

CS49000/CS59000 IDV - Fall 2019

Introduction to Data Visualization

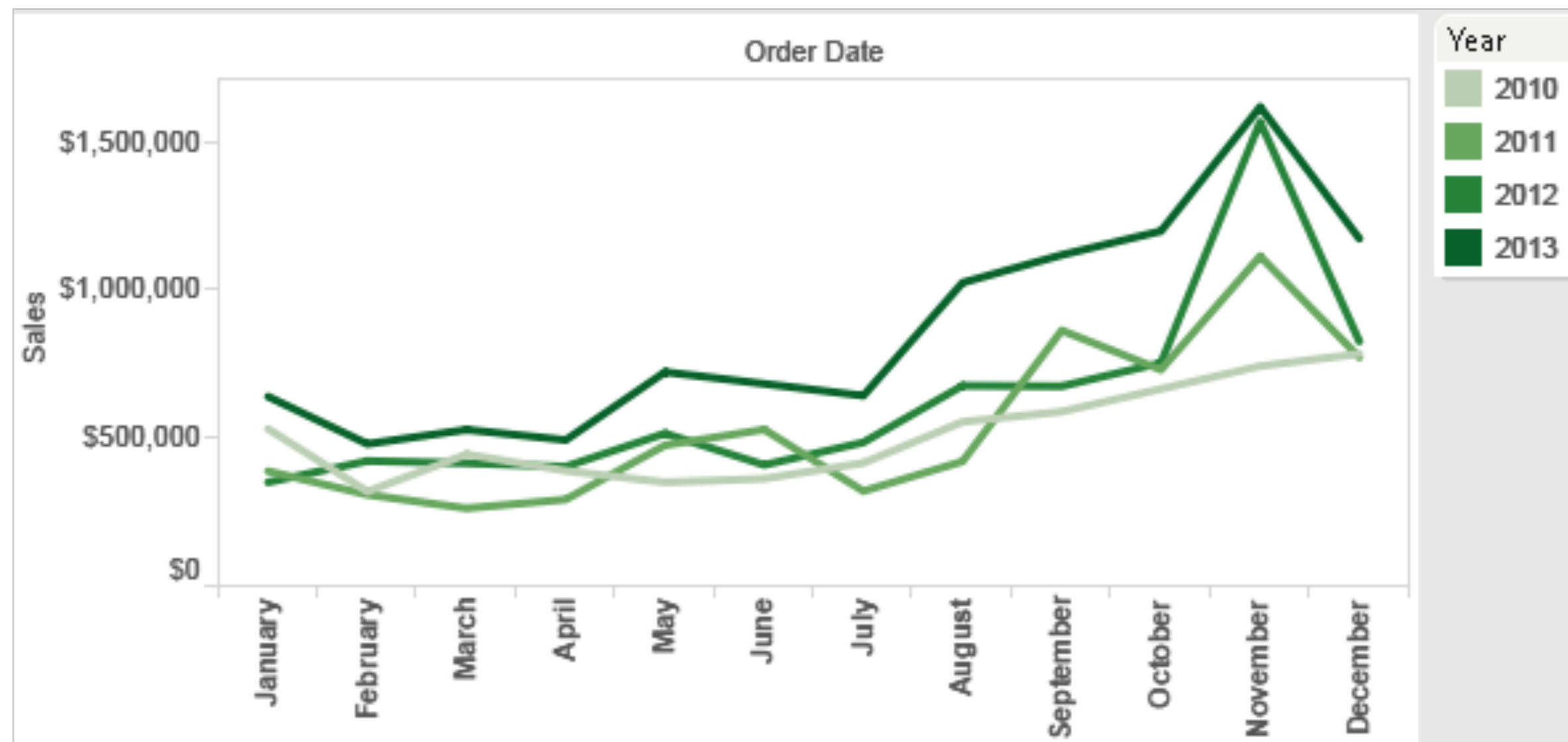
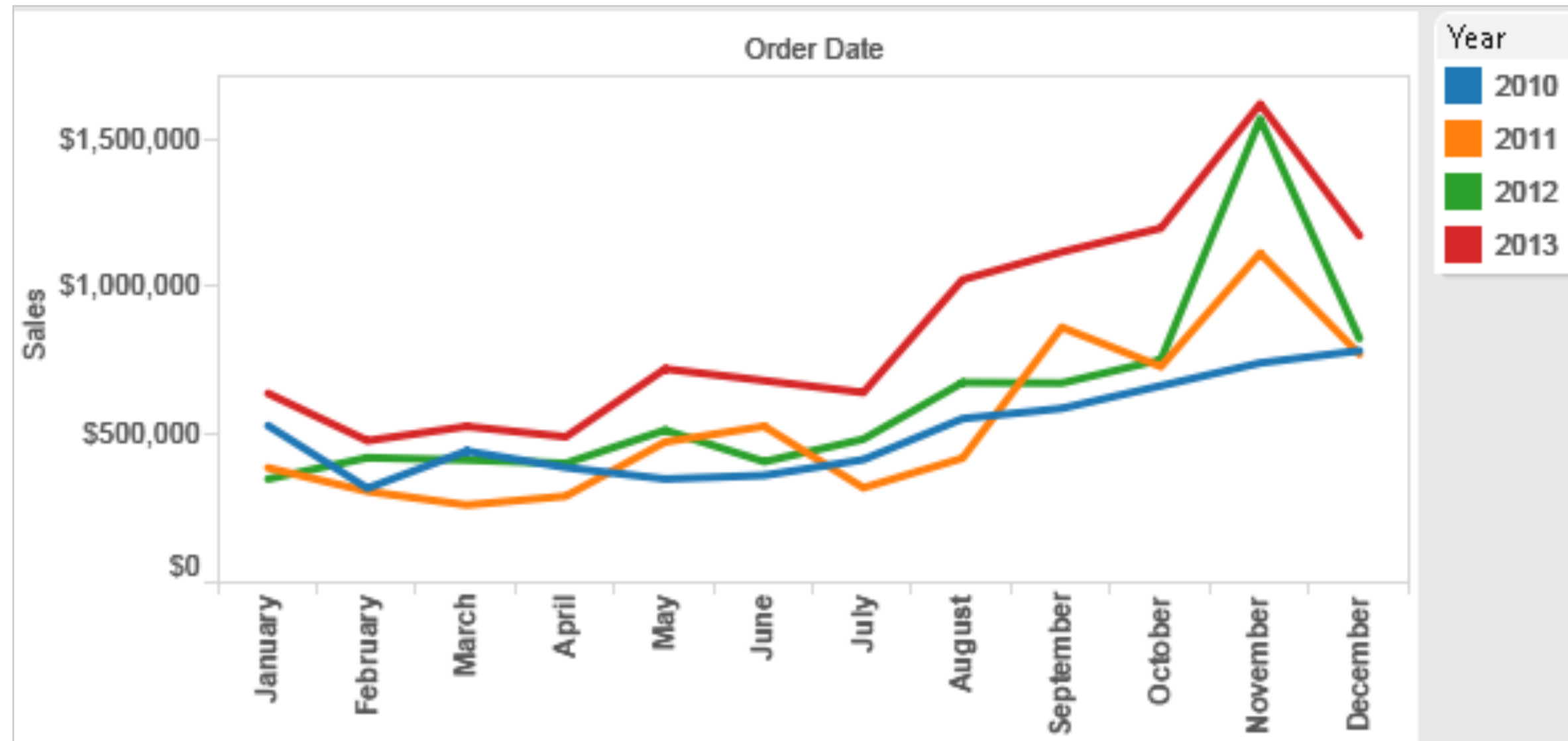
# Color Mapping

## Lecture 12

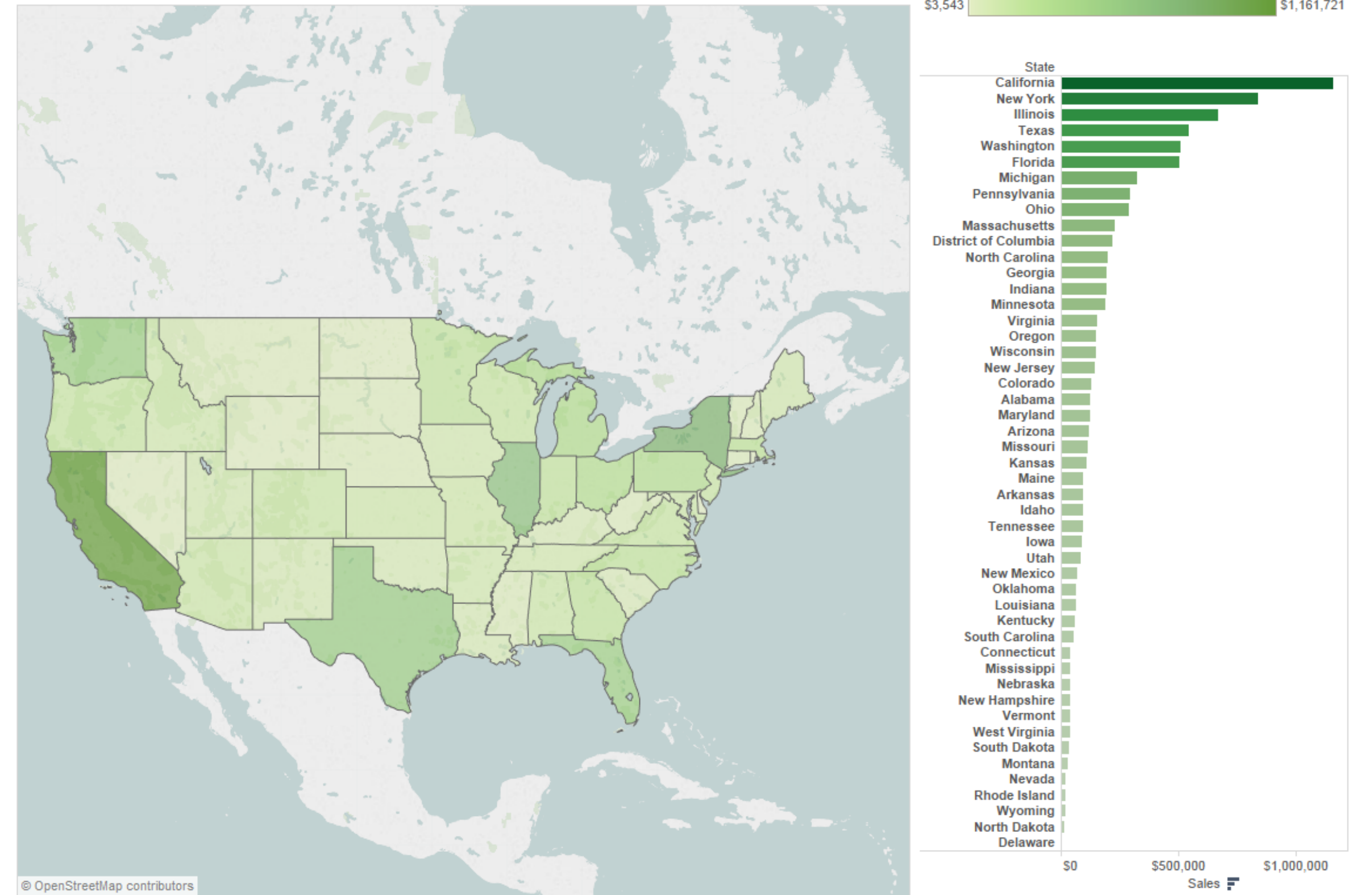
*Slides Credit: T. Munzner, UBC*

October 14, 2020

# Categorical vs ordered color



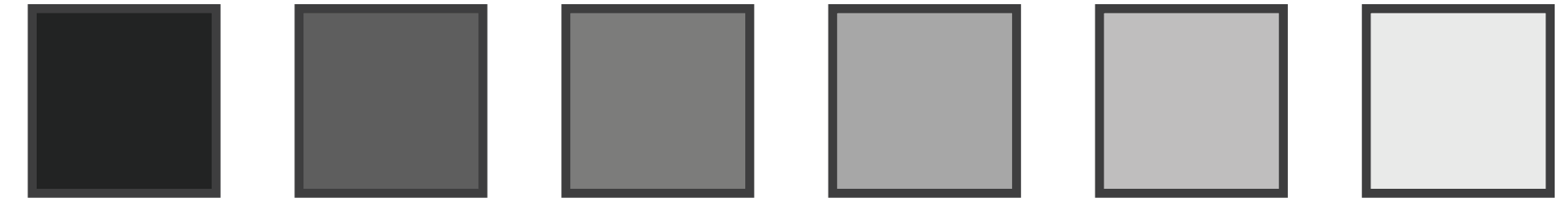
Annual sales by state



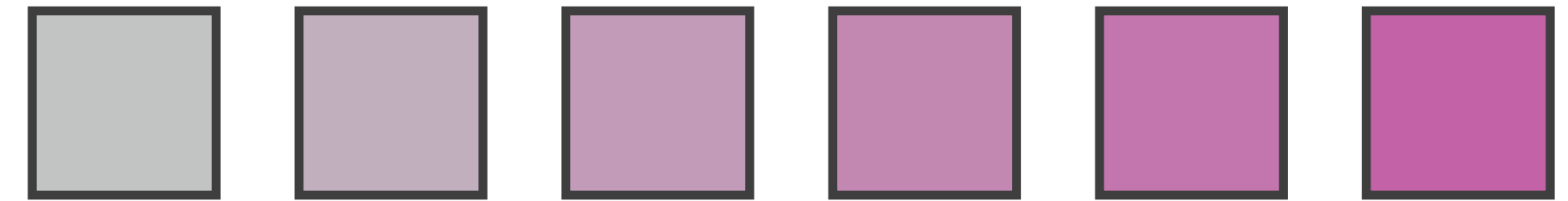
[Seriously Colorful: Advanced Color Principles & Practices. Stone.Tableau Customer Conference 2014.]

# Color: Luminance, saturation, hue

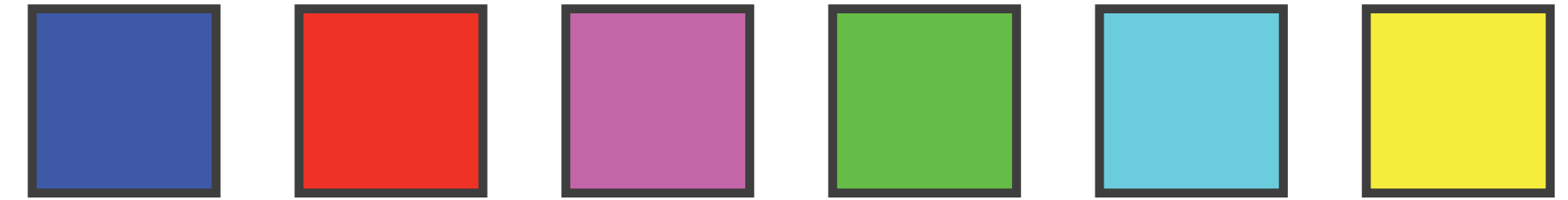
Luminance



Saturation



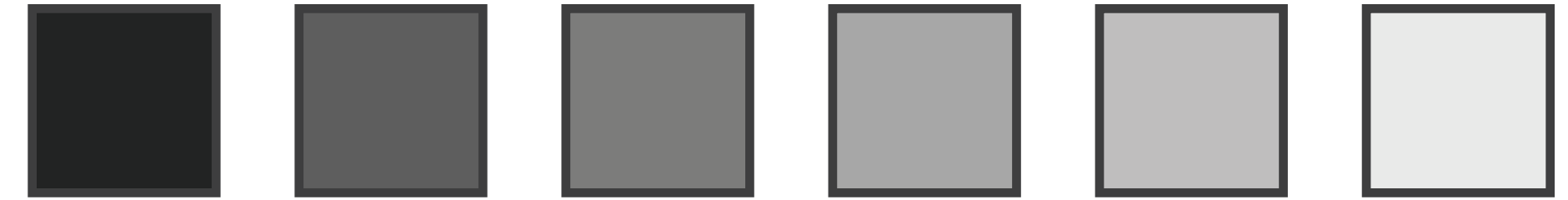
Hue



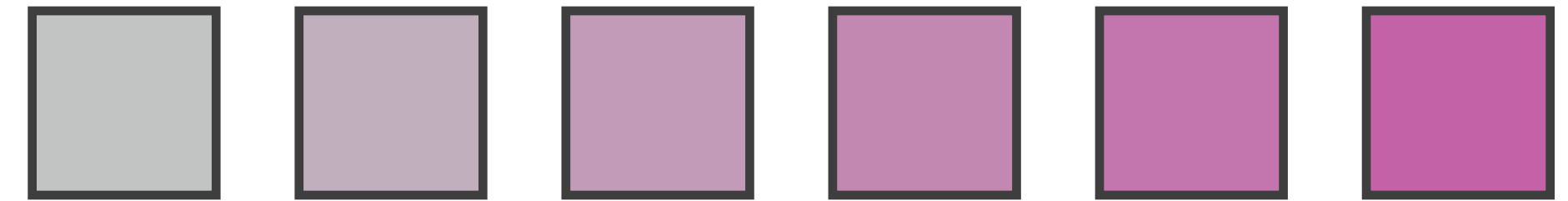
# Color: Luminance, saturation, hue

- 3 channels
  - identity for categorical
    - hue
  - magnitude for ordered
    - luminance
    - saturation

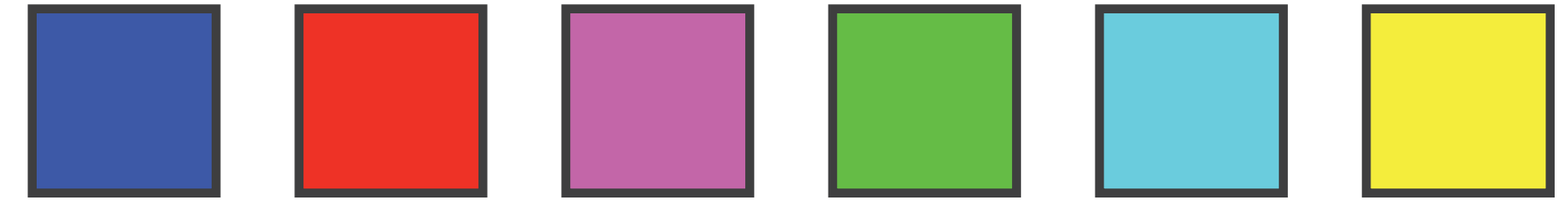
Luminance



Saturation



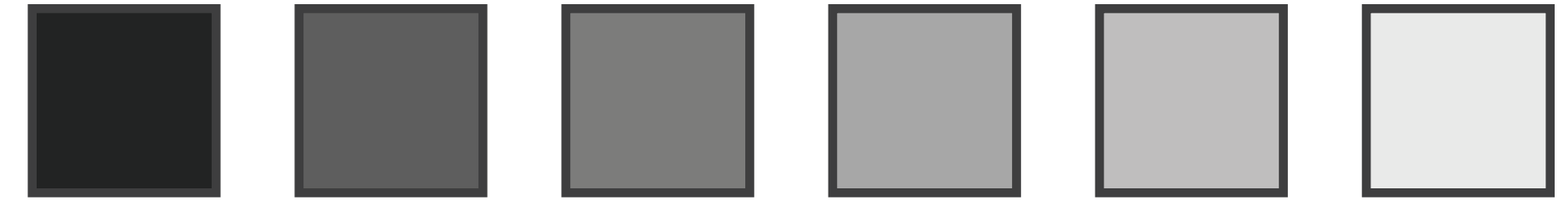
Hue



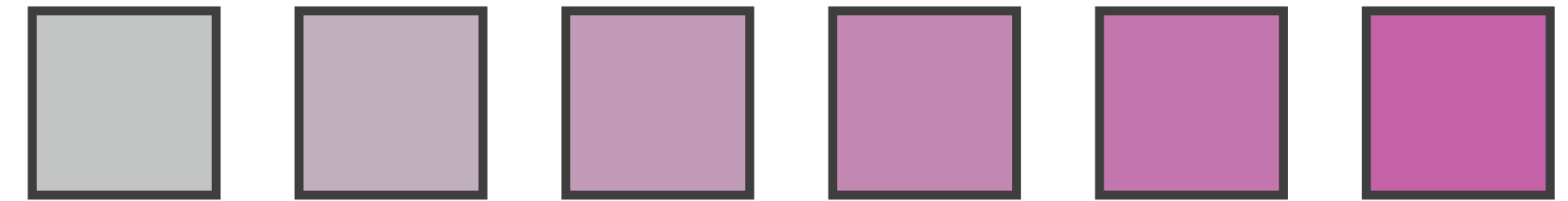
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- 3 channels
  - identity for categorical
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    - luminance
    - saturation
- RGB: poor for encoding

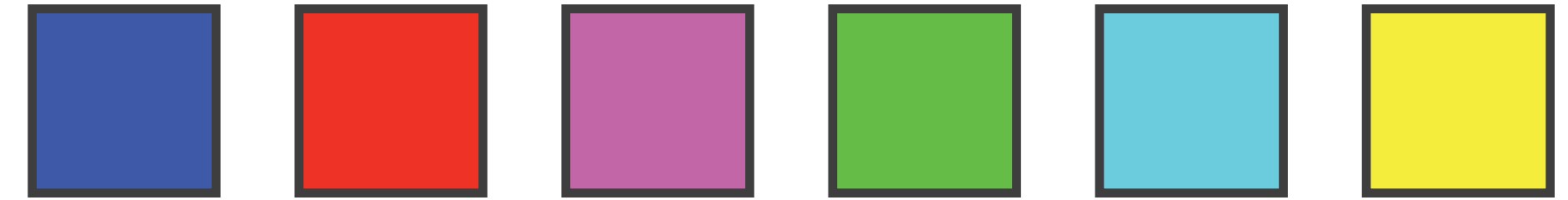
Luminance



Saturation



Hue



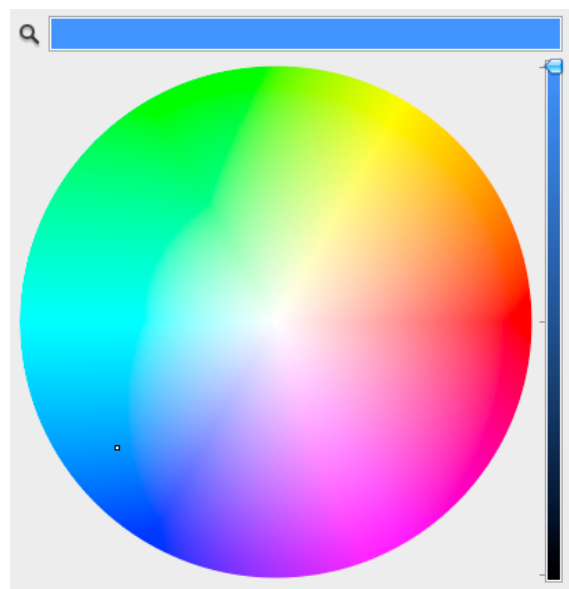
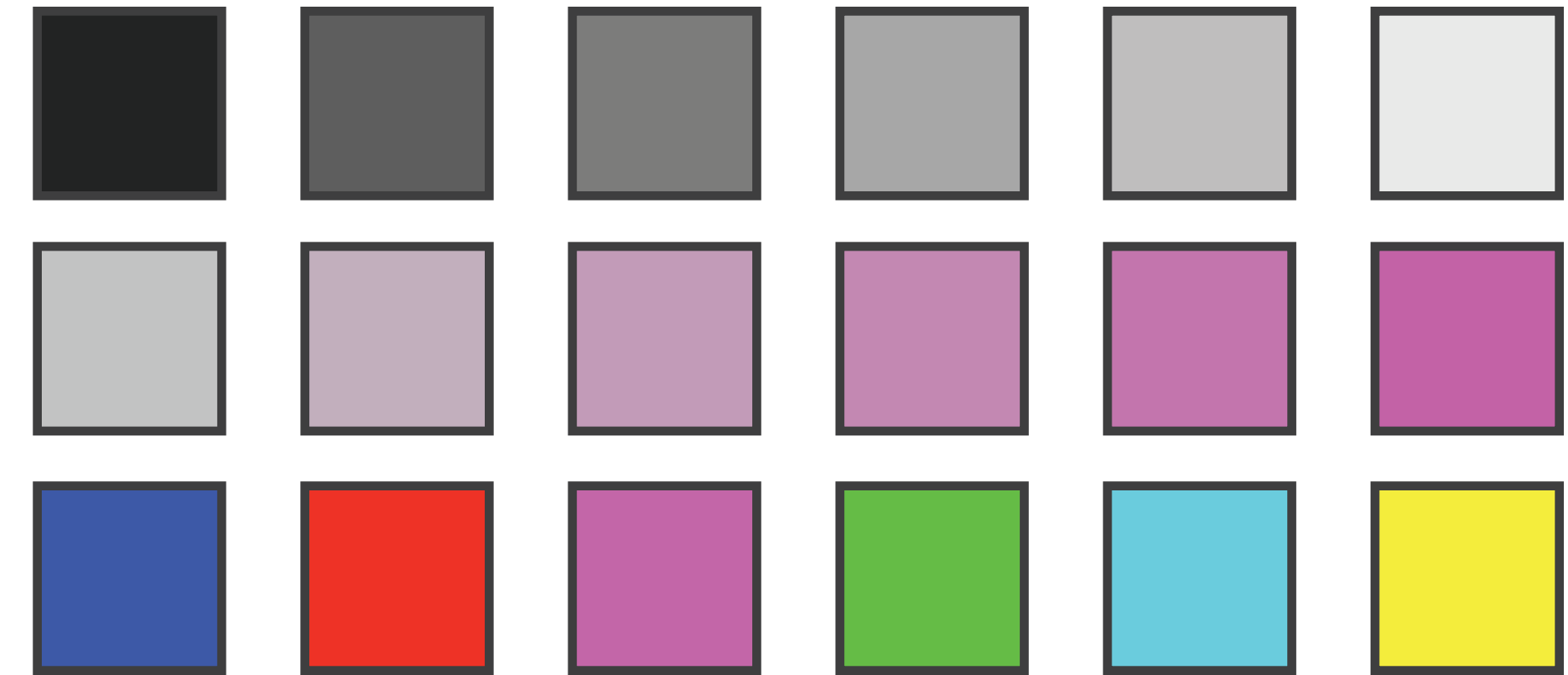
# Color: Luminance, saturation, hue

- 3 channels
  - identity for categorical
    - hue
  - magnitude for ordered
    - luminance
    - saturation
- RGB: poor for encoding
- HSL: better, but beware

Luminance

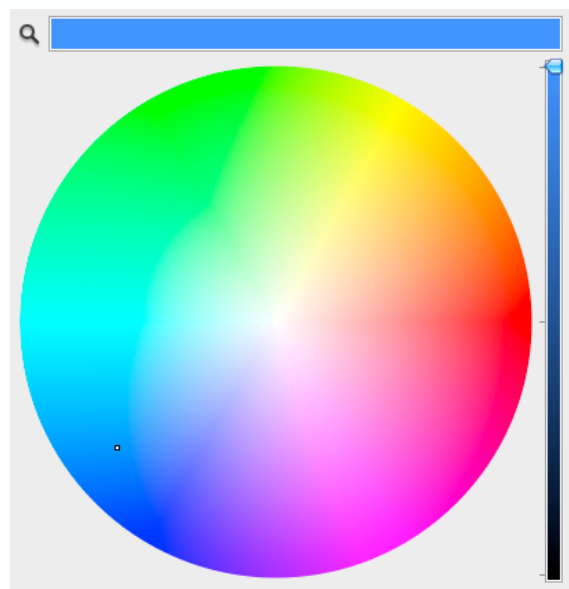
Saturation

Hue

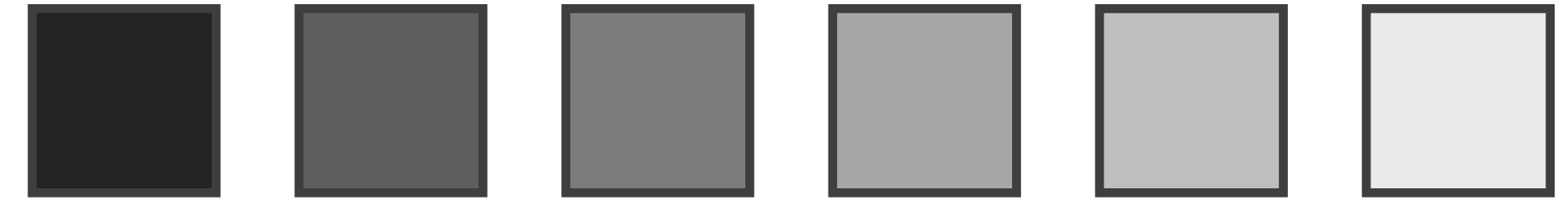


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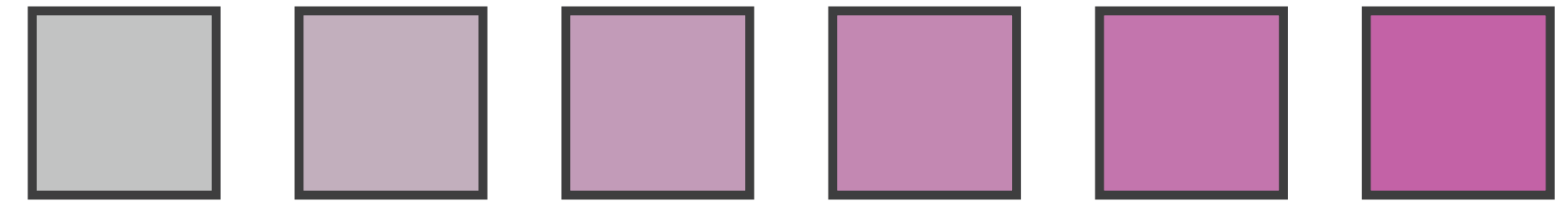
- 3 channels
  - identity for categorical
    - hue
  - magnitude for ordered
    - luminance
    - saturation
- RGB: poor for encoding
- HSL: better, but beware
  - lightness  $\neq$  luminance



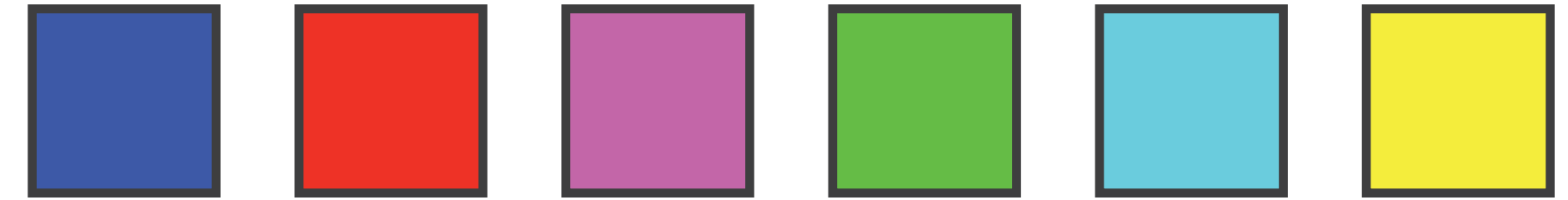
Luminance



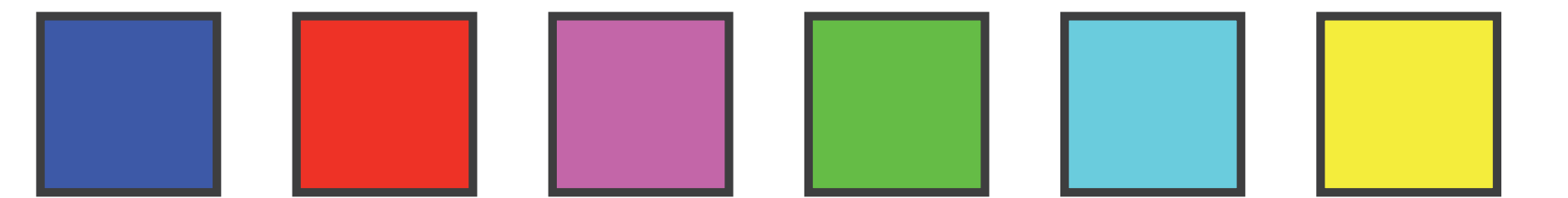
Saturation



Hue

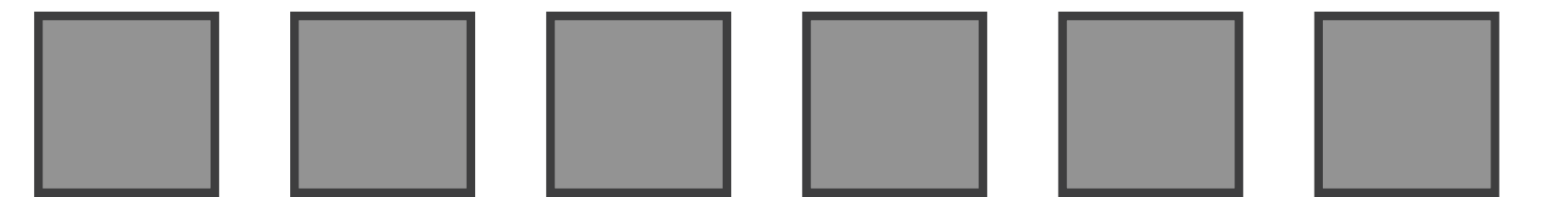


Corners of the RGB color cube

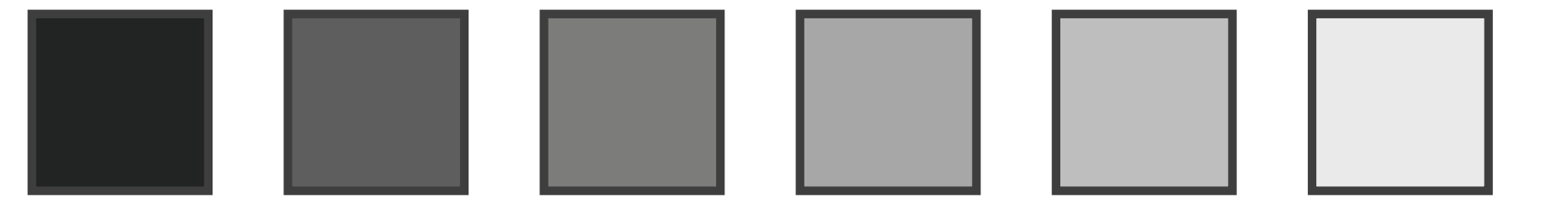


L from HLS

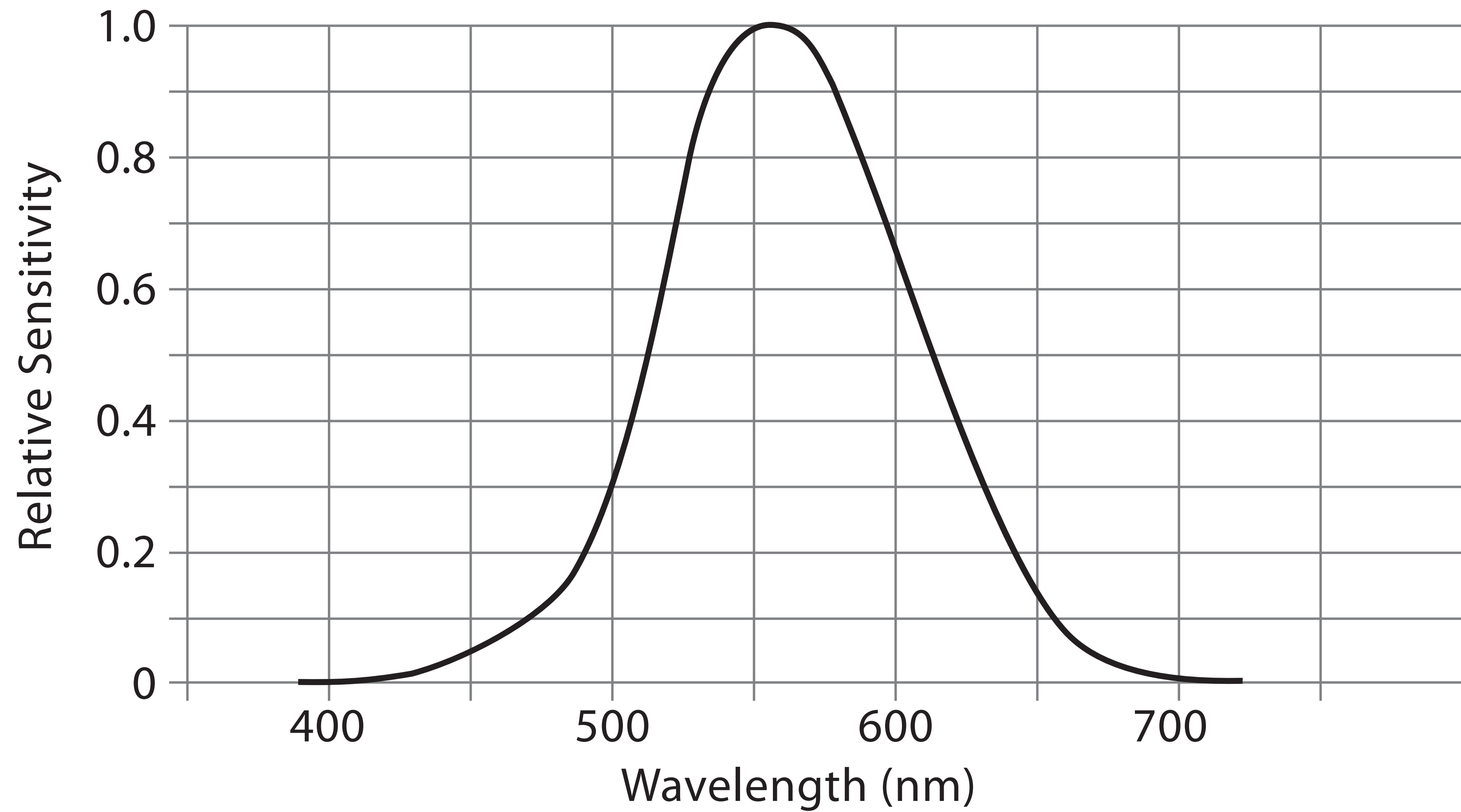
All the same



Luminance values



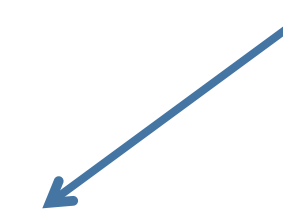
# Spectral sensitivity



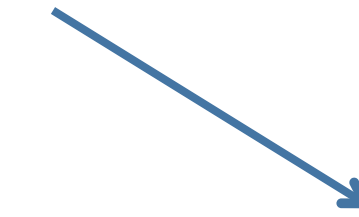


# Opponent color and color deficiency

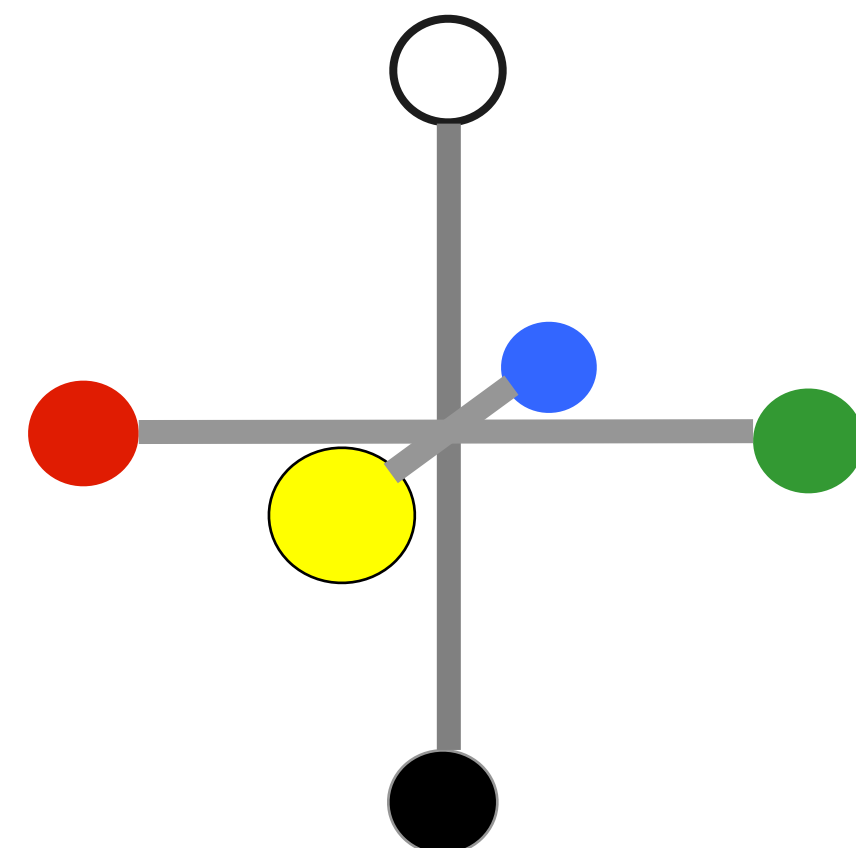
- perceptual processing before optic nerve
  - one achromatic luminance channel L
    - edge detection through luminance contrast
  - two chroma channels, R-G and Y-B axis
- “color blind” if one axis has degraded acuity
  - 8% of men are red/green color deficient
  - blue/yellow is rare



Lightness information



Color information



*[Seriously Colorful: Advanced Color Principles & Practices. Stone.Tableau Customer Conference 2014.]*



# Designing for color deficiency: Check with simulator



**Normal vision**



**Deuteranope**

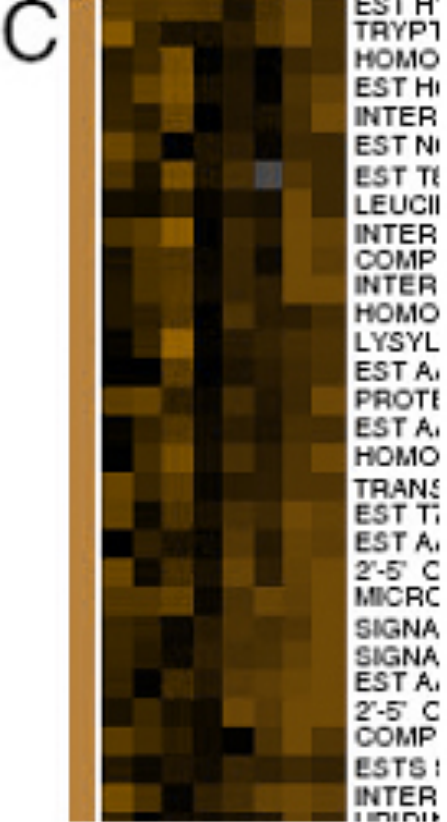
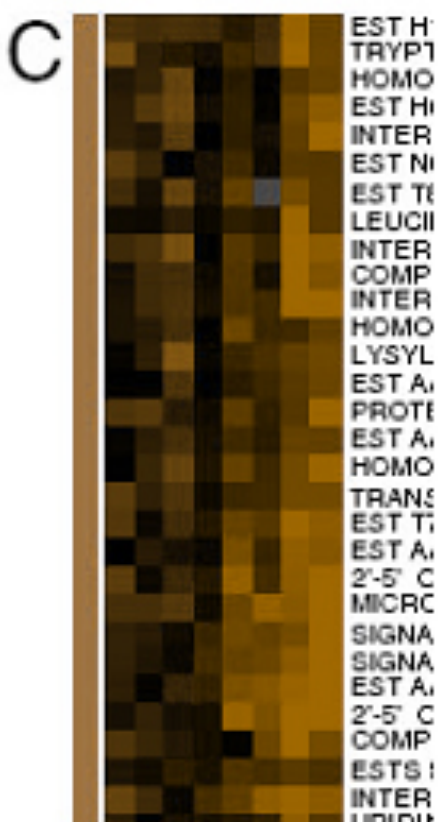
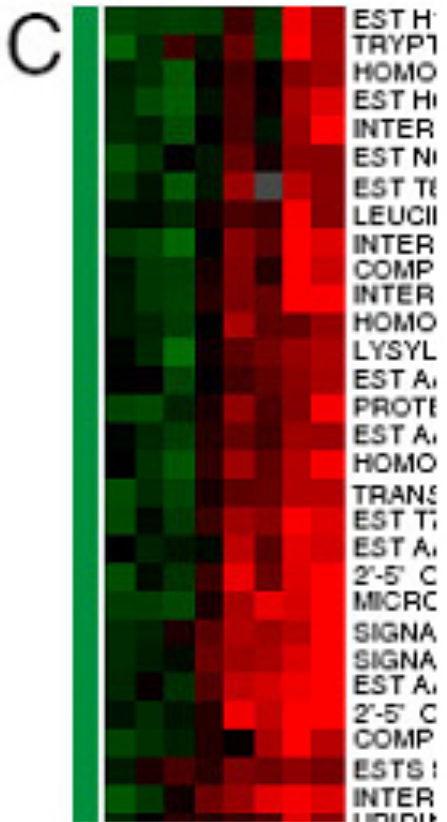


**Protanope**



**Tritanope**

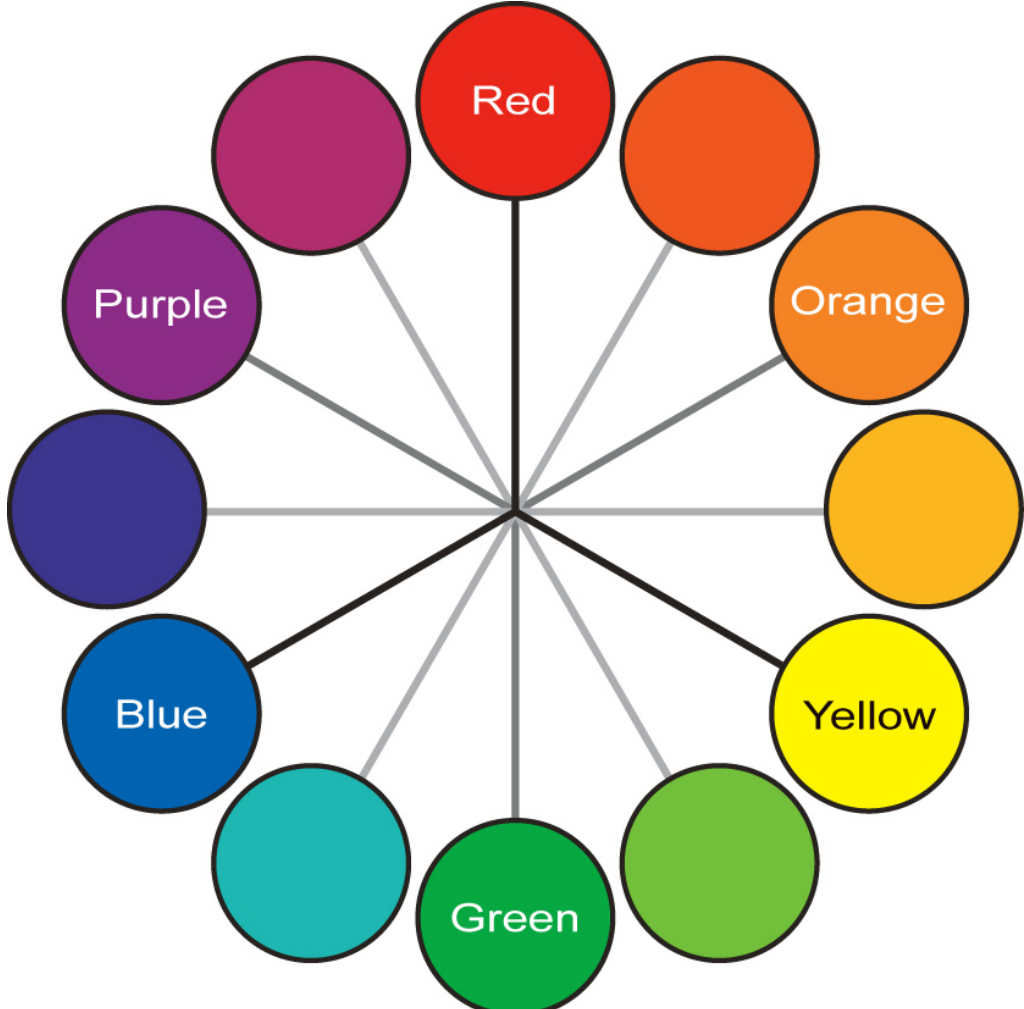
<http://rehue.net>



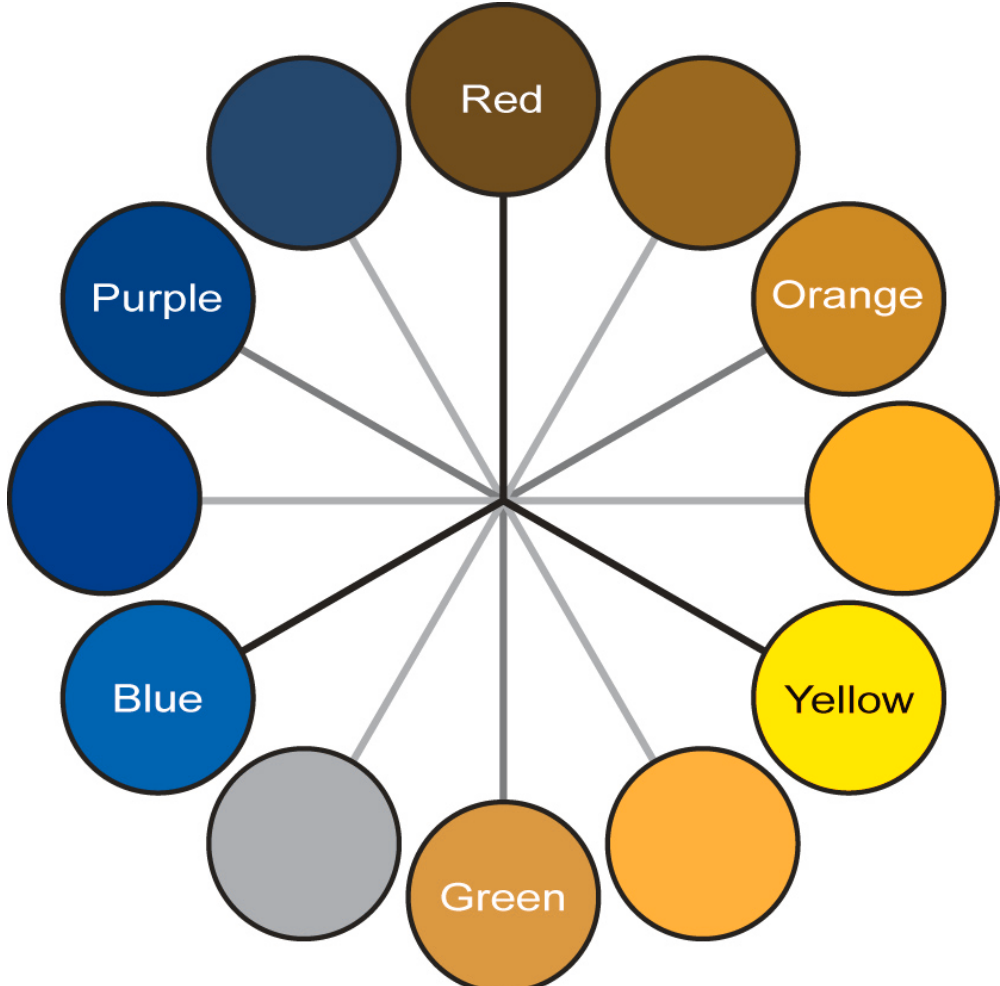
*[Seriously Colorful: Advanced Color Principles & Practices. Stone.Tableau Customer Conference 2014.]*



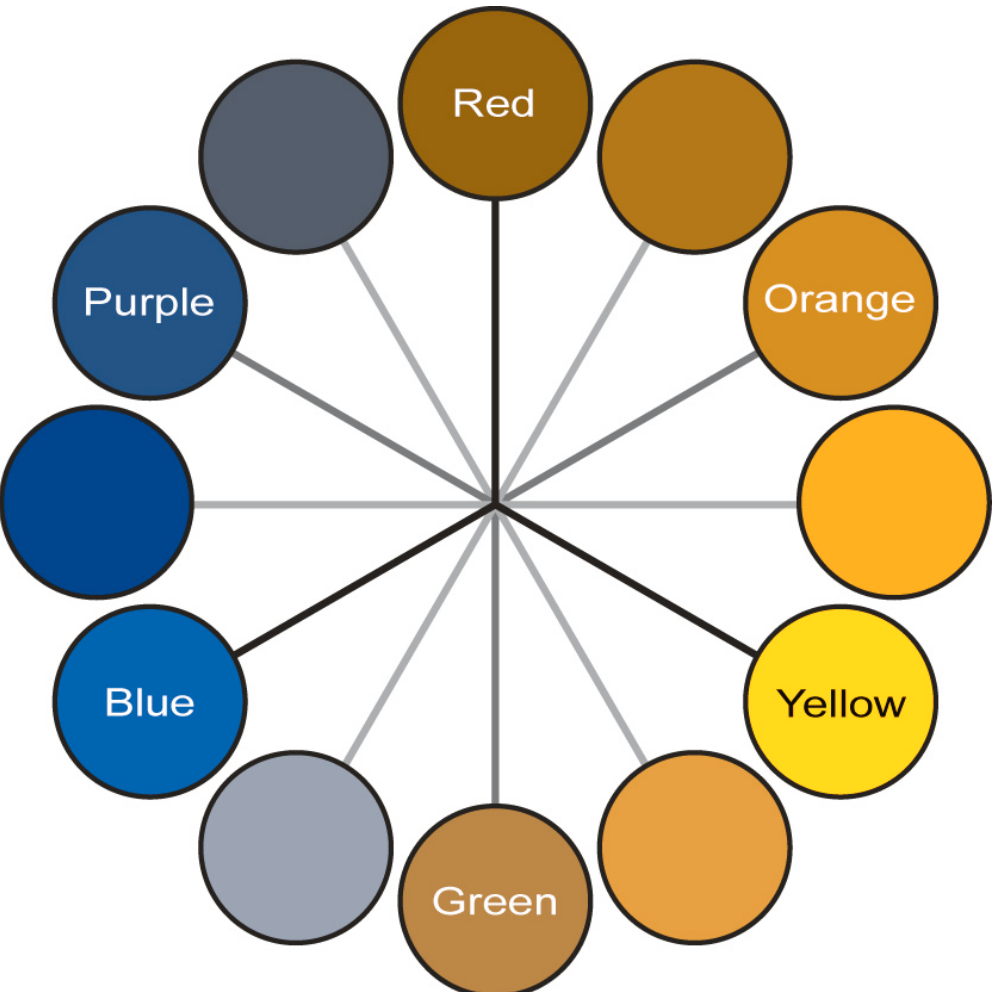
# Color deficiency: Reduces color to 2 dimensions



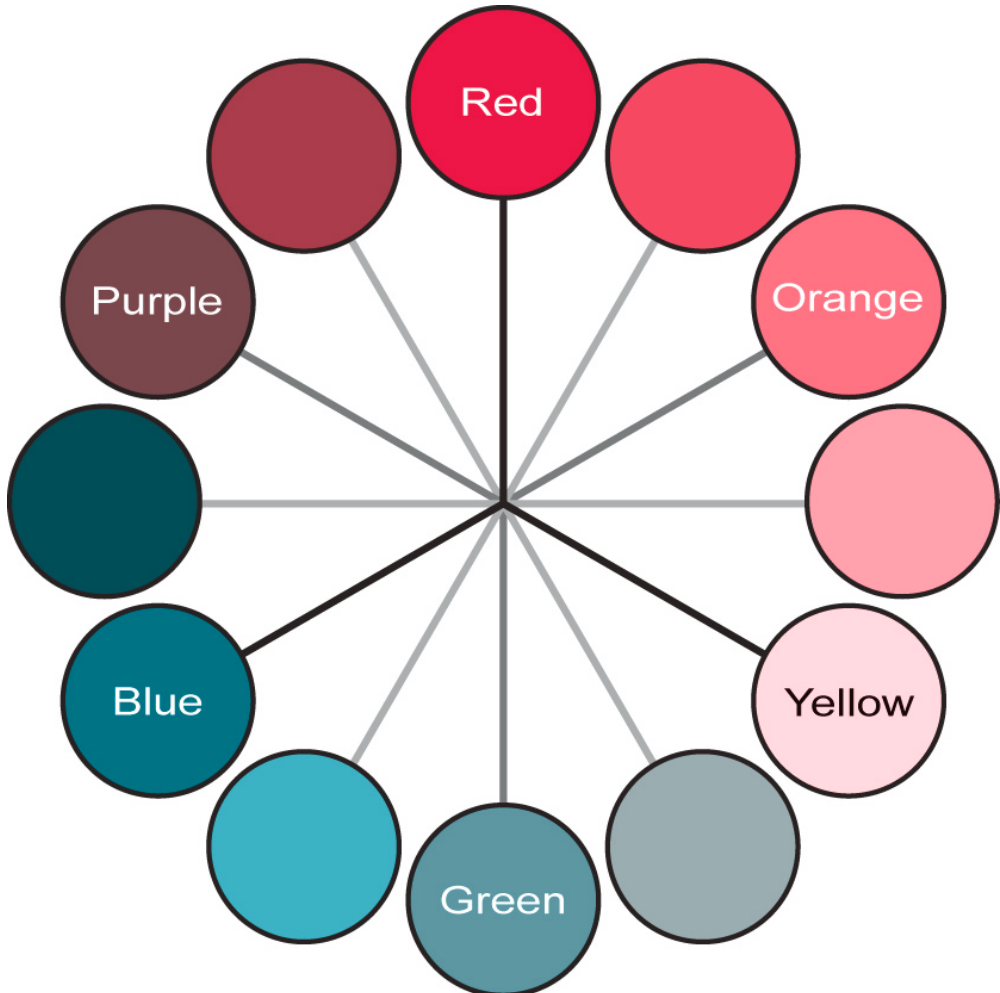
**Normal**



**Protanope**



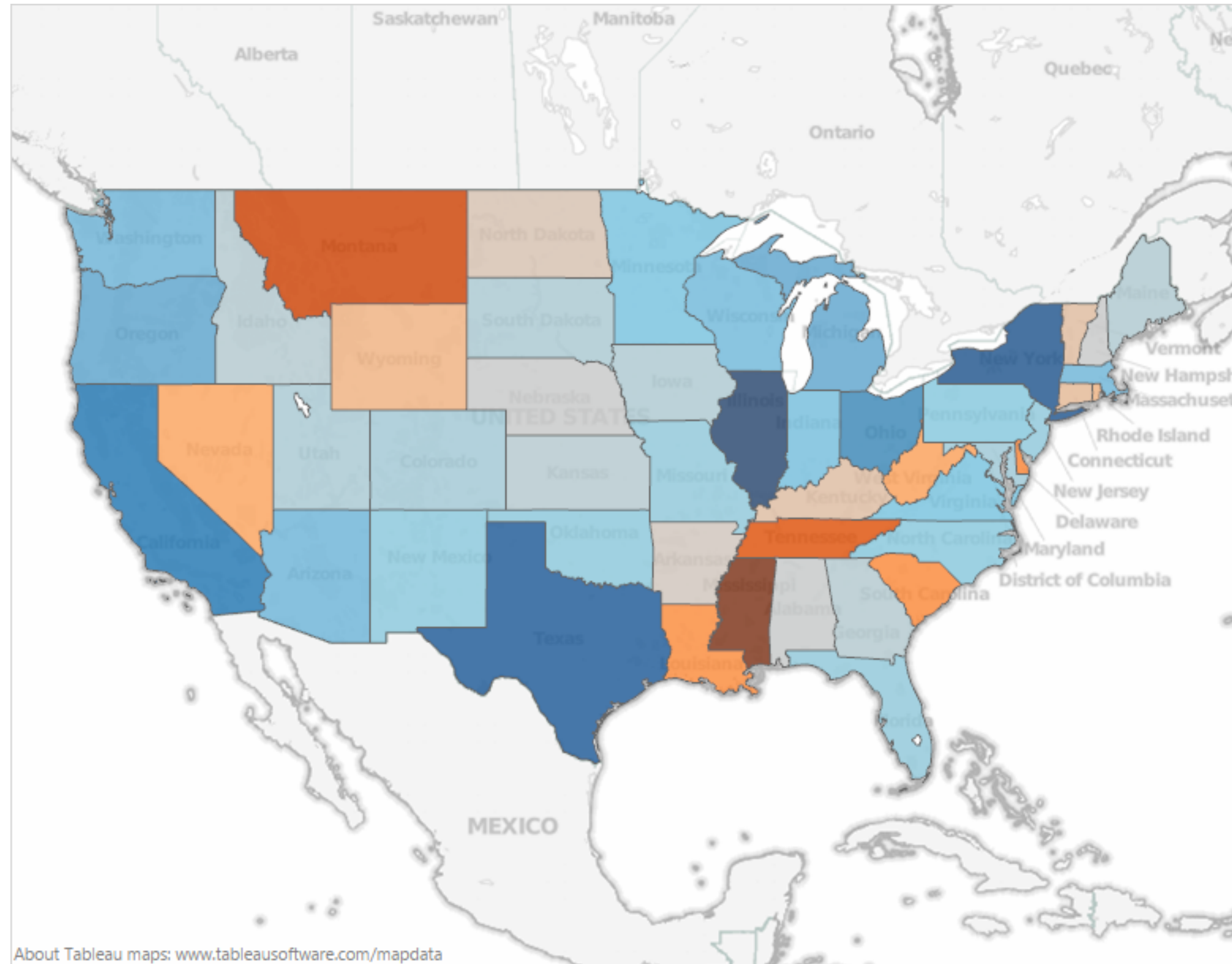
**Deuteranope**



**Tritanope**

[Seriously Colorful: Advanced Color Principles & Practices. Stone.Tableau Customer Conference 2014.]

# Designing for color deficiency: Blue-Orange is safe

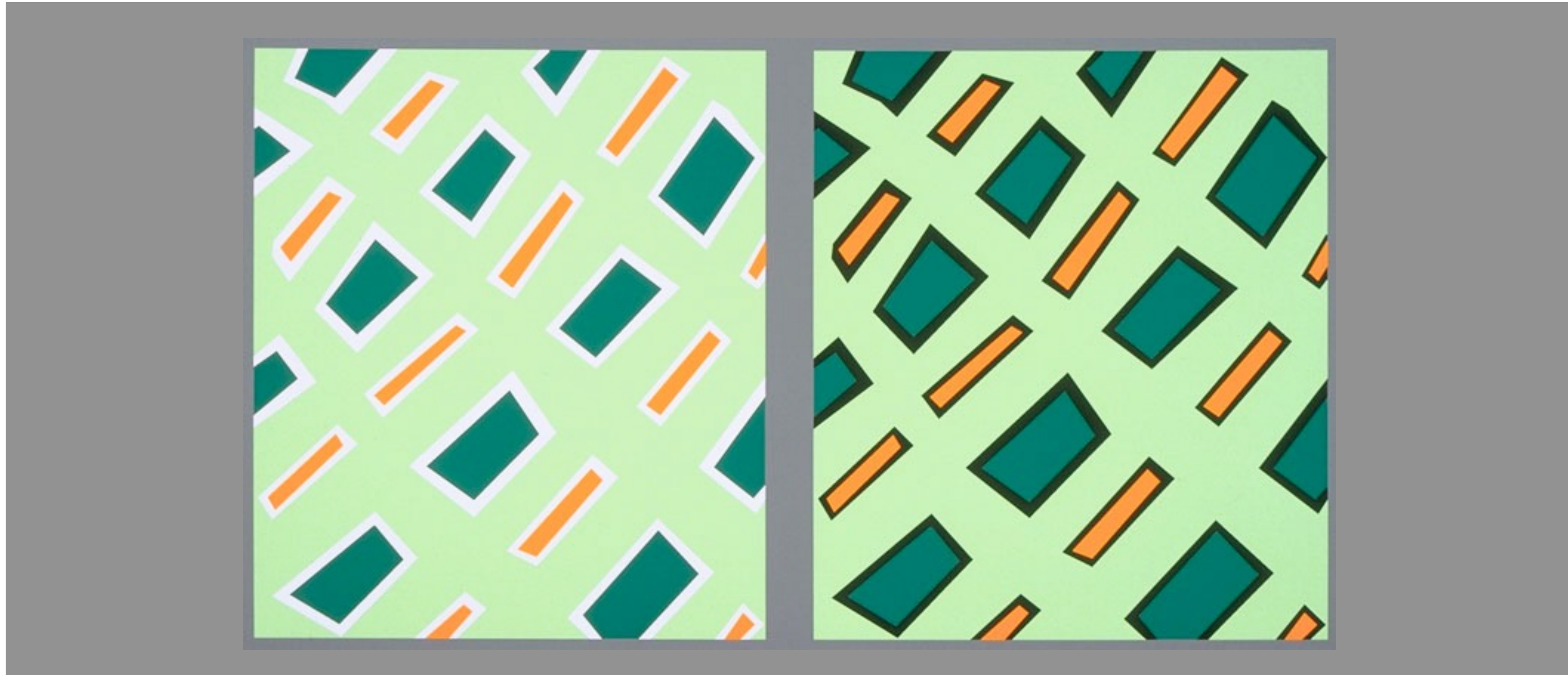


*[Seriously Colorful: Advanced Color Principles & Practices. Stone.Tableau Customer Conference 2014.]*



# Bezold Effect: Outlines matter

- color constancy: simultaneous contrast effect



*[Seriously Colorful: Advanced Color Principles & Practices. Stone.Tableau Customer Conference 2014.]*



# Color/Lightness constancy: Illumination conditions

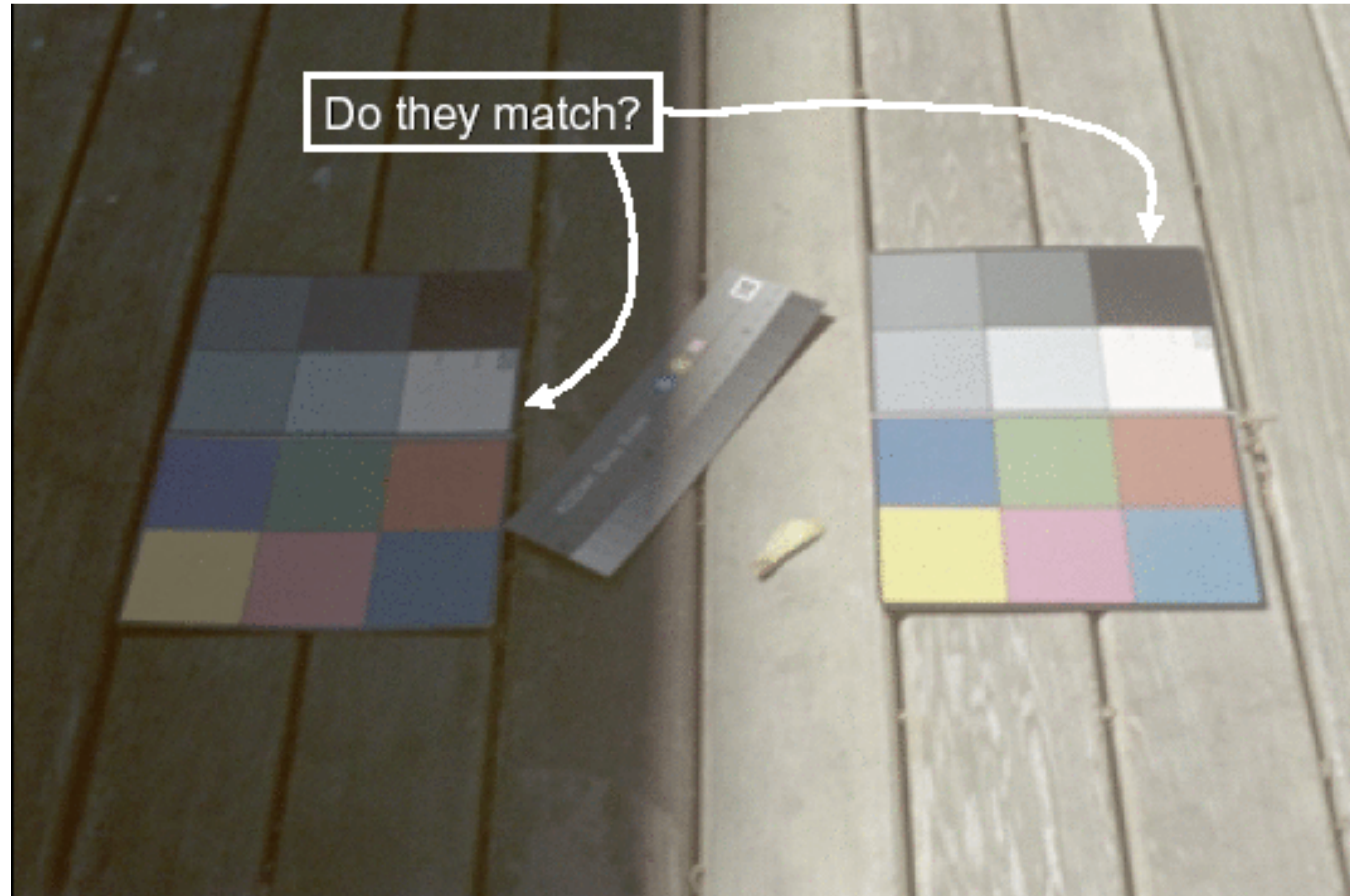


Image courtesy of John McCann



# Color/Lightness constancy: Illumination conditions

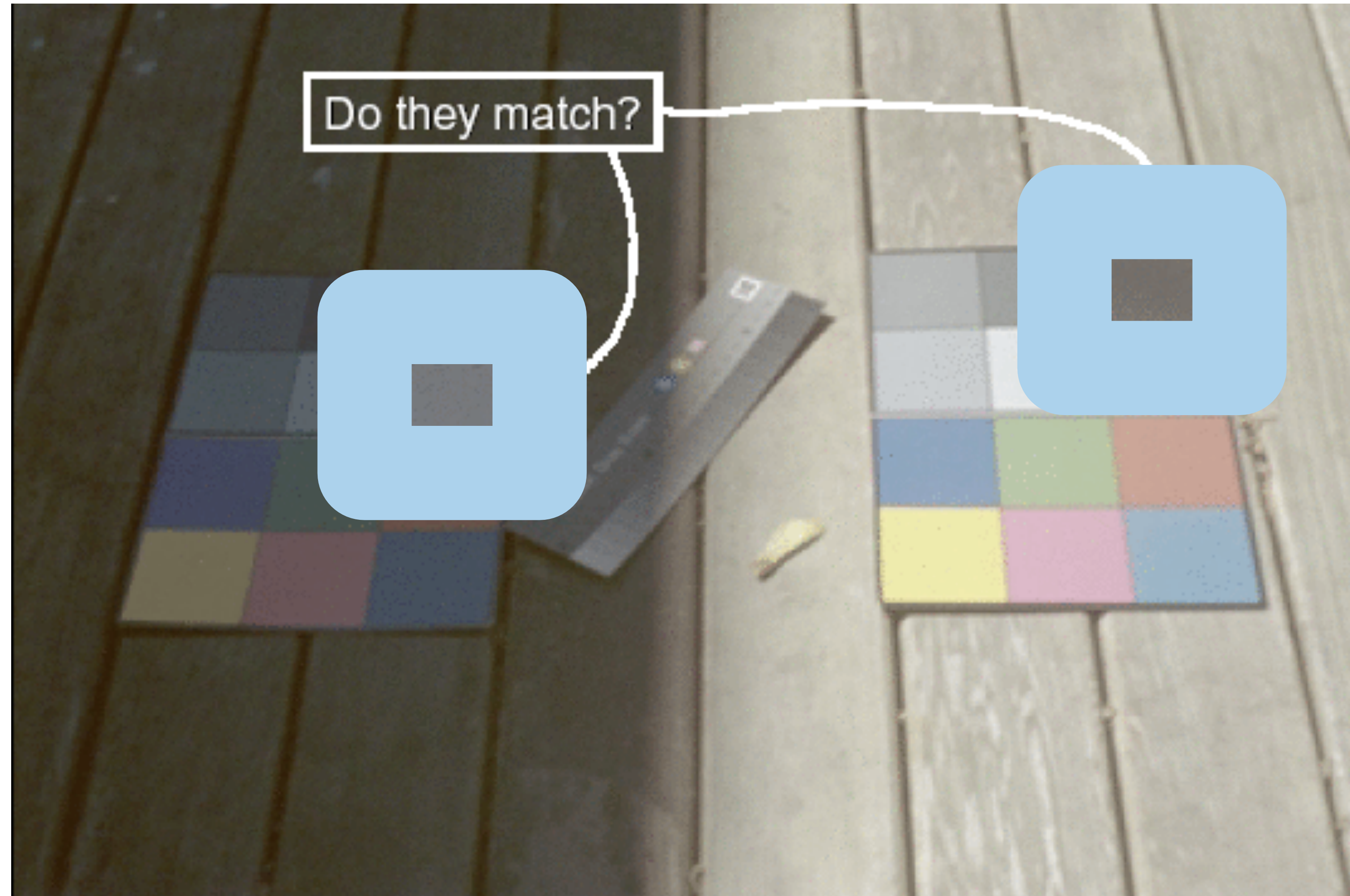


Image courtesy of John McCann

# Colormaps

→ Categorical



→ Ordered

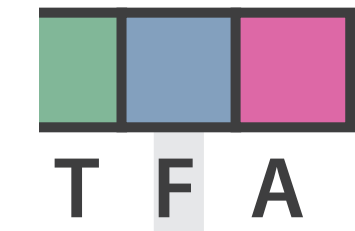
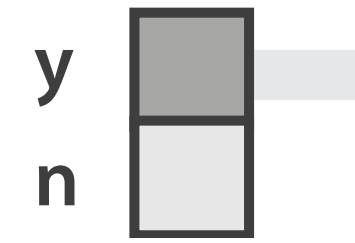
→ *Sequential*



→ *Diverging*

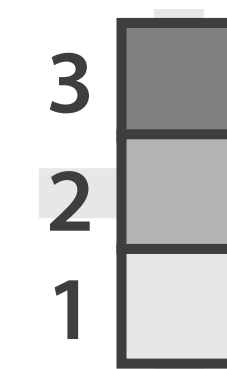
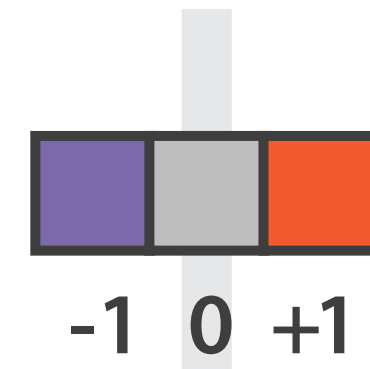


Binary



Categorical

Diverging



Sequential

after [Color Use Guidelines for Mapping and Visualization. Brewer, 1994.  
<http://www.personal.psu.edu/faculty/c/a/cab38/ColorSch/Schemes.html>]



# Colormaps

→ Categorical



→ Ordered

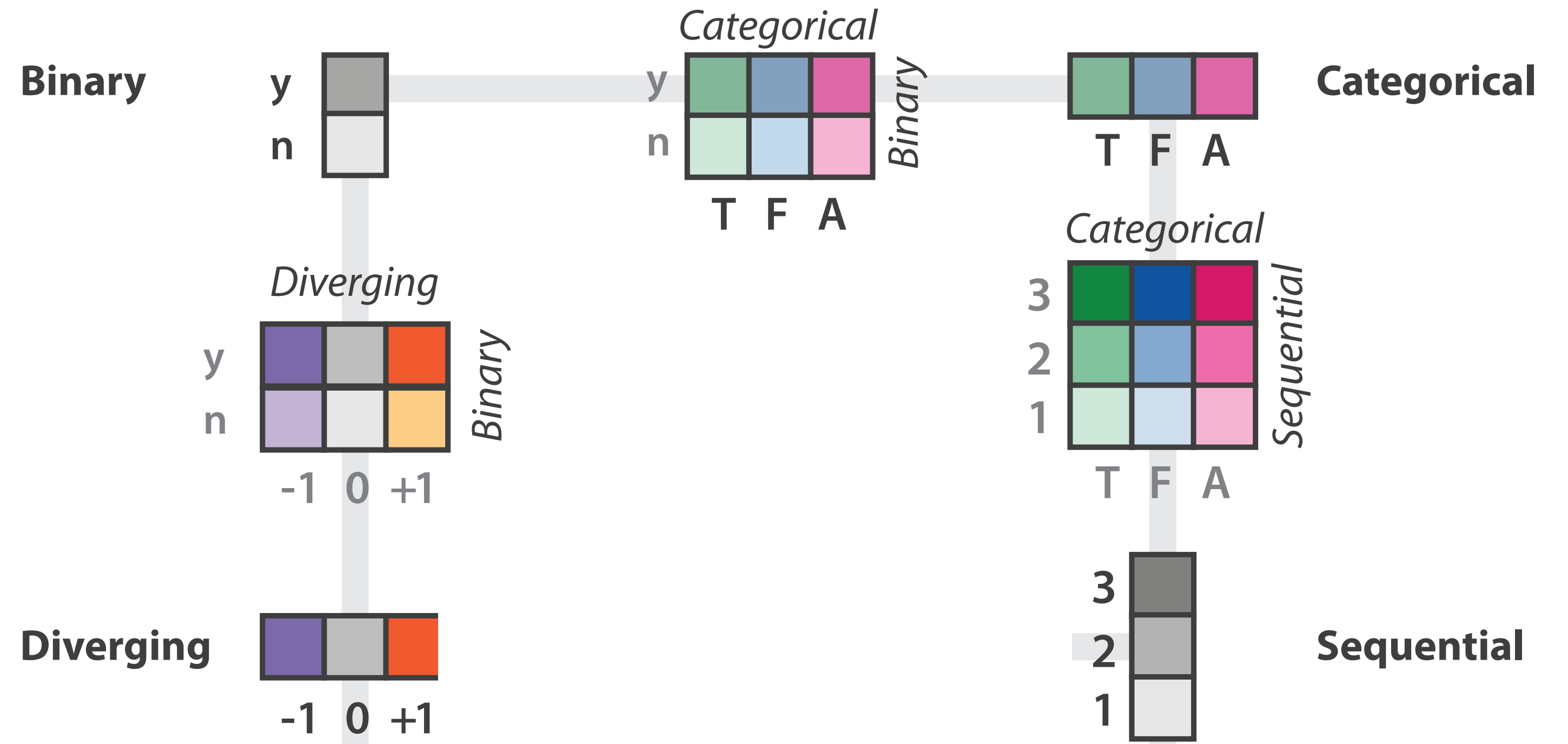
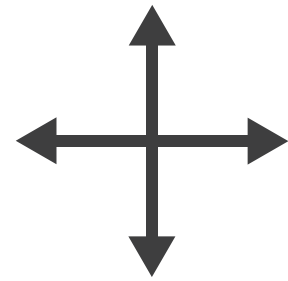
→ *Sequential*



→ *Diverging*



→ Bivariate



after [Color Use Guidelines for Mapping and Visualization. Brewer, 1994.  
<http://www.personal.psu.edu/faculty/c/a/cab38/ColorSch/Schemes.html>]

# Colormaps

→ Categorical



→ Ordered

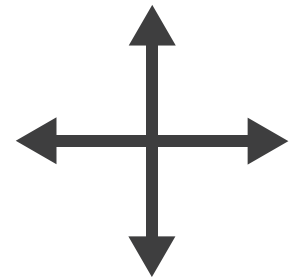
→ Sequential



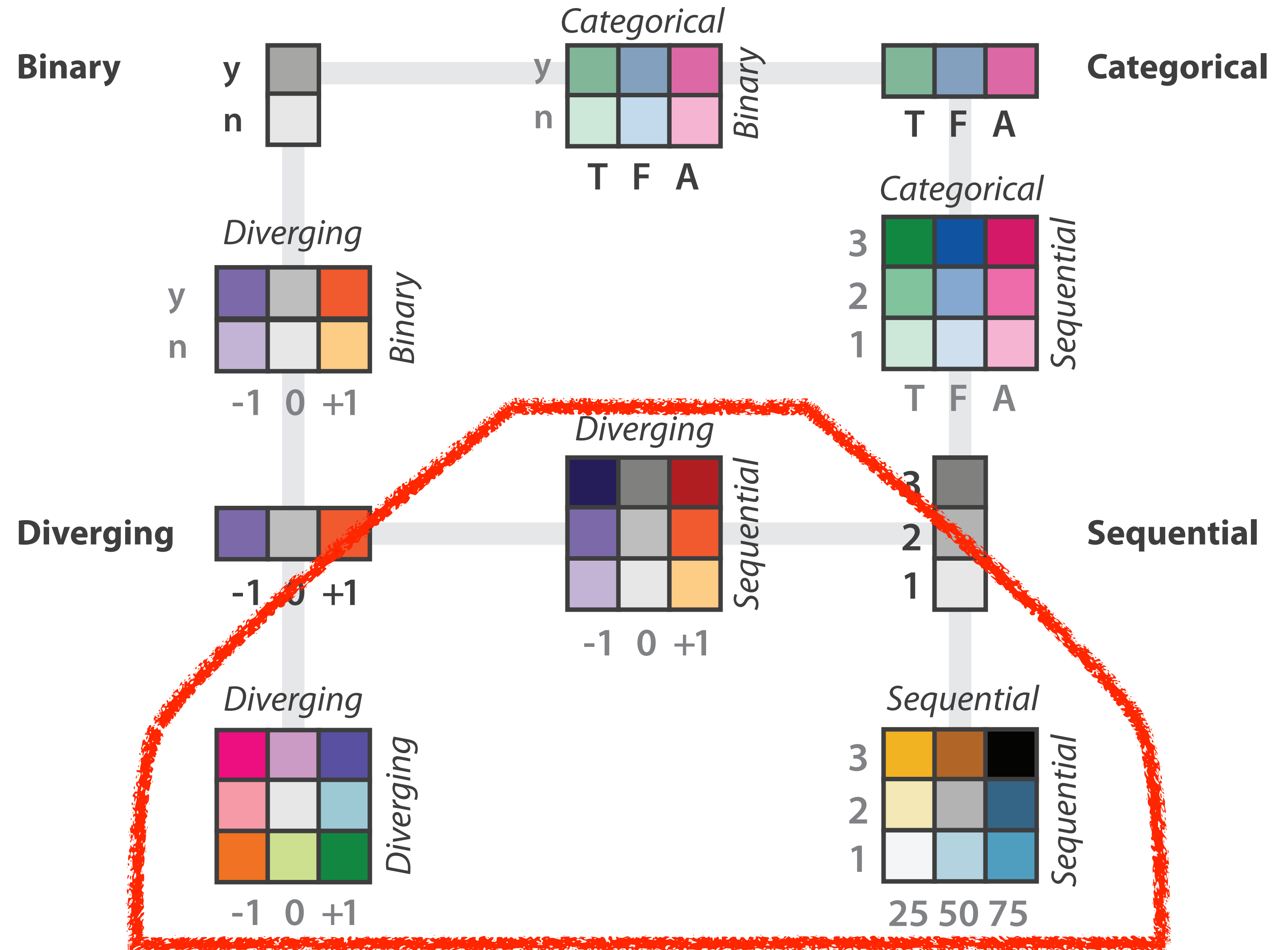
→ Diverging



→ Bivariate



use with care!



after [Color Use Guidelines for Mapping and Visualization. Brewer, 1994.  
<http://www.personal.psu.edu/faculty/c/a/cab38/ColorSch/Schemes.html>]

# Colormaps

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→ Ordered

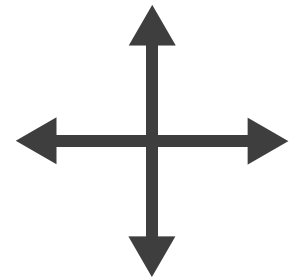
→ Sequential



→ Diverging



→ Bivariate



- color channel interactions

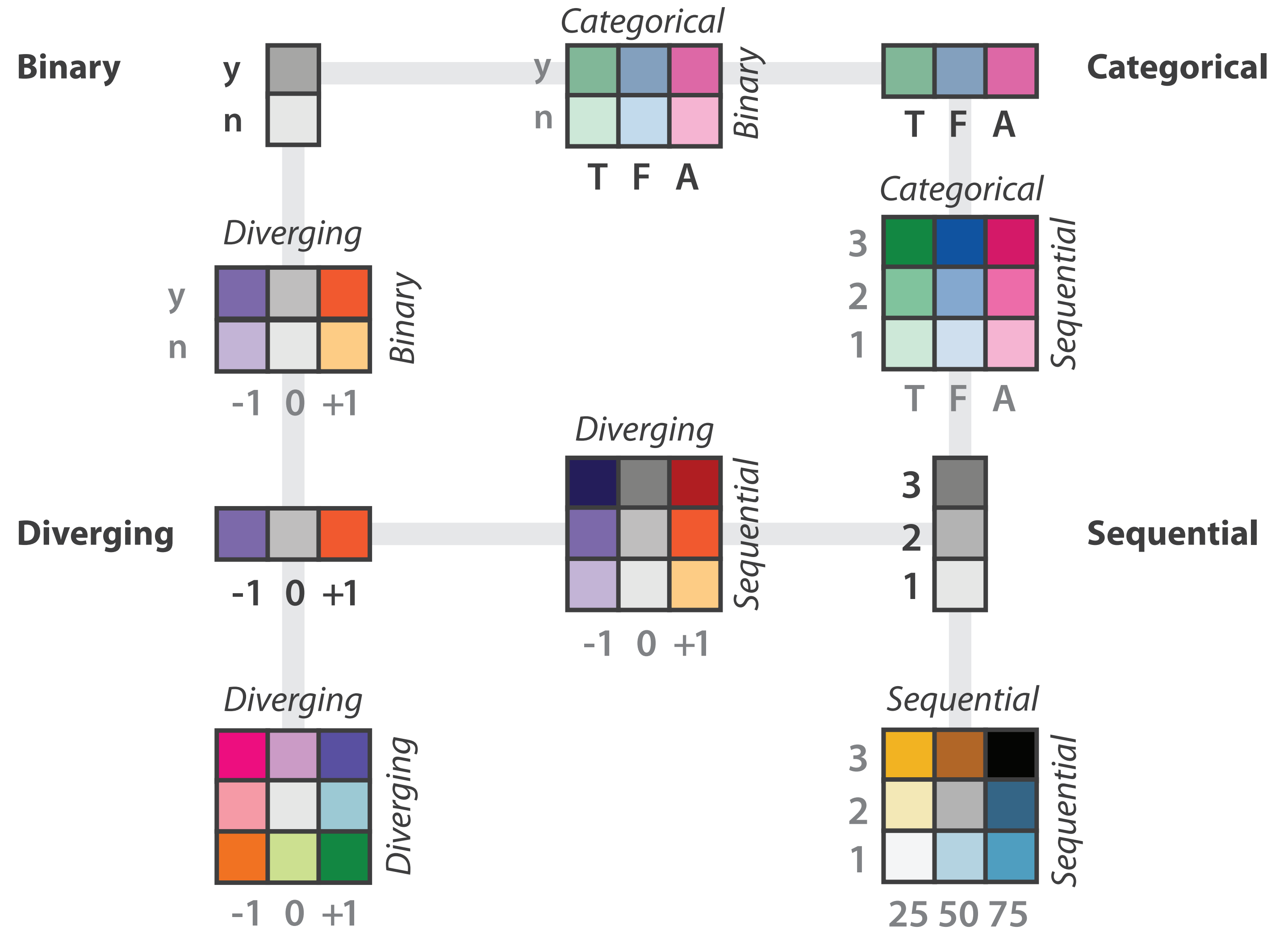
- size heavily affects salience

- small regions need high saturation

- large need low saturation

- saturation & luminance: 3-4 bins max

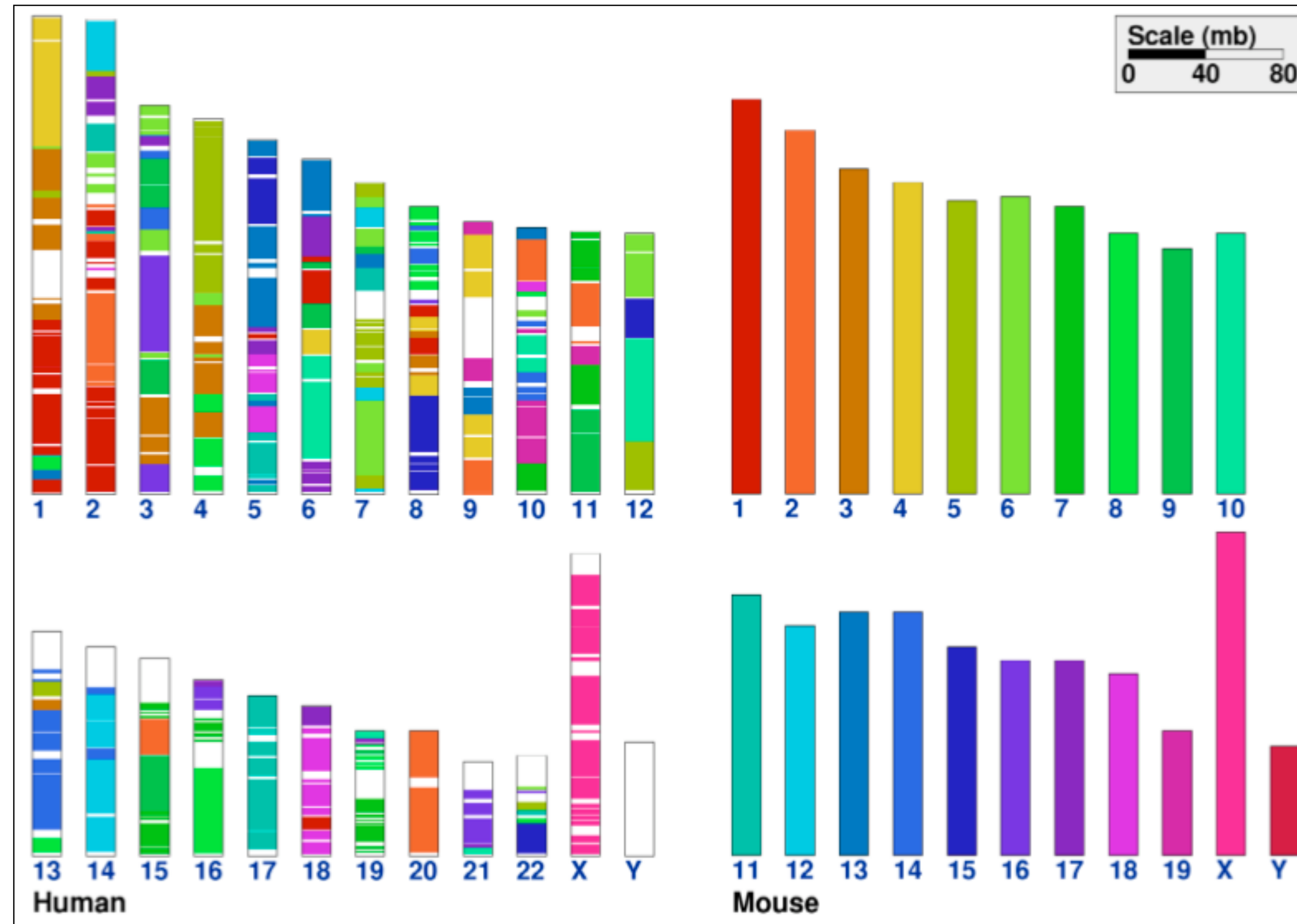
- also not separable from transparency



after [Color Use Guidelines for Mapping and Visualization. Brewer, 1994. <http://www.personal.psu.edu/faculty/cl/cab38/ColorSch/Schemes.html>]

# Categorical color: Discriminability constraints

- noncontiguous small regions of color: only 6-12 bins



[Cinteny: flexible analysis and visualization of synteny and genome rearrangements in multiple organisms. Sinha and Meller. BMC Bioinformatics, 8:82, 2007.]

# ColorBrewer

- <http://www.colorbrewer2.org>
- saturation and area example: size affects saliency!

number of data classes on your map: 10

the nature of your data: qualitative

pick a color scheme: Set3

(optional) only show schemes that are:  
 colorblind safe  
 print friendly  
 photocopy-able

pick a color system: RGB

adjust map context:  
 roads  
 cities  
 borders

select a background: solid color

EXPORT YOUR COLORS >>

© Cynthia Brewer, Mark Harrower and The Pennsylvania State University  
[Support](#)

number of data classes on your map: 8

the nature of your data: qualitative

pick a color scheme: Set1

(optional) only show schemes that are:  
 colorblind safe  
 print friendly  
 photocopy-able

pick a color system: RGB

adjust map context:  
 roads  
 cities  
 borders

select a background: solid color

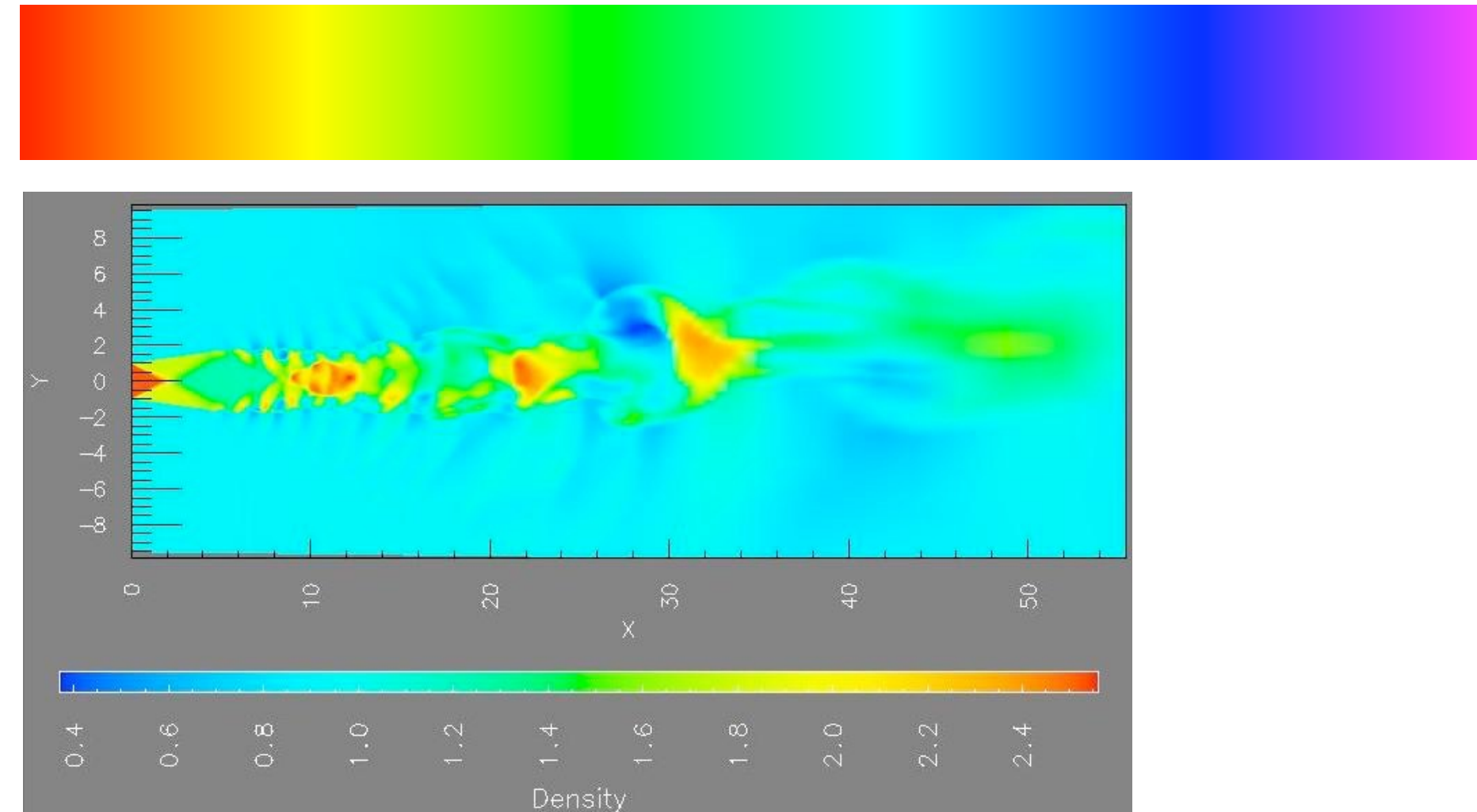
EXPORT YOUR COLORS >>

© Cynthia Brewer, Mark Harrower and The Pennsylvania State University  
[Support](#)

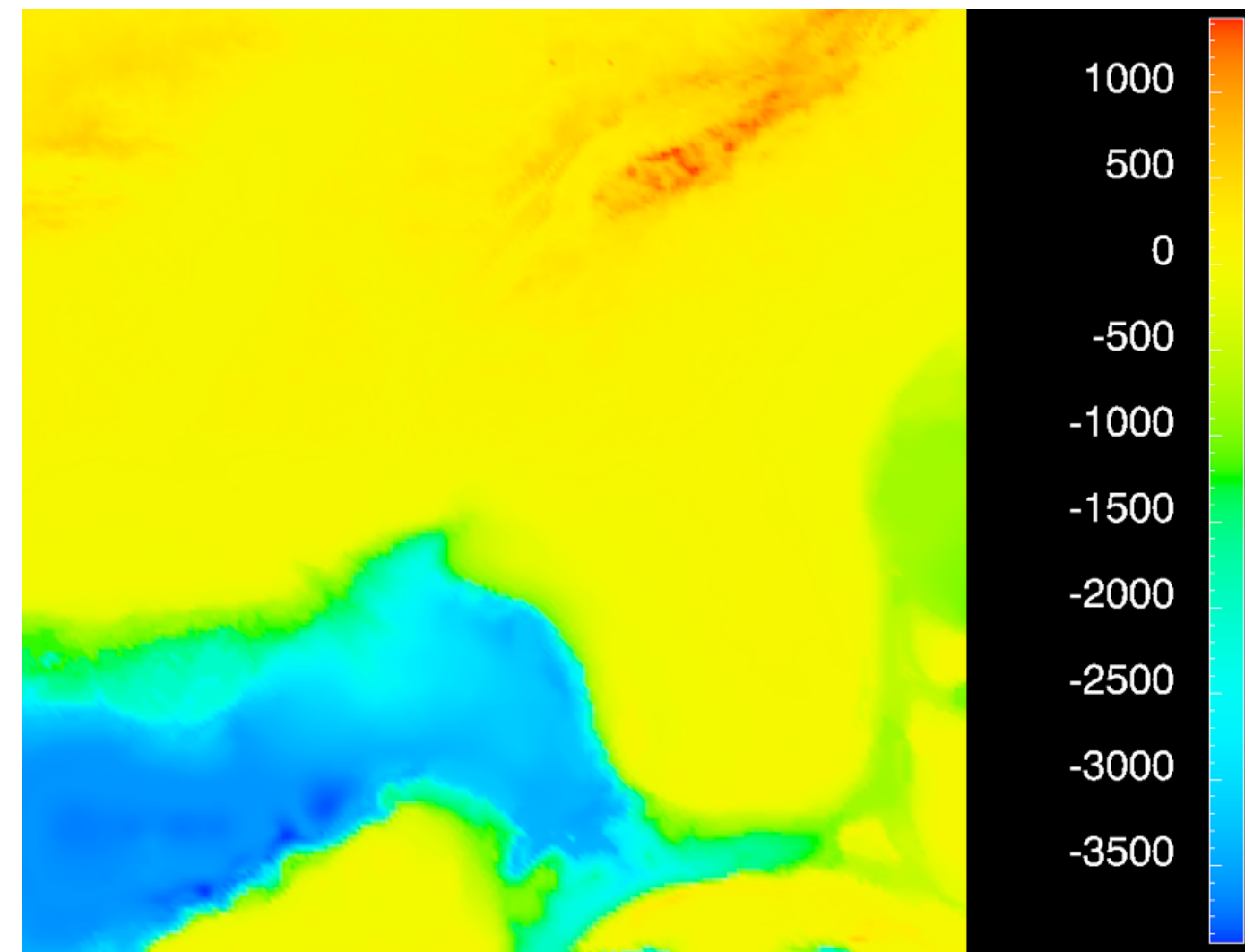


# Ordered color: Rainbow is poor default

- problems
  - perceptually unordered
  - perceptually nonlinear
- benefits
  - fine-grained structure visible and nameable



[A Rule-based Tool for Assisting Colormap Selection. Bergman, Rogowitz, and Treinish. Proc. IEEE Visualization (Vis), pp. 118–125, 1995.]

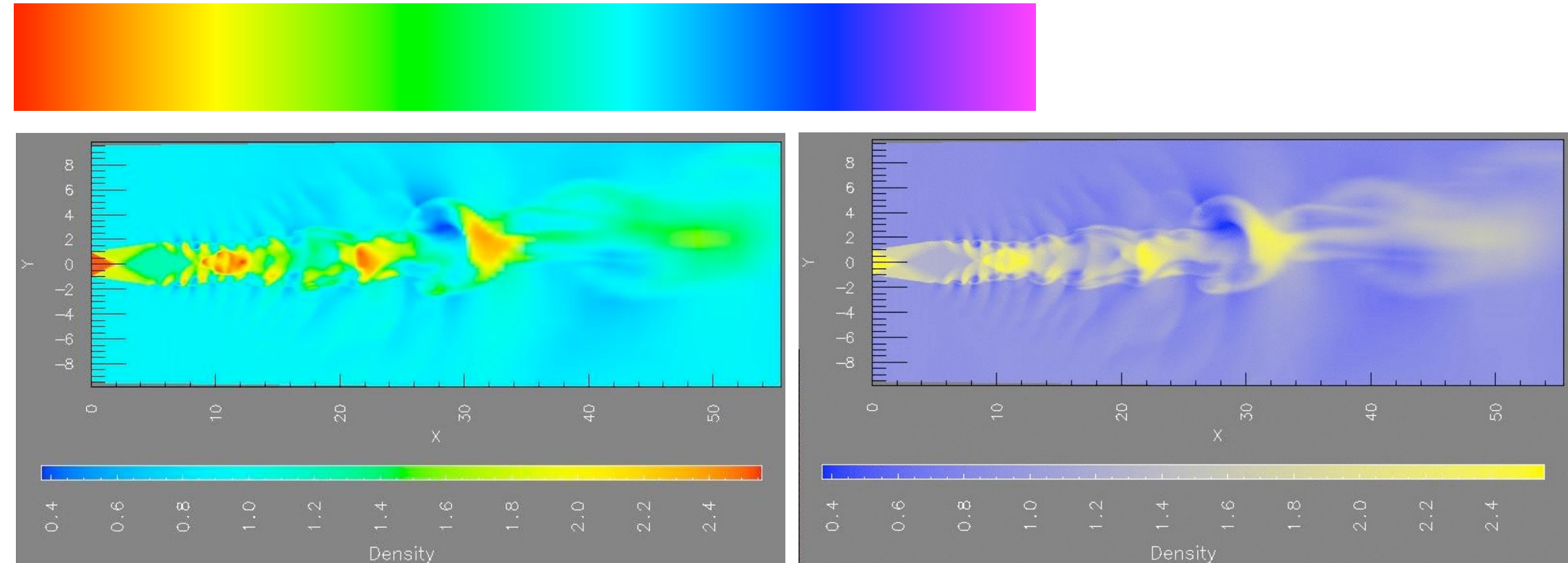


[Why Should Engineers Be Worried About Color? Treinish and Rogowitz 1998. <http://www.research.ibm.com/people/lloyd/color/color.HTM>]

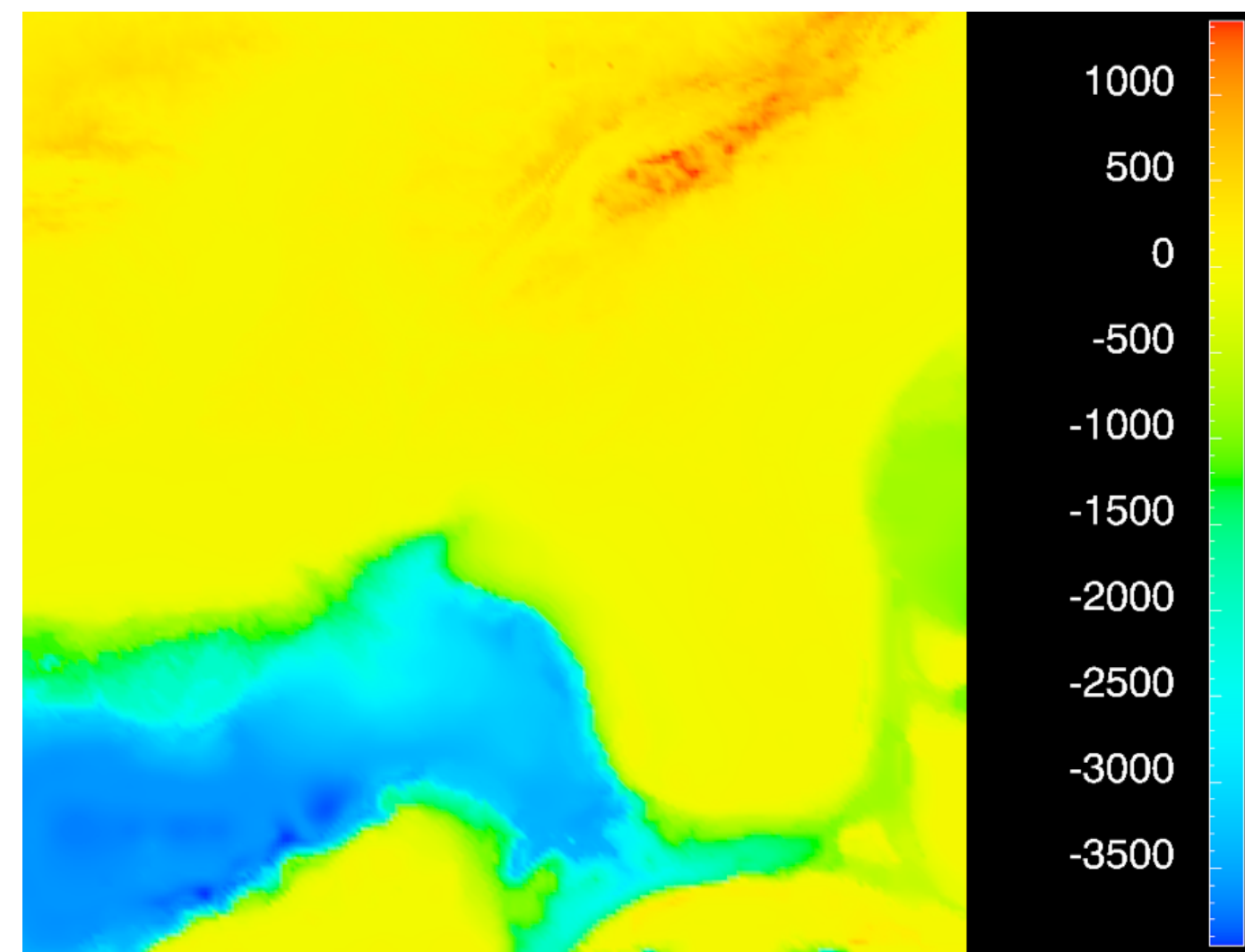
[Transfer Functions in Direct Volume Rendering: Design, Interface, Interaction. Kindlmann. SIGGRAPH 2002 Course Notes]

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  - large-scale structure: fewer hues



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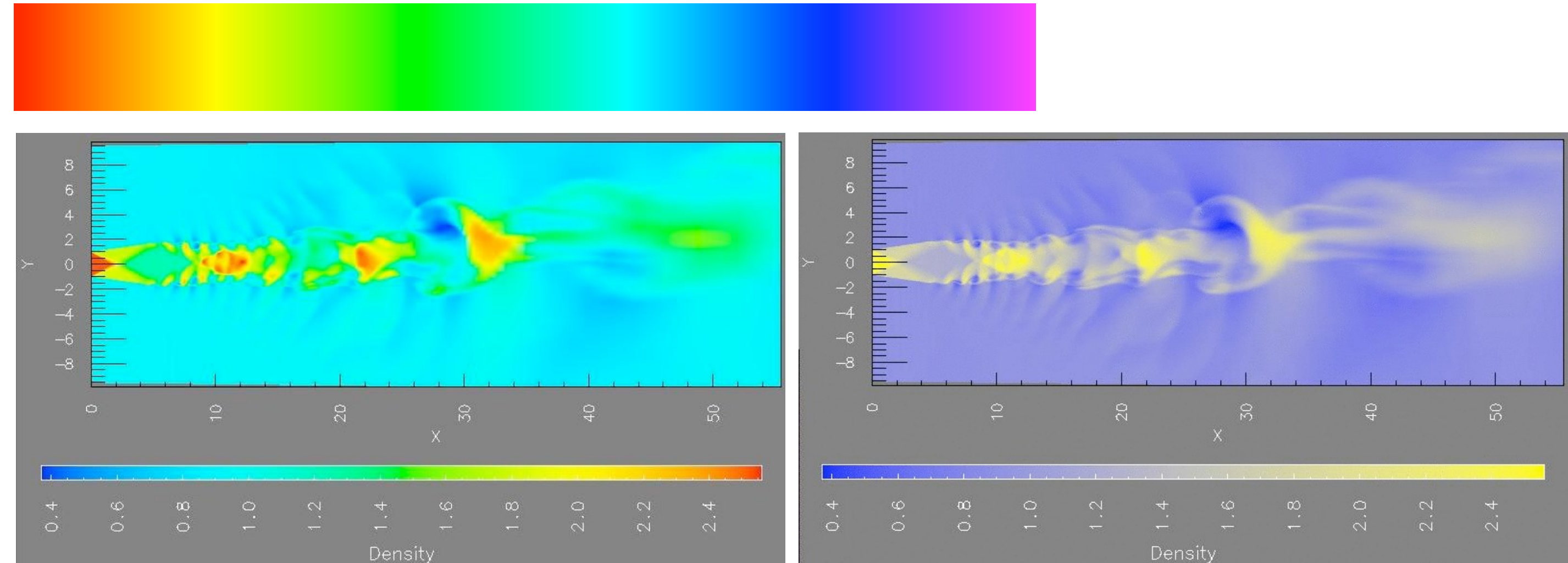


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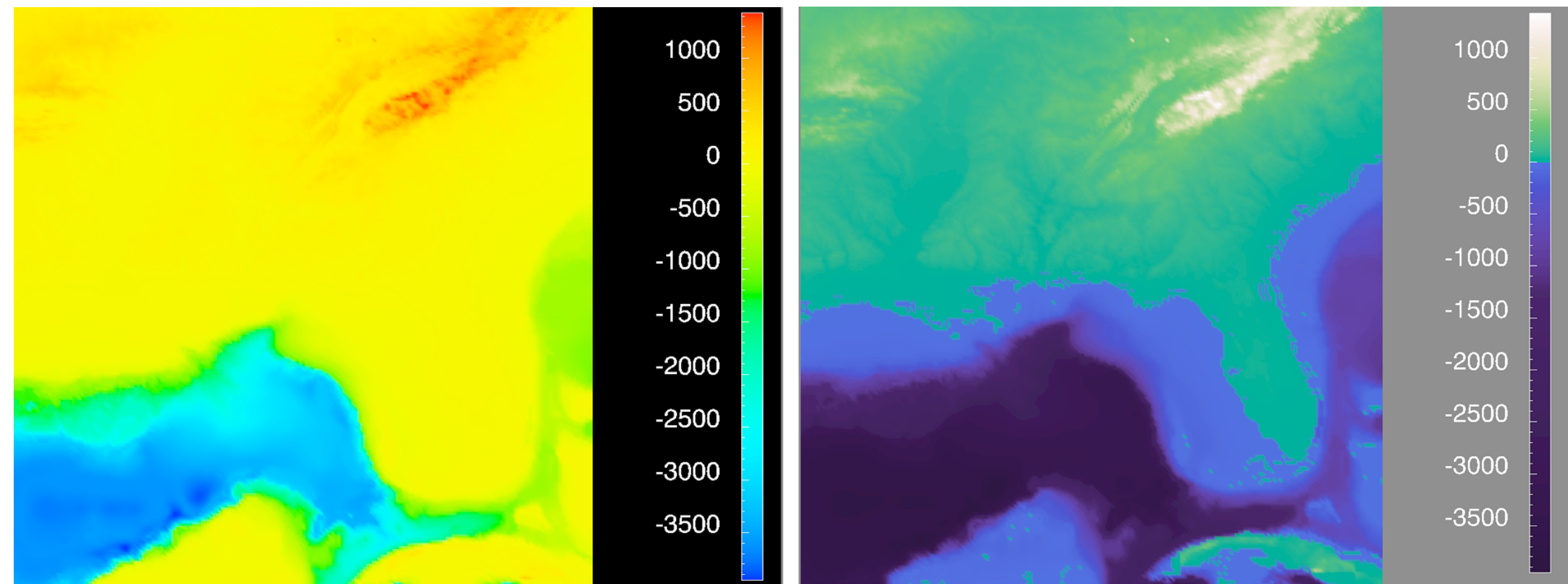


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- problems
  - perceptually unordered
  - perceptually nonlinear
- benefits
  - fine-grained structure visible and nameable
- alternatives
  - large-scale structure: fewer hues
  - fine structure: multiple hues with monotonically increasing luminance [eg viridis R/python]



[A Rule-based Tool for Assisting Colormap Selection. Bergman, Rogowitz, and Treinish. Proc. IEEE Visualization (Vis), pp. 118–125, 1995.]

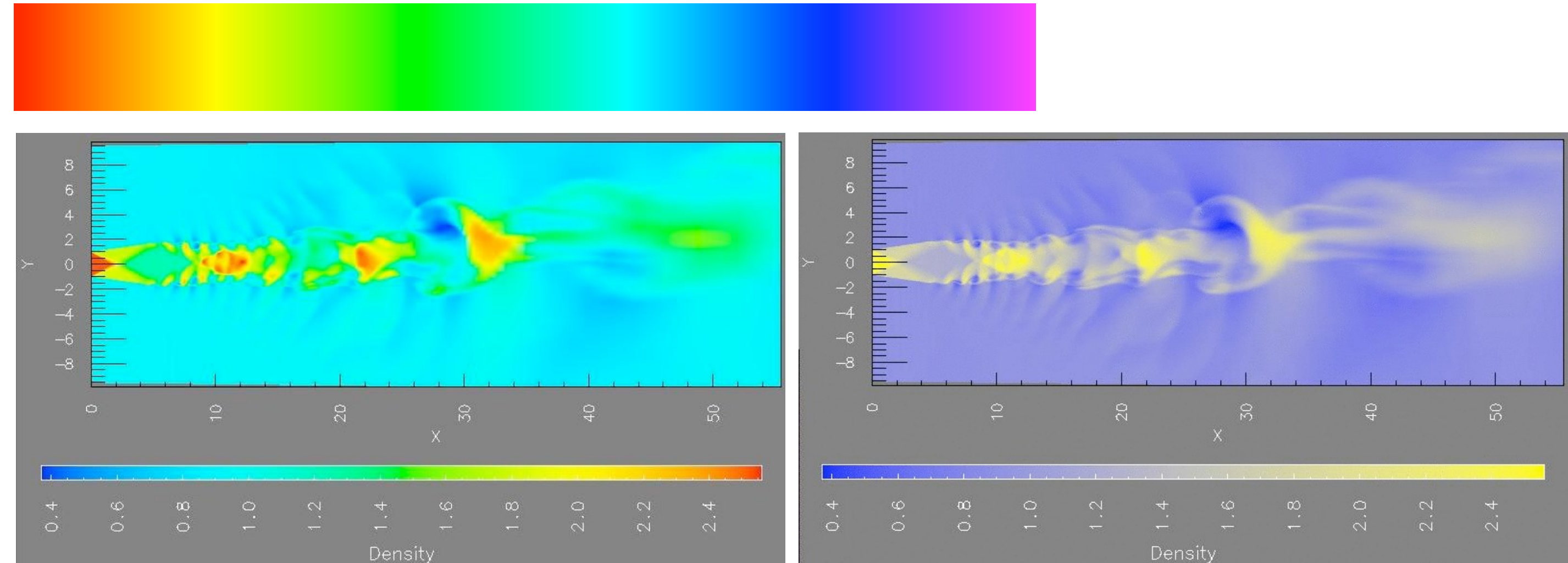


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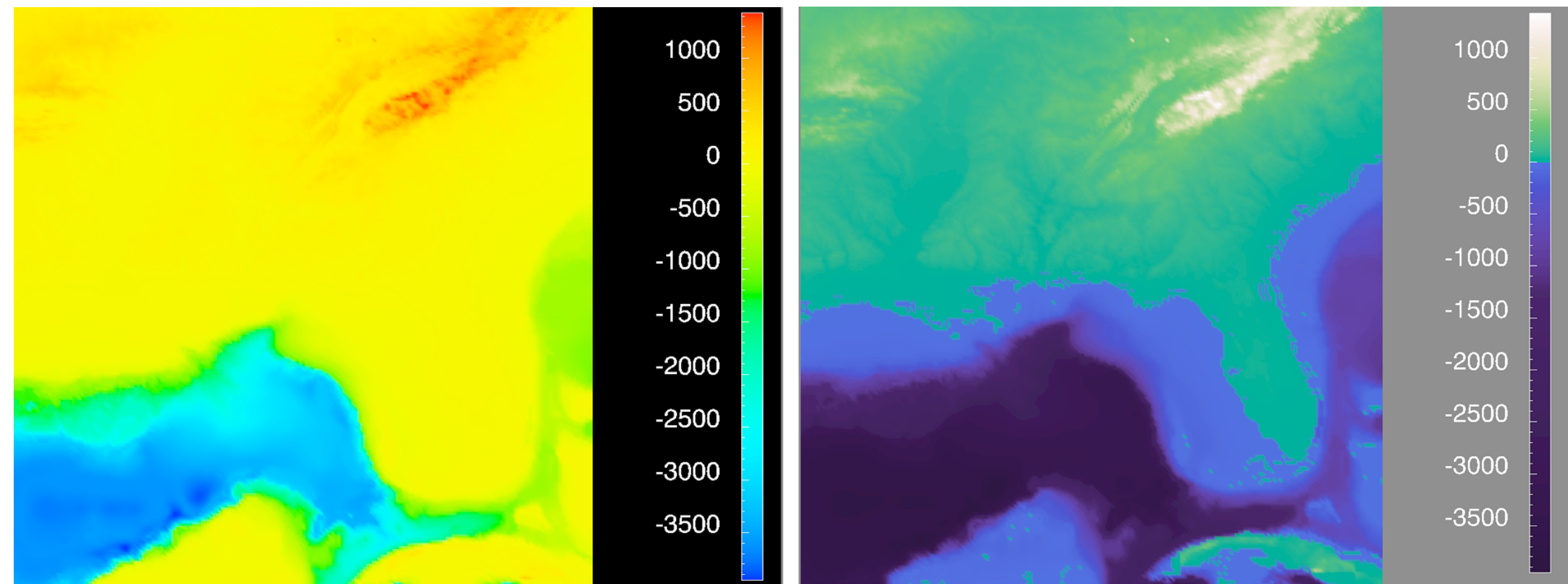


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  - perceptually unordered
  - perceptually nonlinear
- benefits
  - fine-grained structure visible and nameable
- alternatives
  - large-scale structure: fewer hues
  - fine structure: multiple hues with monotonically increasing luminance [eg viridis R/python]
  - segmented rainbows for binned
    - or categorical

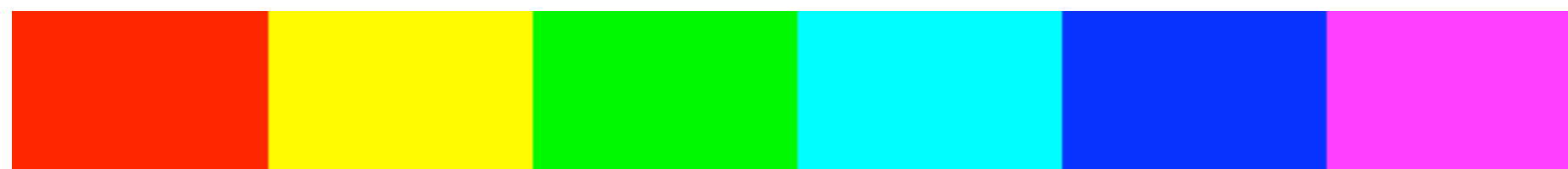


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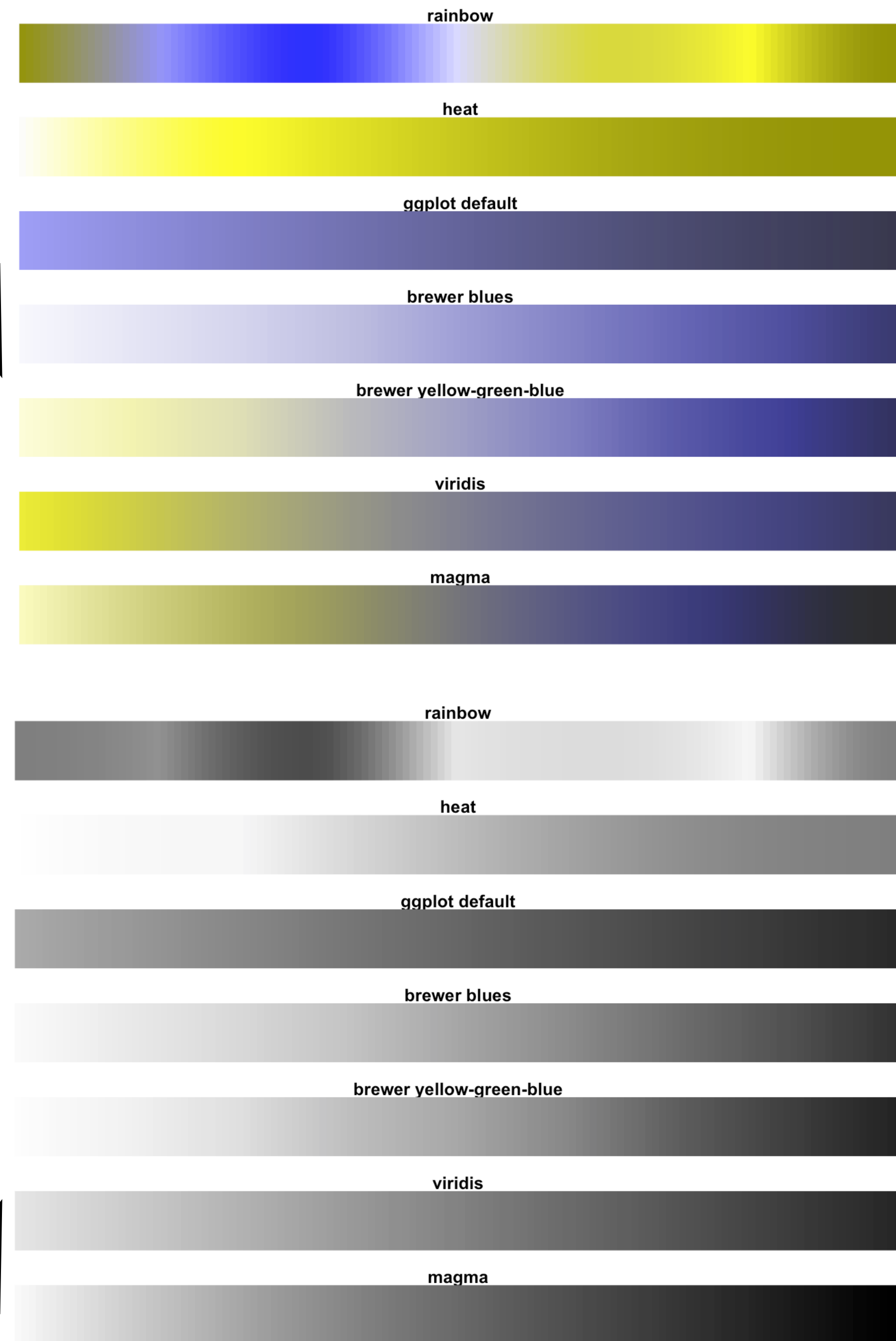
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[Transfer Functions in Direct Volume Rendering: Design, Interface, Interaction. Kindlmann. SIGGRAPH 2002 Course Notes]



# Viridis

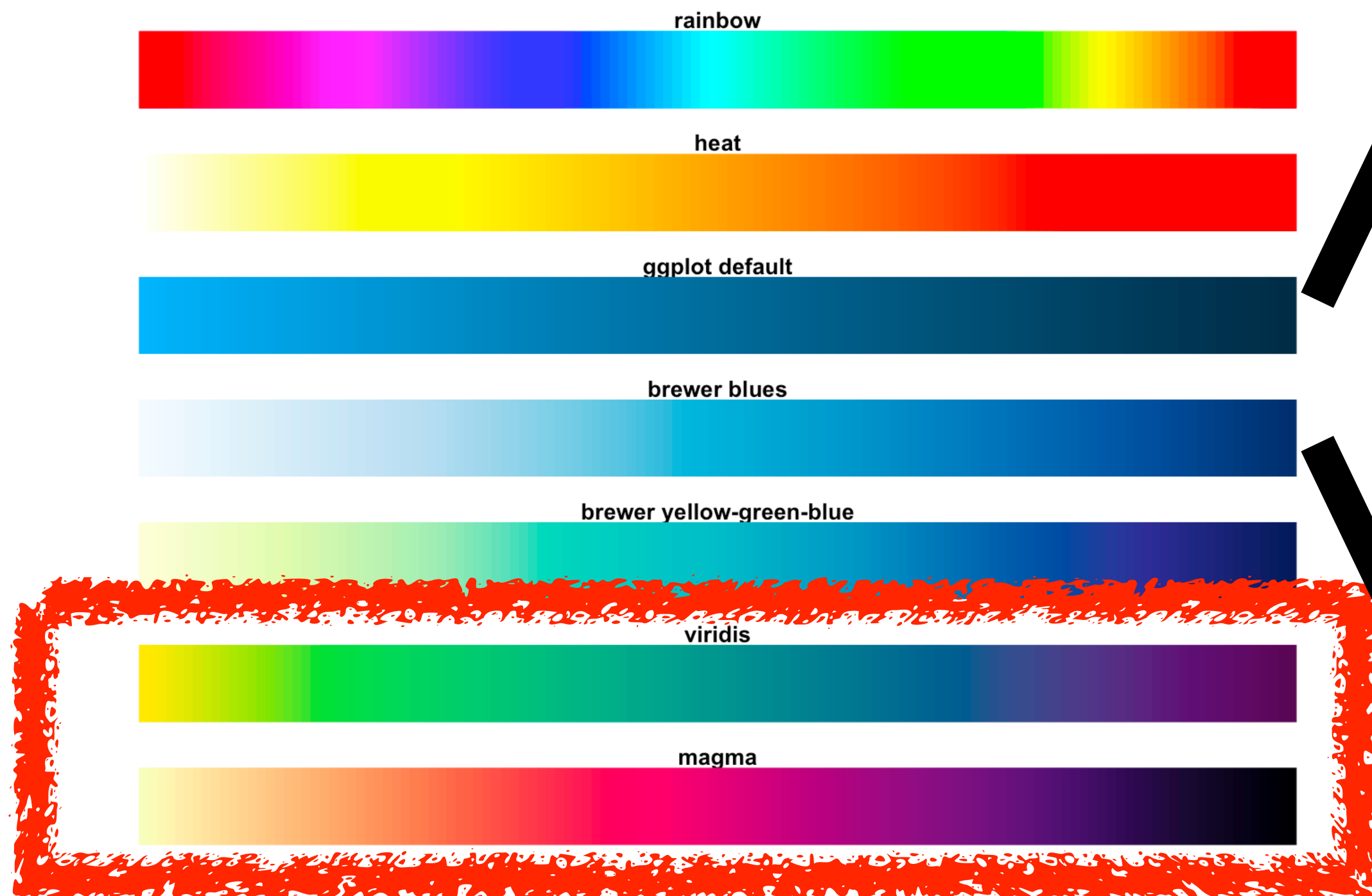
- colorful, perceptually uniform, colorblind-safe, monotonically increasing luminance



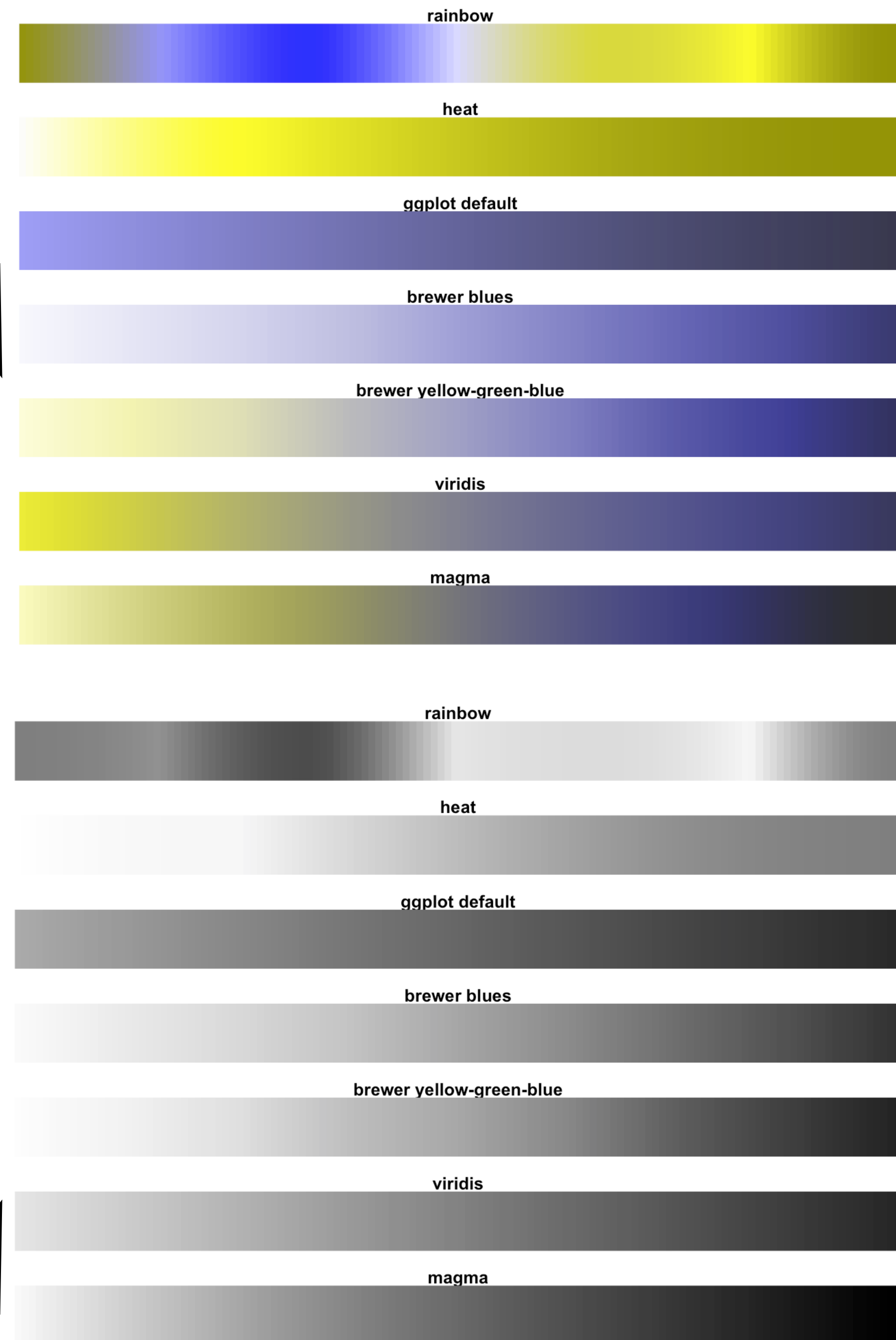
<https://cran.r-project.org/web/packages/viridis/vignettes/intro-to-viridis.html>

# Viridis

- colorful, perceptually uniform, colorblind-safe, monotonically increasing luminance



<https://cran.r-project.org/web/packages/viridis/vignettes/intro-to-viridis.html>



# Similar Color Scales

viridis



magma



plasma



inferno



cividis





# Veridis

US unemployment rate by county

