DS4200: Information Presentation and Visualization

Color, Pop-out, Illusions

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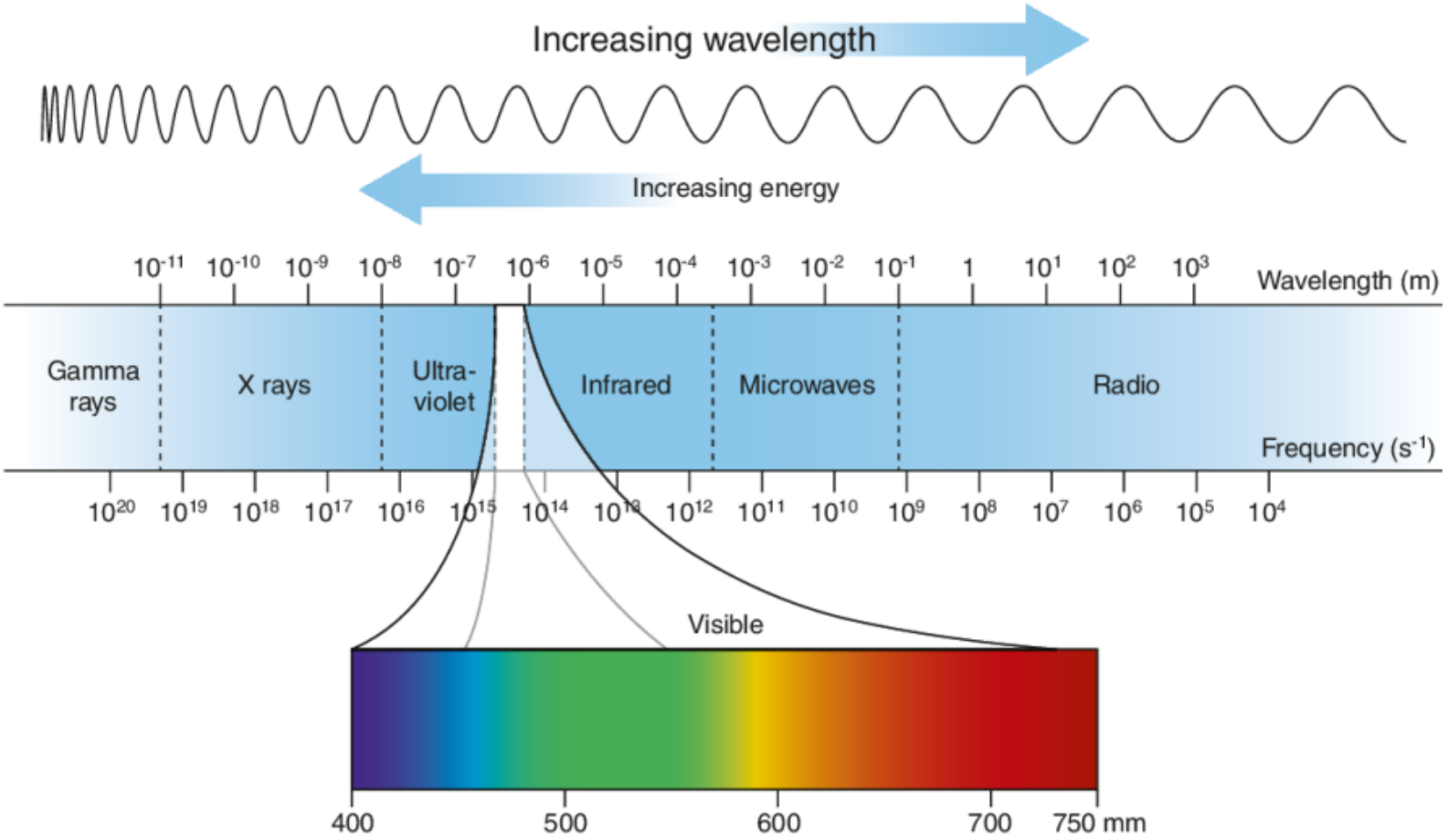
Goals for today

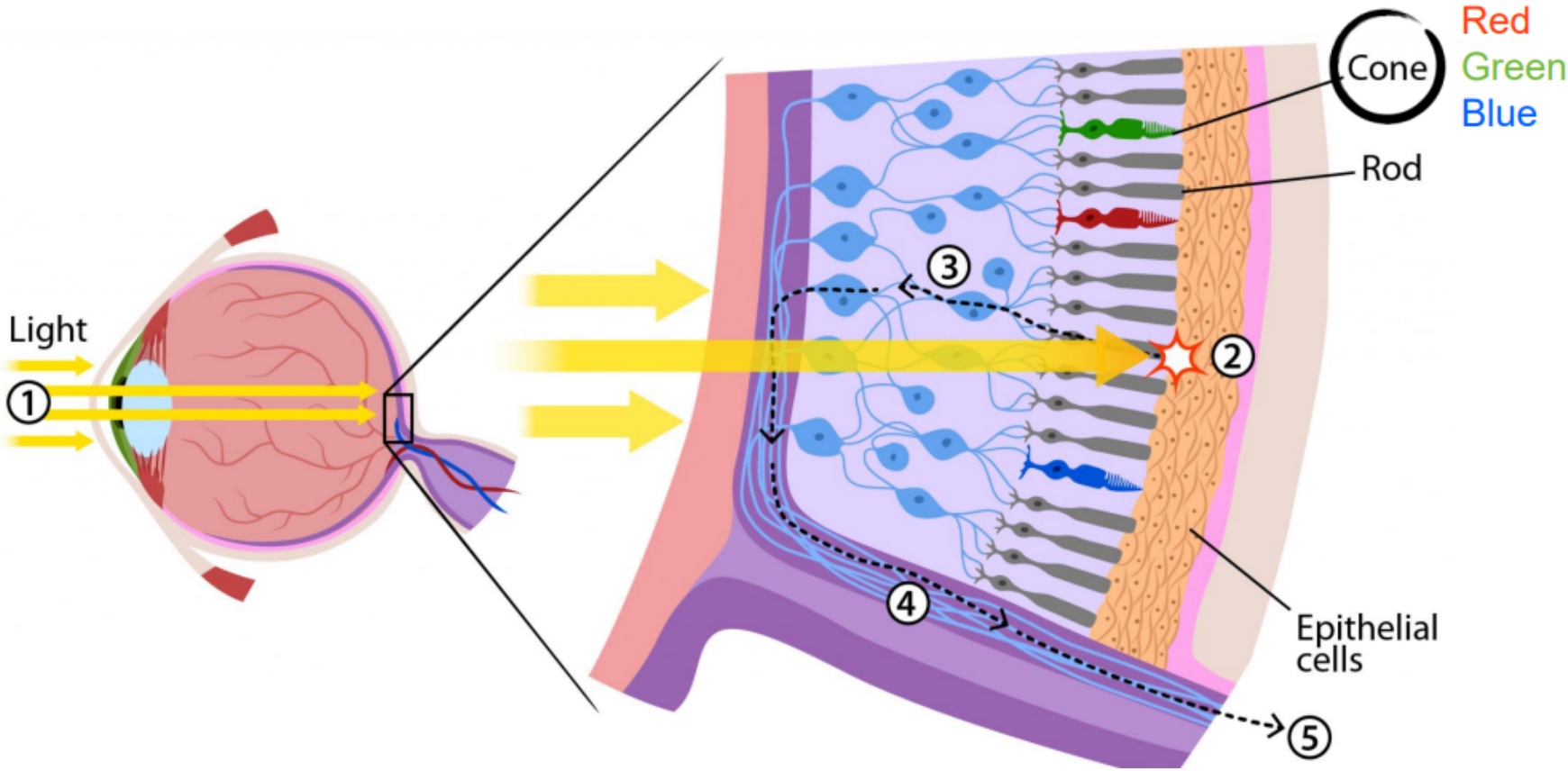
- Effectively use color as a channel for visual encodings including different colormap types
- Understand how we process color in the visual system
- Address the accommodations in the colors choices
- Understand the interaction between colors and lighting
- Understand how illusions and tricks can affect perception

What is color?

Color = Wavelength

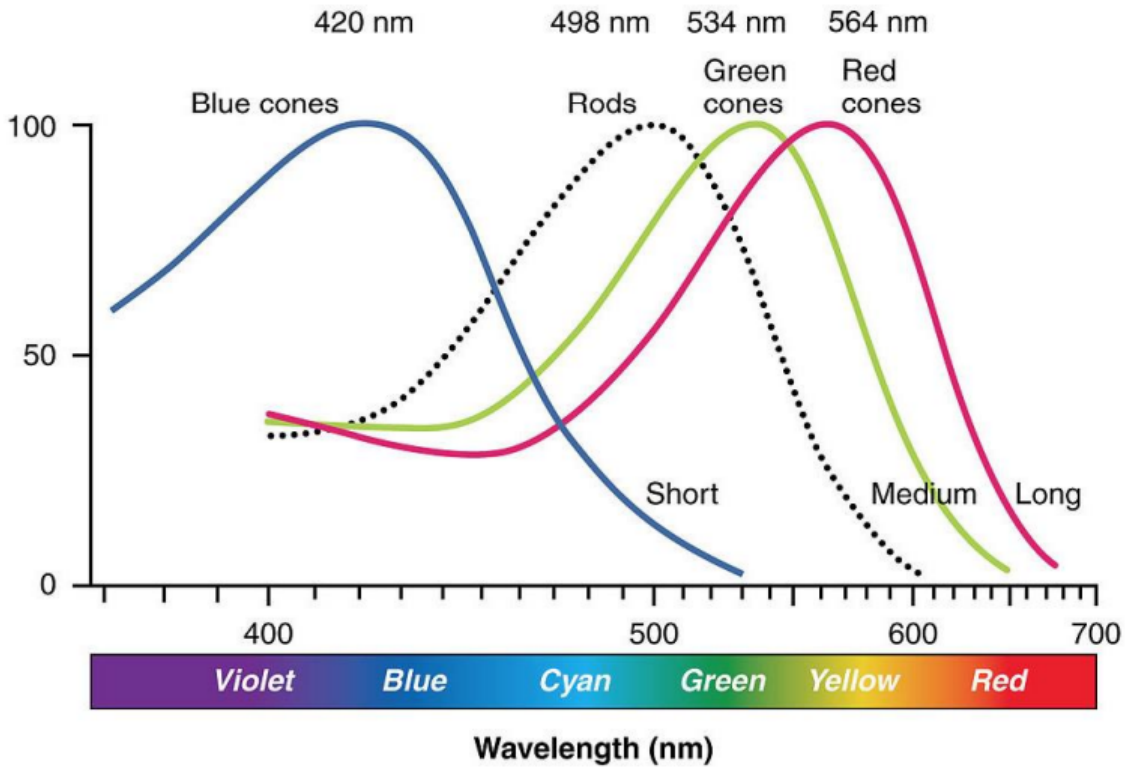


Wavelength means Signals



Trichromacy: possessing three independent channels for conveying color information

Variable activation



This is why darkness (lightness) is an effective encoding channel!

Rods:120 million

Cones: 5-6 million

This is why we are so sensitive to red!

Cones:

64% red-sensitive

32% green-sensitive

2% blue-sensitive.

Color channels

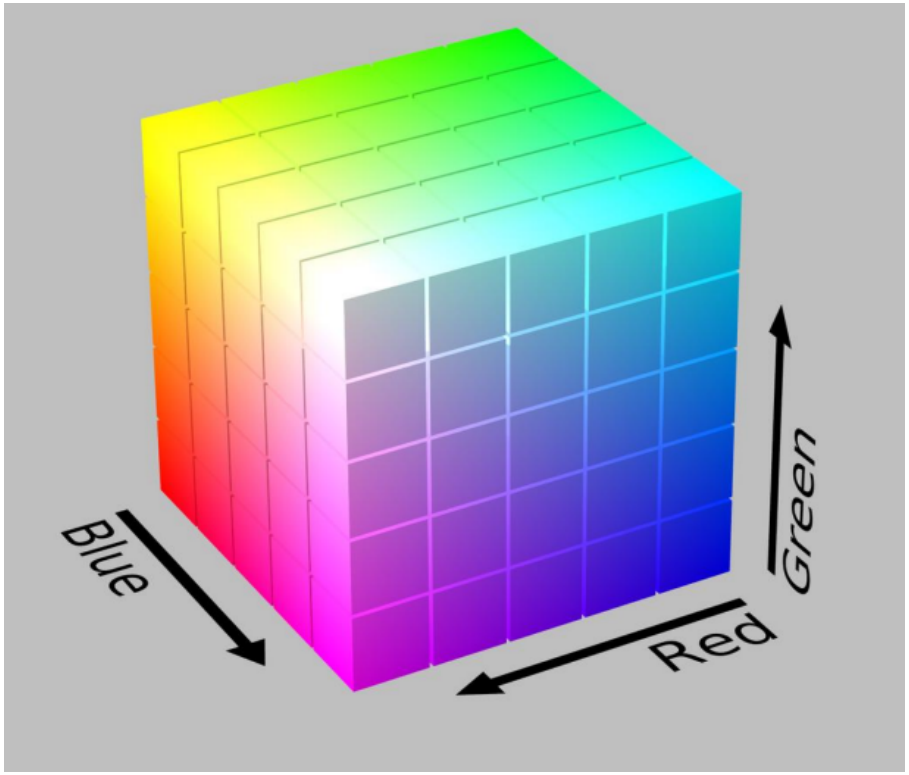
The visual system immediately processes these signals into three opponent color channels:

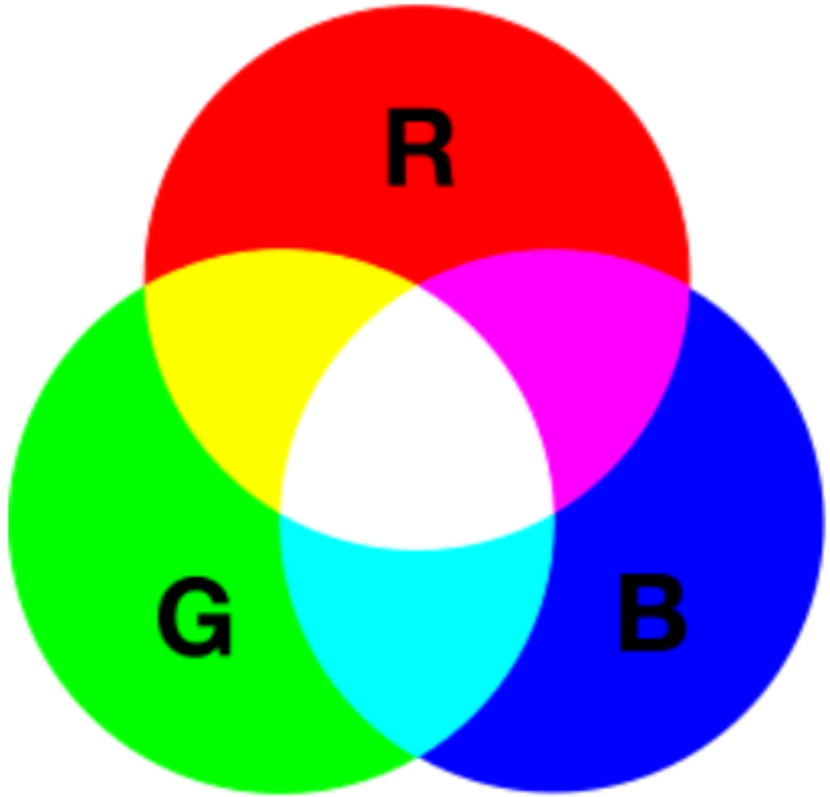
- One from red to green (lower resolution)
- One from blue to yellow (lower resolution)
- One from black and white encoding luminescence information (higher resolution)

This split between luminescence and chromaticity.

Modeling Color with RGB

The colors can be adequately described using three separate axes. the most popular one is RGB system.



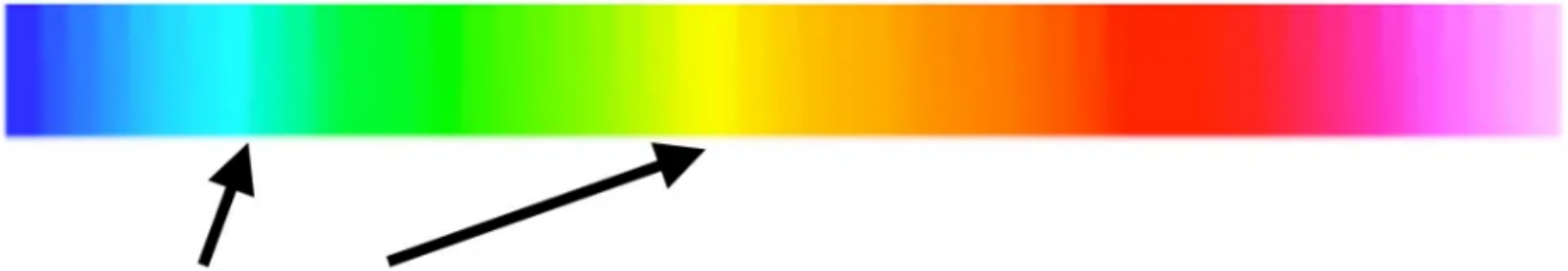


Problems with RGB system

- Limited Gamut: It cannot accurately represent colors that fall outside the gamut (range of colors), such as certain highly saturated colors found in nature.
- Device-Dependent: RGB values are device-dependent, meaning they can appear differently on various displays and under different lighting conditions.
- Non-Uniform Perception: The human eye is more sensitive to changes in certain parts of the color spectrum than others, which is not fully reflected in the RGB model.

Problems with RGB system

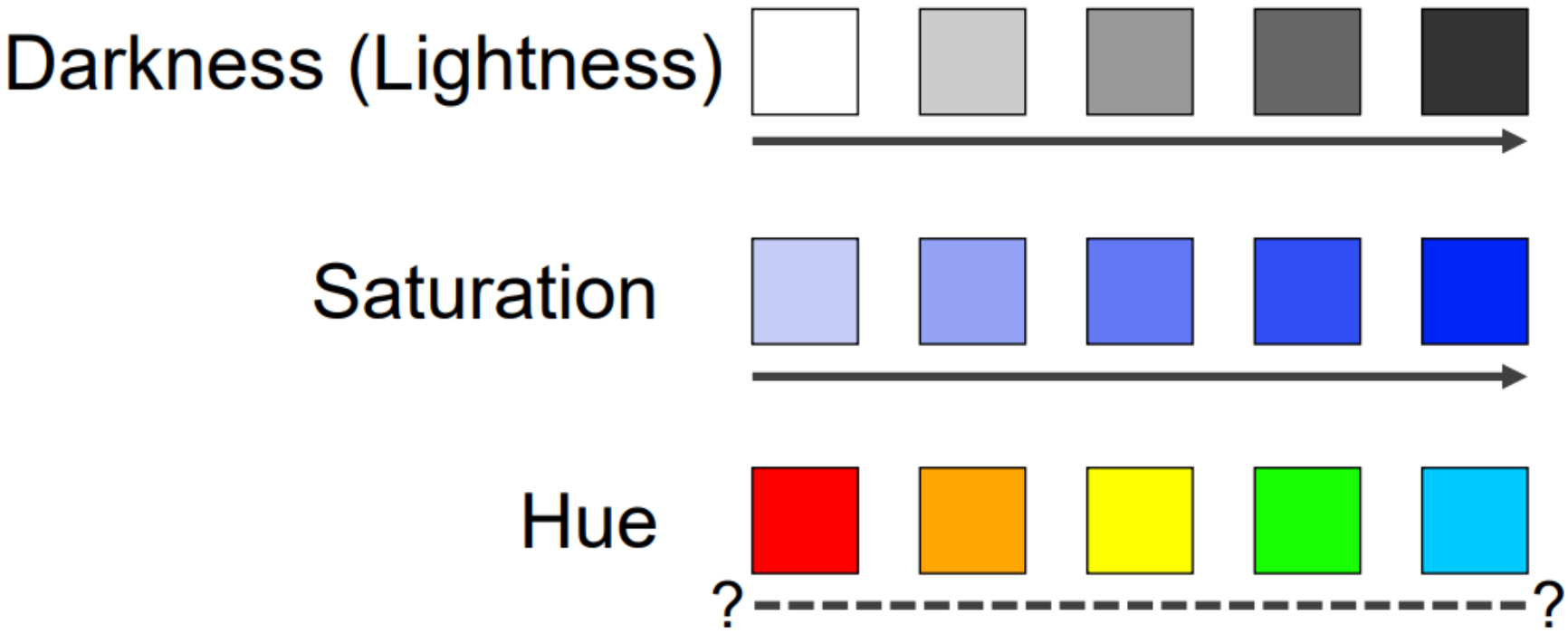
Non Perceptual Uniform Colormap



Features of the Colormap not of Changes in Data

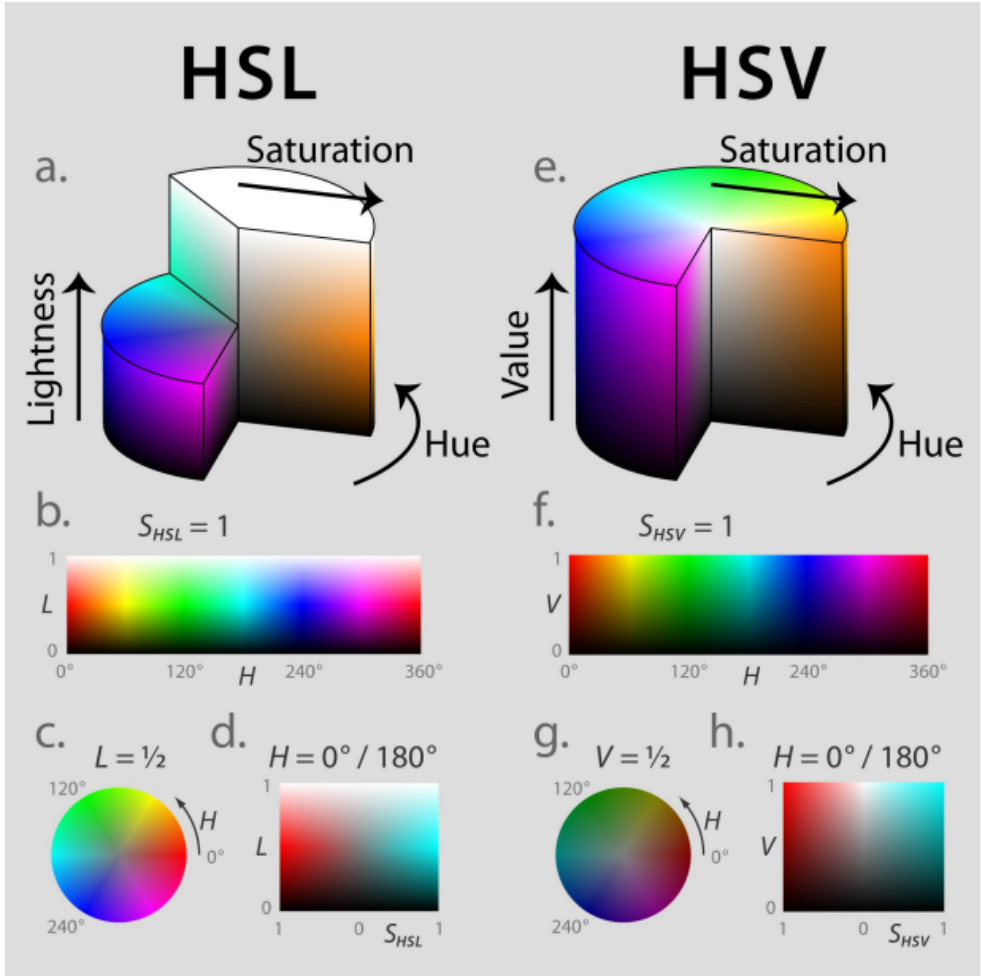
Perceptual Uniform Colormap

Hue–Saturation–Lightness system (HSL)



Modeling Color with HSL or HSV

Another system is the HSV space, where V stands for grayscale value and is linearly related to L.



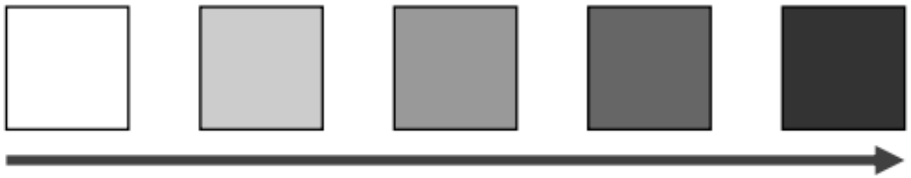
The fourth channel: Transparency

- Encoded by decreasing the opacity of a mark from fully opaque to completely see-through
- Cannot be used independently of the other color channels because of its strong interaction effects
- Interacts strongly with luminance and saturation coding and should not be used in conjunction with them at all
- It is frequently used redundantly

The most important color channel

Among HSL, which is the most important one?

Darkness (Lightness) Channel



- No edges without darkness difference
- No shading without darkness variation
- Has higher spatial sensitivity than color channels
- Contrast defines legibility, attention, layering
- Controlling darkness is primary rule of design

Darkness (Lightness) Channel

Darkness (Lightness) Channel

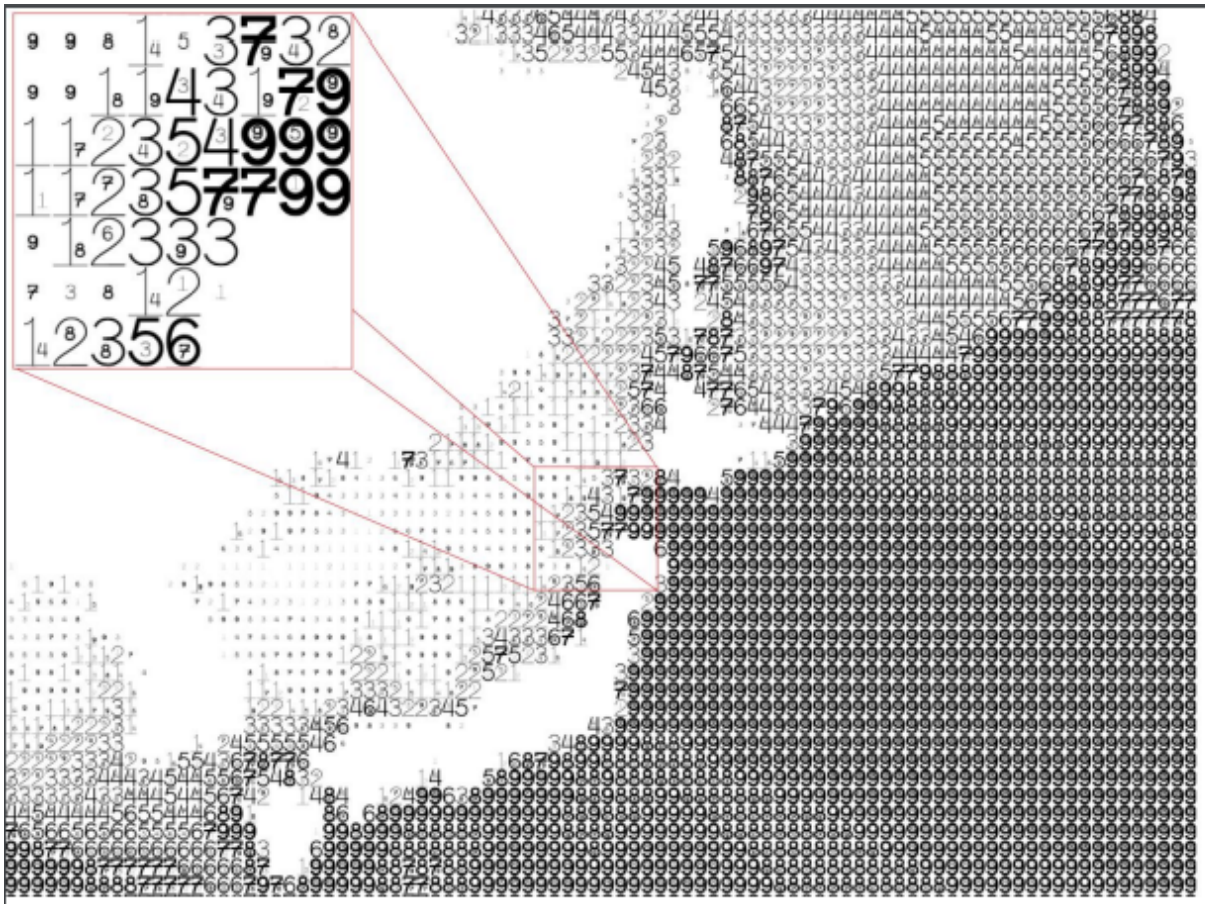
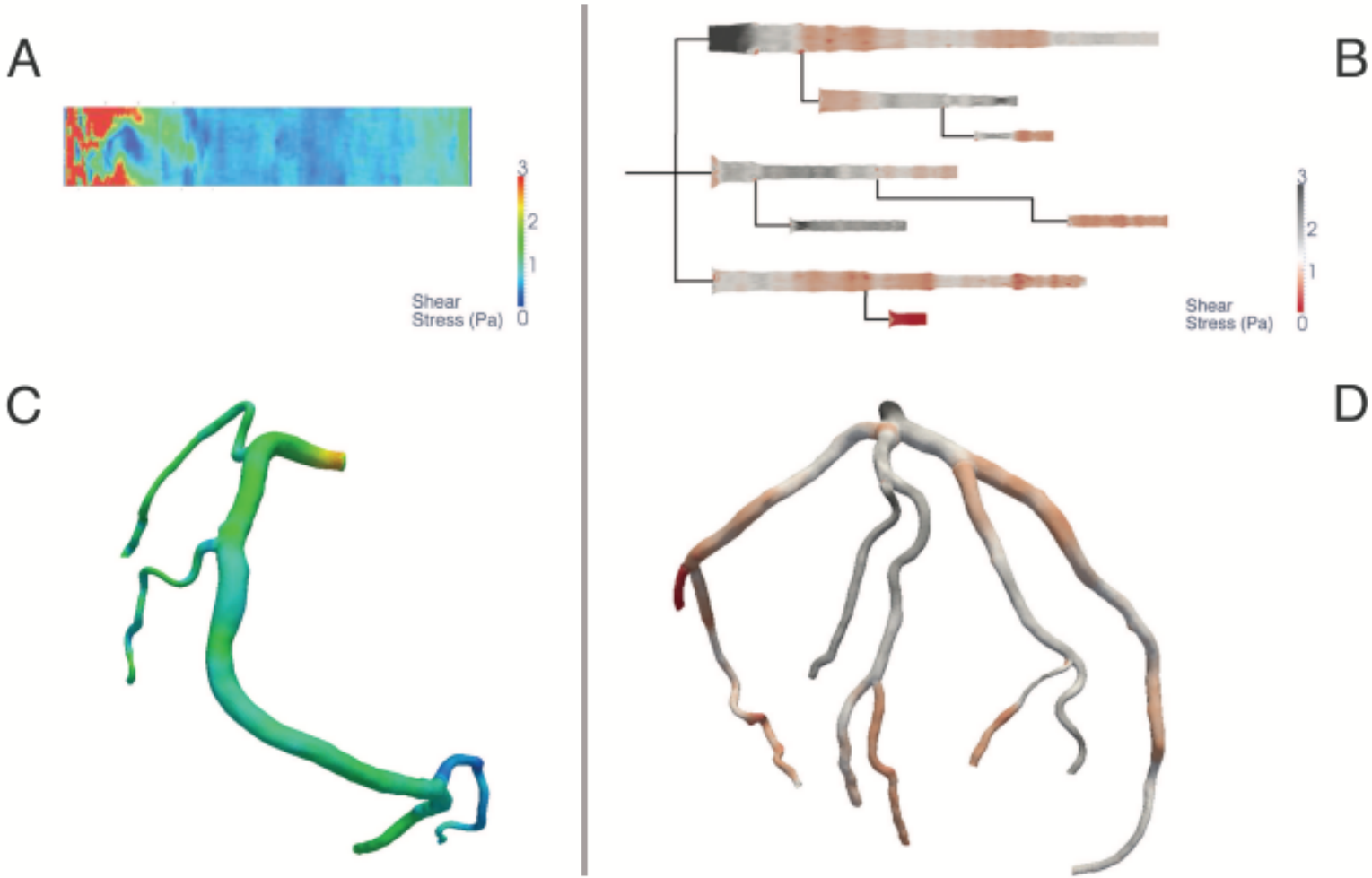


Figure 8: Maximum wave amplitudes for the Japan 2011 tsunami. Amplitudes were clipped at 99cm. Data adapted from NOAA; http://www.noaa.gov/.

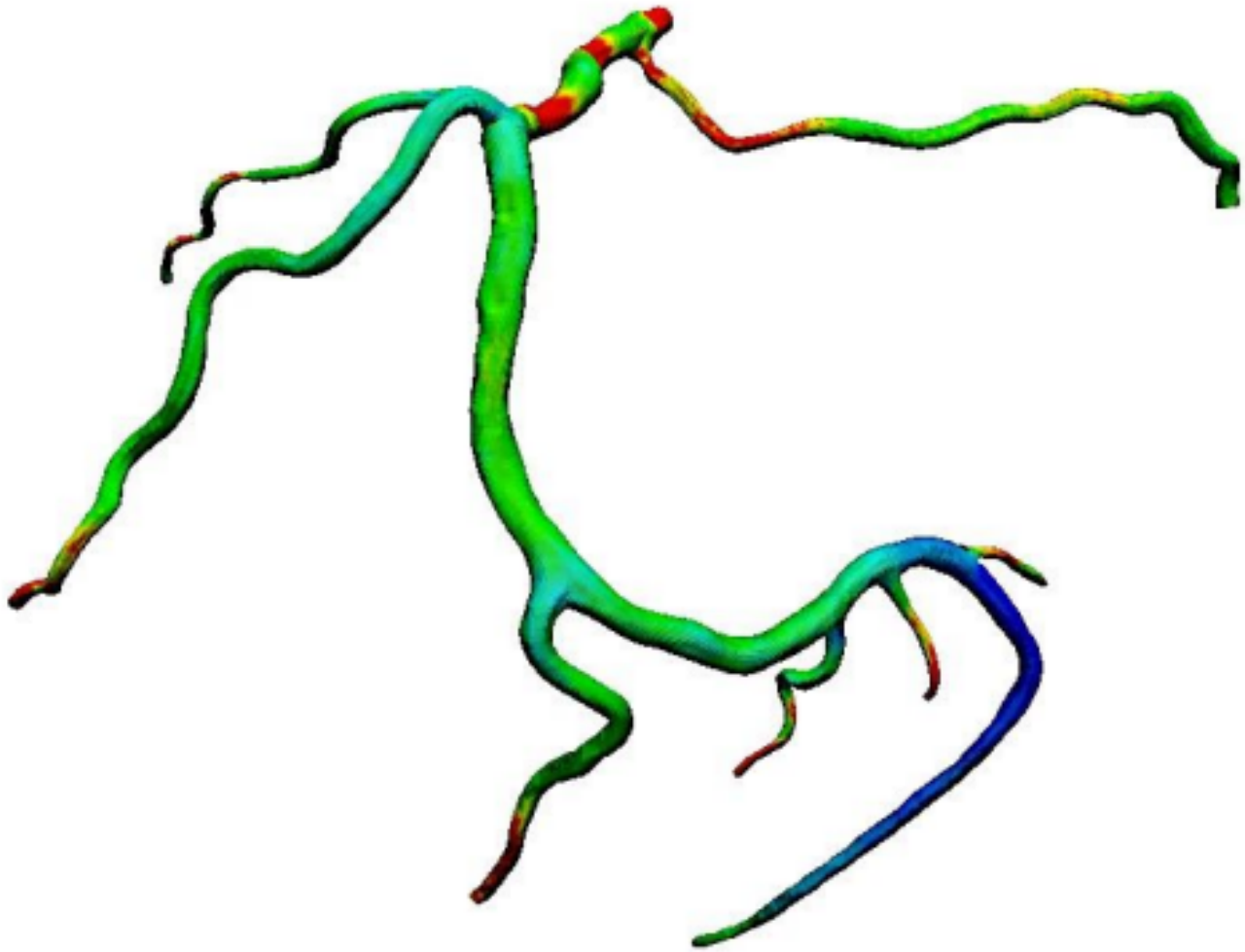
Nacenta et al., 2012 29

Example: Heart Disease Diagnosis



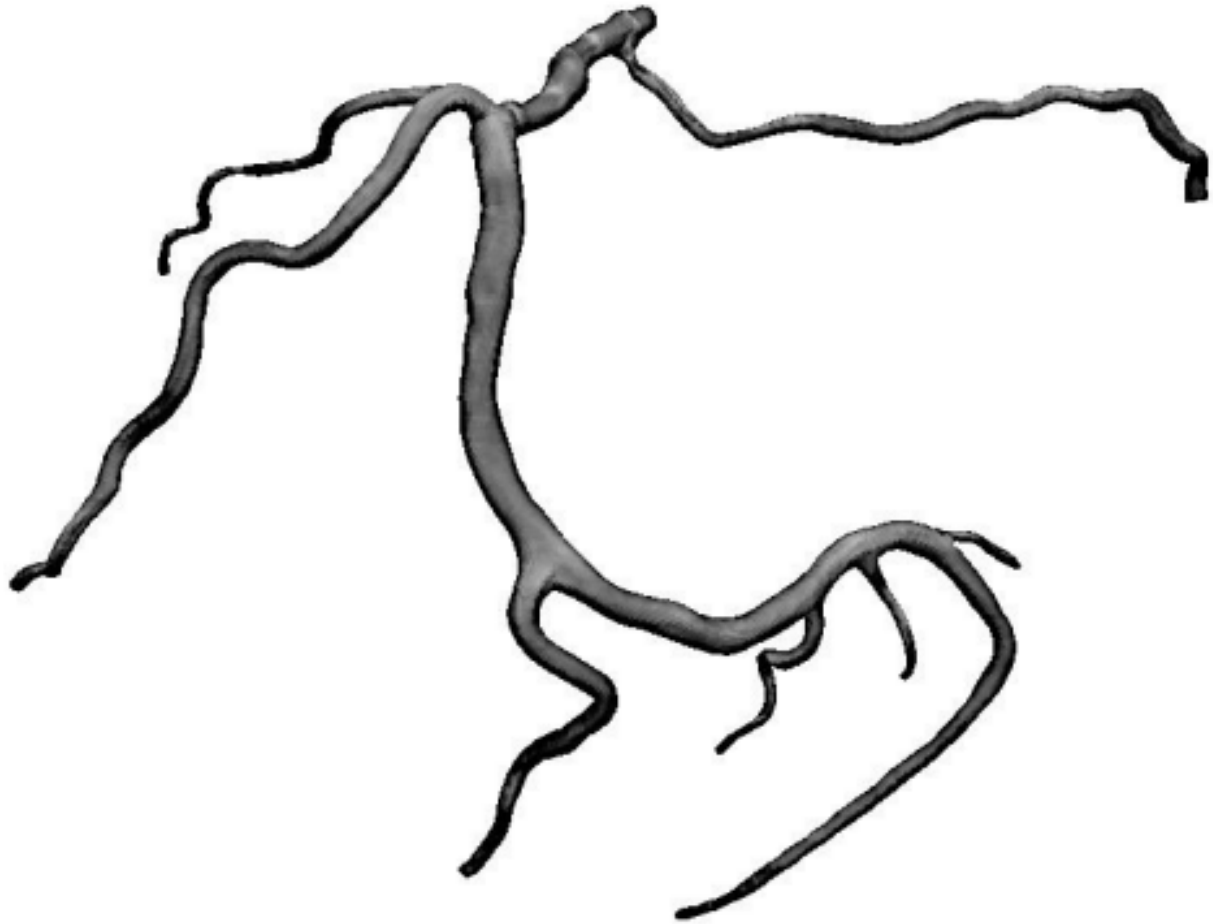
https://iis.seas.harvard.edu/papers/2011/borkin11-infoviz.pdf

“Get it right in black and white”



39% Diseased Regions Found

“Get it right in black and white”



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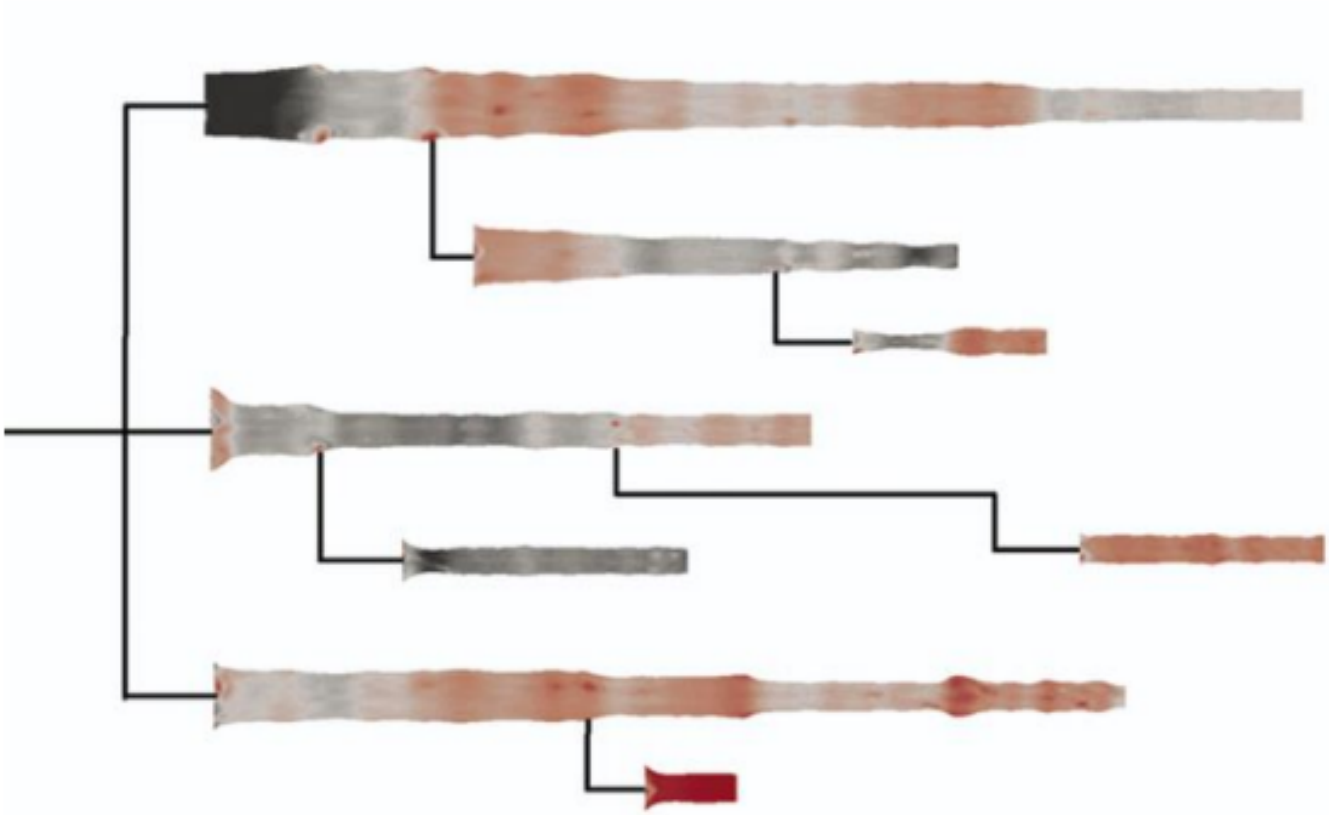
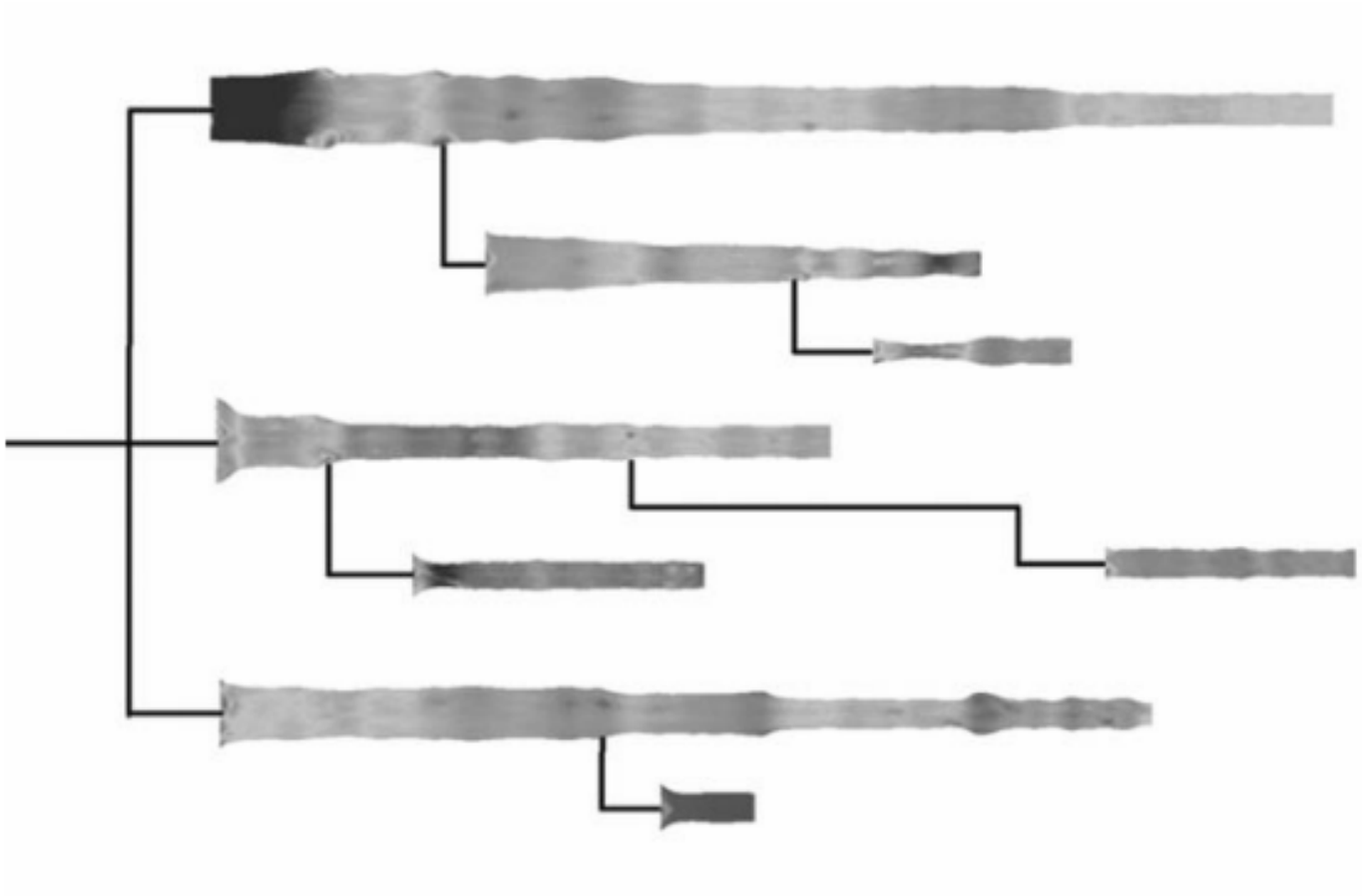


91% Diseased Regions Found

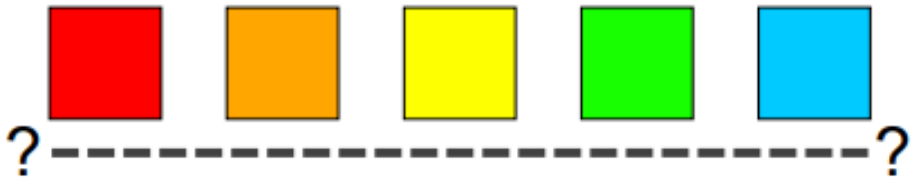
“Get it right in black and white”



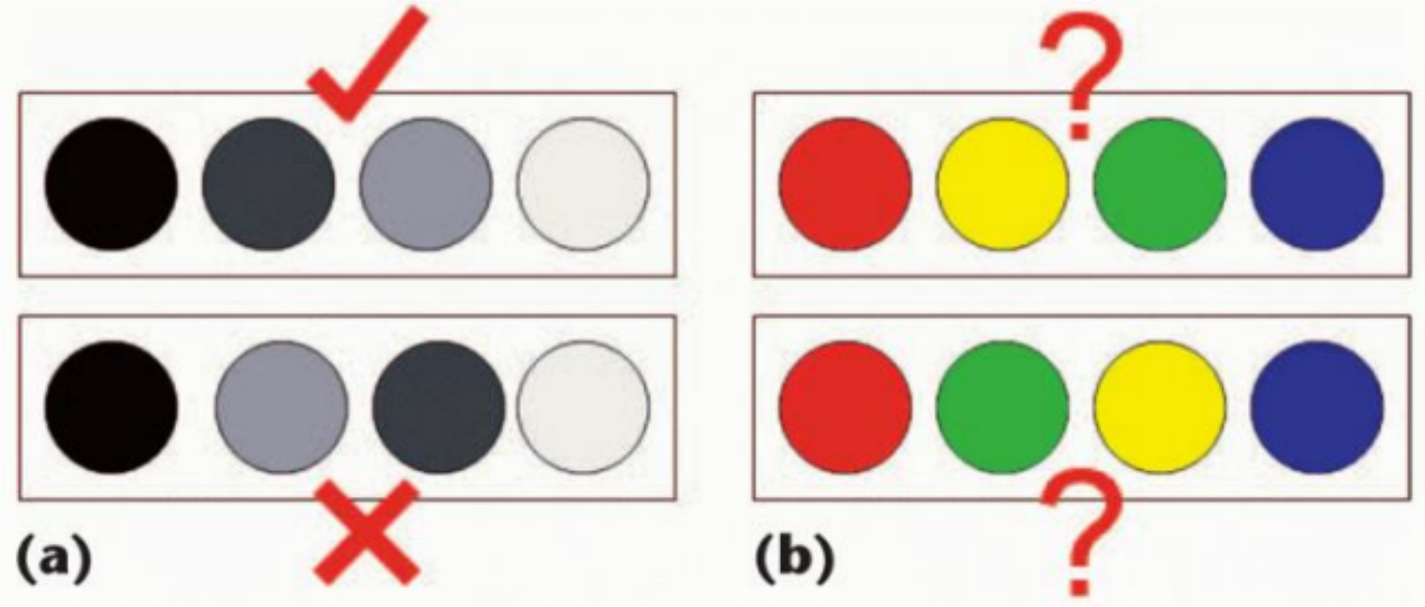
91% Diseased Regions Found

Hue Channel

On the other hand, hue channel can be misleading.



No perceptual ordering (confusing)



Color Maps

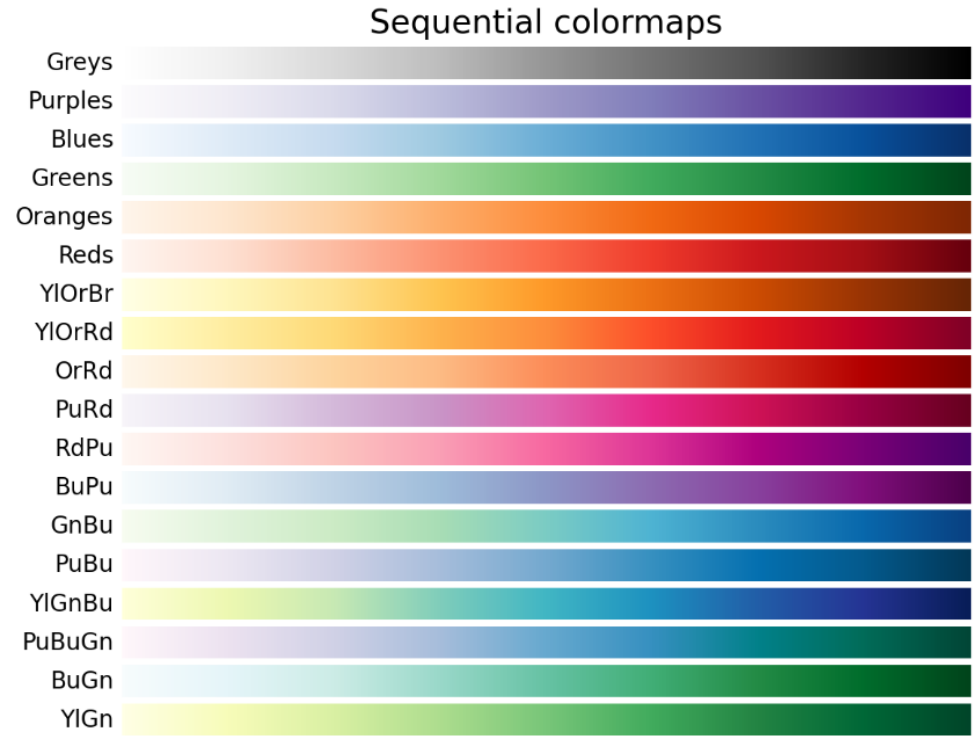
Color Maps: map between value (domain) and color (range)

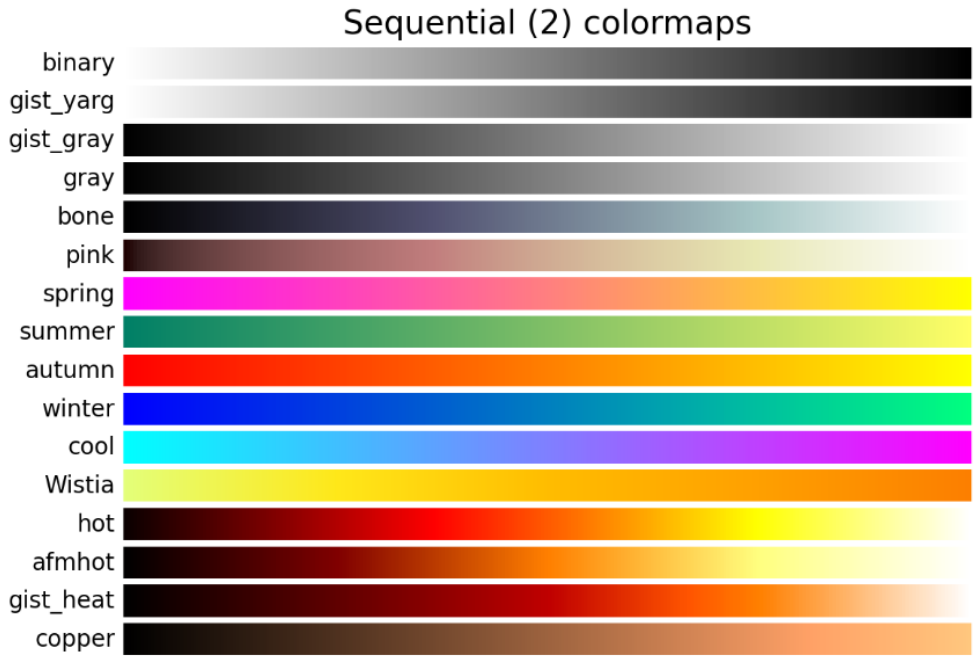
Three main types:

- Sequential
- Categorical
- Diverging

Color Maps: Sequential

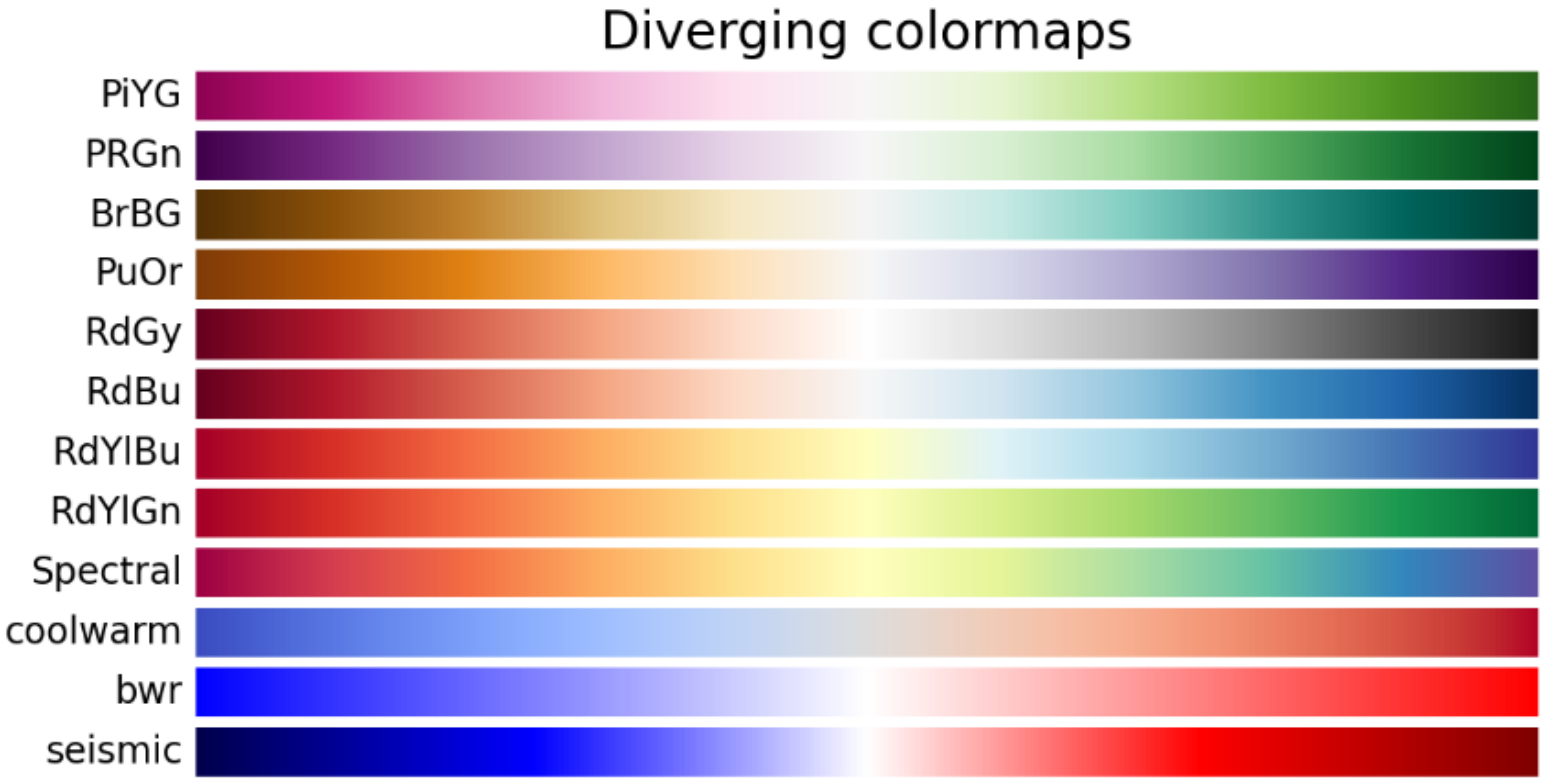
Best for ordered data that progresses from low to high (ordinal, quantitative data). Darkness (lightness) channel effectively employed





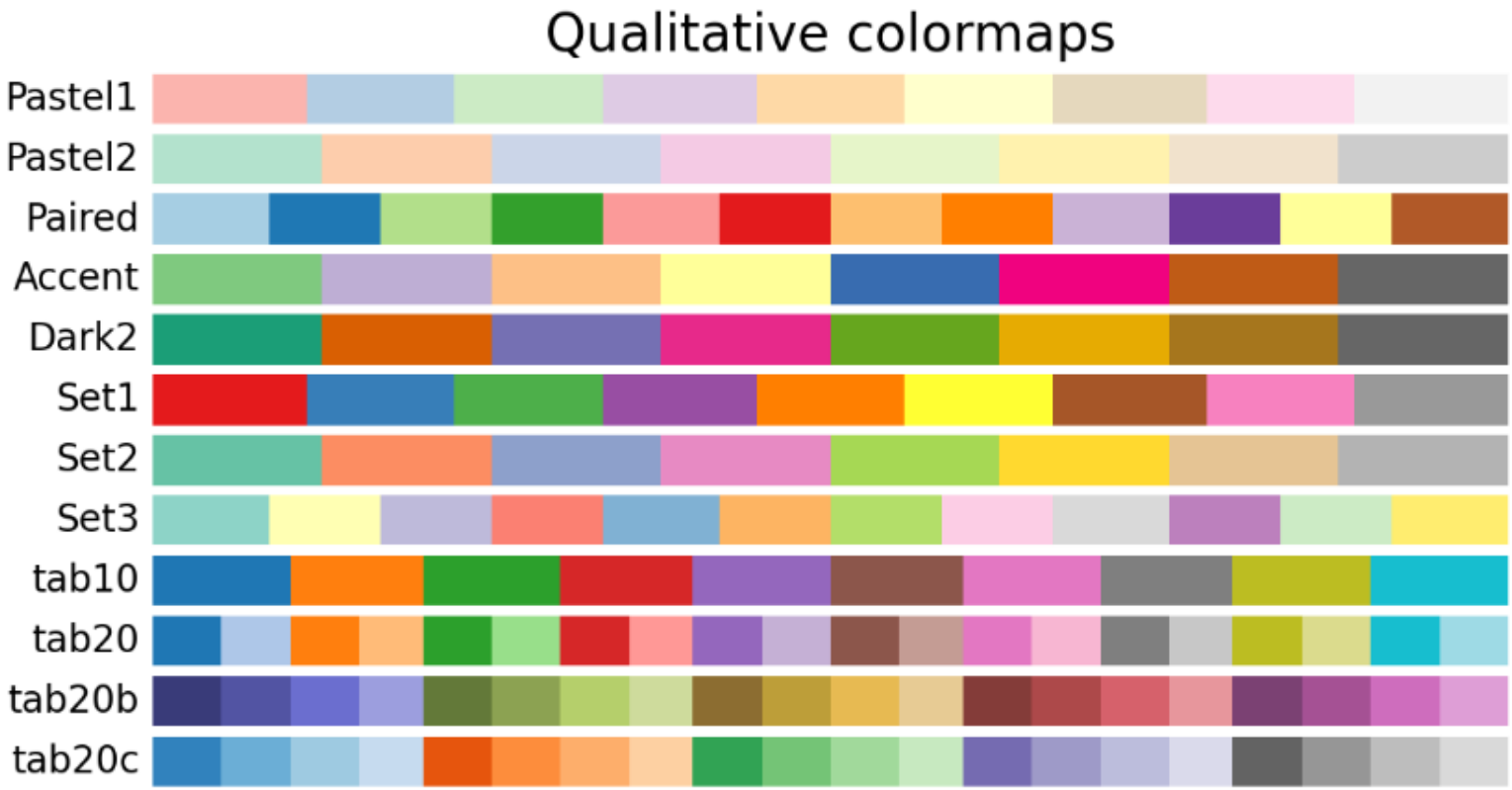
Color Maps: Diverging

For data with a "diverging" (mid) point (quantitative data). Equal emphasis on mid-range critical values and extremes at both ends of the data range.



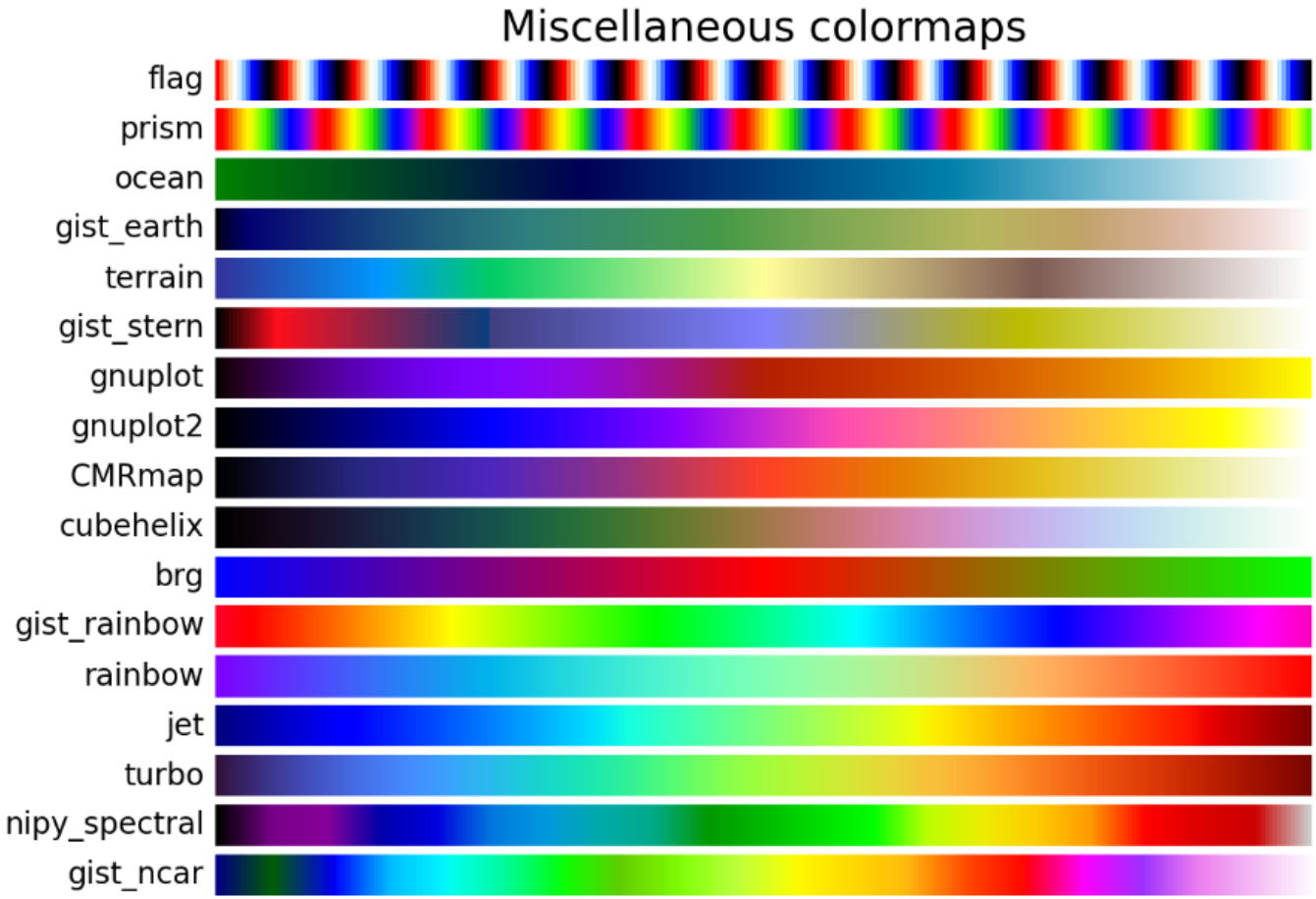
Color Maps: Categorical

Does not imply magnitude differences (categorical/nominal data). Distinct hues with similar emphasis



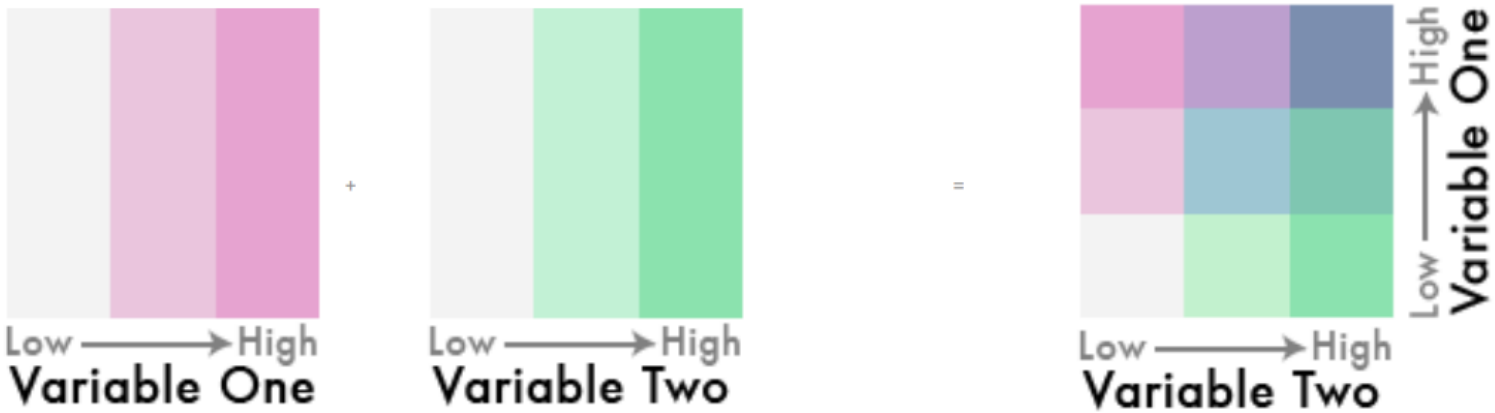
Color Maps: Miscellaneous

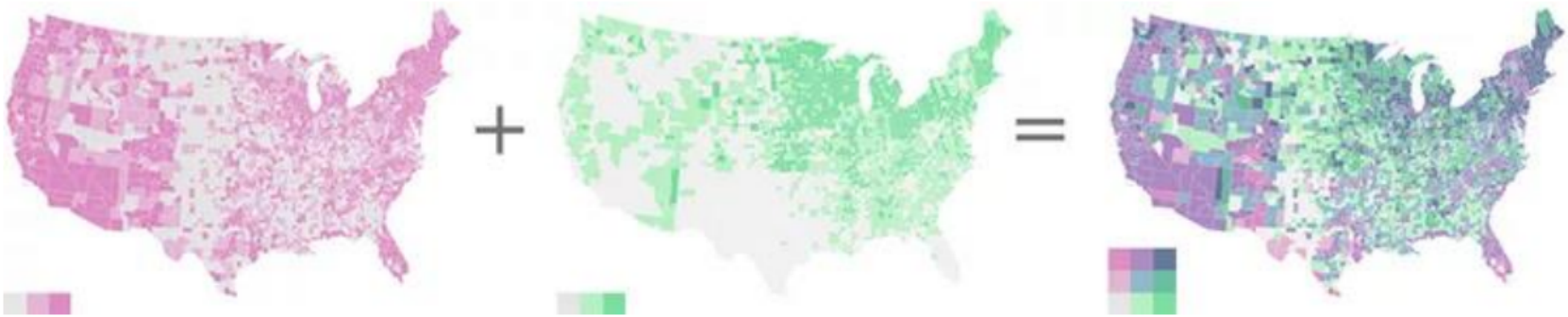
These are designed for special use. Not recommend for most of the cases.



Color Maps: Bivariate

Displays two variables Combination of two sequential color schemes. These are very difficult to design effectively, make intelligible, and be color blind friendly.





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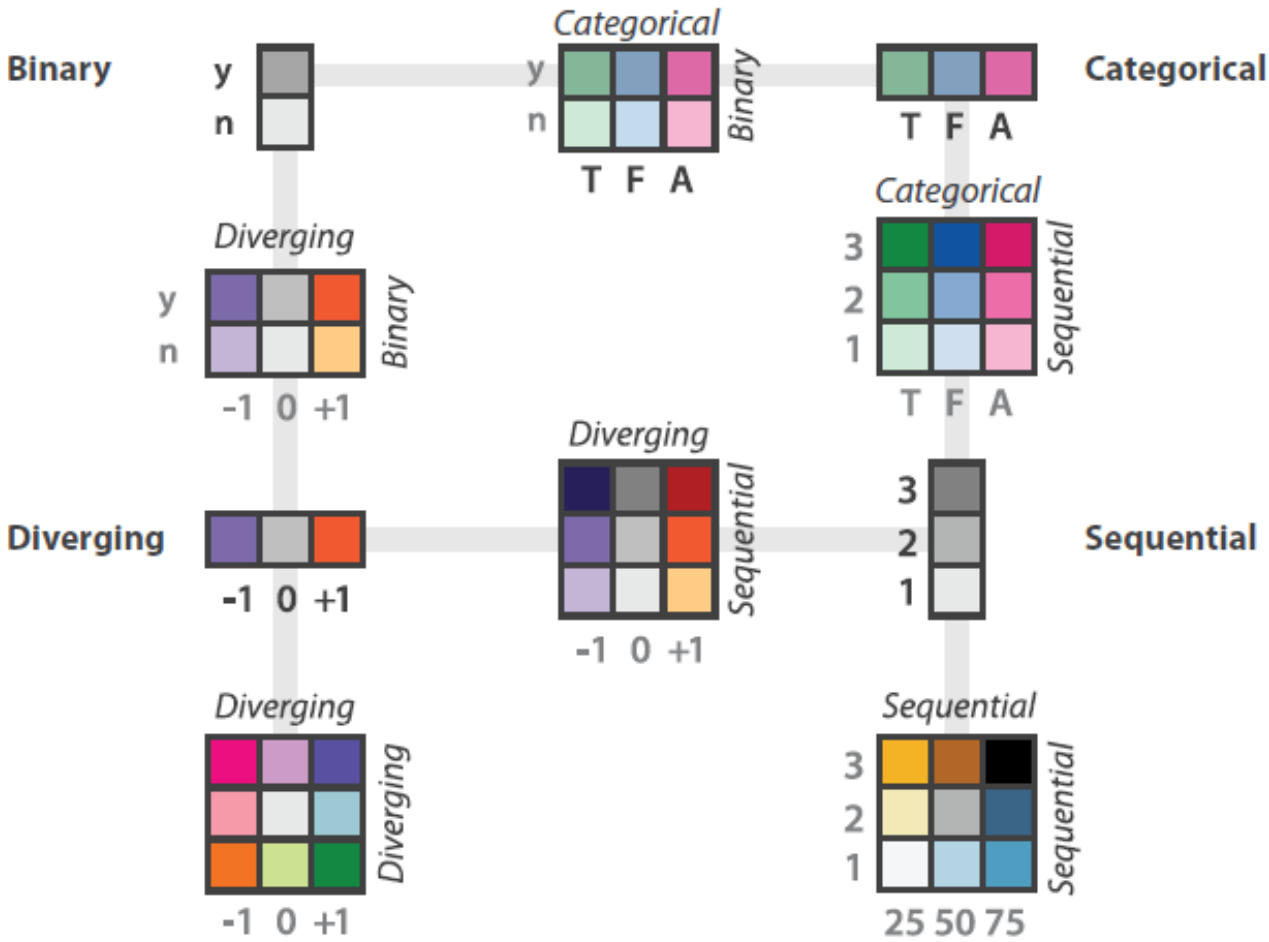
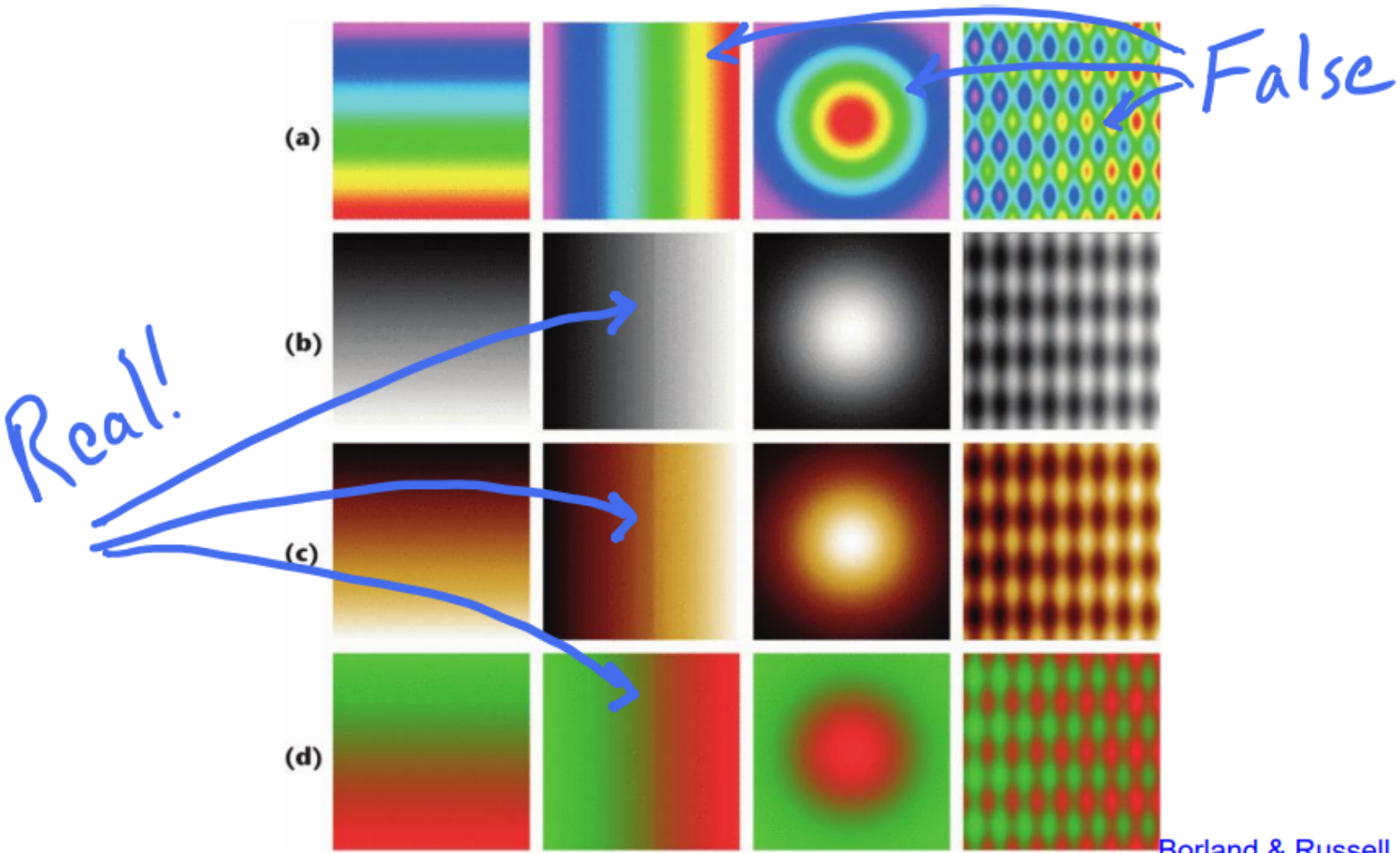


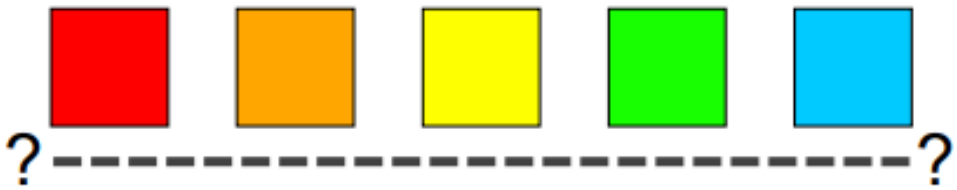
Rainbow Color Map (Hue)

Why this color map is a poor choice for quantitative data...



Borland & Russell, 2007 33

Rainbow Color Map (Hue)



Why this color map is a poor choice for quantitative data...

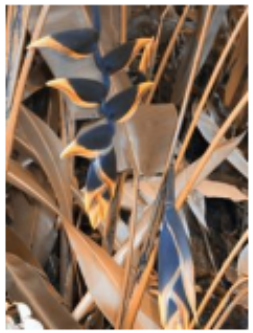
- No perceptual ordering (confusing)
- No darkness variation (obscures details)
- Viewers perceive sharp transitions in color as sharp transitions in the data, even when this is not the case (misleading)

In-class activities: Oilslick

- Working in groups, go to https://mrgris.com/projects/oilslick/
- Experiment with the different layers, different zoom levels, and different locations
- Think of answers to these questions: What areas are particularly interesting? Which layer / color scale works best, and for which tasks?

Color Deficiencies (Color Blindness)

Protanope = faulty red cones



Deuteranope = faulty green cones

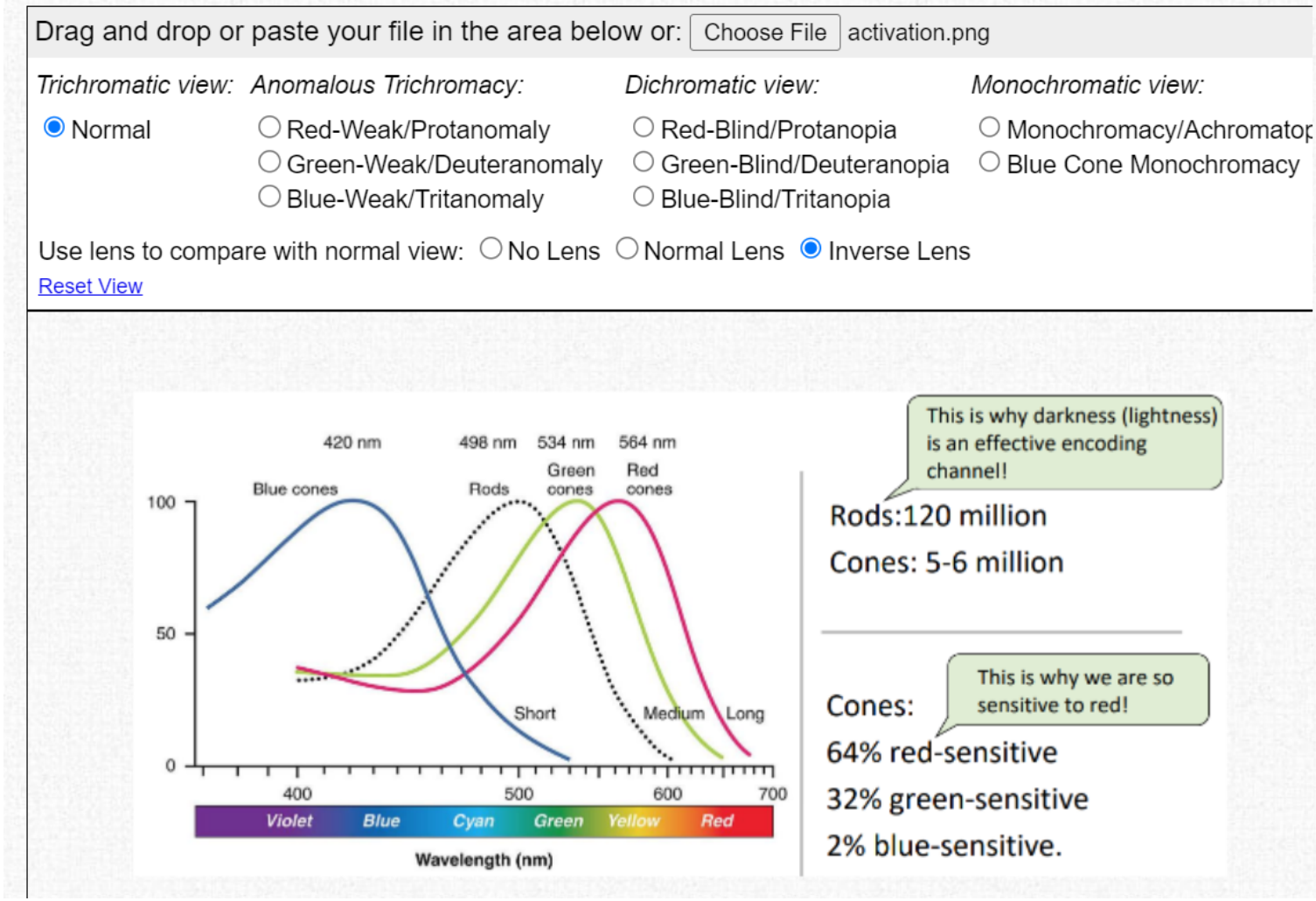
normal

Tritanope = faulty blue cones

Based on Slides by Hanspeter Pfister, Maureen Stone

https://www.youtube.com/watch?v=FKSOe5NK_qQ

Check your images/colormaps for issues!



https://www.color-blindness.com/coblis-color-blindness-simulator/

Color Illusion

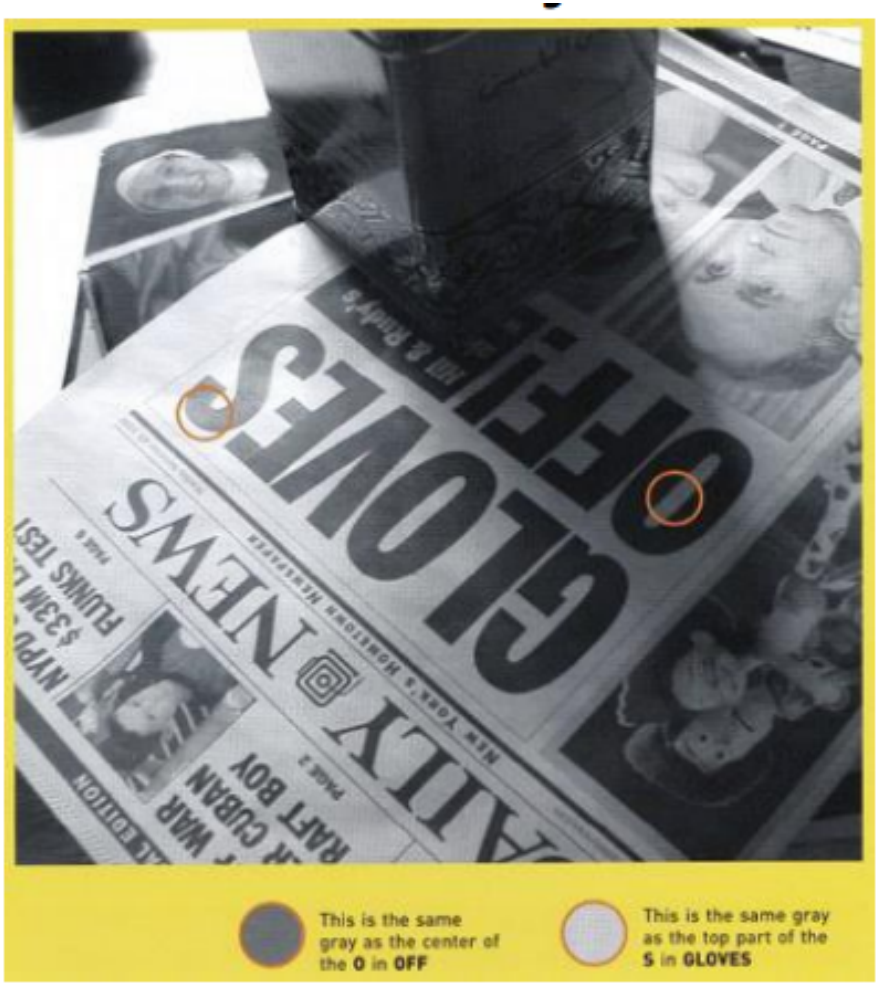
Color illusions occur because of the way our eyes and brain perceive color, which is influenced by the surrounding environment, lighting conditions, and contextual factors. Our perception of color is not absolute; instead, it is shaped by contextual interpretation and visual processing mechanisms.

- Brightness Illusion
  - Checker Shadow Illusion
  - Munker-White Illusion
  - Dress Illusion
- Gradient Bar Illusion
- Simultaneous Contrast
- Color context effect
  - flanking contours
- How color affects the other perspective

Interaction between colors and lighting

The perception that the apparent brightness of light and dark surfaces remains more or less the same under different luminance conditions is called darkness (lightness) constancy.

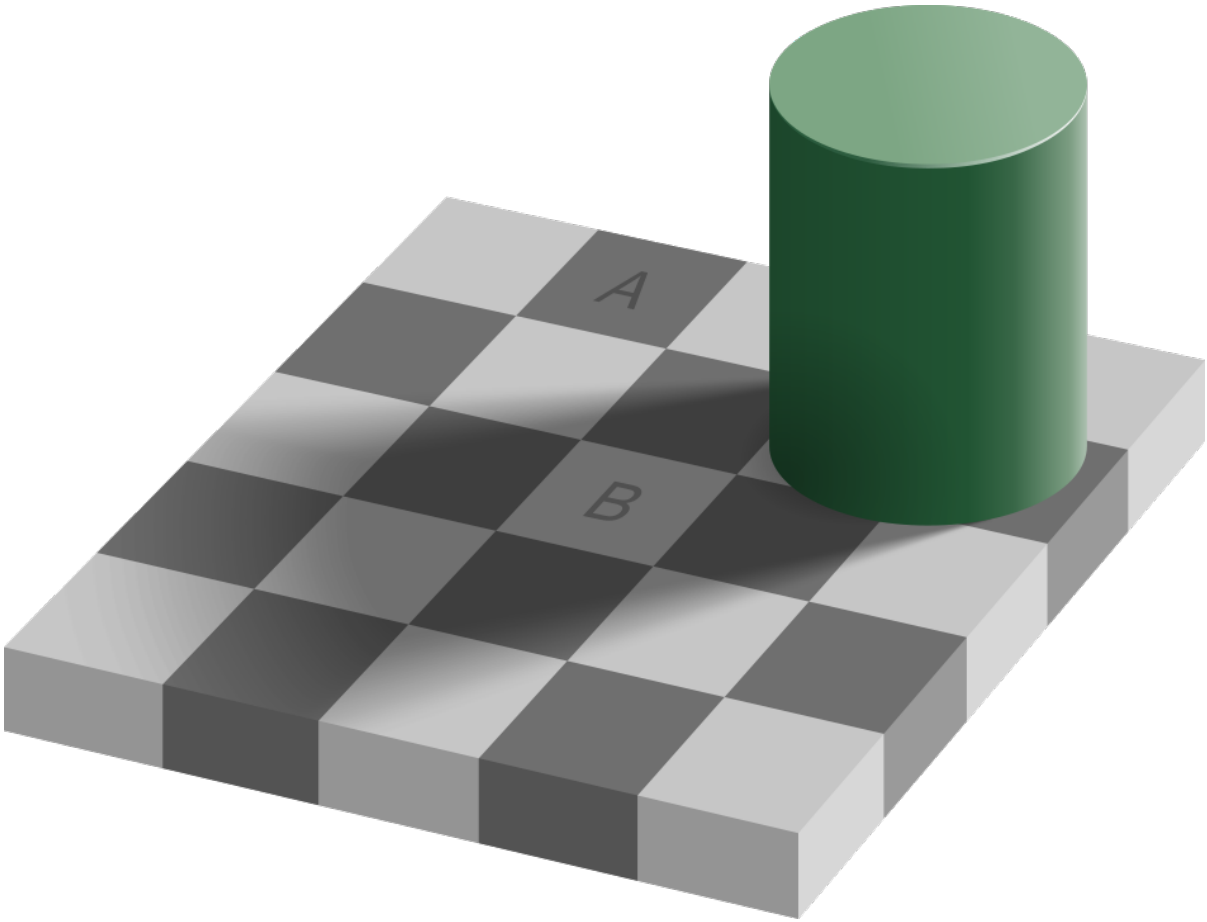
A red apple will still look red on a sunny day or cloudy day



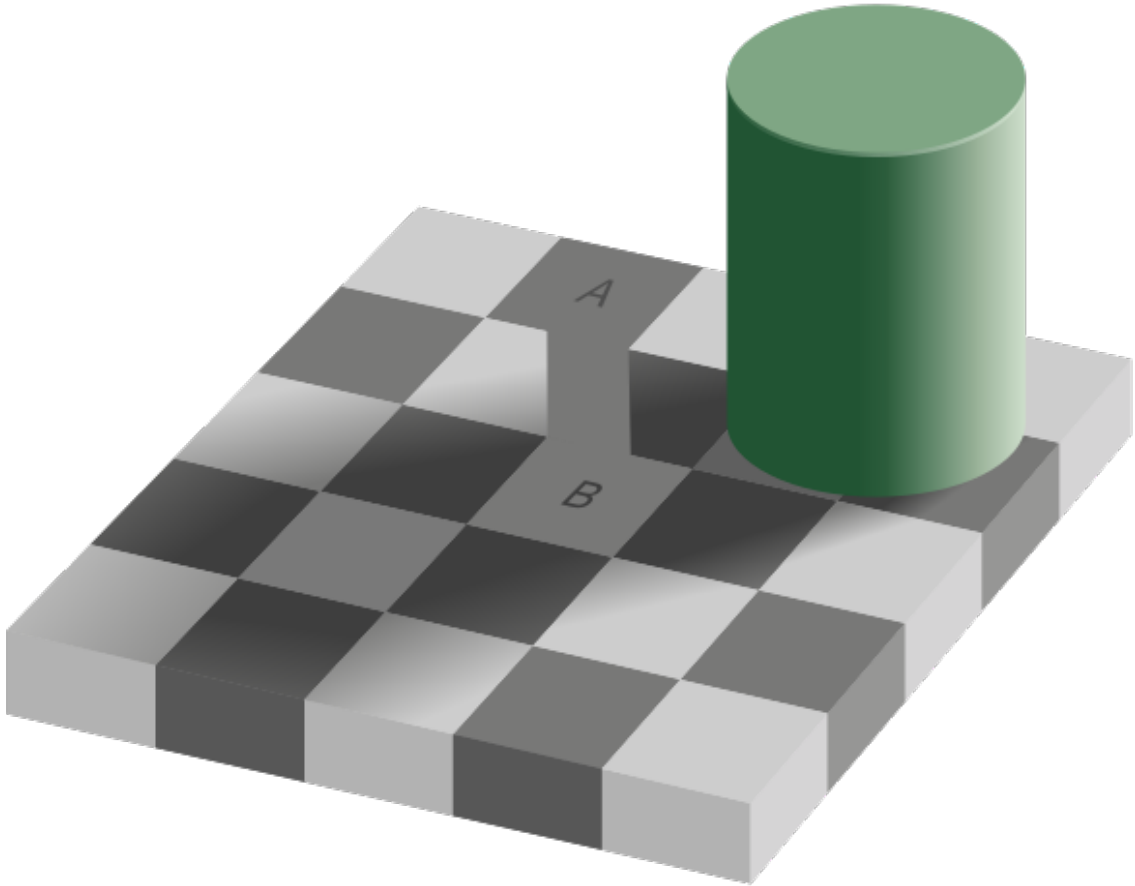
Dress Illusion

https://michaelbach.de/ot/col-dress/index.html

Brightness illusion



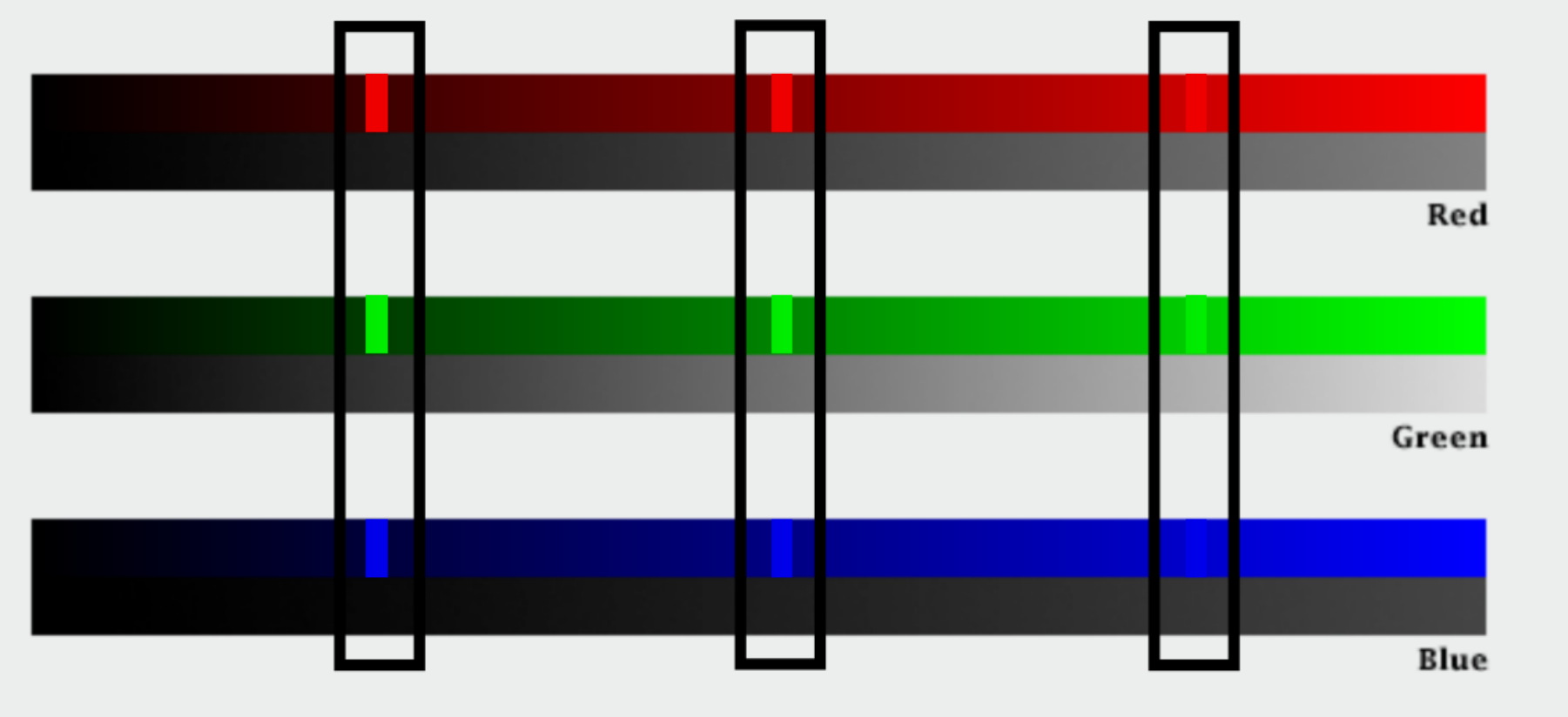
Brightness illusion



https://michaelbach.de/ot/lum-adelsonCheckShadow/index.html

Brightness illusion

Munker-White illusion: https://michaelbach.de/ot/lum-white/index.html



Gradient Bar Illusion

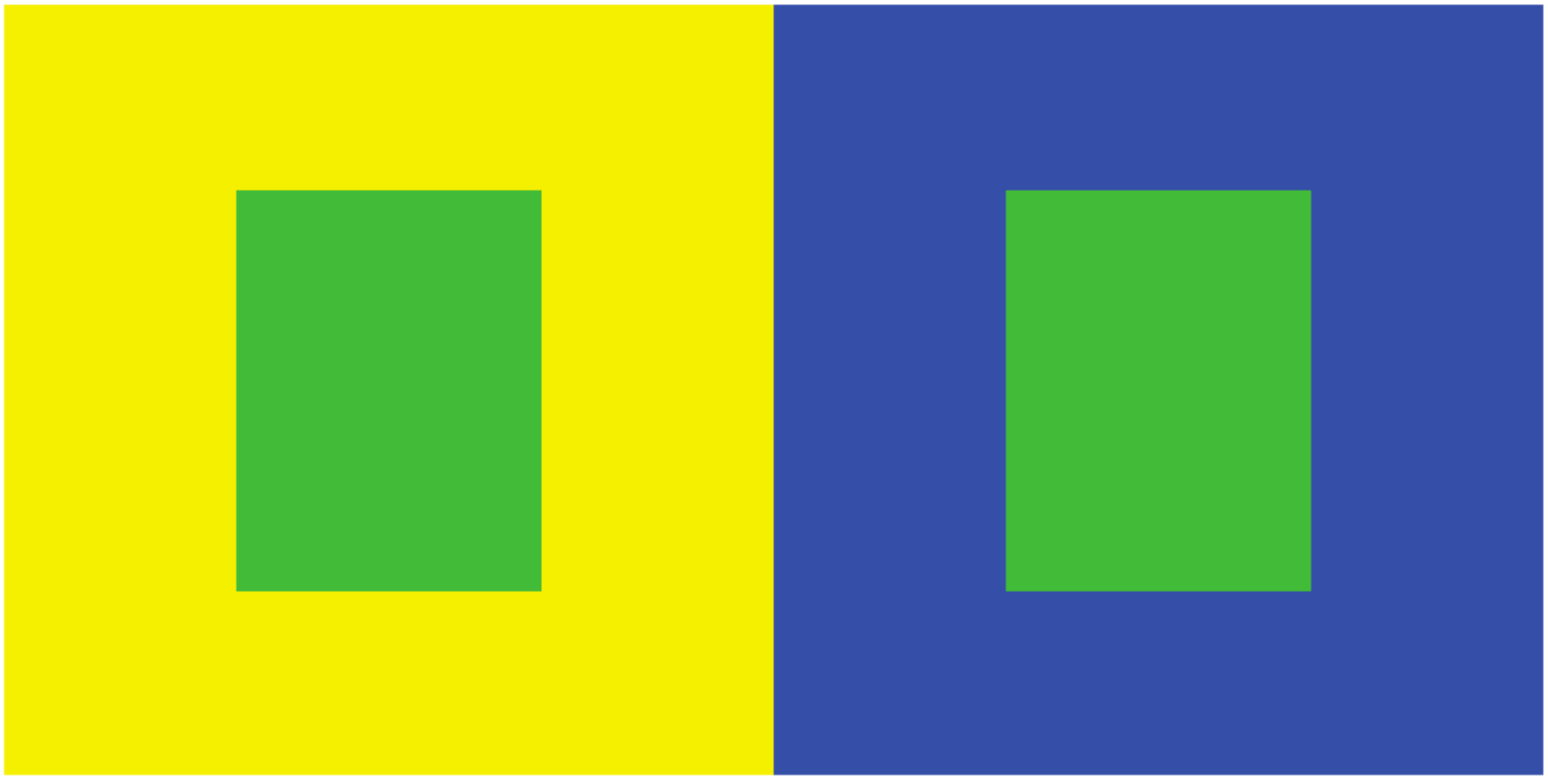
Gradient Bar Illusion

https://demonstrations.wolfram.com/GradientBarIllusion/

Gradient Bar Illusion

Avoid gradients as backgrounds or bars!

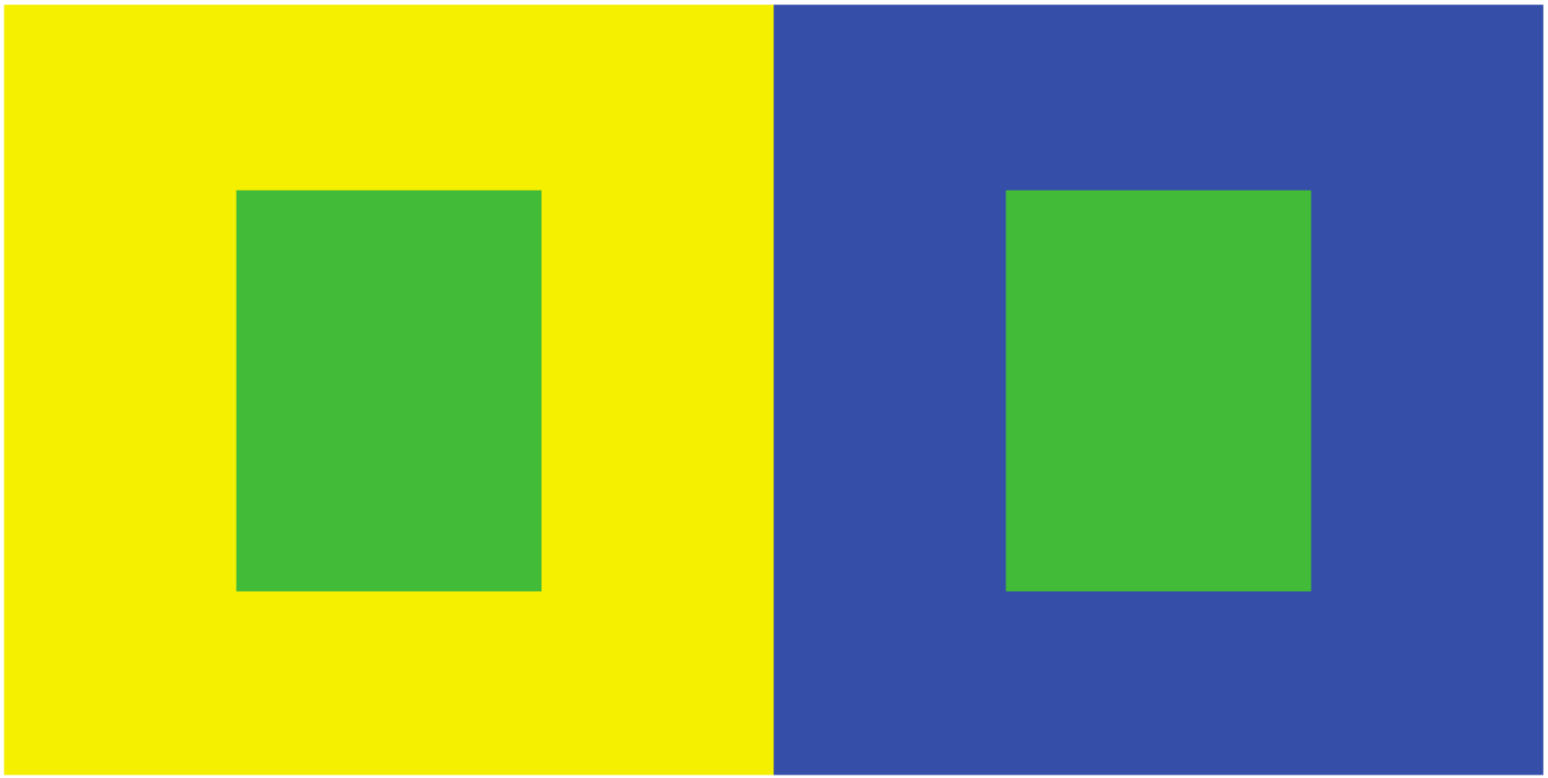
Simultaneous Contrast



Simultaneous Contrast

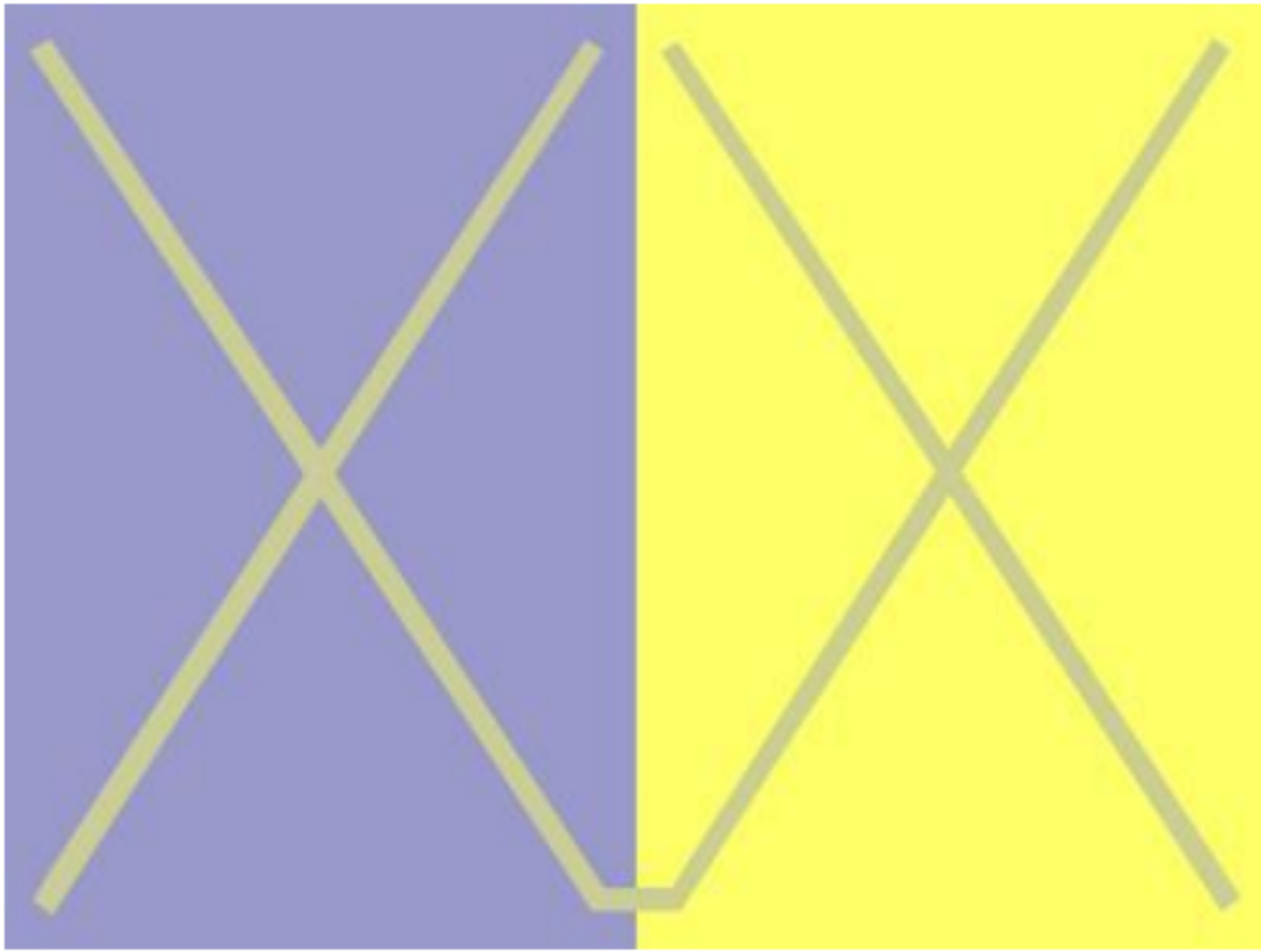
https://demonstrations.wolfram.com/TheSimultaneousContrastEffect/

Simultaneous Contrast

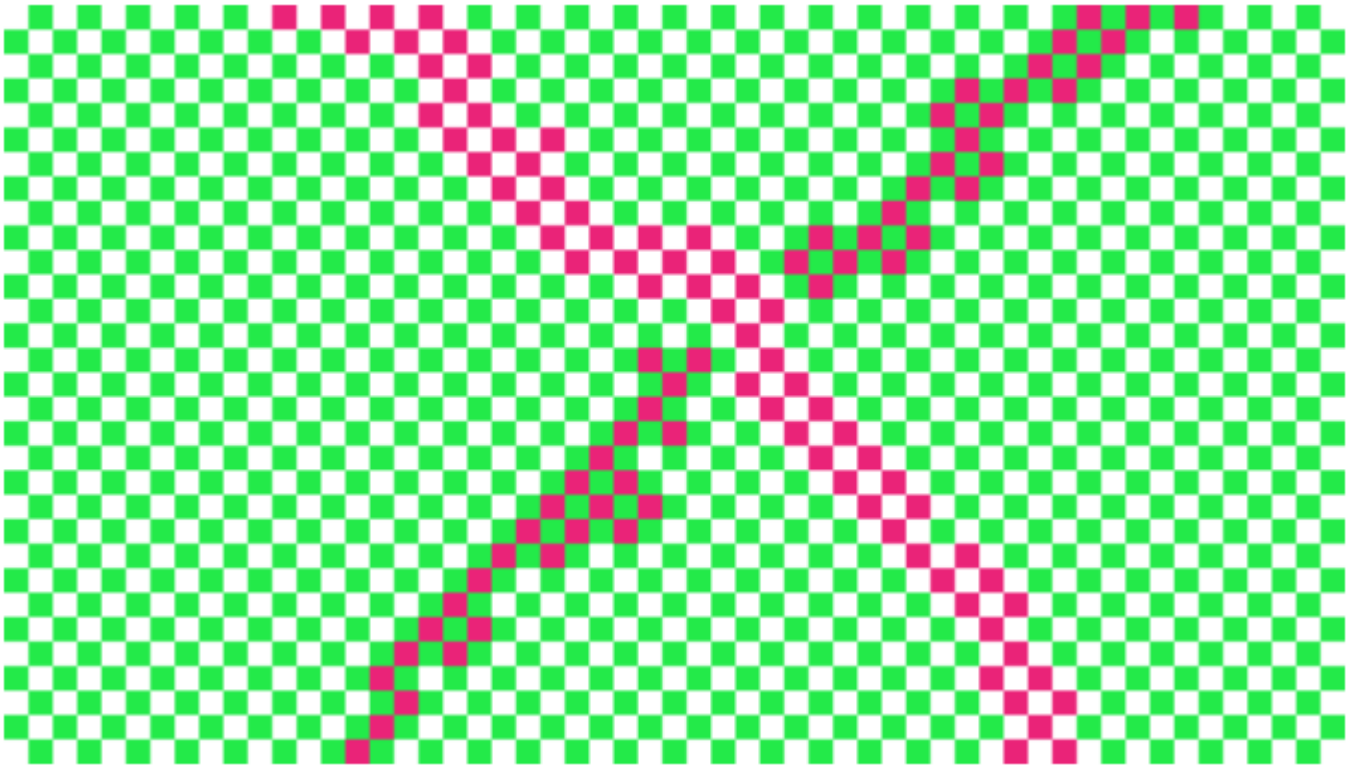


- Be careful with bars and scatter plot points - the colors may appear differently with different background colors and neighboring colors!
- Be aware that colors in legends may appear different than on the plot!

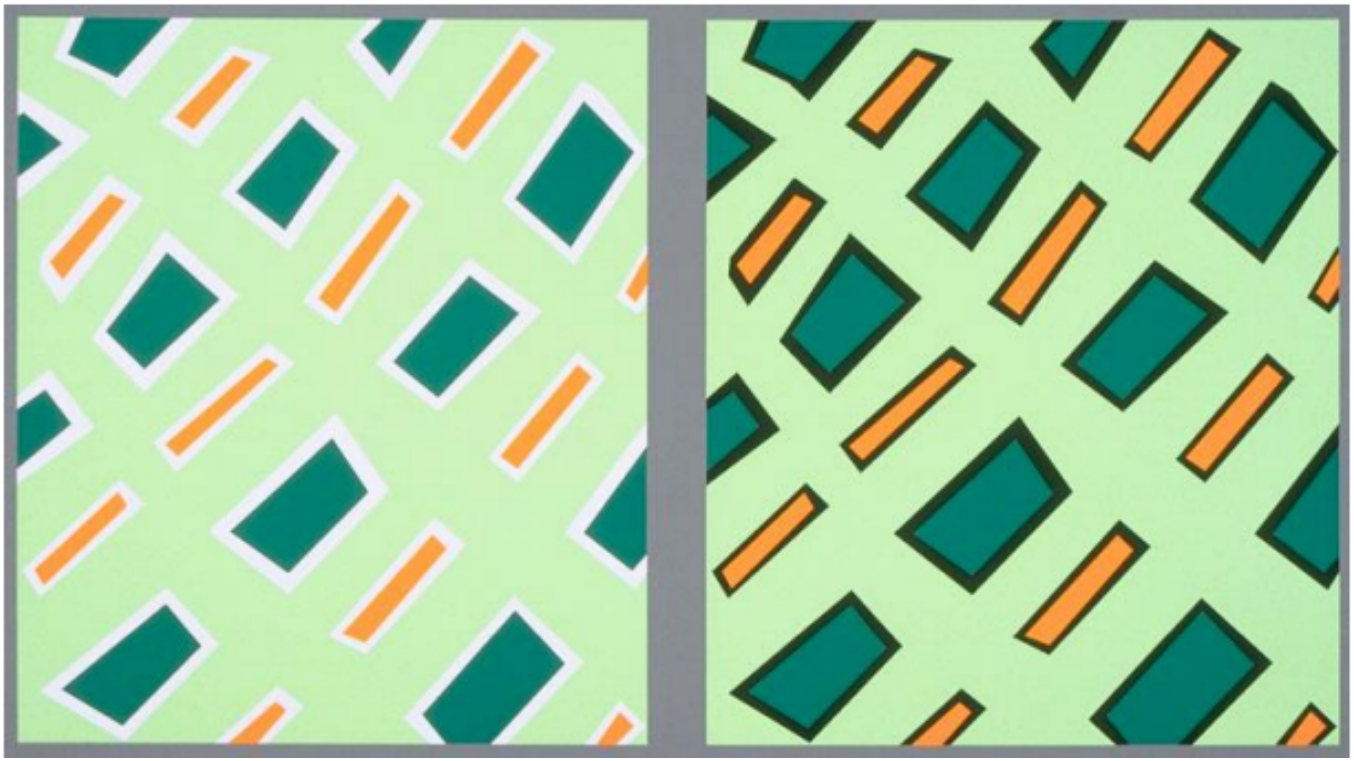
More examples on Simultaneous Contrast



Not only the background color

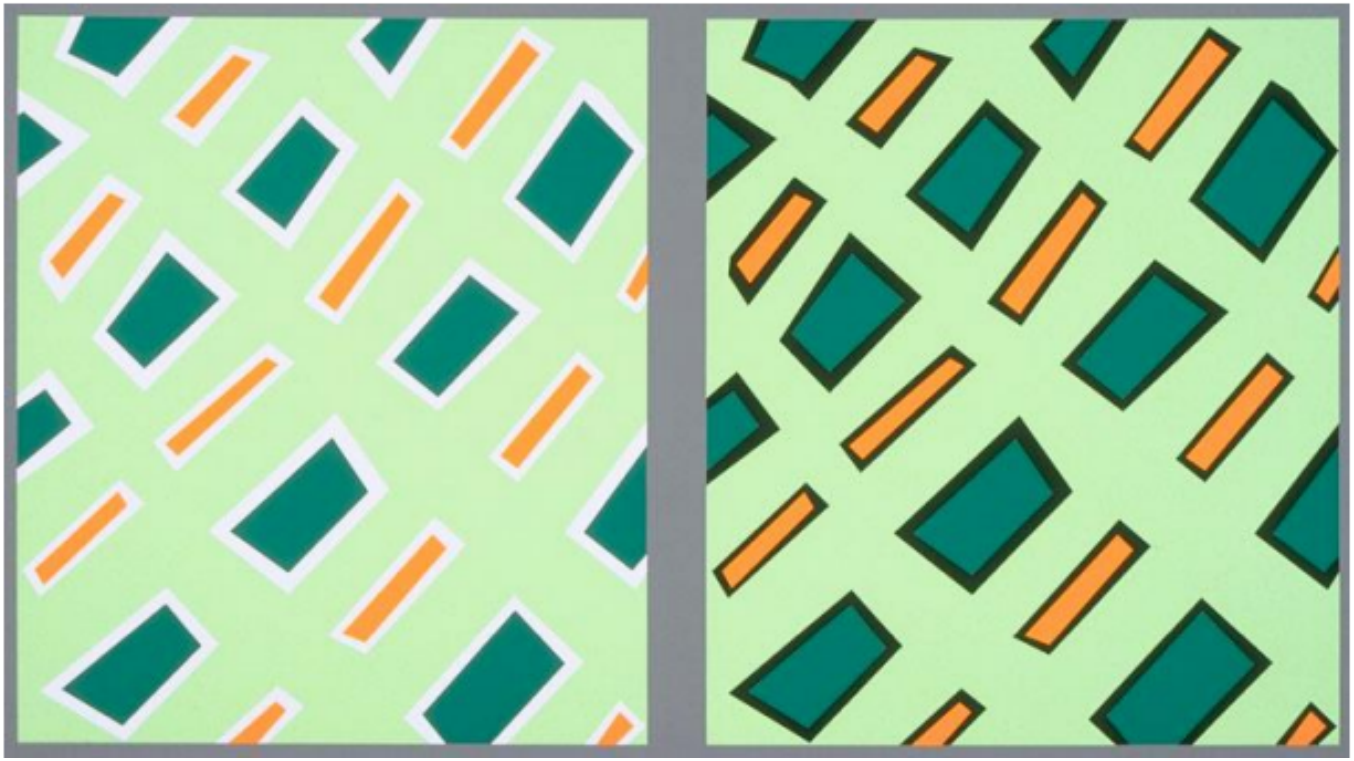


Flanking contours



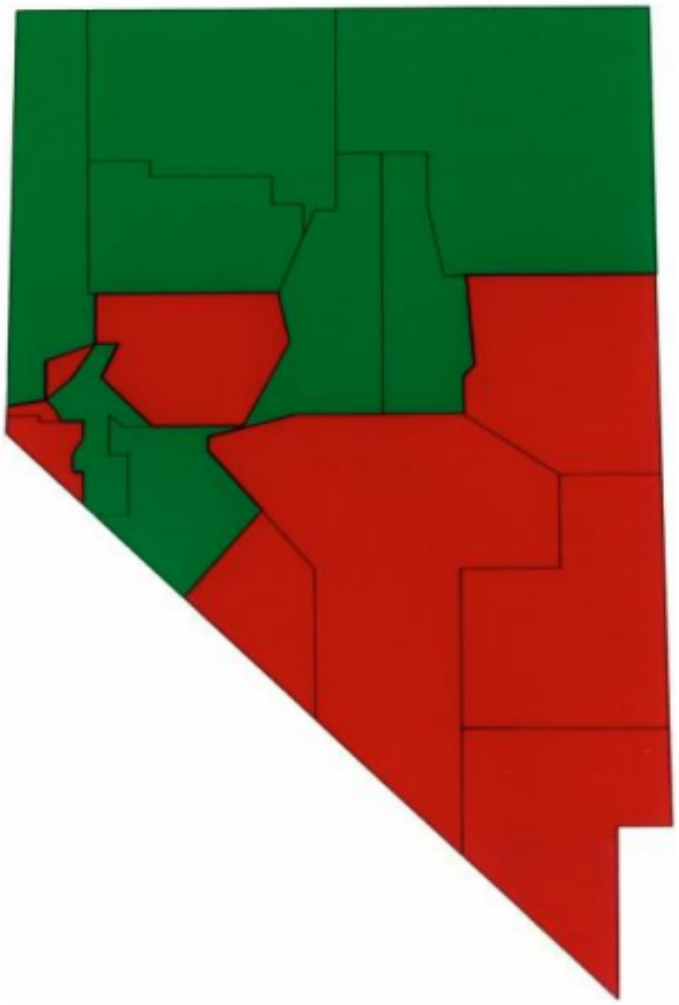
https://michaelbach.de/ot/col-fromContour/index.html

Flanking contours



- Be aware of color changes when adding borders around bars and plots!
- Be aware that colors in legends may appear different than on the plot!

Which area is larger (green or red)?



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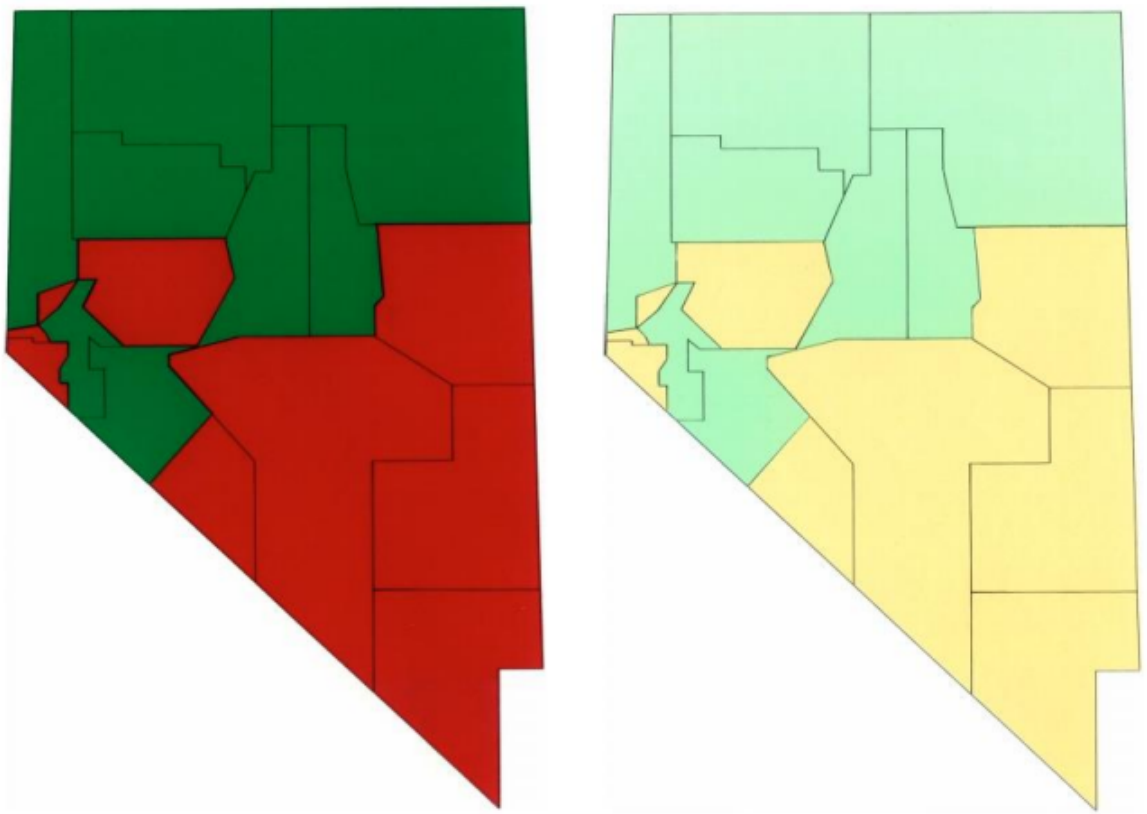
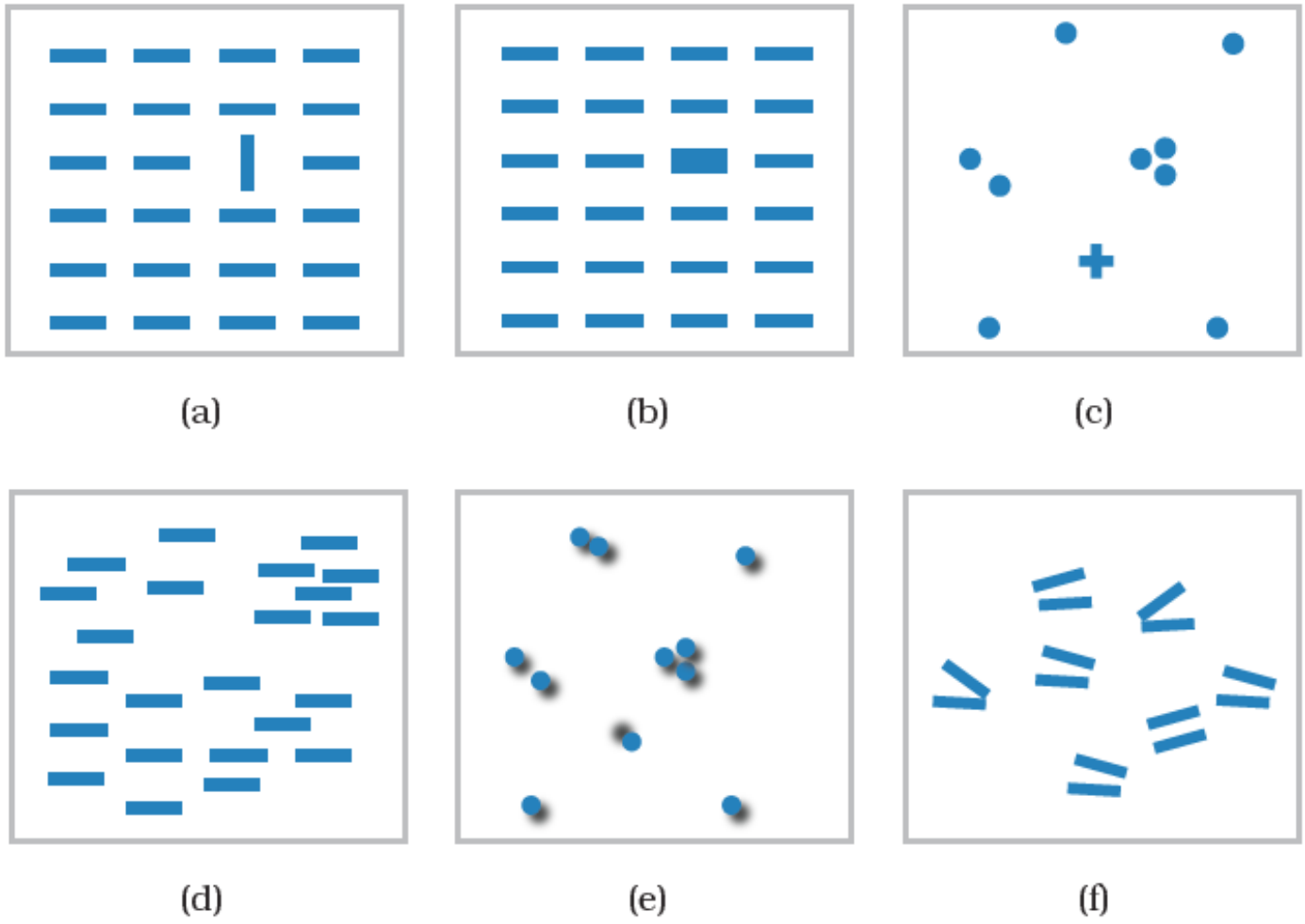


Areas are equal!.

Study participants favored red in the highly saturated case (left) but were more correct with the desaturated case (right)

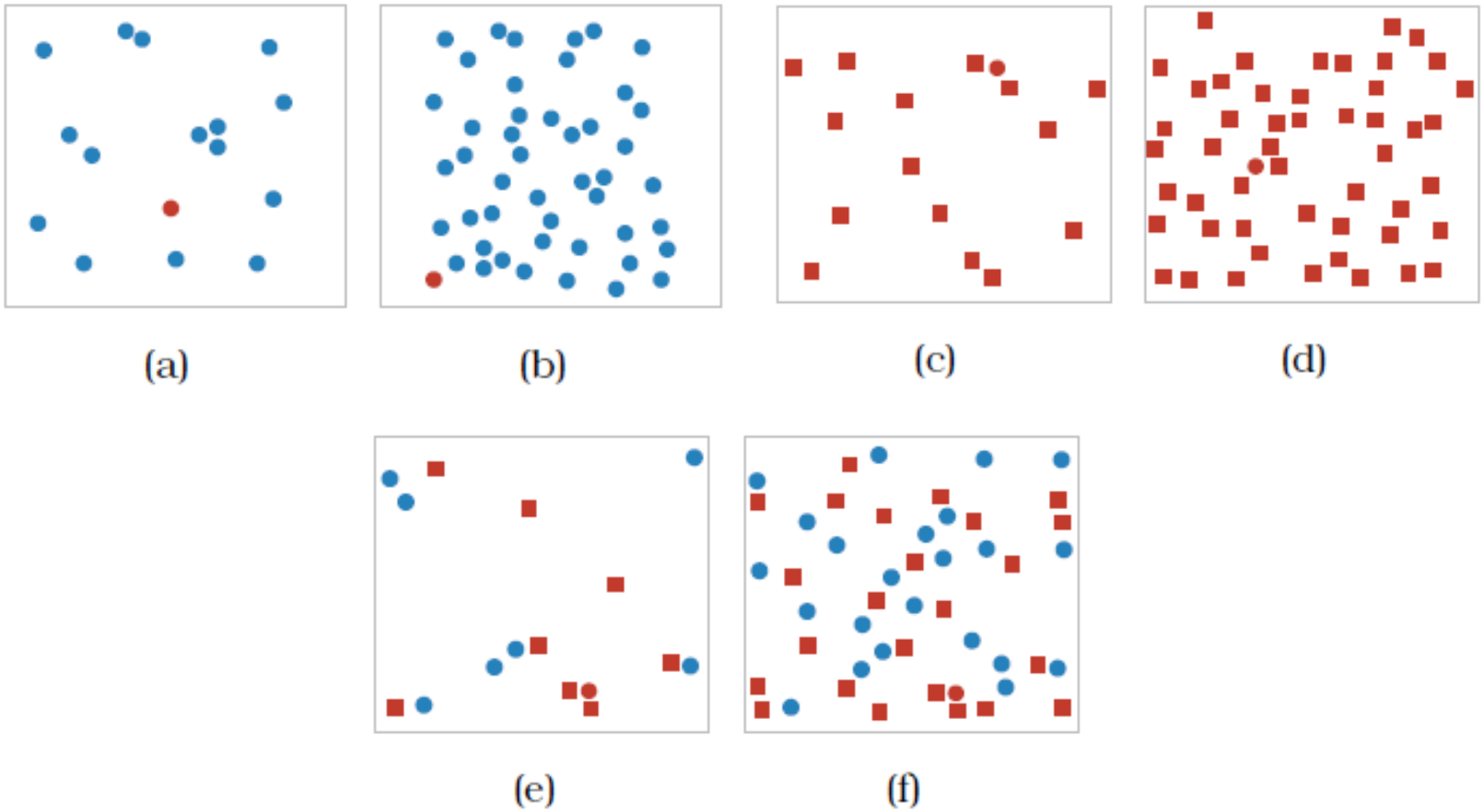
Pop-out effect

Many visual channels provide visual popout, where a distinct item stands out from many others immediately.



Pop-out effect

Goal: looking for the red circle!

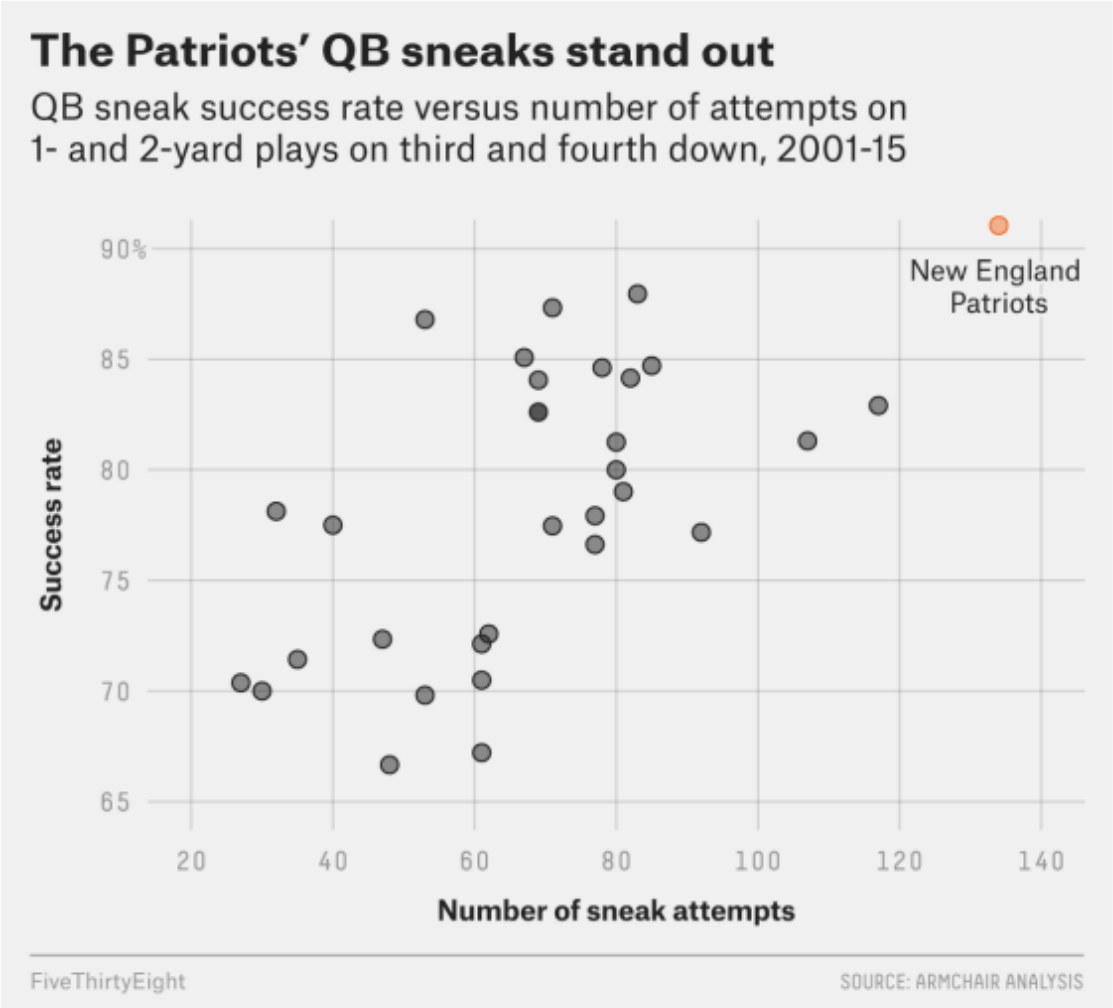


Pop-out effect example

A quarterback sneak is a play in American football and Canadian football in which the quarterback, upon taking the center snap, dives ahead while the offensive line surges forward. It is usually only used in very short yardage situations.

https://en.wikipedia.org/wiki/Quarterback_sneak

Which pop-out effects are used in this example visualization?



Davis & Lopez, 2017

Color Mixing Pitfalls

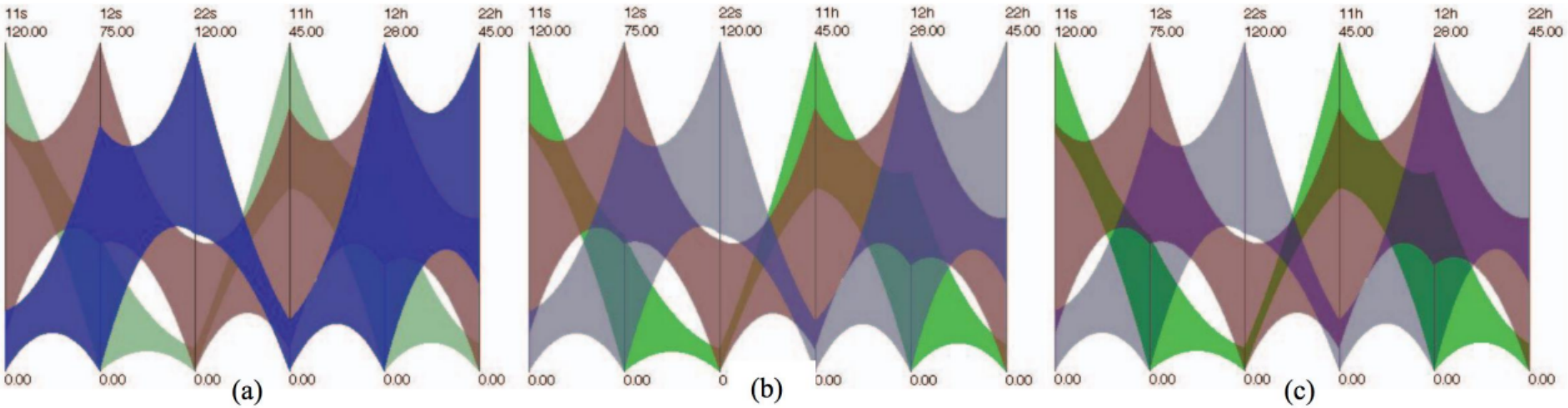
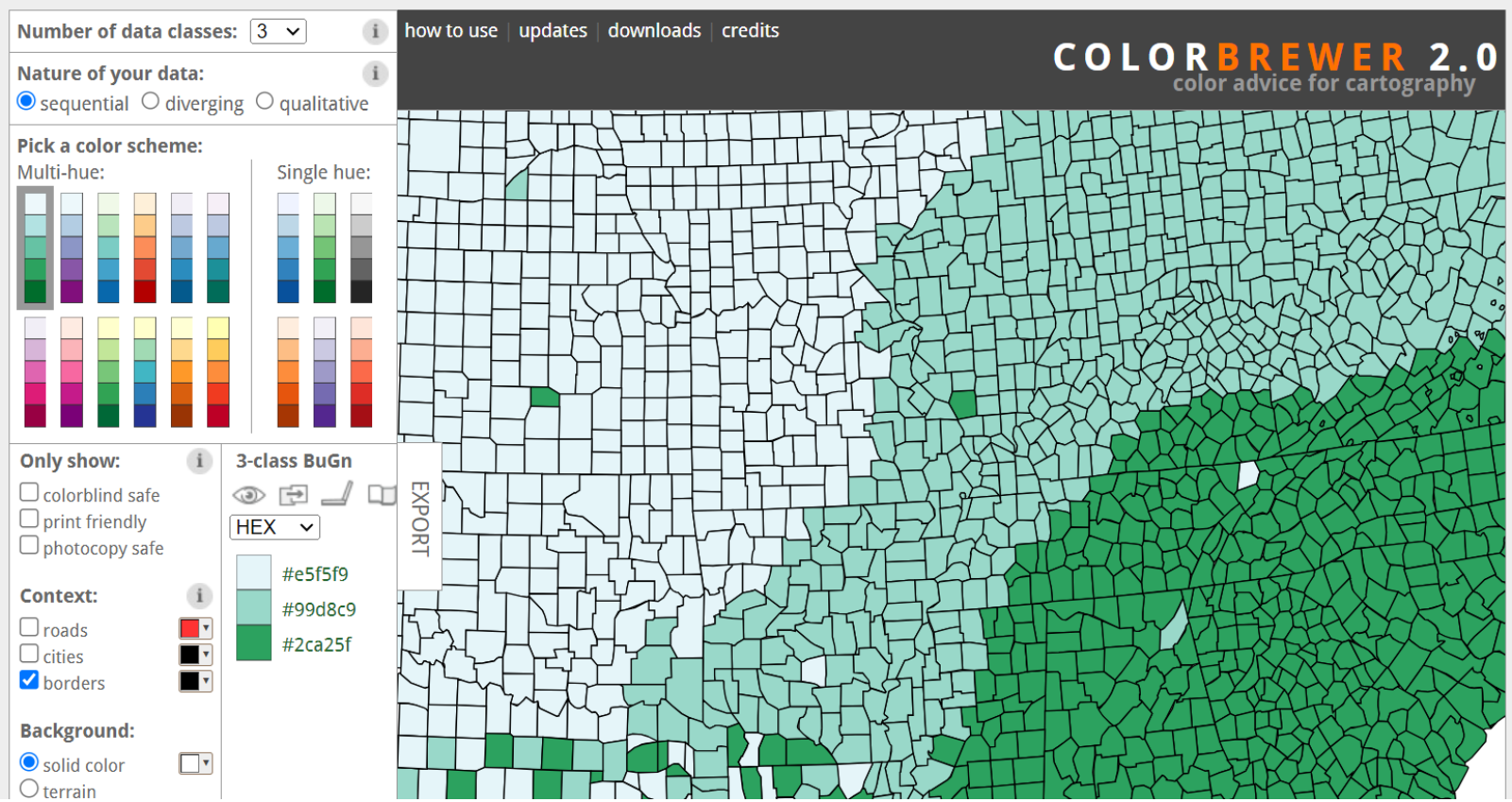


Fig. 12: Illustrative visualizations of a six-dimensional dataset using illustrative parallel coordinates. (a) Ideal visualization with appropriate weightings and color choices, and the use of the local model in overlapping areas. (b) Improper weightings are employed. The blue cluster no longer seems to be in front. (c) The use of improper weightings and the disabling of the local model results in a confusing visualization.

Tools for picking colormaps

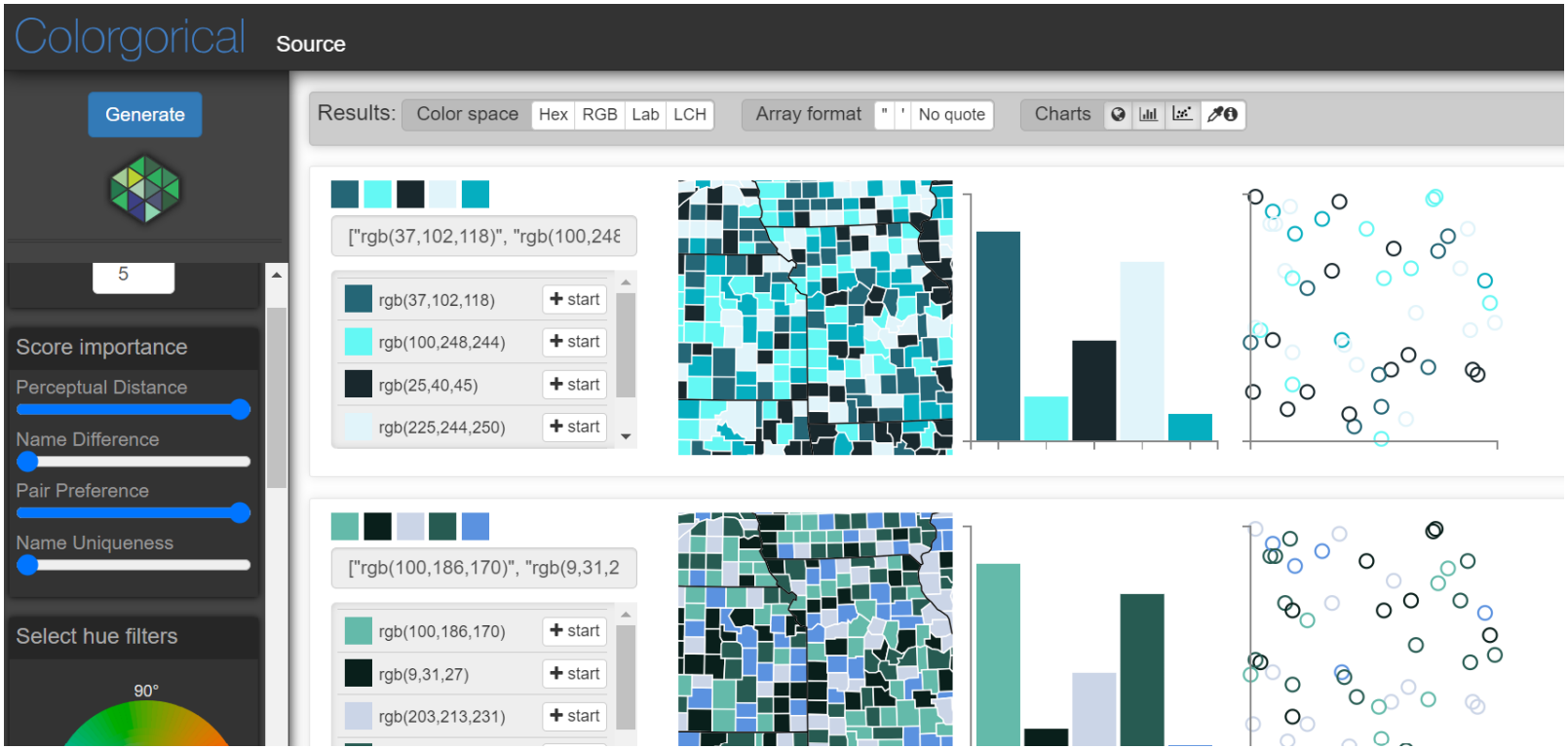
Color Brewer



https://colorbrewer2.org/

Tools for picking colormaps

Colorgorical



http://vrl.cs.brown.edu/color

Other useful tools

- Get a list of colors from an image: https://html-color.codes/image-color
- Analyze your palette: https://projects.susielu.com/viz-palette
- Analyze the name similarity of colors in your palette: http://vis.stanford.edu/color-names/analyzer/
- Easy picking a multi-hued color scale: http://tristen.ca/hcl-picker/
- Easily correcting darkness (lightness) for a scale: http://gka.github.io/palettes/
- virdis colors: https://cran.r-project.org/web/packages/viridis/

Color Advice Summary

Use a limited hue palette

- Control color "pop out" with low-saturation colors
- Avoid clutter from too many competing colors

Use neutral backgrounds

- Control **impact** of color
- Minimize simultaneous contrast

Use Color Brewer etc. for picking scales

Don't forget aesthetics!