# Ch 10: Color

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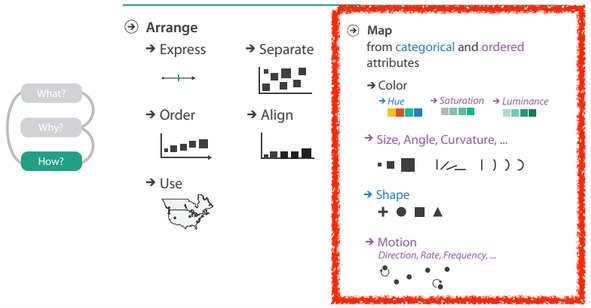
*CPSC 547, Information Visualization*
*Day 11: 7 Feb 2017*

http://www.cs.ubc.ca/~tmm/courses/547-17

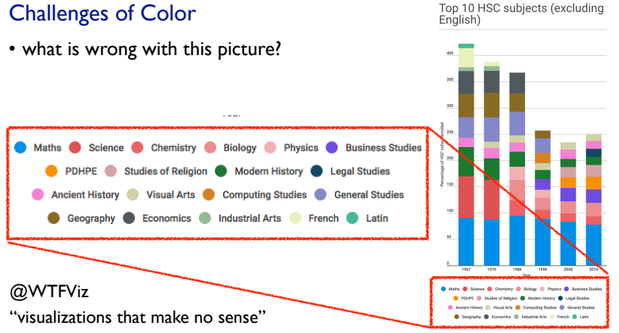
## Idiom design choices: Encode






## Challenges of Color

- what is wrong with this picture?

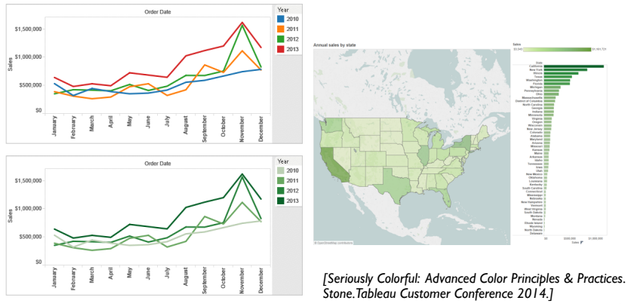



@WTFViz
"visualizations that make no sense"

http://viz.wtf/post/150780948819/maths-enrolments-drop-to-lowest-rate-in-50-years



## Categorical vs ordered color

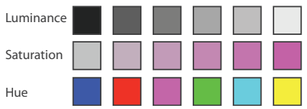



*[Seriously Colorful: Advanced Color Principles & Practices. Stone.Tableau Customer Conference 2014.]*



## Decomposing color

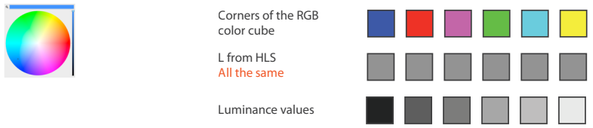
- first rule of color: do not talk about color!
  - color is confusing if treated as monolithic
- decompose into three channels
  - ordered can show magnitude
    - luminance
    - saturation
  - categorical can show identity
    - hue
- channels have different properties
  - what they convey directly to perceptual system
  - how much they can convey: how many discriminable bins can we use?





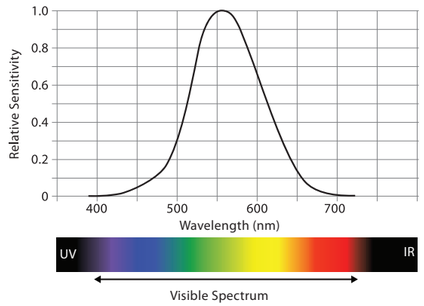

## Color spaces

- RGB: poor for encoding
- HSL: better, but beware
  - lightness ≠ luminance





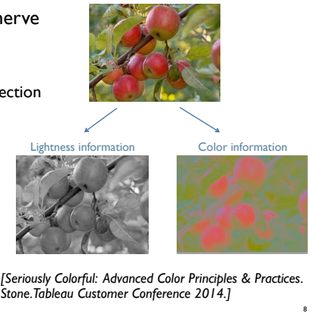

## Spectral sensitivity






## Opponent color and color deficiency

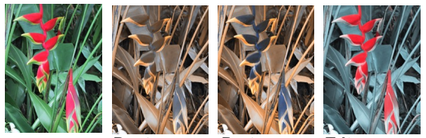
- perceptual processing before optic nerve
  - one achromatic luminance channel L
    - intrinsic perceptual ordering
    - need luminance contrast for edge detection
  - two chroma channels, R-G and Y-B axis
- "color blind" if one chroma axis has degraded acuity
  - 8% of men are red/green color deficient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



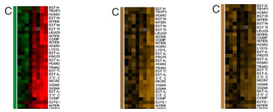

*[Seriously Colorful: Advanced Color Principles & Practices. Stone.Tableau Customer Conference 2014.]*



## Designing for color deficiency: Check with simulator




http://rehue.net

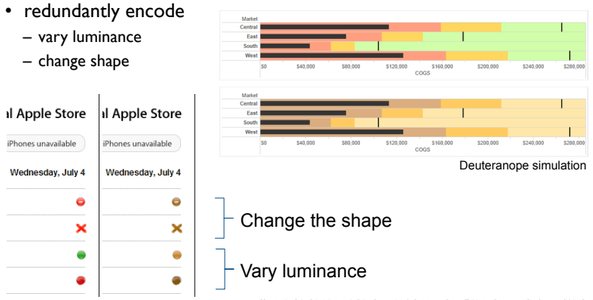


*[Seriously Colorful: Advanced Color Principles & Practices. Stone.Tableau Customer Conference 2014.]*



## Designing for color deficiency: Avoid encoding by hue alone

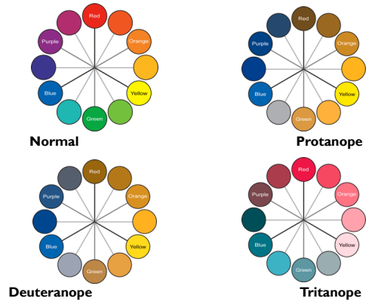
- redundantly encode
  - vary luminance
  - change shape




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



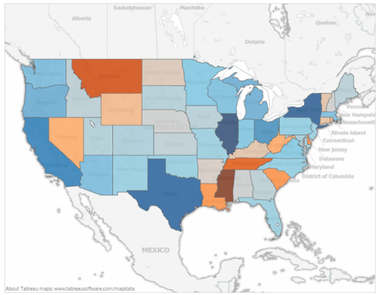
## Color deficiency: Reduces color to 2 dimensions




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



## Designing for color deficiency: Blue-Orange is safe



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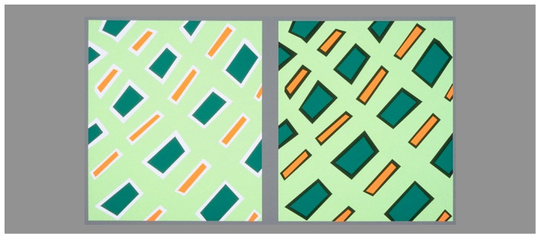
## Bezold Effect: Outlines matter

- color constancy: simultaneous contrast effect



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## Color/Lightness constancy: Illumination conditions

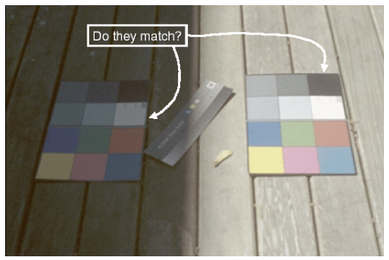


Image courtesy of John McCann



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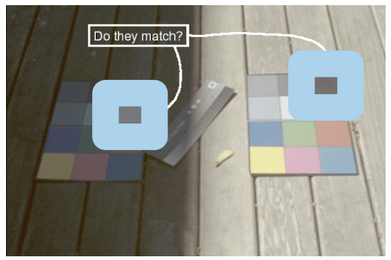


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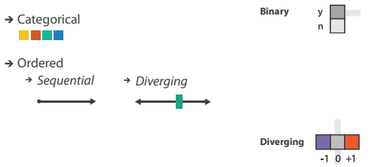
## Colormaps




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

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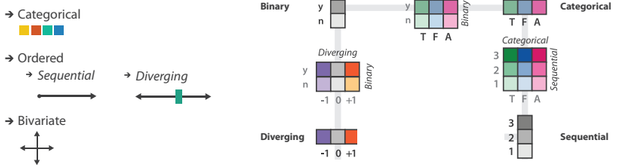


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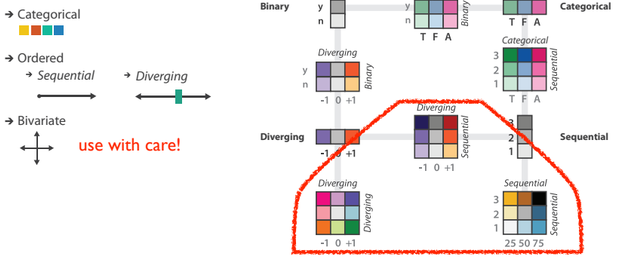


*after [Color Use Guidelines for Mapping and Visualization. Brewer, 1994. http://www.personal.psu.edu/faculty/c/a/cab38/ColorSch/Schemes.html]*



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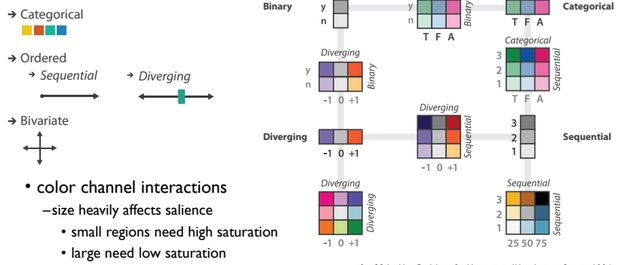


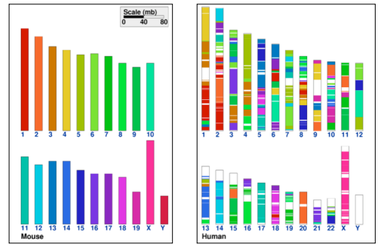

- color channel interactions
  - –size heavily affects salience
    - small regions need high saturation
    - large need low saturation
  - –saturation & luminance: 3-4 bins max
    - also not separable from transparency

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



## Categorical color: limited number of discriminable bins

- human perception built on relative comparisons
  - –great if color contiguous
  - –surprisingly bad for absolute comparisons
- noncontiguous small regions of color
  - –fewer bins than you want
  - –rule of thumb: 6-12 bins, including background and highlights
  - –*so what can we do instead?*

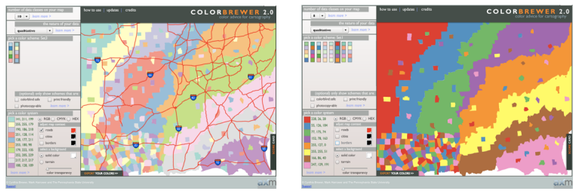



*[Cinteny: flexible analysis and visualization of synteny and genome rearrangements in multiple organisms. Sinha and Meller. BMC Bioinformatics, 8:82, 2007.]*



## ColorBrewer

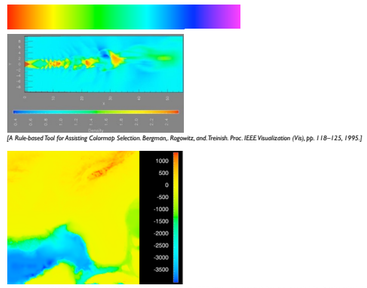
- http://www.colorbrewer2.org
- saturation and area example: size affects salience!






## 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/l/lloydt/color/color.HTM]*

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



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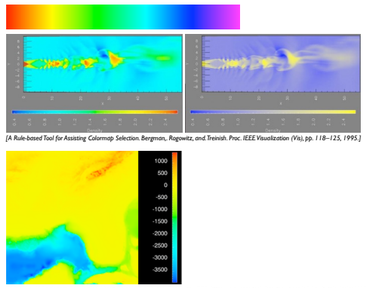
- alternatives
  - –large-scale structure: fewer hues



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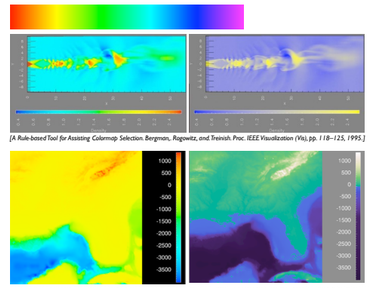
  - –fine structure: multiple hues with monotonically increasing luminance [eg viridis R/python]



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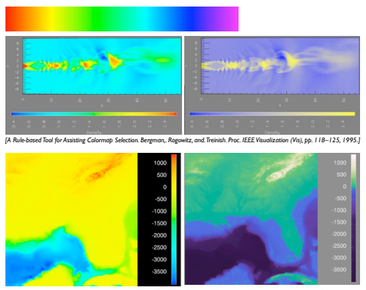
- alternatives
  - –large-scale structure: fewer hues
  - –fine structure: multiple hues with monotonically increasing luminance [eg viridis R/python]
  - –segmented rainbows for binned
    - or categorical



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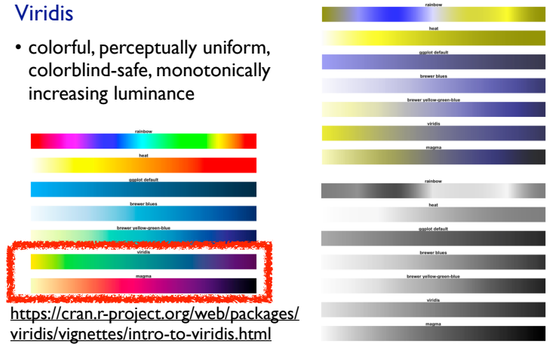
## Viridis

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

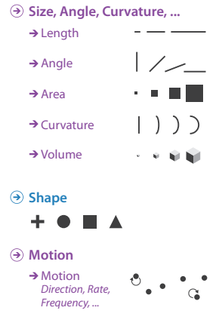



https://cran.r-project.org/web/packages/viridis/vignettes/intro-to-viridis.html



## Map other channels

- size
  - –length accurate, 2D area ok, 3D volume poor
- angle
  - –nonlinear accuracy
    - horizontal, vertical, exact diagonal
- shape
  - –complex combination of lower-level primitives
  - –many bins
- motion
  - –highly separable against static
    - binary: great for highlighting
  - –use with care to avoid irritation






## Angle

Sequential ordered line mark or arrow glyph

Diverging ordered arrow glyph

Cyclic ordered arrow glyph



## Next Time

- to read
  - –VAD Ch. 11: Manipulate View
  - –Interactive Visualization of Genealogical Graphs. Michael J. McGuffin, Ravin Balakrishnan. Proc. InfoVis 2005, pp 17-24.