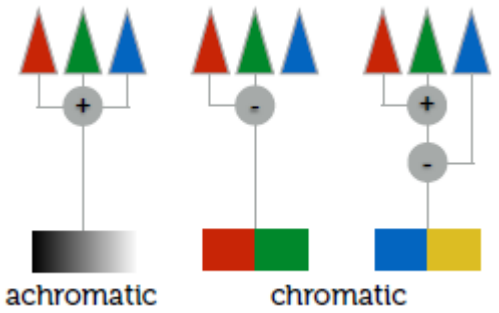
- Humans have 3 different types of cones (trichromatic)
  - S: Blue
  - M: Green
  - L: Red
- Note: response curves overlap
- Each type of cone
  - Contains specific photosensitive pigment
  - Each pigment sensitive to a certain wavelength of light
- Response is most likely a combination of both wavelength and intensity
  - Interaction between at least two types of cones is necessary for color perception

Human Color Perception



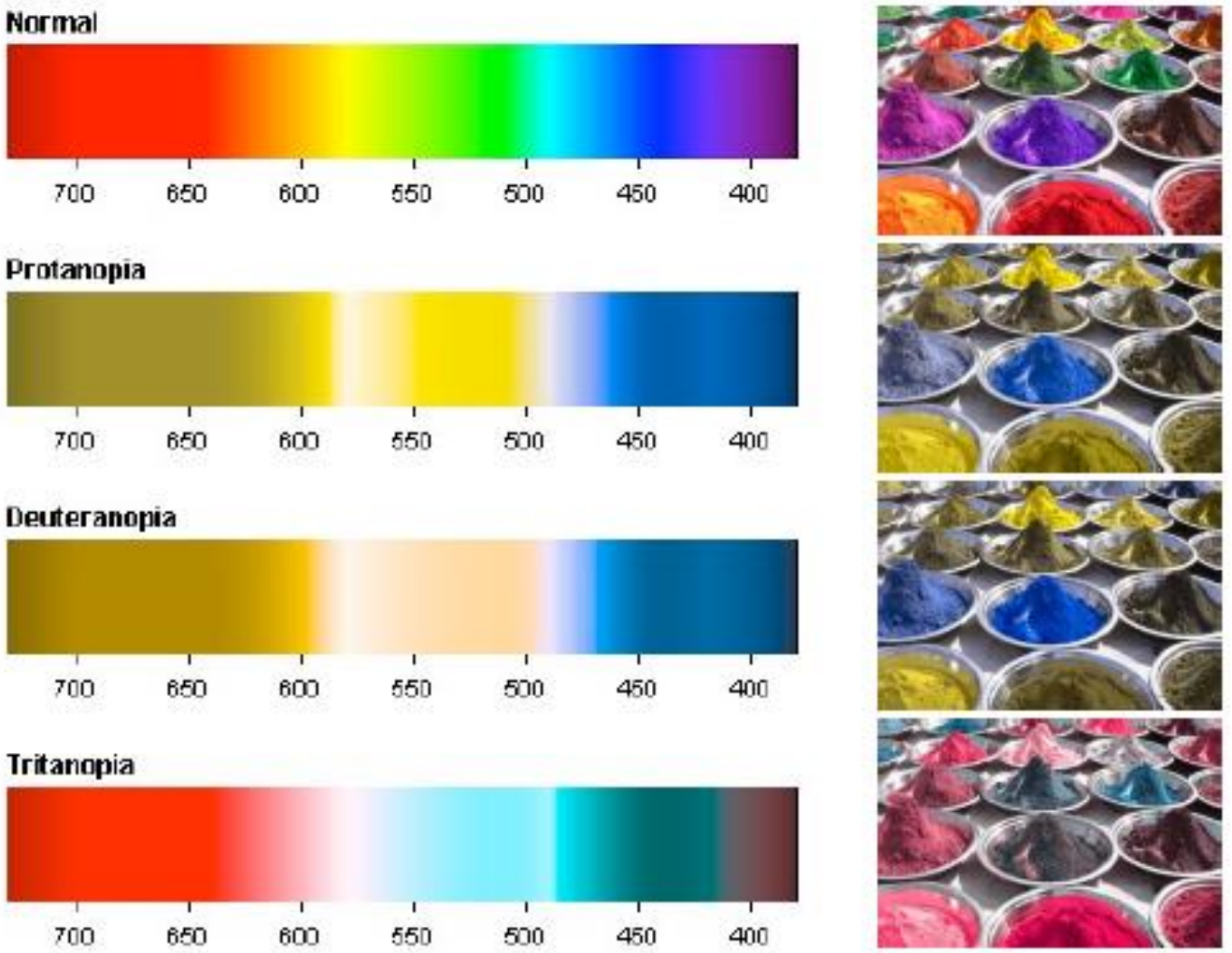
Opponent Process Model

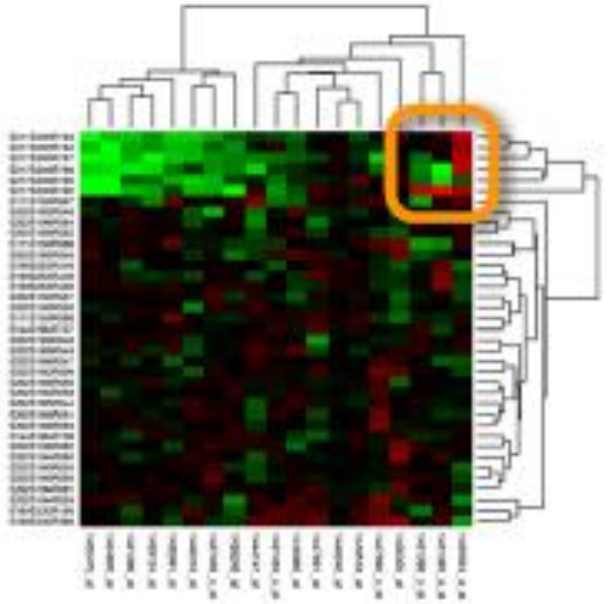
- Cones respond to different areas of the visible light spectrum
- Certain wavelengths generate greater responses
- Color determined by responses from the different cones
- How eyes receive signals – trichromatic theory
- How signals are processed – opponent process theory
- Differences between the response of the cones is detected by the visual system
- Three opponent channels:
  - Red vs green
  - Blue vs yellow
  - Black vs white (luminance)
- Opposite colors are never perceived together
  - For example, no reddish green or bluish yellow

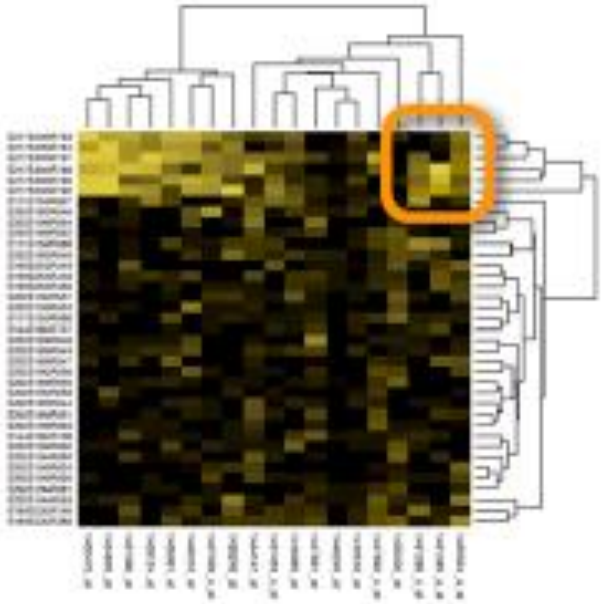


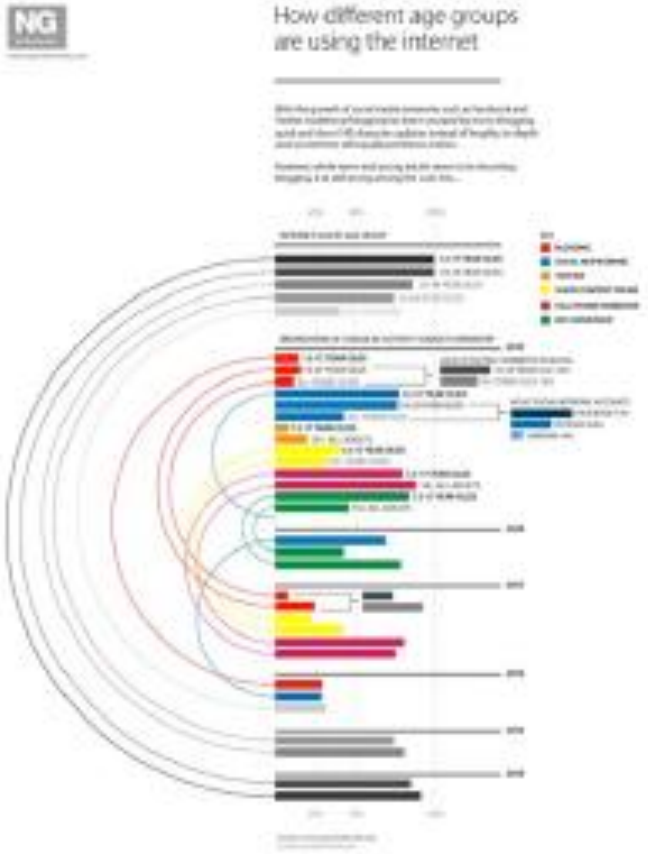
Color Deficiencies/Blindness

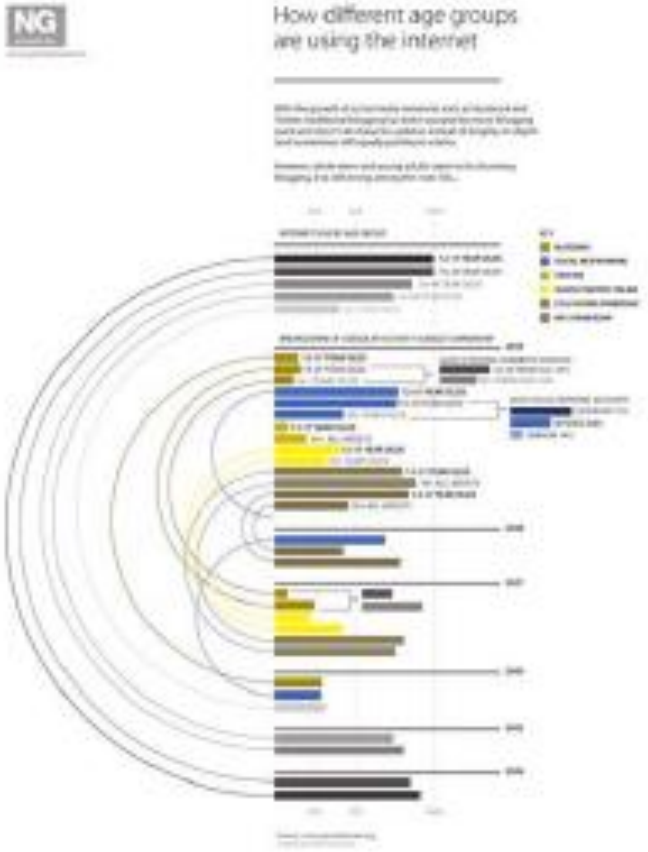
- Faulty cones
- Faulty pathways
- Sex-linked: 8% of (North American) males and 0.4% of females
  - Abnormal distribution of cones (ex, missing S, M, or L types)
  - Either dichromatic (2 types of cones) or anomalous trichromatic (one type of cones has a defect)
  - Protanopia (L missing), Protanomaly (L defect)
  - Deuteranopia (M missing), Deuteranomaly (M defect) : most common
  - Tritanopia (S missing), Tritanomaly (S defect) : rare
  - Dichromacy is rarer than anomalous trichromacy
  - Opponent process model/opponent color theory
    - explains why colors cannot be differentiated


Normal
700
650
600
550
500
450
400
Protanopia
700
650
600
550
500
450
400
Deuteranopia
700
650
600
550
500
450
400
Tritanopia
700
650
600
550
500
450
400

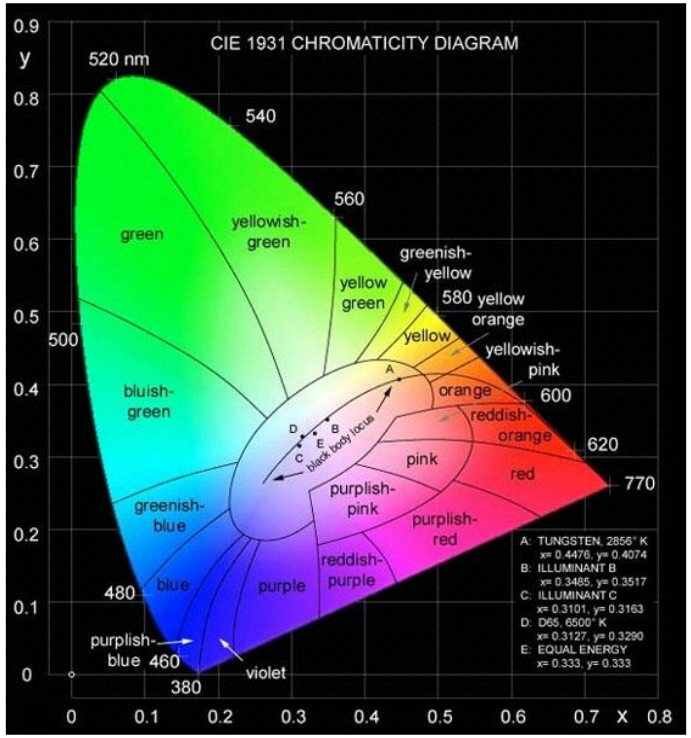





NG
How different age groups are using the internet


NG
How different age groups are using the internet

Space of Human Color

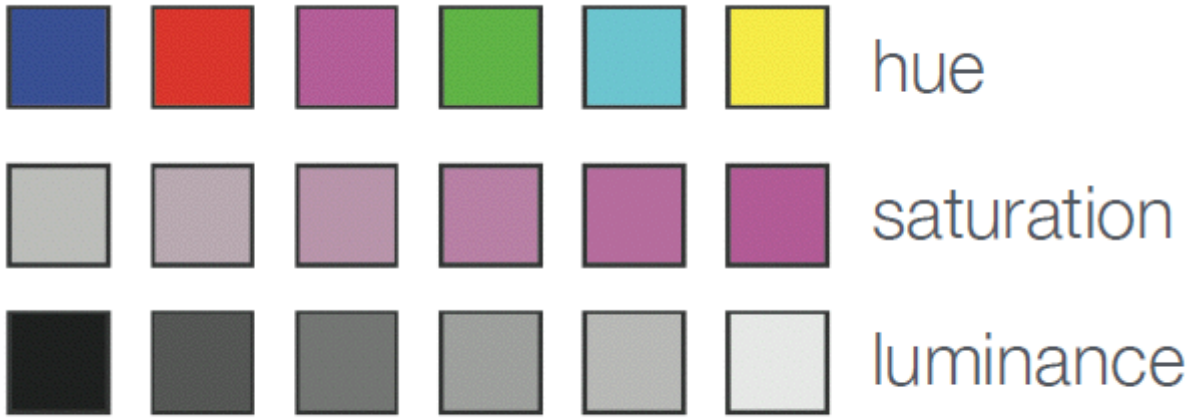


Color Models

- Definition: representation of color using some basis
- RGB
  - Uses three numbers (red, blue, green) to represent color
  - Useful for monitors, but not perceptually uniform
- Hue-Saturation-Lightness (HSL)
  - More intuitive and useful
  - Hue – pure colors
  - Saturation – amount of white mixed with the pure color
    - Ex. pink is a partially desaturated red
  - Lightness – amount of black mixed with that color
- HSV
  - Similar to HSL, but V stands for grayscale value and is linearly related to L

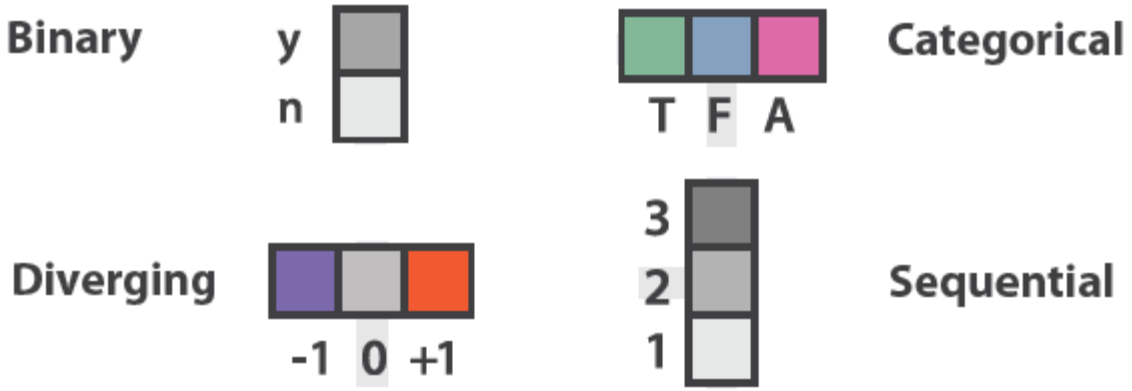
Luminance

- HSL does not truly reflect the way we perceive color
- Lightness (L) of the colors is the same, but we perceive luminance differently
- Our perception (L*)


hue
saturation
luminance

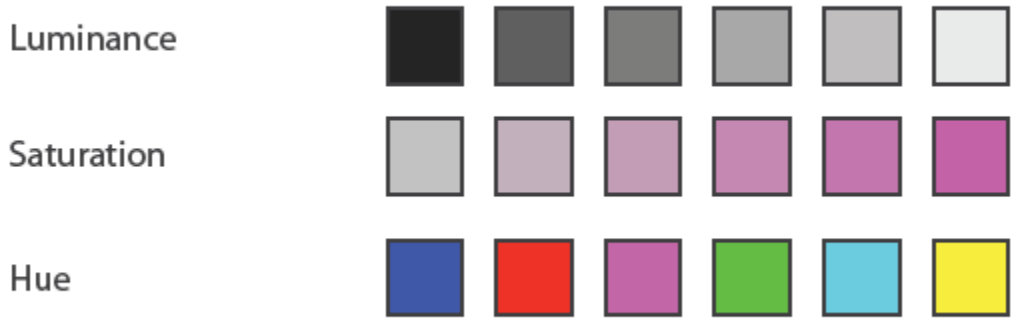
Colormap

- Definition: specifies mapping between colors and data values
- Should follow expressiveness principle
- Types of colormaps



Categorical vs. Ordered

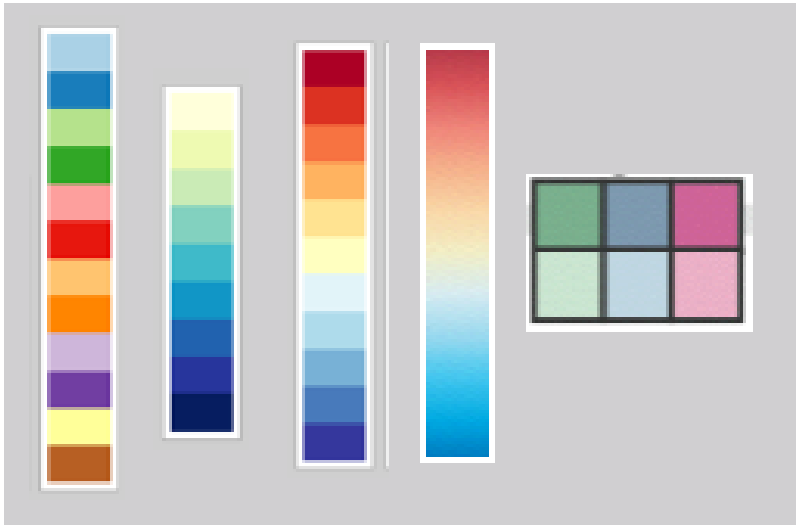
- Categorical data: no implicit ordering (hue)
- Ordered data: saturation and luminance



Colormap

- Categorical vs ordered
- Sequential vs diverging
- Segmented vs continuous
- Univariate vs bivariate

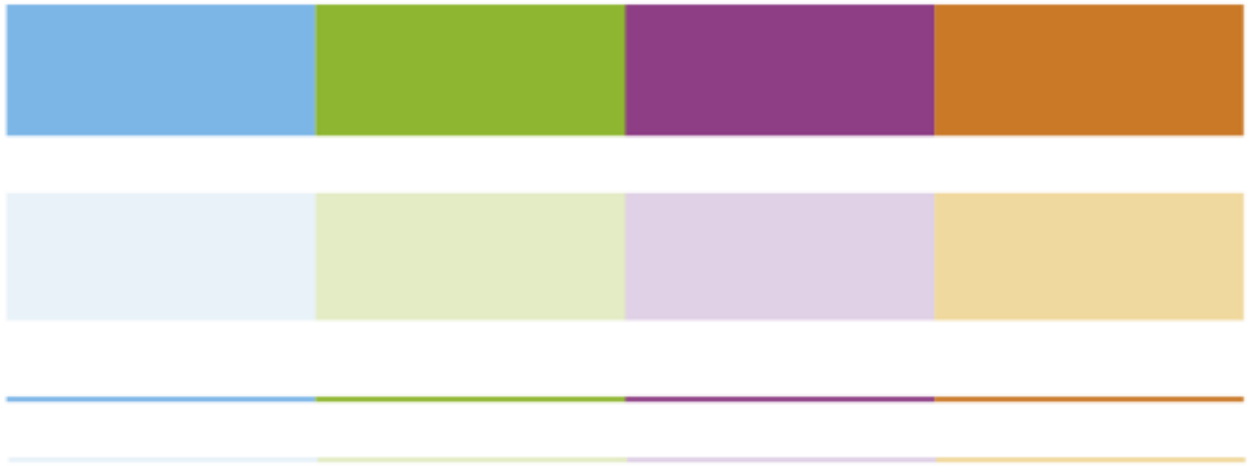
- Match colormaps to attribute type characteristics (expressiveness)



Categorical Colormap Guidelines

- Don’t use too many colors; try to keep less than 12
- Remember, background coloring, e.g. grayscale, white, gridlines, etc…
- Nameable colors help with categorical variables; ex, blue vs green instead of light blue vs blue vs dark blue
- Don’t forget about other marks you might wish to use in the visualization
- Saturation and hue are not separable in small regions
  - Use bright, highly saturated colors in small regions
- Saturation interacts strongly with size
  - More difficult to perceive in small regions
  - Use just two saturation levels for points and lines
- Higher saturation makes large areas look bigger
  - Therefore, use lower saturation pastel colors for large regions and backgrounds

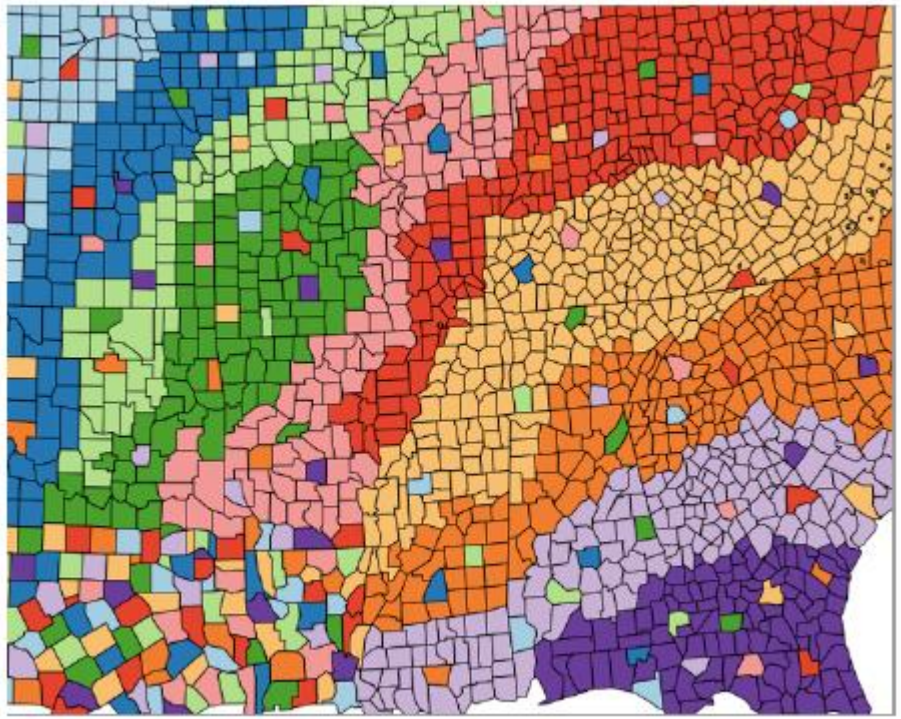
Size and Color



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

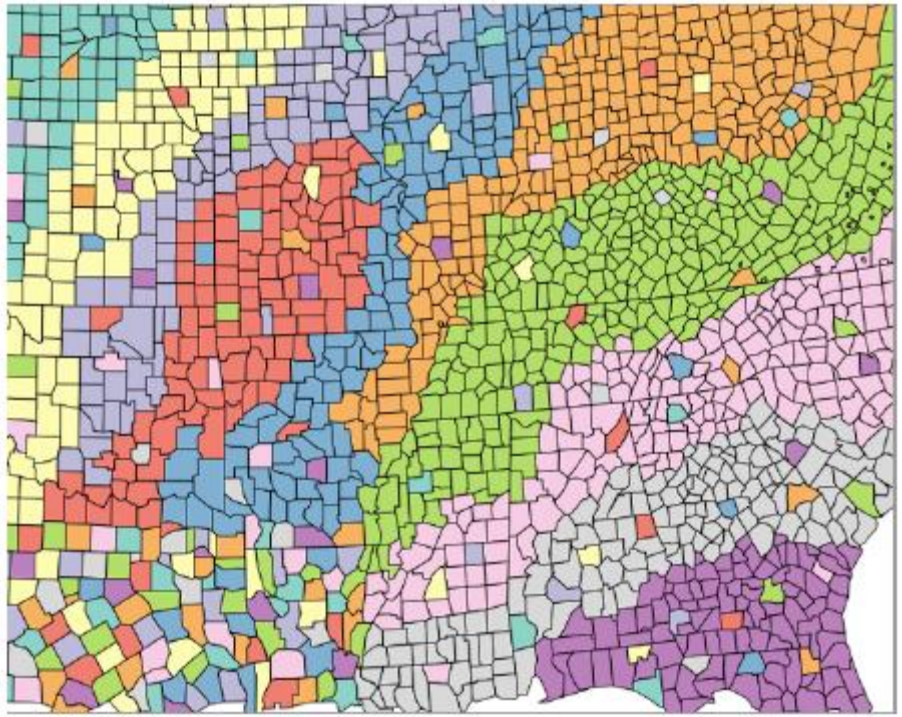
-Jacques Bertin

Categorical Colormaps



https://colorbrewer2.org/

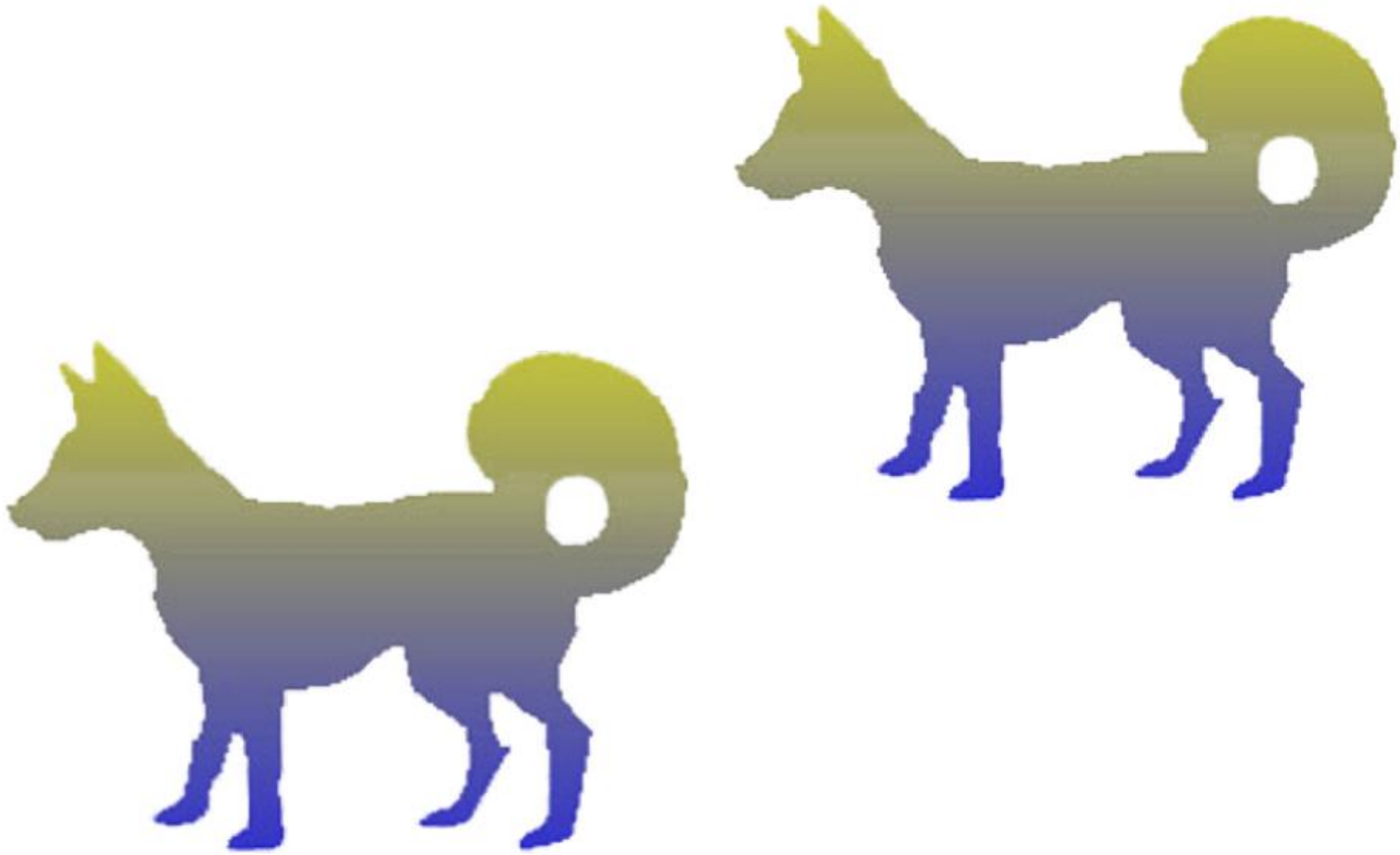
Categorical Colormaps

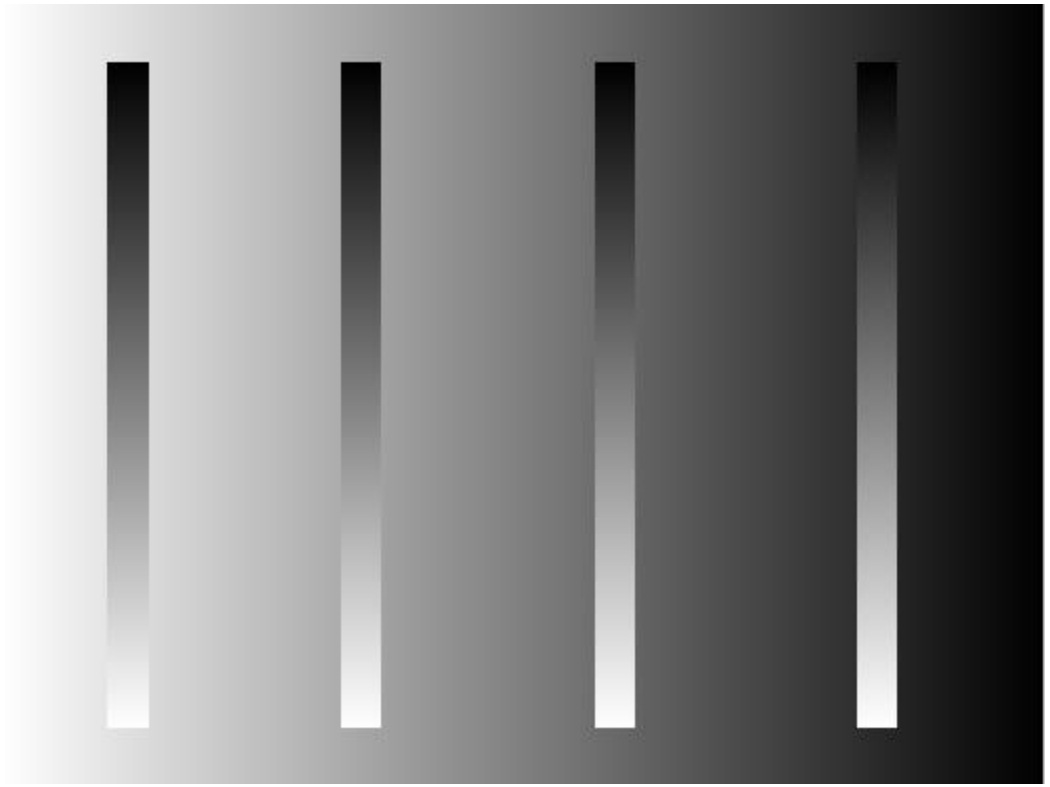


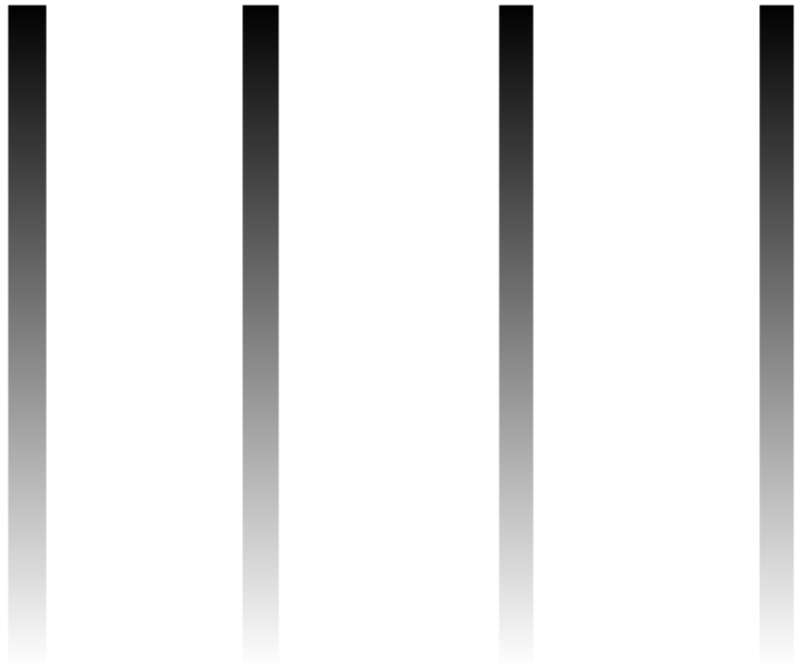
https://colorbrewer2.org/

simultaneous contrast

simultaneous contrast





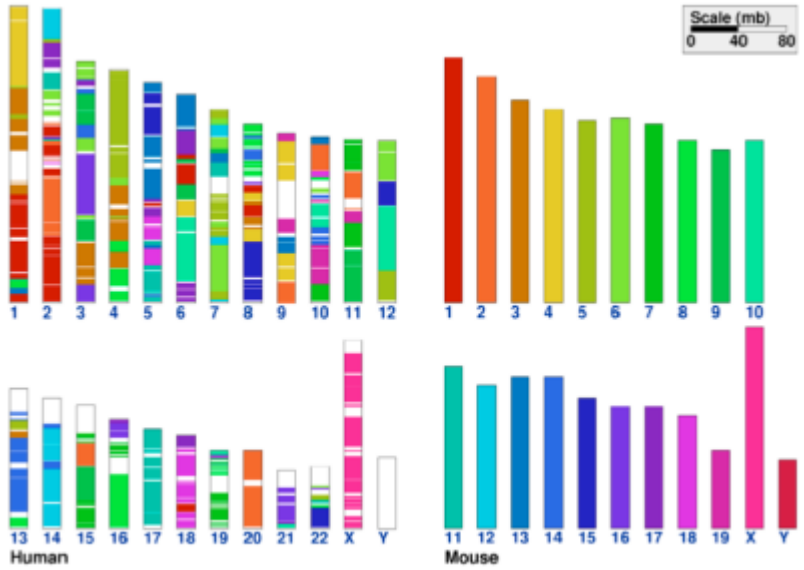


Luminance Contrast

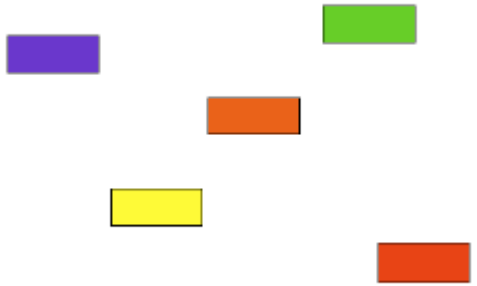
Showing small blue text on a black background is a bad idea.
There is insufficient luminance contrast.

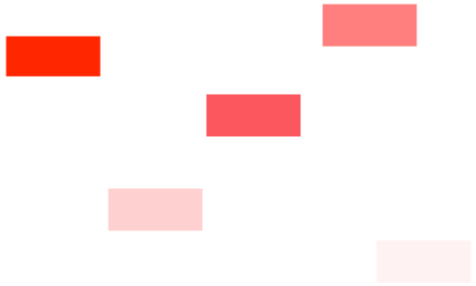
Distinguishability

Only good at discerning between 6-12 simultaneous colors



Ordering Colors

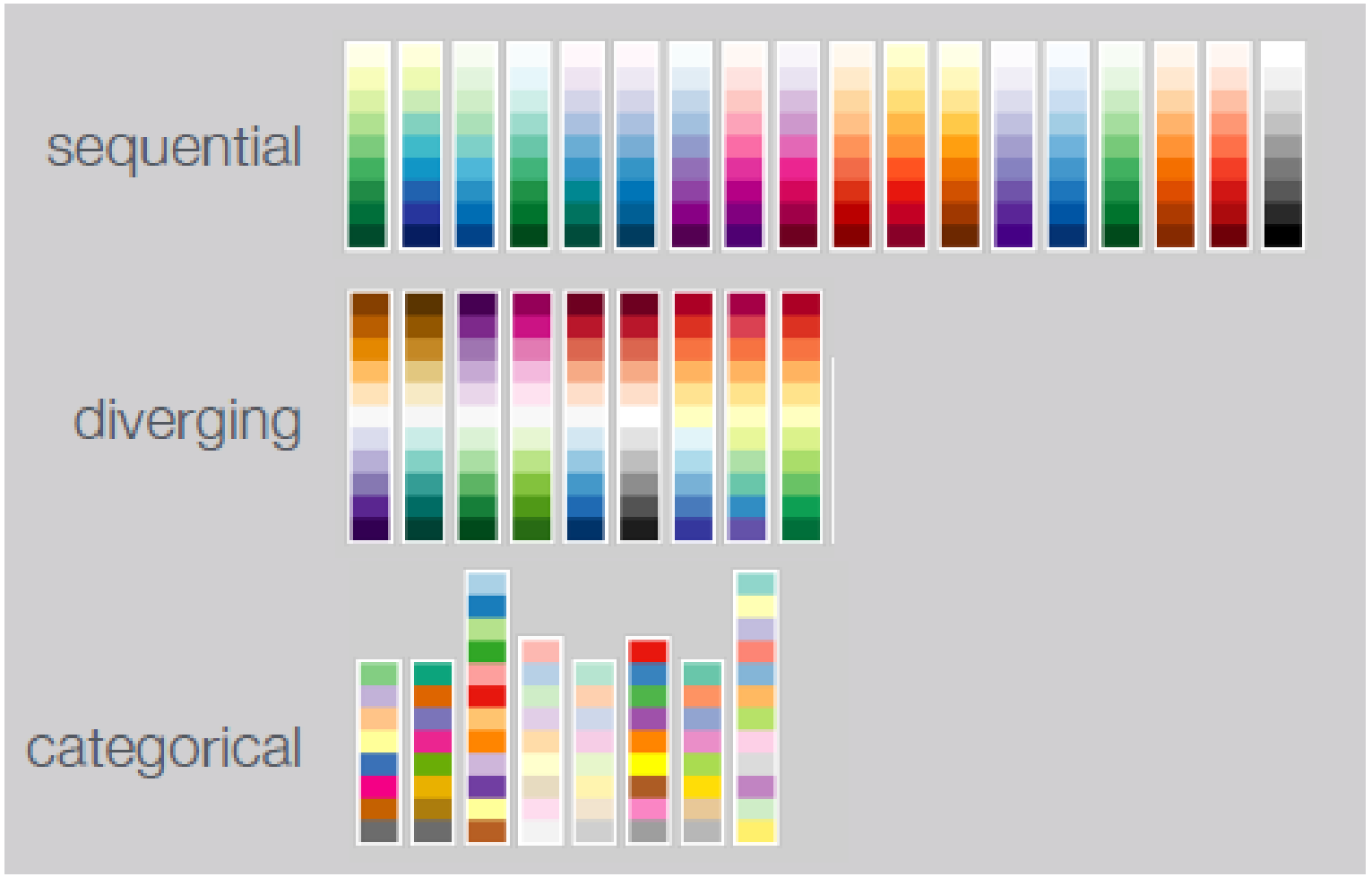




Color Blindness Tips and Tools

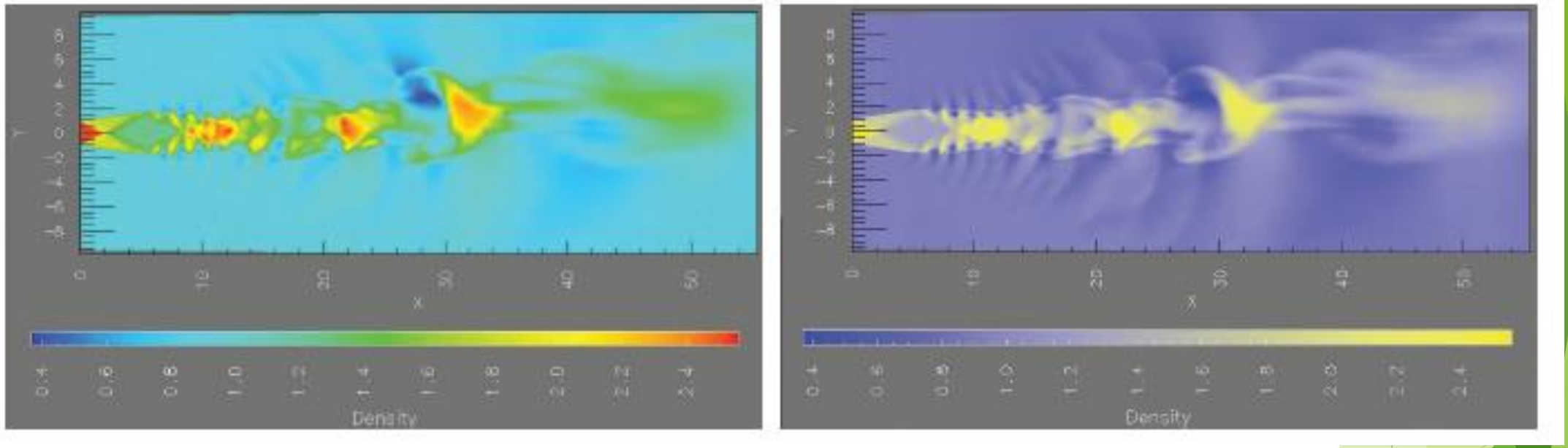
- Avoid hue, try to use another channel redundantly if necessary
- Avoid red-green divergent colormaps
- Tools for colorblindness simulation
  - Adobe tools
  - http://www.color-blindness.com/coblis-color-blindness-simulator/
- Color tools
  - http://colorbrewer2.org/
  - http://tristen.ca/hcl-picker/

ColorBrewer Palates



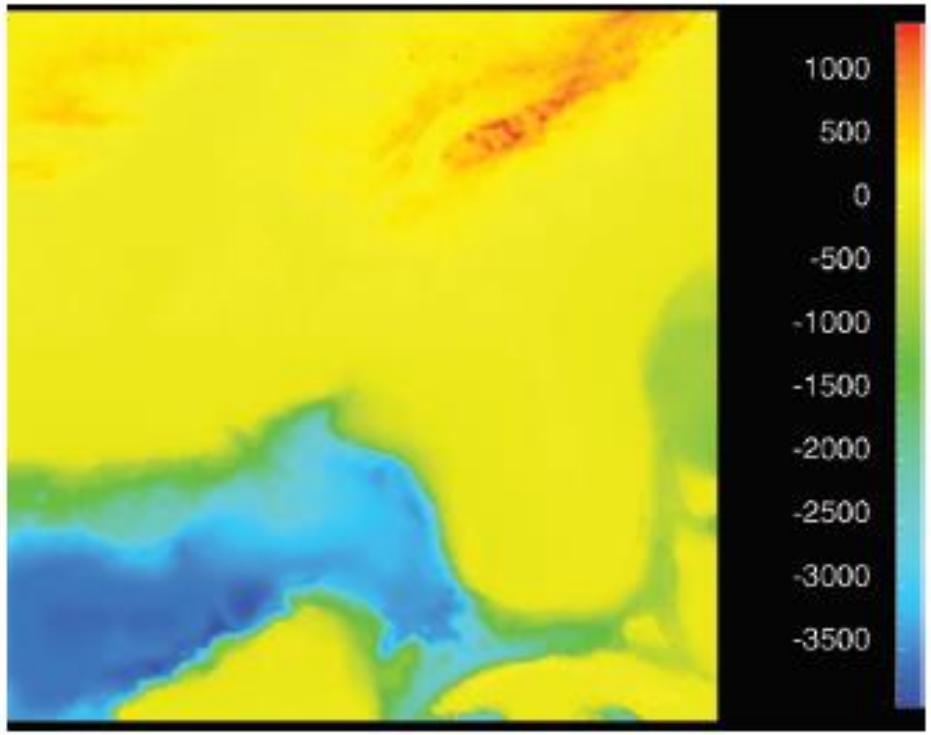
Ordered Colormaps

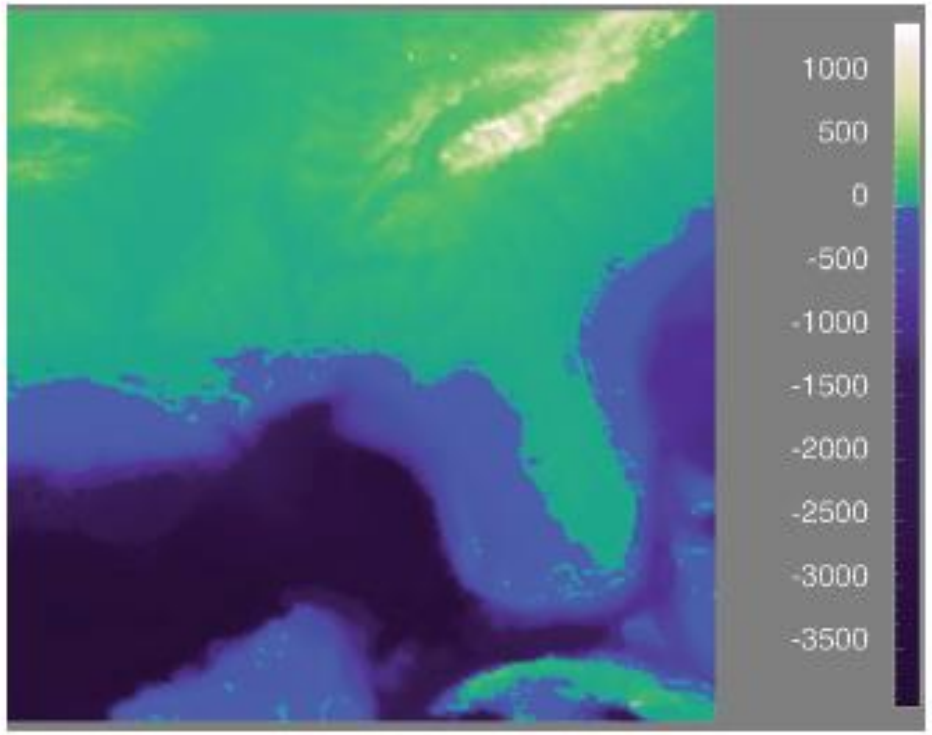
- Use for ordinal or quantitative attributes
- Sequential: [0,N]
- Diverging (has neutral color midpoint with two hues at endpoints): [-N,0,N]
- Can use hue, saturation, and luminance
- Make note: hue is not a magnitude channel
- Can be continuous (smooth) or segmented (sharp boundaries)


Y
X
Density
Y
X
Density

Hue: Perceptual Problems of Rainbow Colormaps

- Unfortunate they are a default choice in most software packages
- Hue is an identity channel, but could indicate order (when not familiar with visualization topic)
- Scale is not perceptually linear
- Fine detail cannot be perceived; luminance channel would be a much better choice b/c contrast is required for edge detection
- Solution: design monotonically increasing luminance colormaps
  - Luminance is a magnitude channel
  - Subtle changes in luminance more accurately perceived than subtle changes in hue


1000
500
0
-500
-1000
-1500
-2000
-2500
-3000
-3500


1000
500
0
-500
-1000
-1500
-2000
-2500
-3000
-3500

Sources/Credits

- Tamara Munzner, Visualization Analysis & Design, A K Peters Visualization Series, CRC Press, 2014.
- Utah, Miriah Meyer, Visualization (2014).
- UMass Dartmouth, David Koop, Data Visualization (2015).