Color

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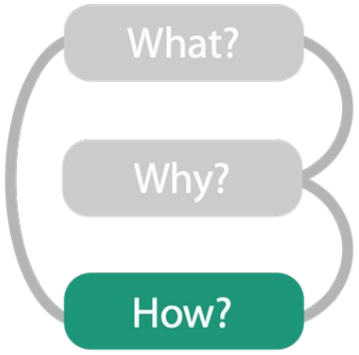
Slides taken, reformatted, and used from Tamara Munzner (UBC, Canada)

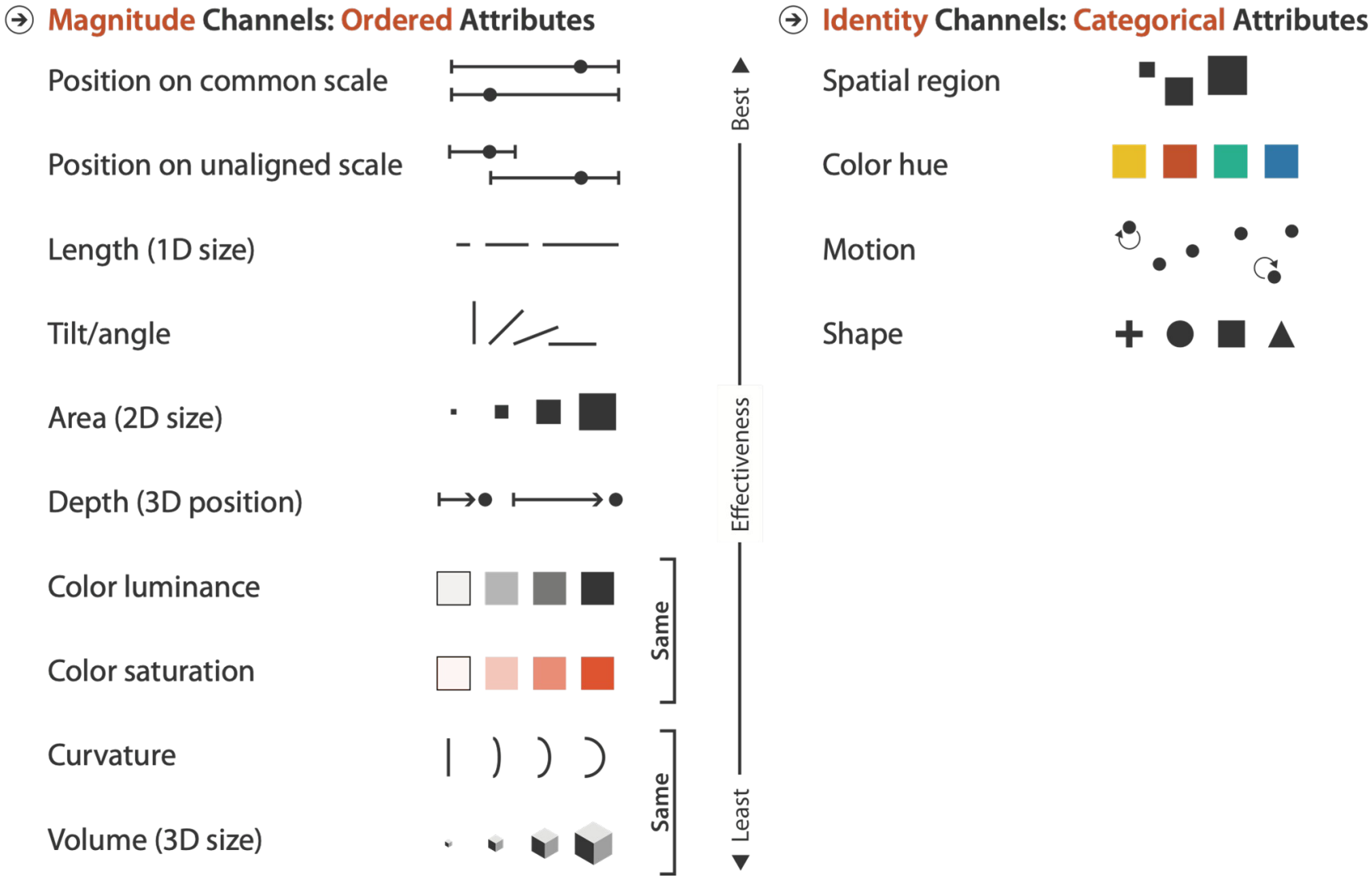
Idiom design choices: visual encoding

Encode

- **Arrange**
  - Express
  - Separate
  - Order
  - Align
  - Use
- **Map**
  from categorical and ordered attributes
  - Color
    - *Hue*
    - *Saturation*
    - *Luminance*
  - Size, Angle, Curvature, ...
  - Shape
  - Motion
    Direction, Rate, Frequency, ...



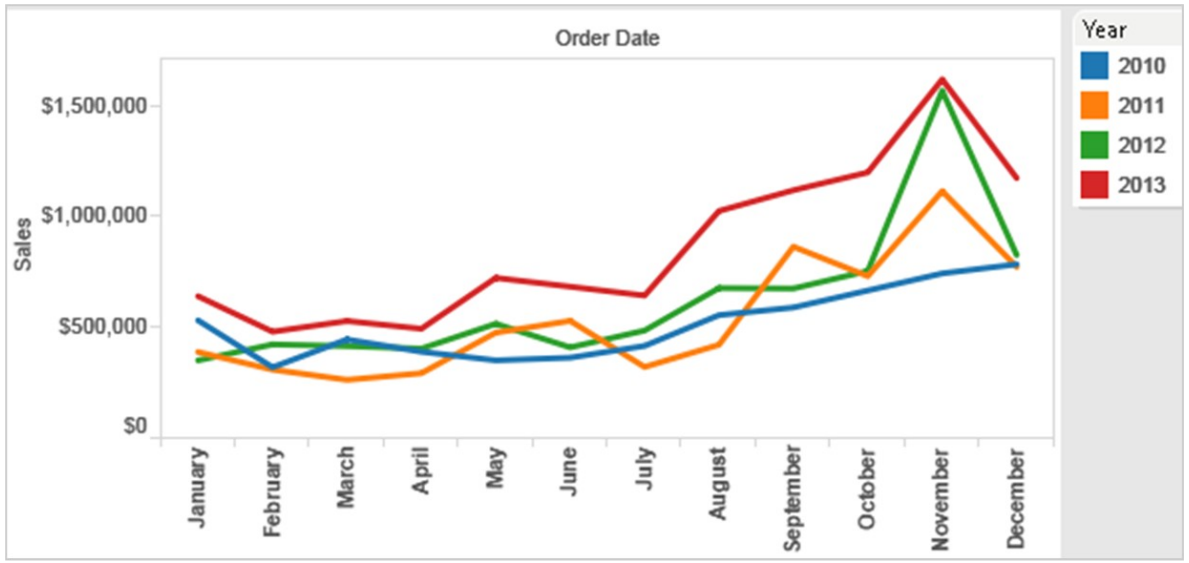
Channels: what's up with color?

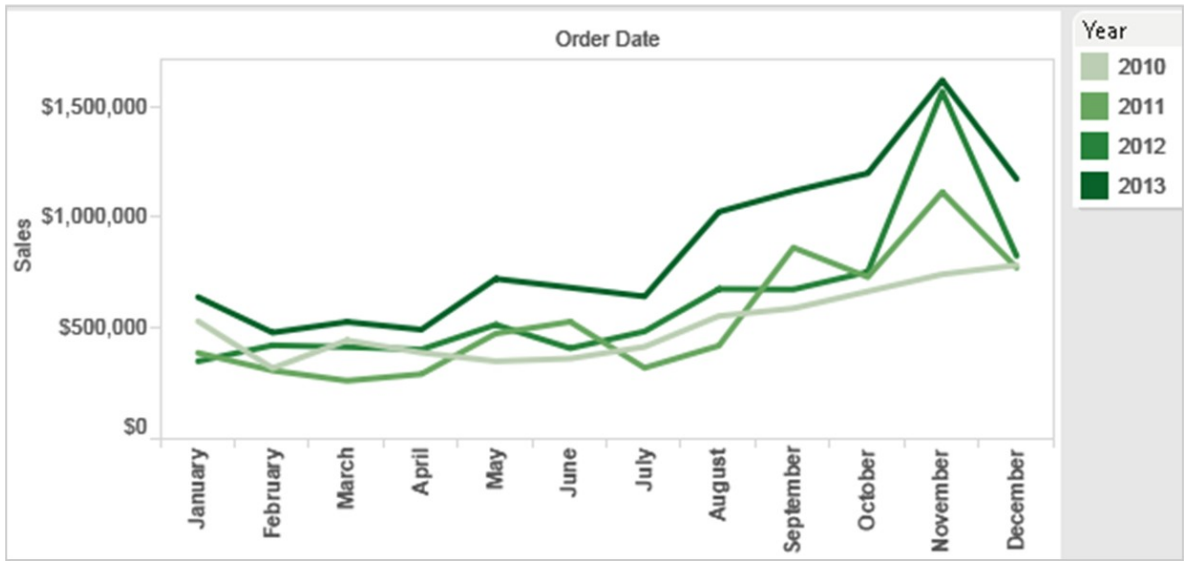


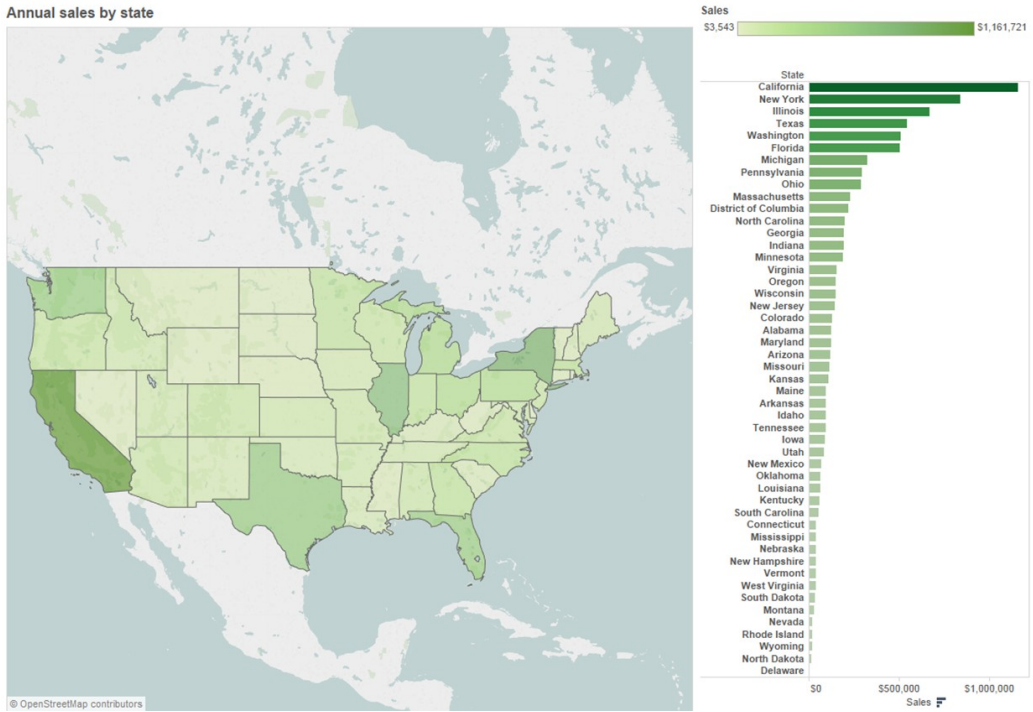
Decomposing color

- First rule of color: do not (just) talk about color!
  - Color is confusing if treated as monolithic
- Decompose into three channels
  - Ordered can show magnitude
    - Luminance: how bright (B/W)
    - Saturation: how colorful
  - Categorical can show identity
    - Hue: what color
- Channels have different properties
  - What they convey directly to perceptual system
  - How much they can convey
    - How many discriminable bins can we use?

Categorical vs ordered color

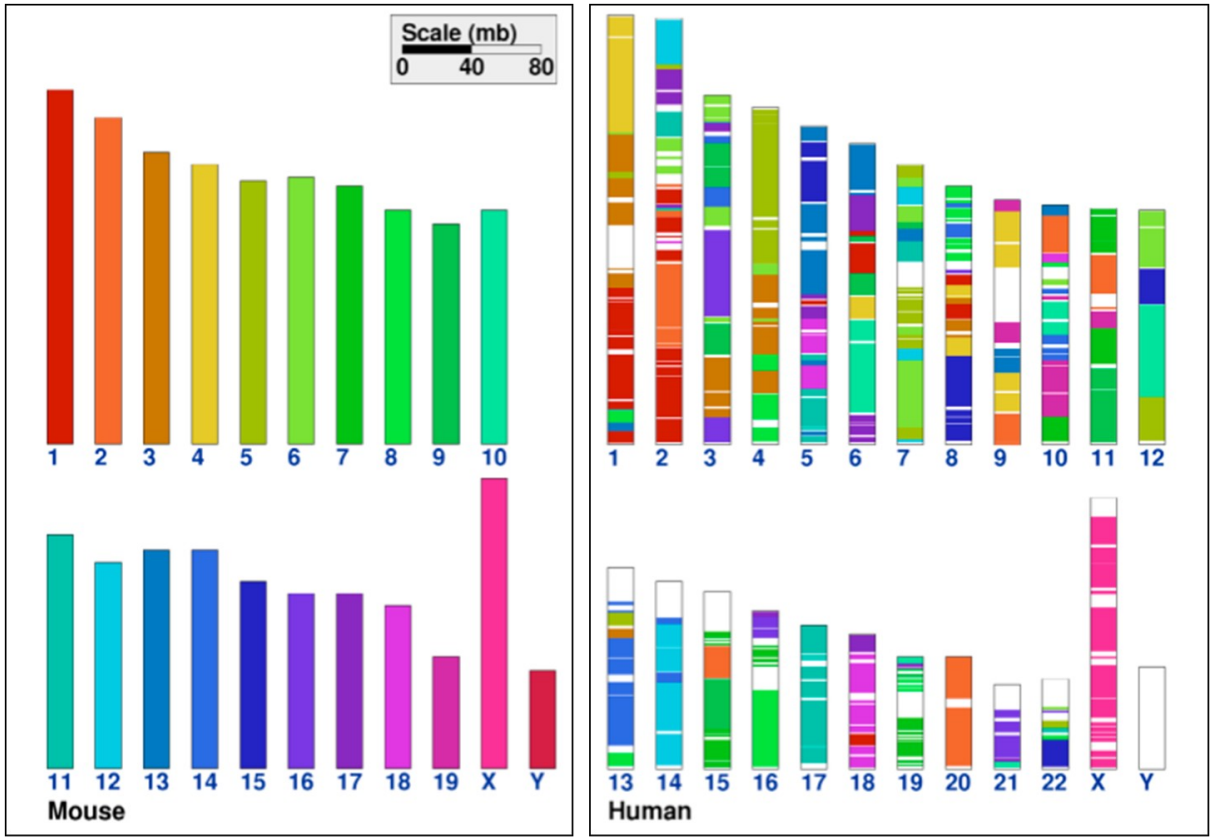






Categorical color: limited number of discernable bins

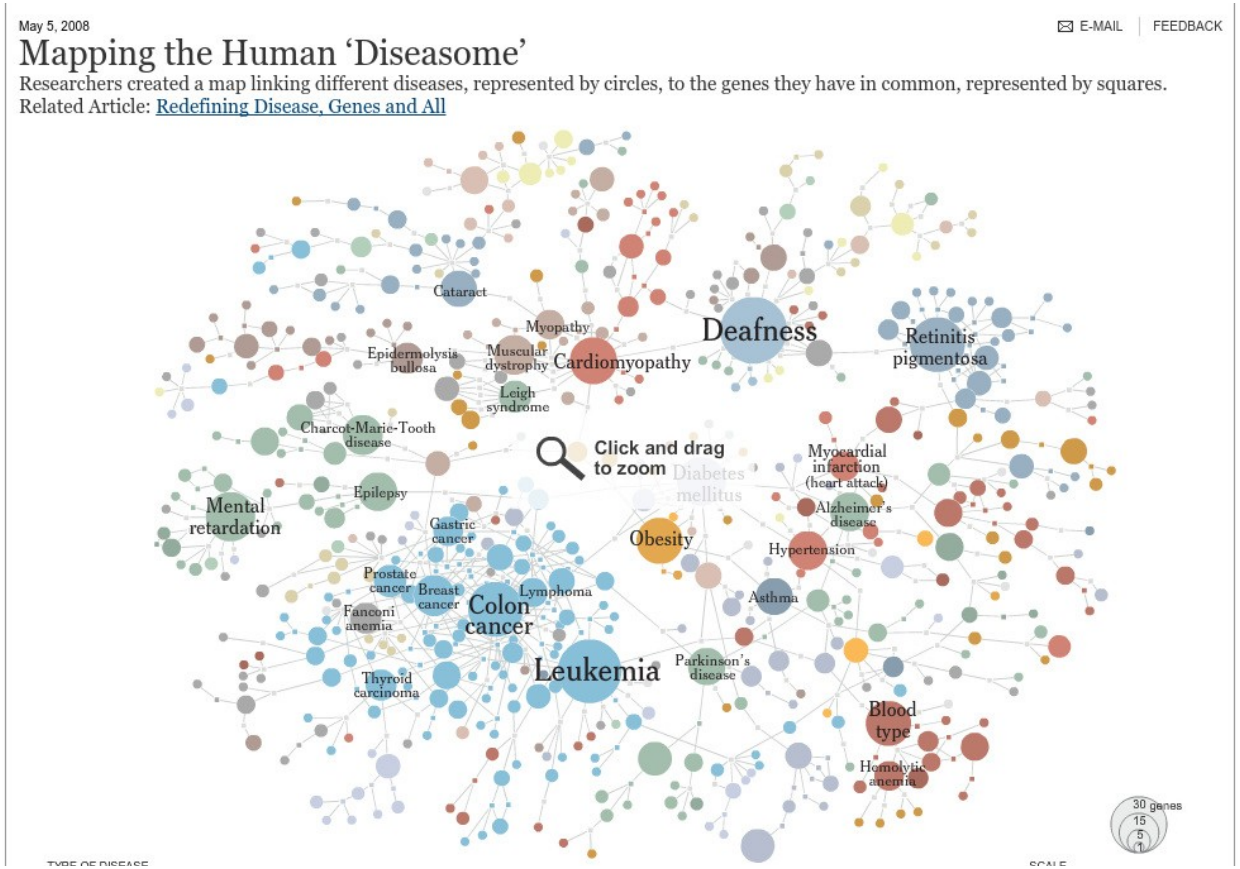
- Human perception built on relative comparisons
  - Great if color contiguous
  - Surprisingly bad for absolute comparisons
- Noncontiguous small regions of color
  - Fewer bins than you want
  - Rule of thumb: 6-12 bins, including background and highlights

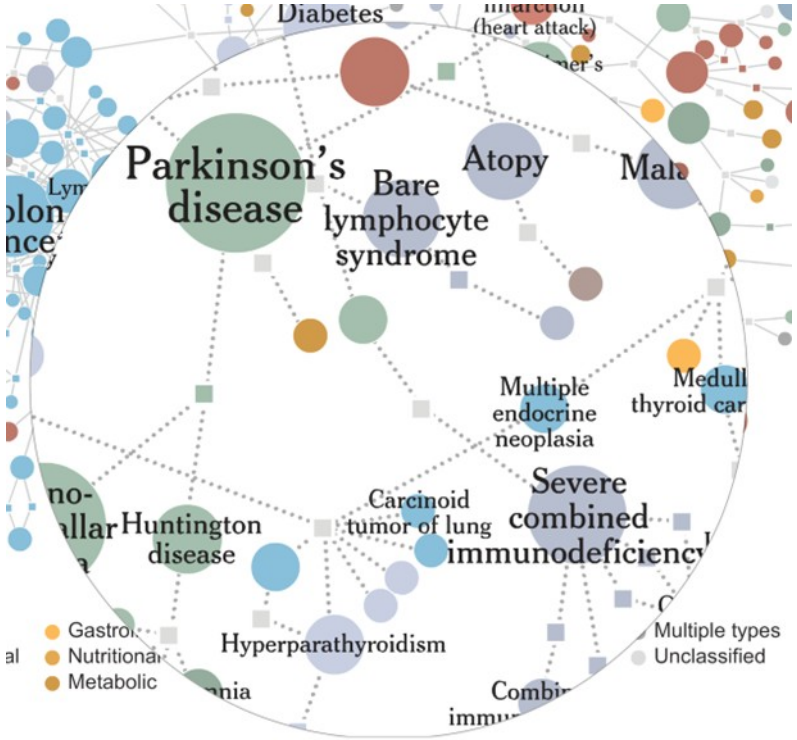


[Cinteny: flexible analysis and visualization of synteny and genome rearrangements in multiple organisms. Sinha and Meller. BMC Bioinformatics, 8:82, 2007.]

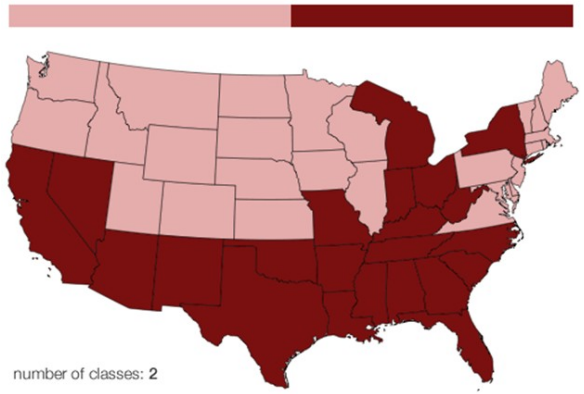
Categorical color: limited number of discriminable bins

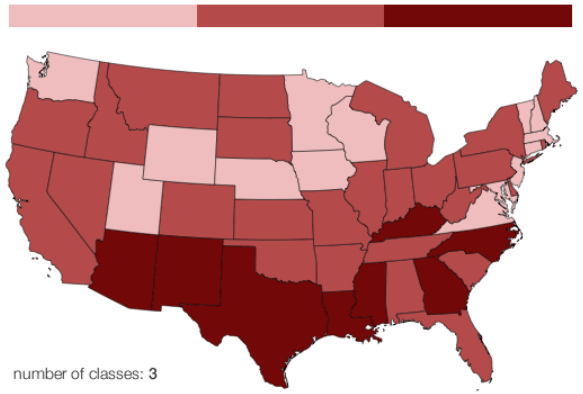
Cancer · Connective tissue · Cardiovascular · Endocrine · Gastrointestinal · Ear, nose, throat · Developmental · Multiple types
Bone · Muscular · Hematological · Immunological · Nutritional · Ophthalmological · Neurological · Unclassified
Skeletal · Dermatological · Renal · Metabolic · Respiratory · Psychiatric

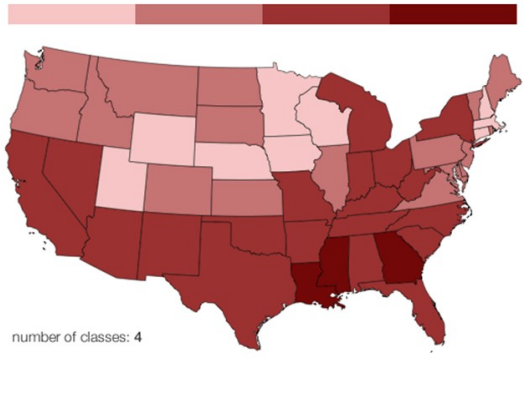


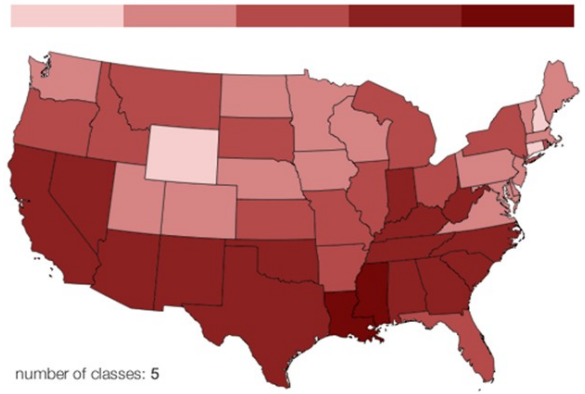


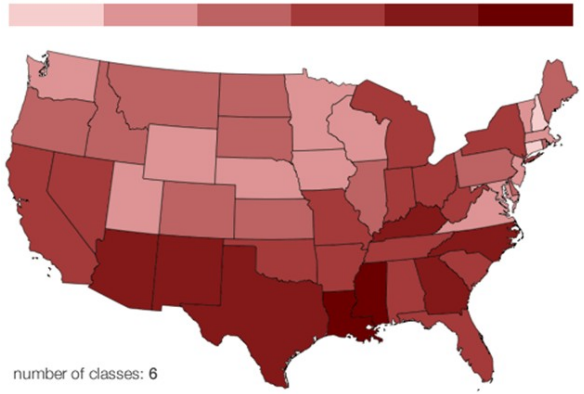
Ordered color: limited number of discriminable bins

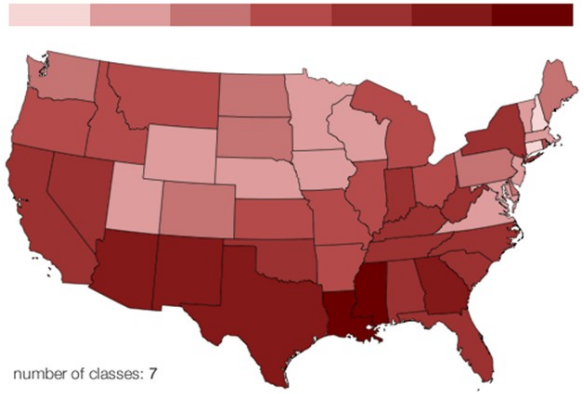


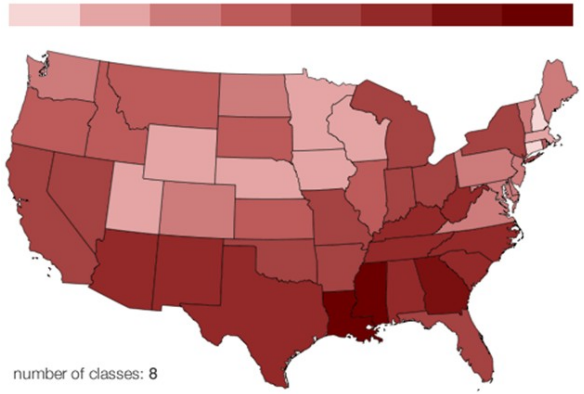






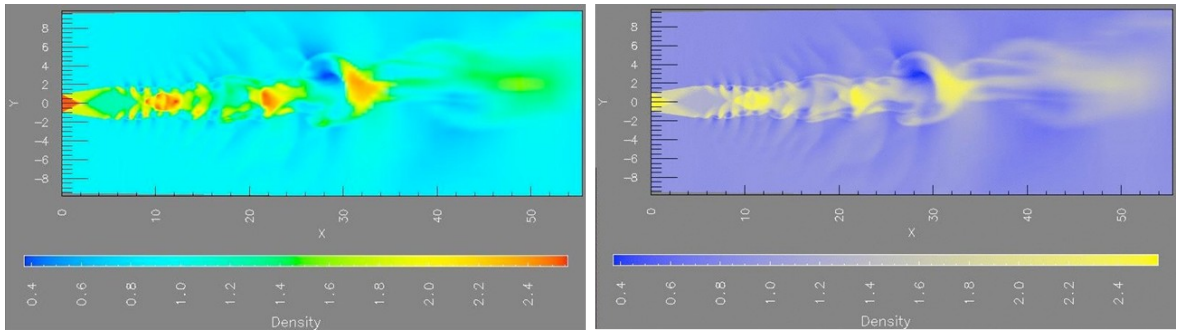


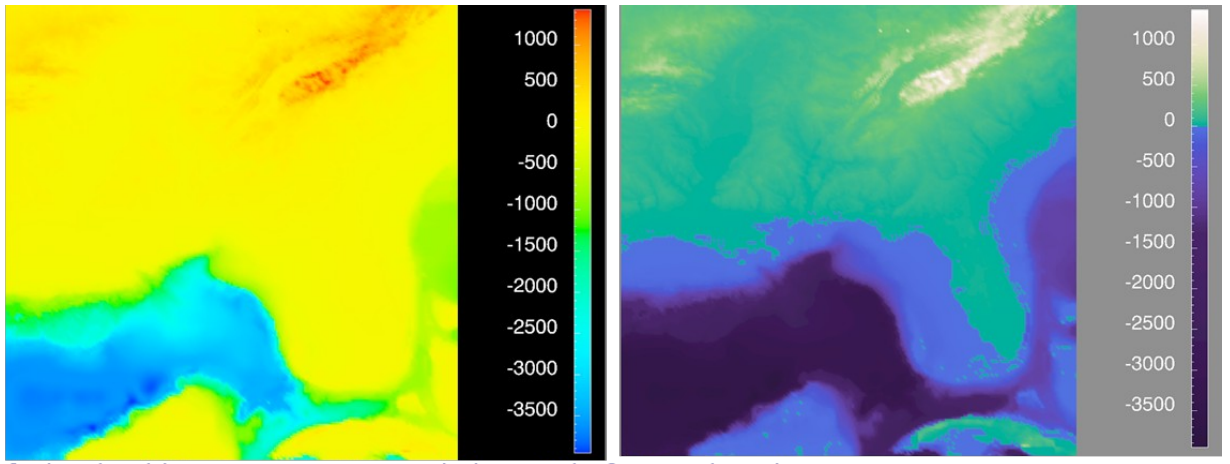




Ordered color: Rainbow is poor default

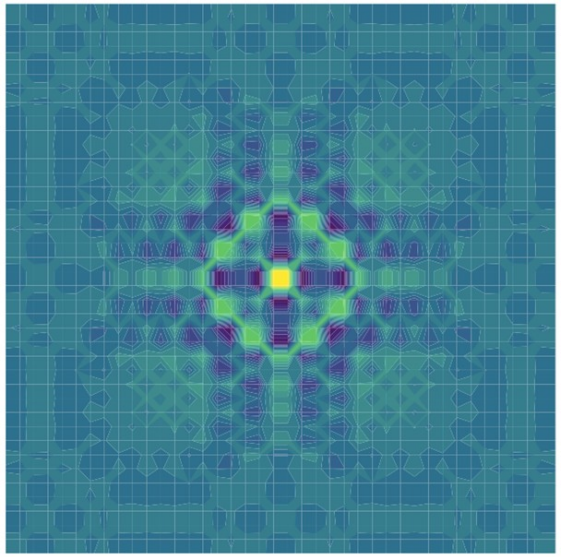
- Problems
  - Perceptually unordered
  - Perceptually nonlinear
- Benefits
  - Fine-grained structure visible and nameable
- Alternatives
  - Large-scale structure: fewer hues
  - Fine structure: multiple hues with monotonically increasing luminance





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

Viridis / Magma: sequential color

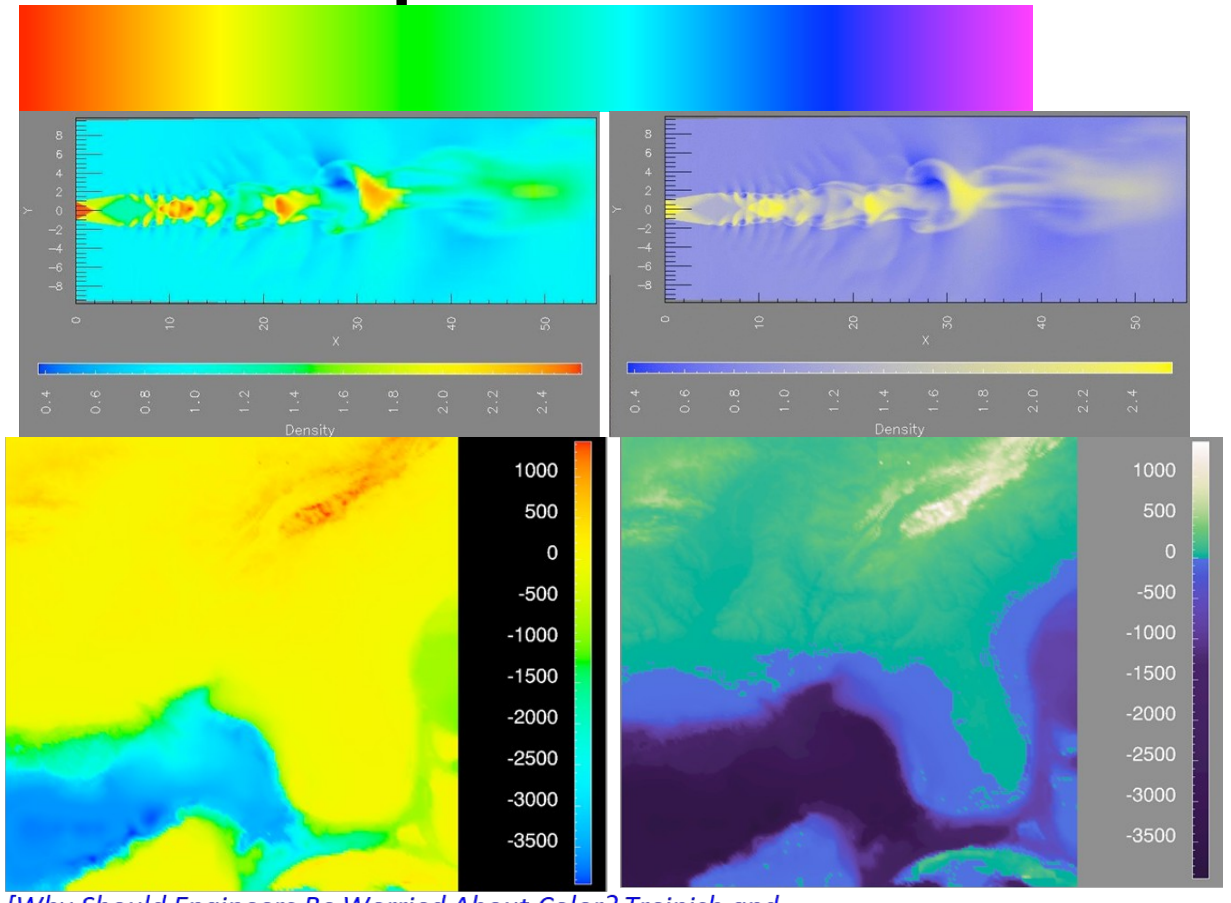


- Monotonically increasing luminance, perceptually uniform
- Colorful, colorblind
  n, D3

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

Ordered color: Rainbow is poor default

- 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
- Legit for categorical
  - Segmented saturated rainbow is good!



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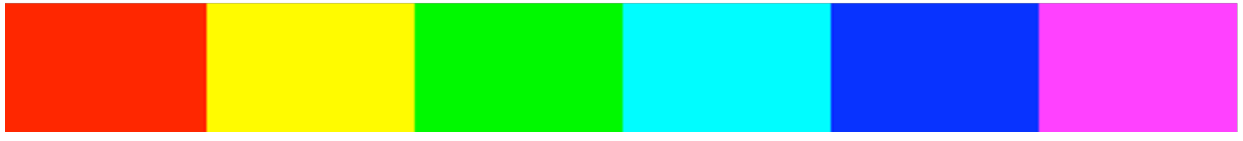
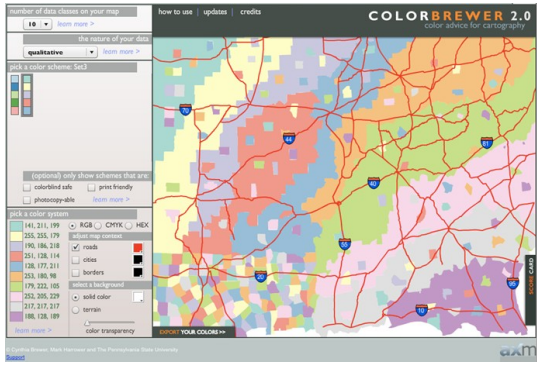
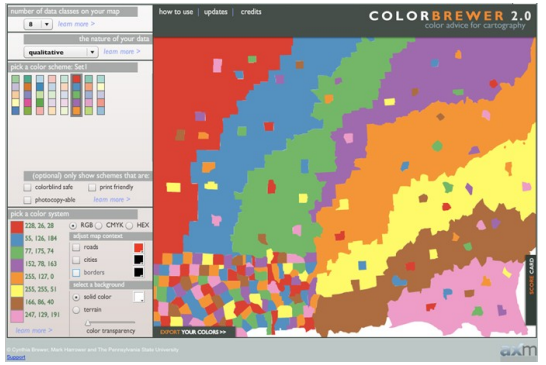


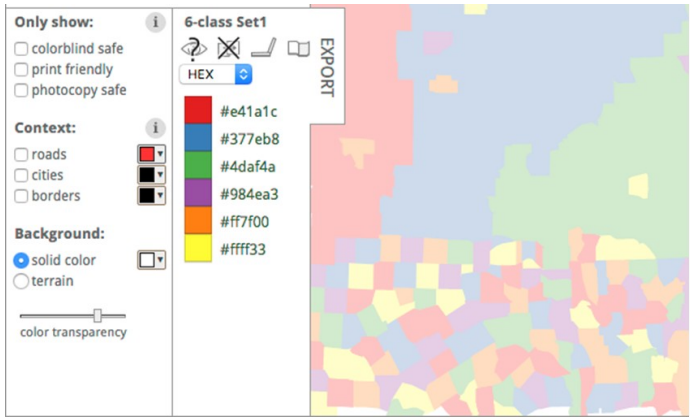
[Transfer Functions in Direct Volume Rendering: Design, Interface, Interaction. Kindlmann. SIGGRAPH 2002 Course Notes]

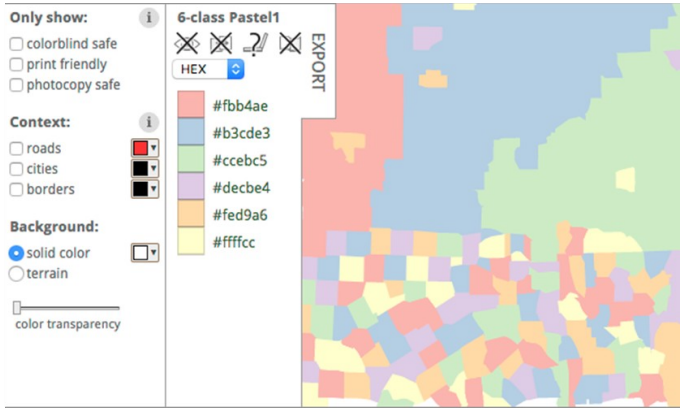
Interaction between channels: not fully separable

- Color channel interactions
  - Size heavily affects salience
  - Small regions need high saturation
  - Large regions low saturation
- Saturation and luminance
  - Not separable from each other
  - Also, not separable from transparency
  - Small separated regions: 2 bins safest (use only one of these channels), 3-4 bins max
  - Contiguous regions: many bins (use only one of these channels)









http://colorbrewer2.org/