Lecture 5: Color

Information Visualization
CPSC 533C, Fall 2009

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UBC Computer Science

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Papers Covered

Representing Colors as Three Numbers, Maureen Stone, IEEE CG&A 25(4):78-85, Jul 2005.
http://www.stonesc.com/pubs/Stone%20CGA%2007-2005.pdf

Ware, Chapter 3: Lightness, Brightness, Contrast, and Constancy

Ware, Chapter 4: Color

Tufte, Chapter 5: Color and Information

How Not to Lie with Visualization, Bernice E. Rogowitz and Lloyd A. Treinish, Computers In Physics 10(3) May/June 1996, pp 268-273.
http://www.research.ibm.com/dx/proceedings/pravda/truevis.htm

Further Reading

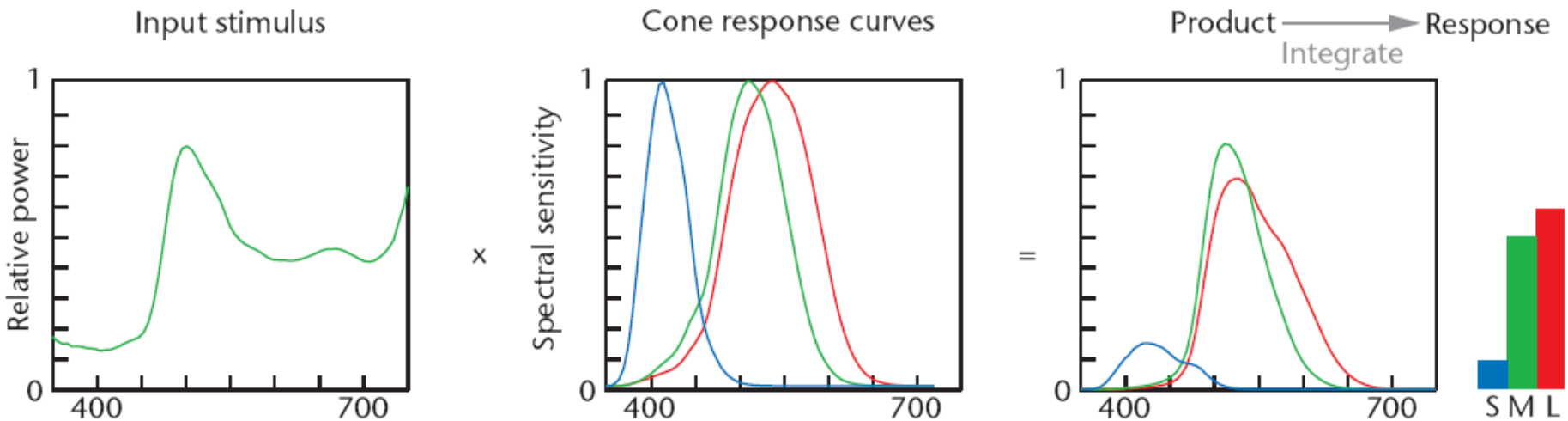
A Field Guide To Digital Color, Maureen Stone, AK Peters 2003.

Face-based Luminance Matching for Perceptual Colormap Generation. Gordon Kindlmann, Erik Reinhard, Sarah Creem. IEEE Visualization 2002. http://www.cs.utah.edu/~gk/papers/vis02

Color use guidelines for data representation. C. Brewer, 1999. http://www.personal.psu.edu/faculty/c/a/cab38/ColorSch/ASApaper.html

Trichromacy

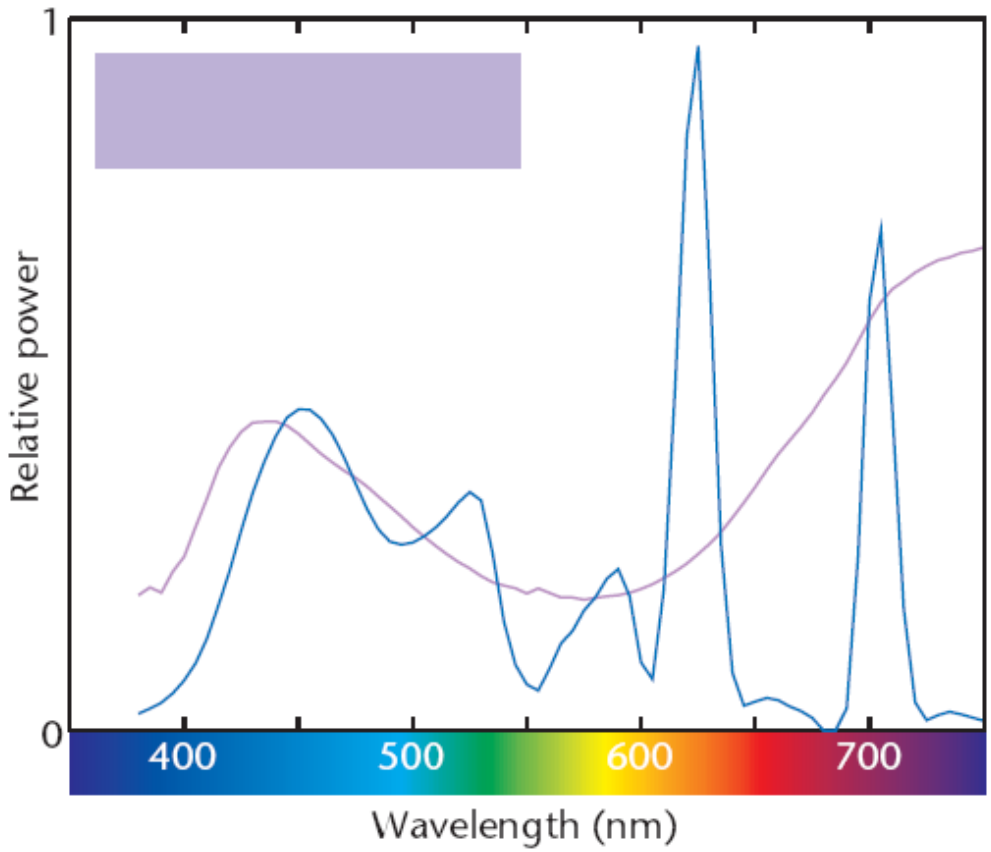
- different cone responses area function of wavelength
- for a given spectrum
  - multiply by response curve
  - integrate to get response



[Stone, Representing Color As Three Numbers, CG&A 25(4):78-85, www.stonesc.com/pubs/Stone%20CGA%2007-2005.pdf]

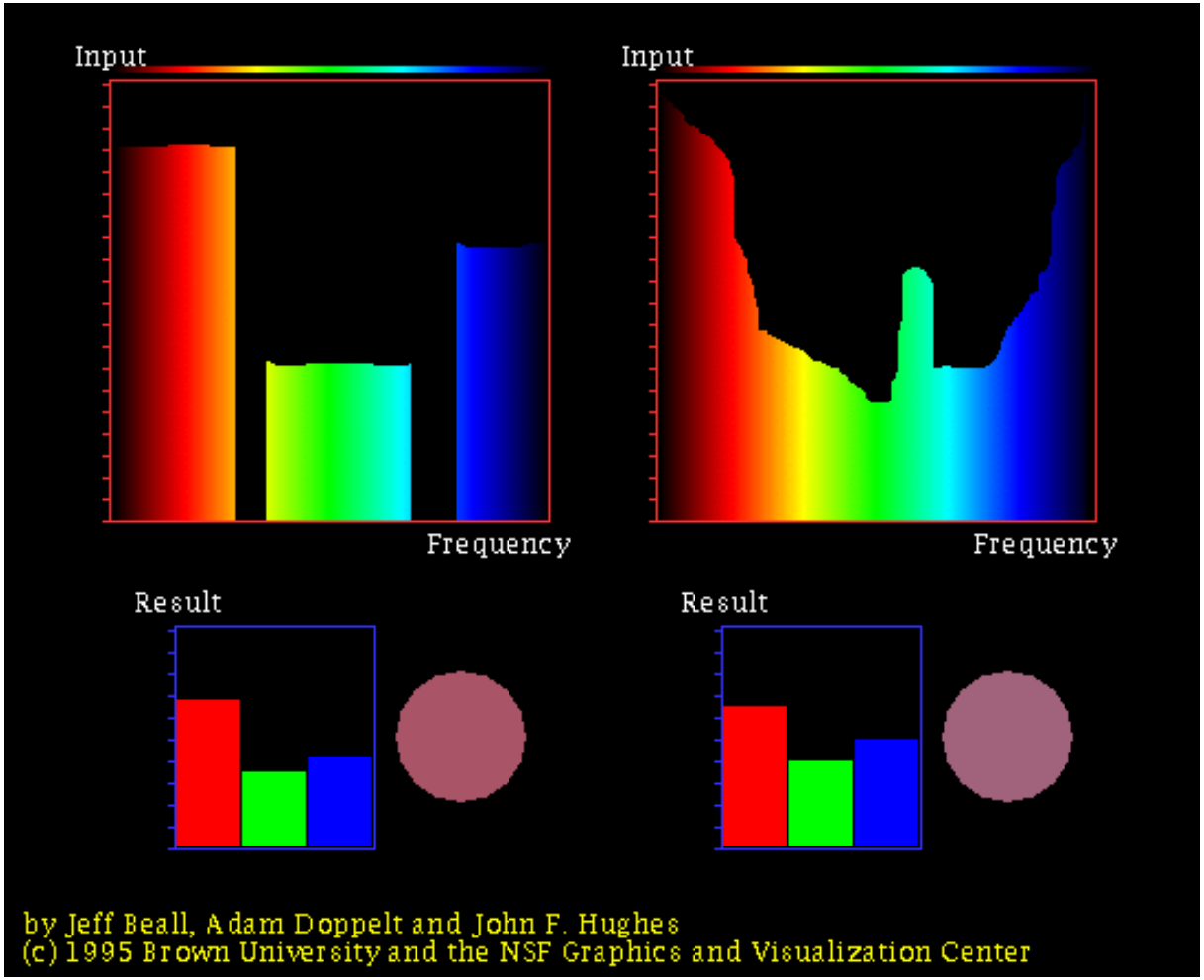
Metamerism

- brain sees only cone response
- different spectra appear the same



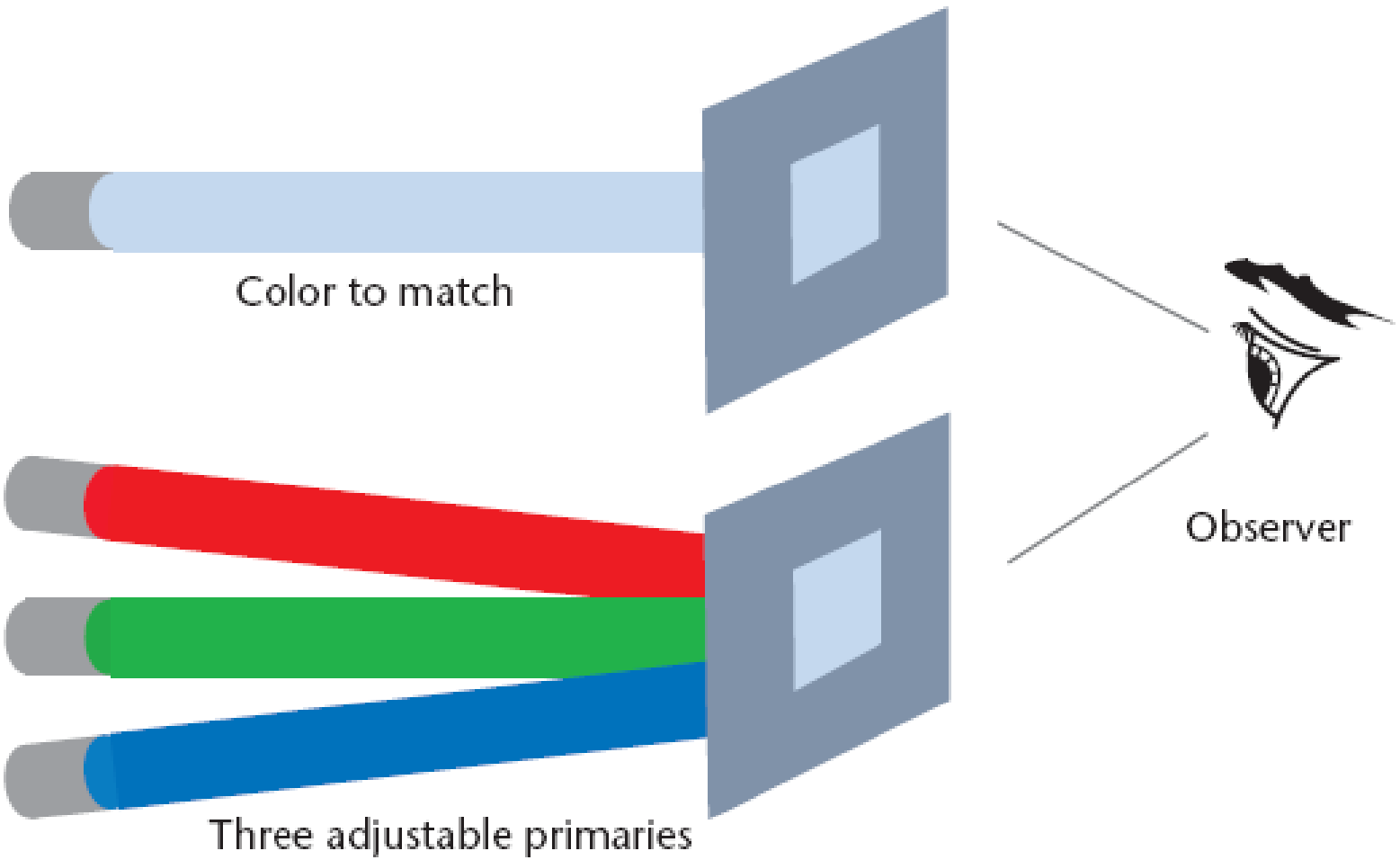
[Stone, Representing Color As Three Numbers, CG&A 25(4):78-85, www.stonesc.com/pubs/Stone%20CGA%2007-2005.pdf]

Metamerism Demo



[www.cs.brown.edu/exploratories/freeSoftware/repository/edu/brown/cs/exploratories/applets/spectrum/metamers_java_browser.html]

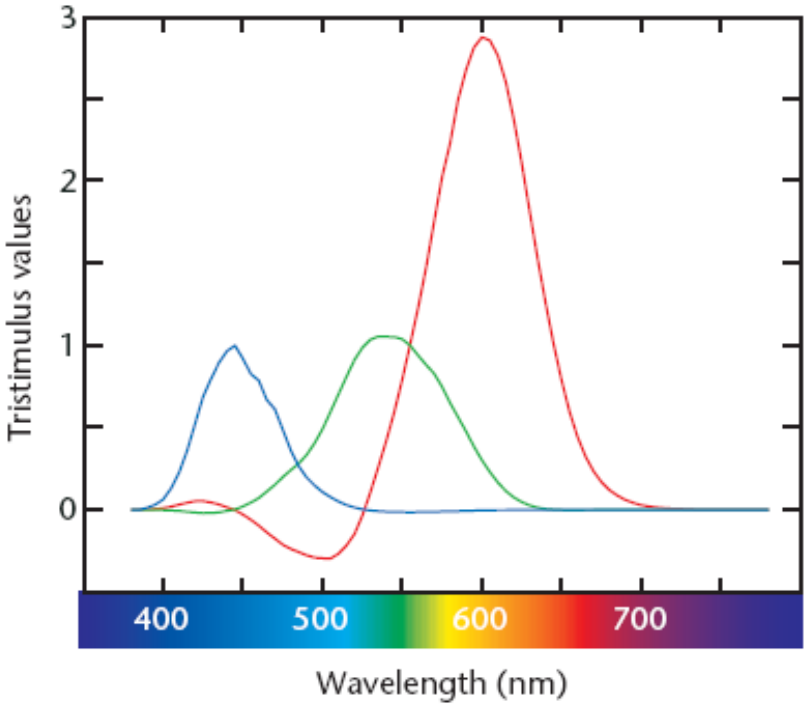
Color Matching Experiments



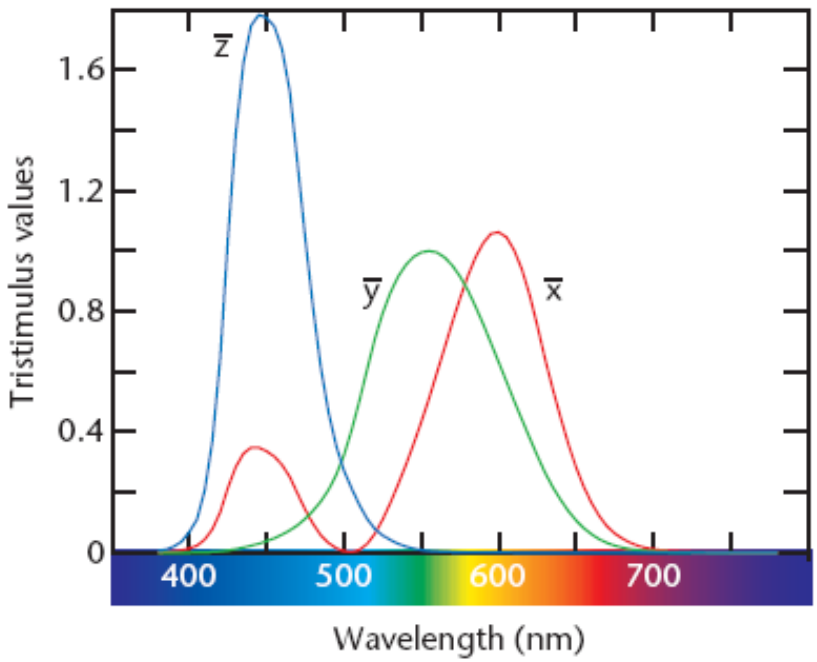
[Stone, Representing Color As Three Numbers, CG&A 25(4):78-85, www.stonesc.com/pubs/Stone%20CGA%2007-2005.pdf]

Color Matching Functions

Stiles-Burch, negative lobe

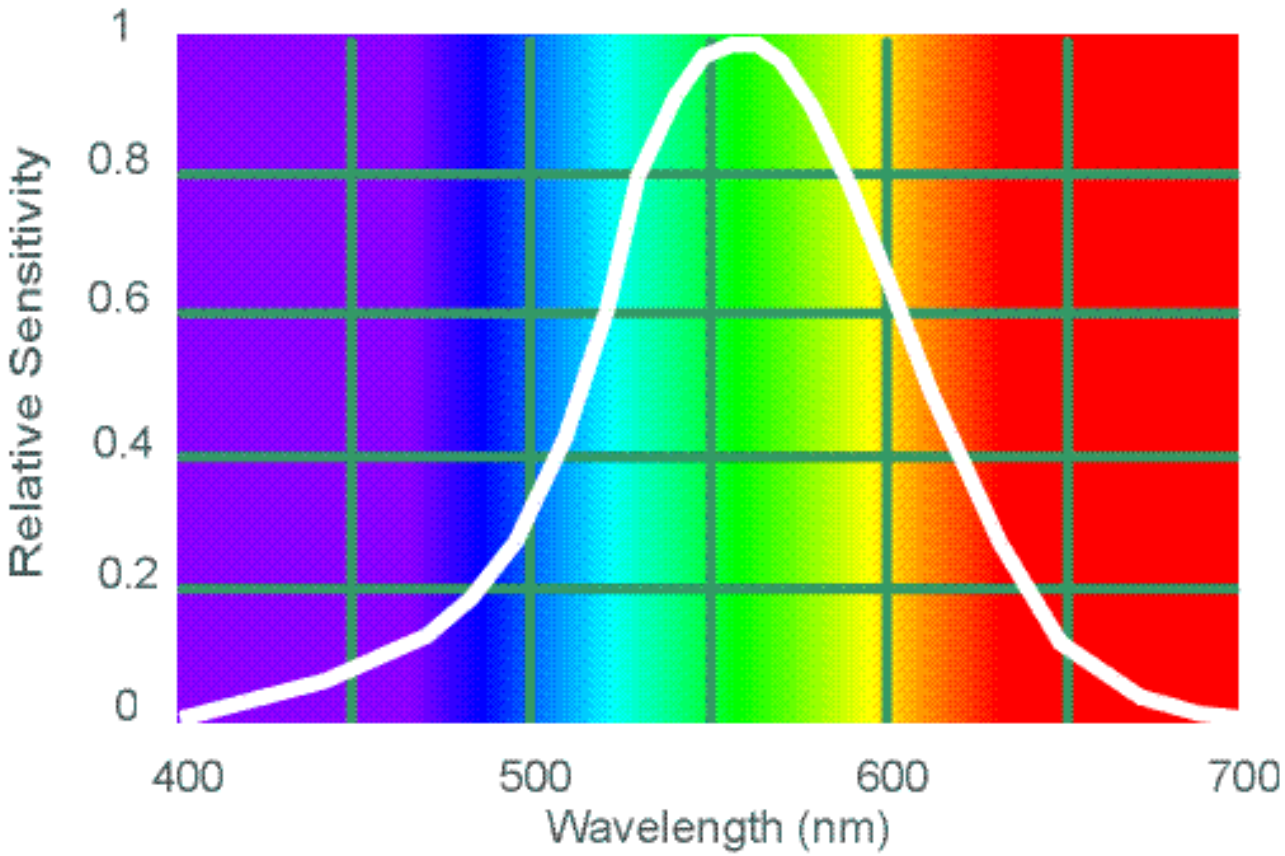


CIE standard, all positive



[Stone, Representing Color As Three Numbers, CG&A 25(4):78-85, www.stonesc.com/pubs/Stone%20CGA%2007-2005.pdf]

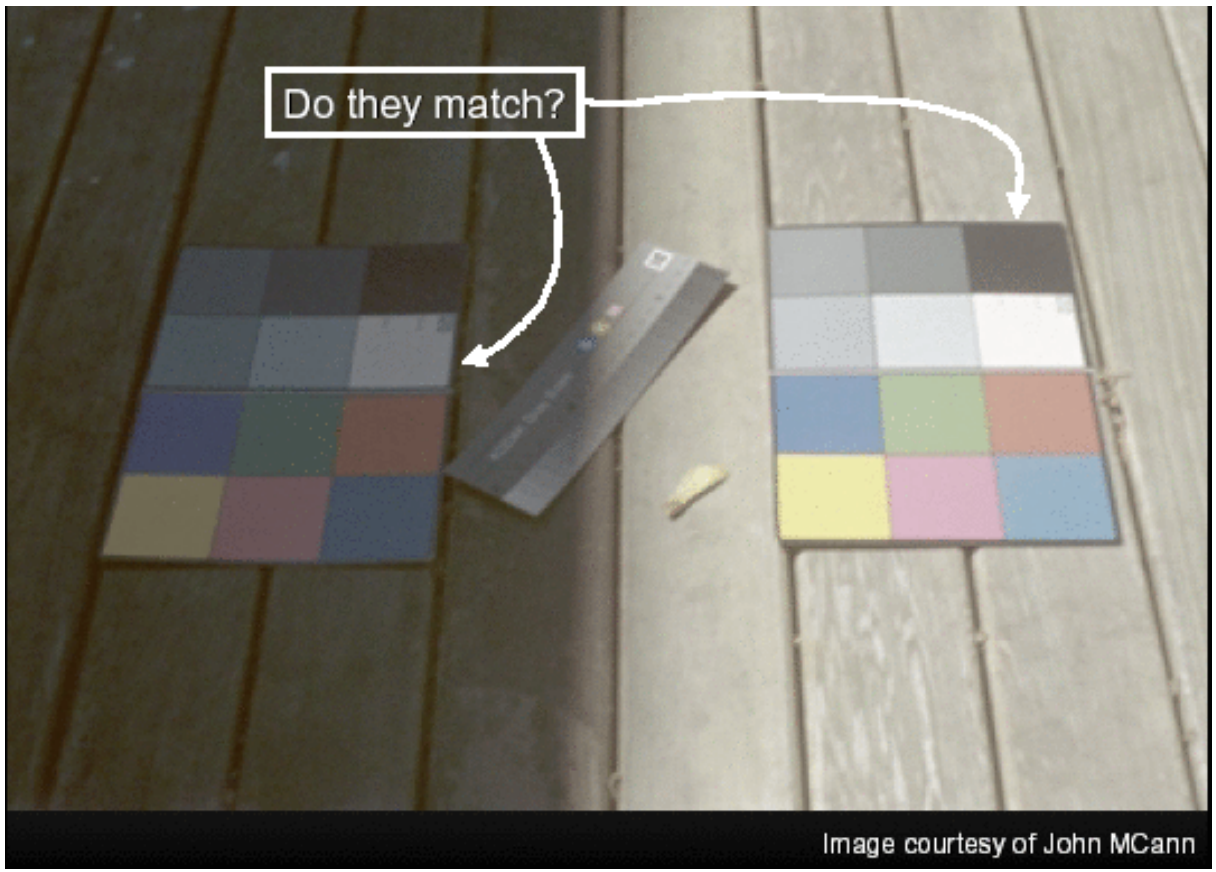
Spectral Sensitivity



[Joy of Visual Perception, Peter Kaiser. http://www.yorku.ca/eye/photopik.htm]

Color Constancy

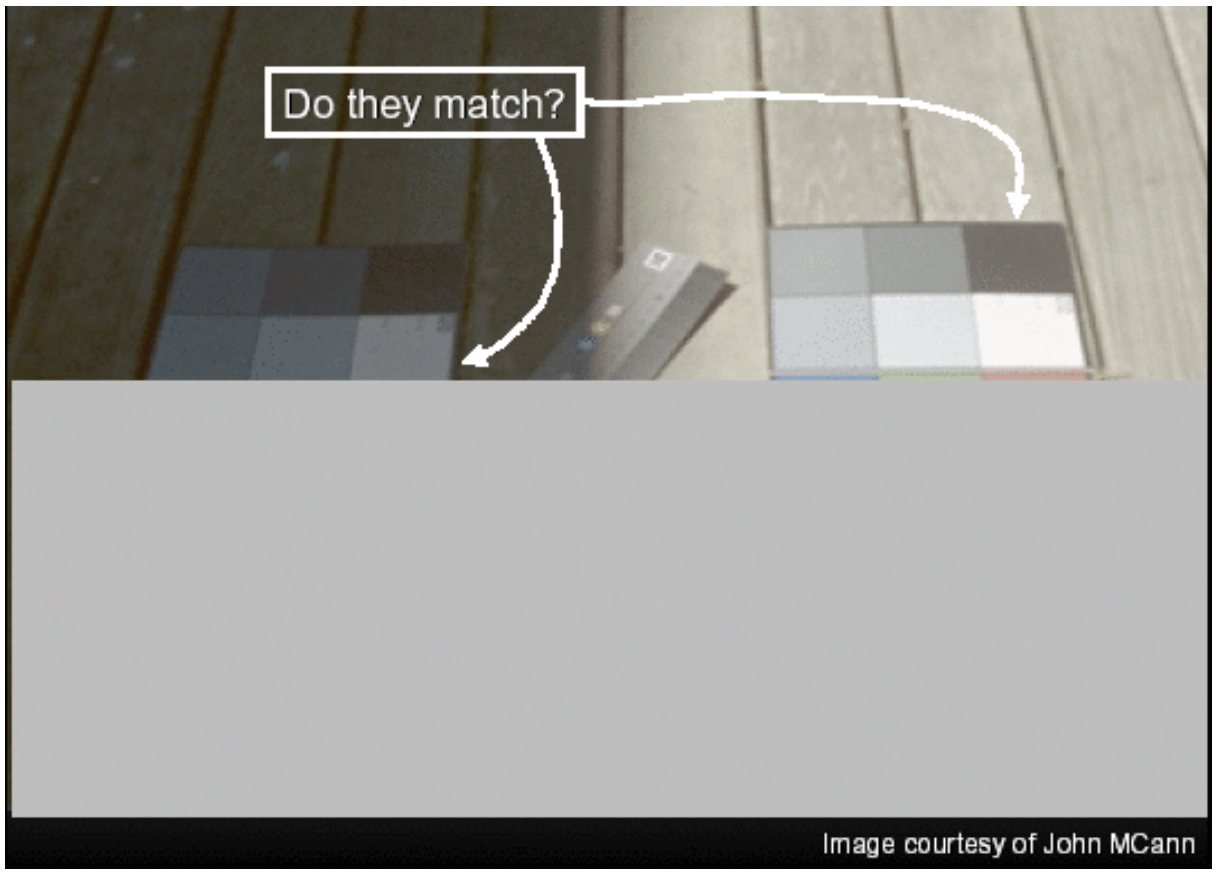
- relative judgements



[courtesy of John McCann, from Stone 2001 SIGGRAPH course graphics.stanford.edu/courses/cs448b-02-spring/04cdrom.pdf]

Color Constancy

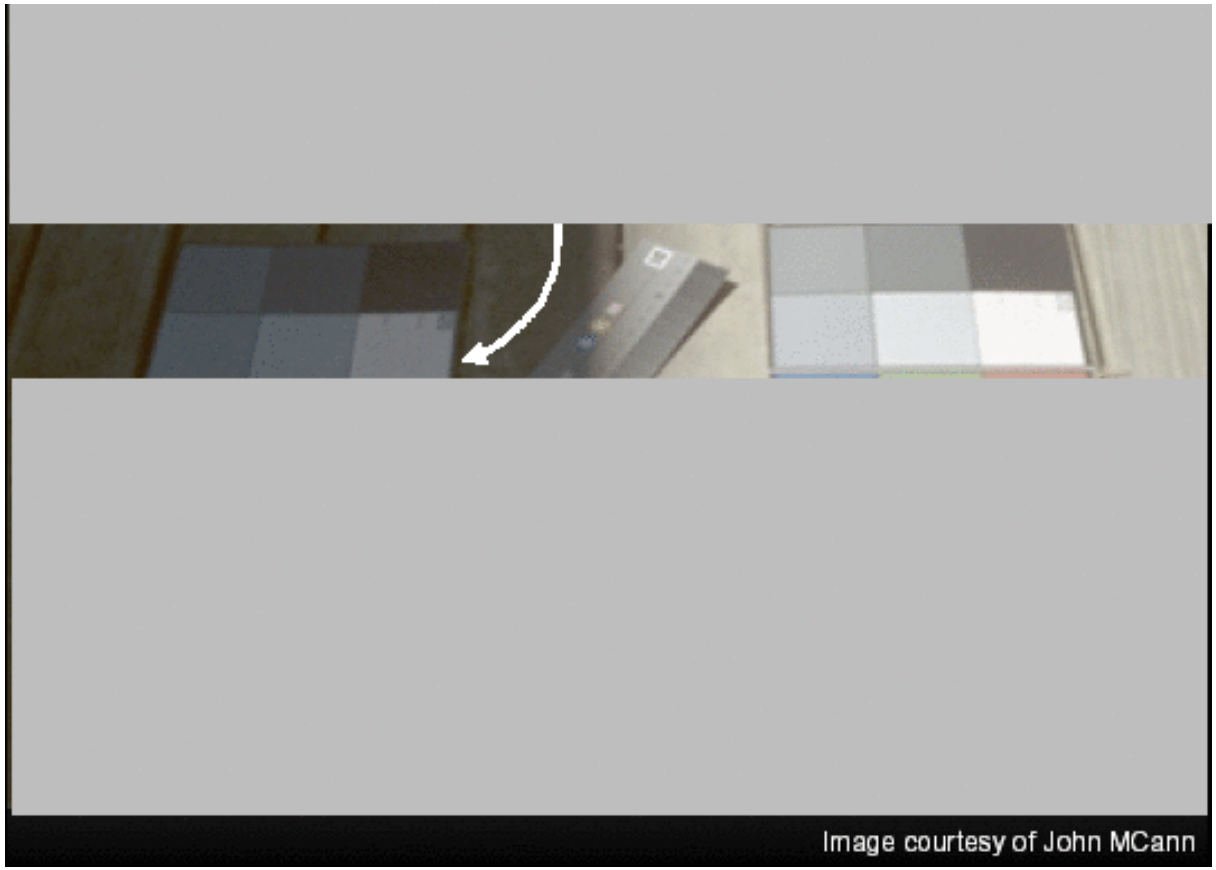
- relative judgements



[courtesy of John McCann, from Stone 2001 SIGGRAPH course graphics.stanford.edu/courses/cs448b-02-spring/04cdrom.pdf]

Color Constancy

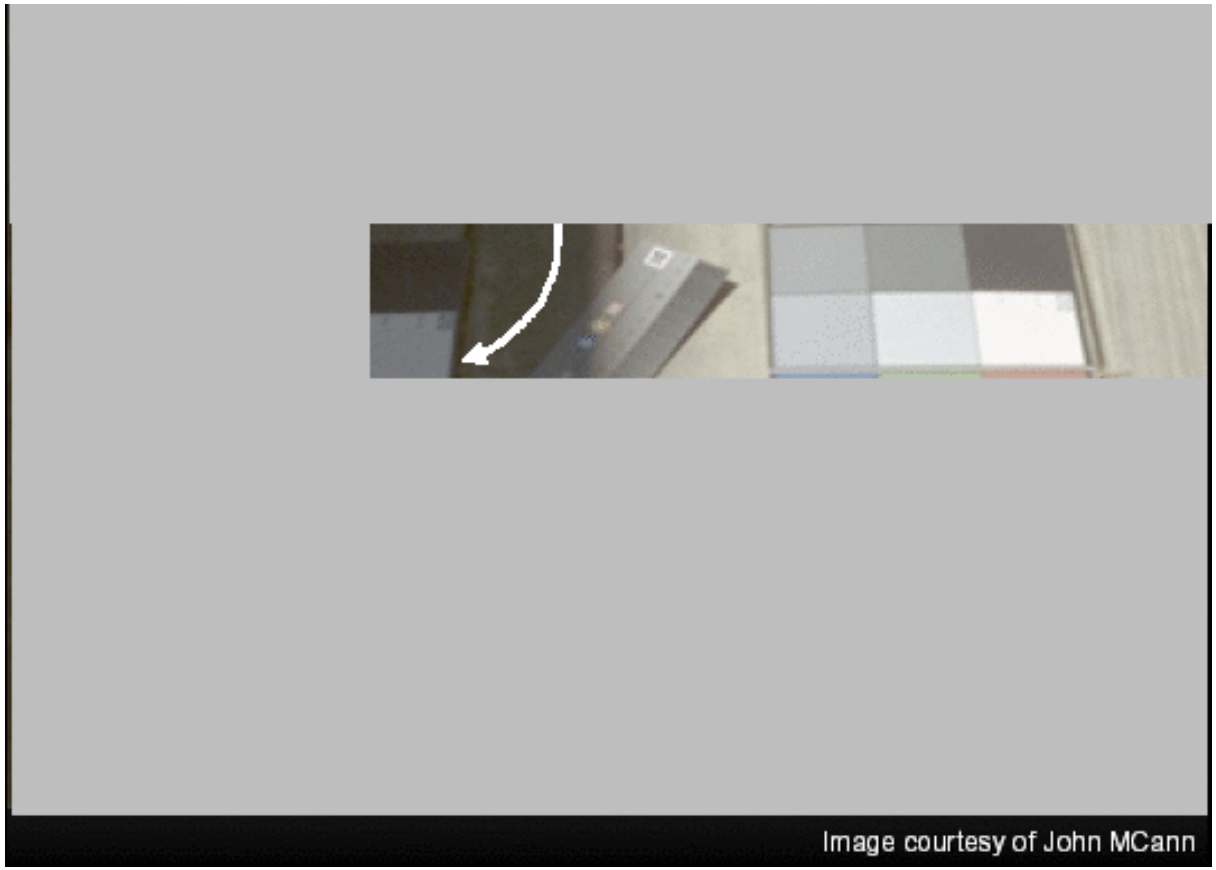
- relative judgements



[courtesy of John McCann, from Stone 2001 SIGGRAPH course graphics.stanford.edu/courses/cs448b-02-spring/04cdrom.pdf]

Color Constancy

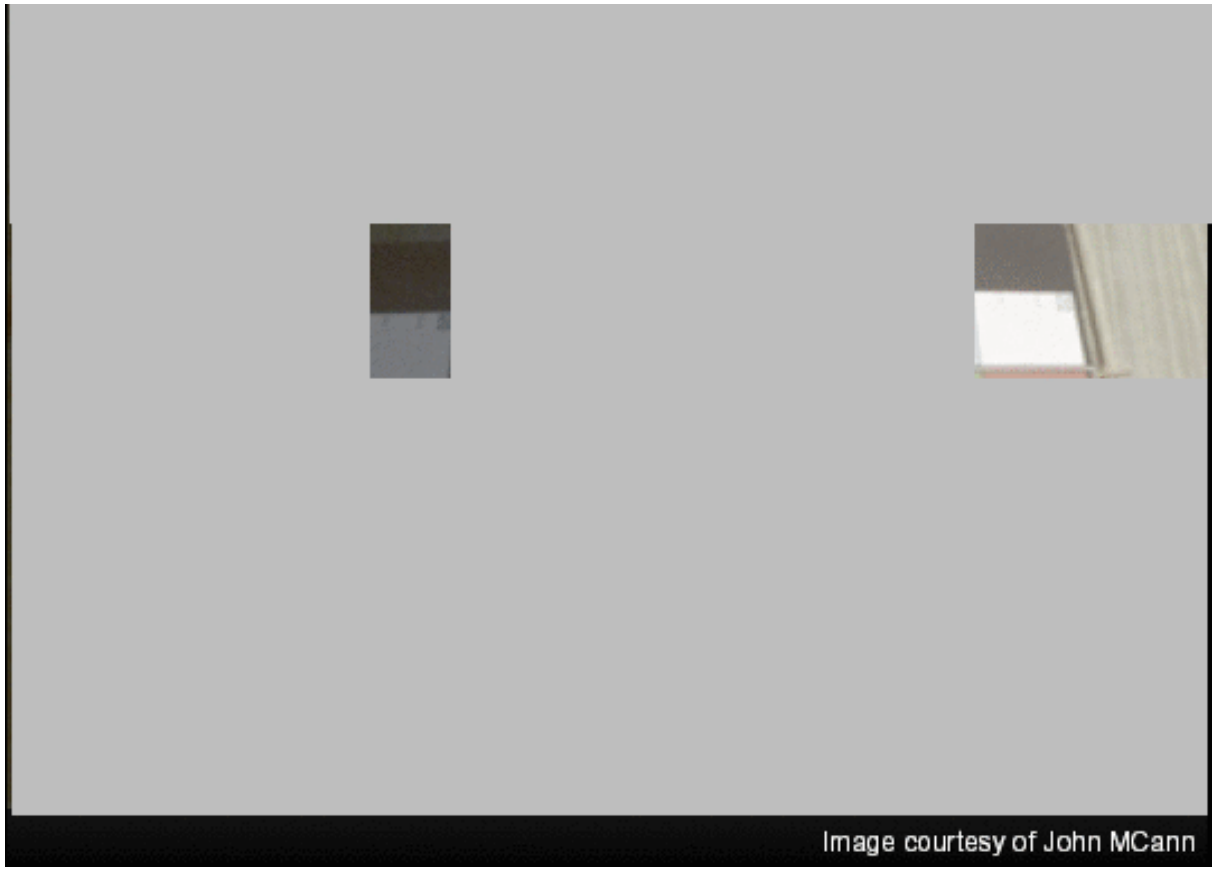
- relative judgements



[courtesy of John McCann, from Stone 2001 SIGGRAPH course graphics.stanford.edu/courses/cs448b-02-spring/04cdrom.pdf]

Color Constancy

- relative judgements



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Color Constancy

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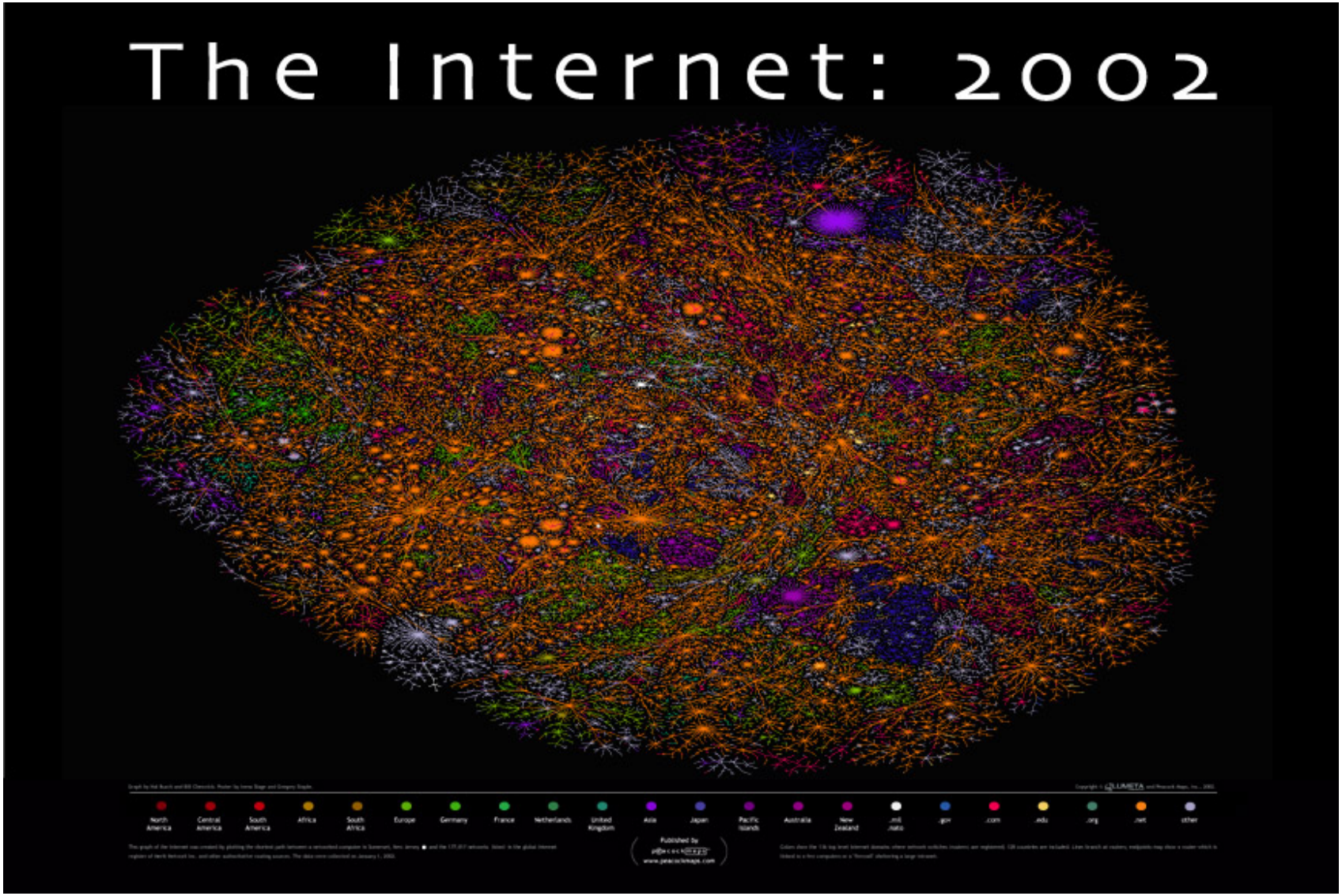
[courtesy of John McCann, from Stone 2001 SIGGRAPH course graphics.stanford.edu/courses/cs448b-02-spring/04cdrom.pdf]

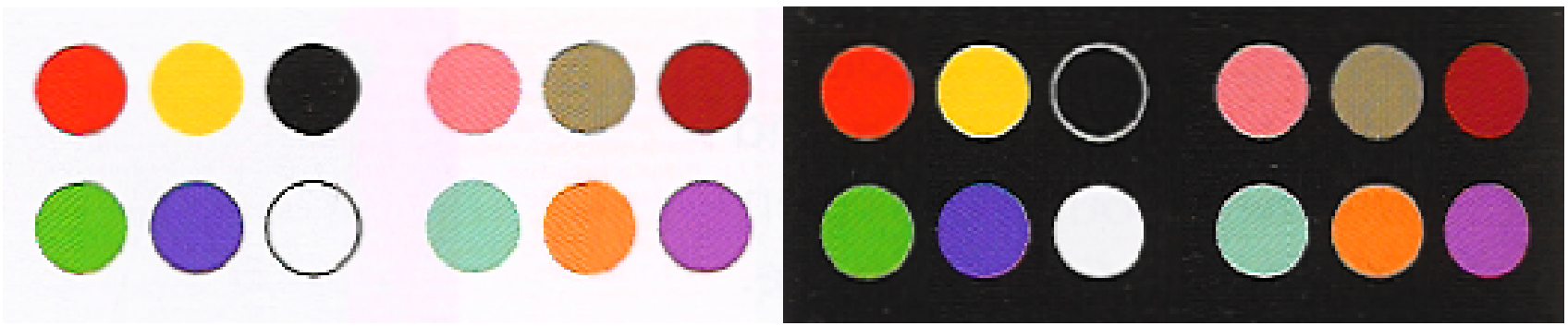
Coloring Categorical Data

22 colors, but only 8 distinguishable 



Coloring Categorical Data

- discrete small patches separated in space
- limited distinguishability: around 8-14
  - channel dynamic range: low
  - choose bins explicitly for maximum mileage
- maximally discriminable colors from Ware
  - maximal saturation for small areas

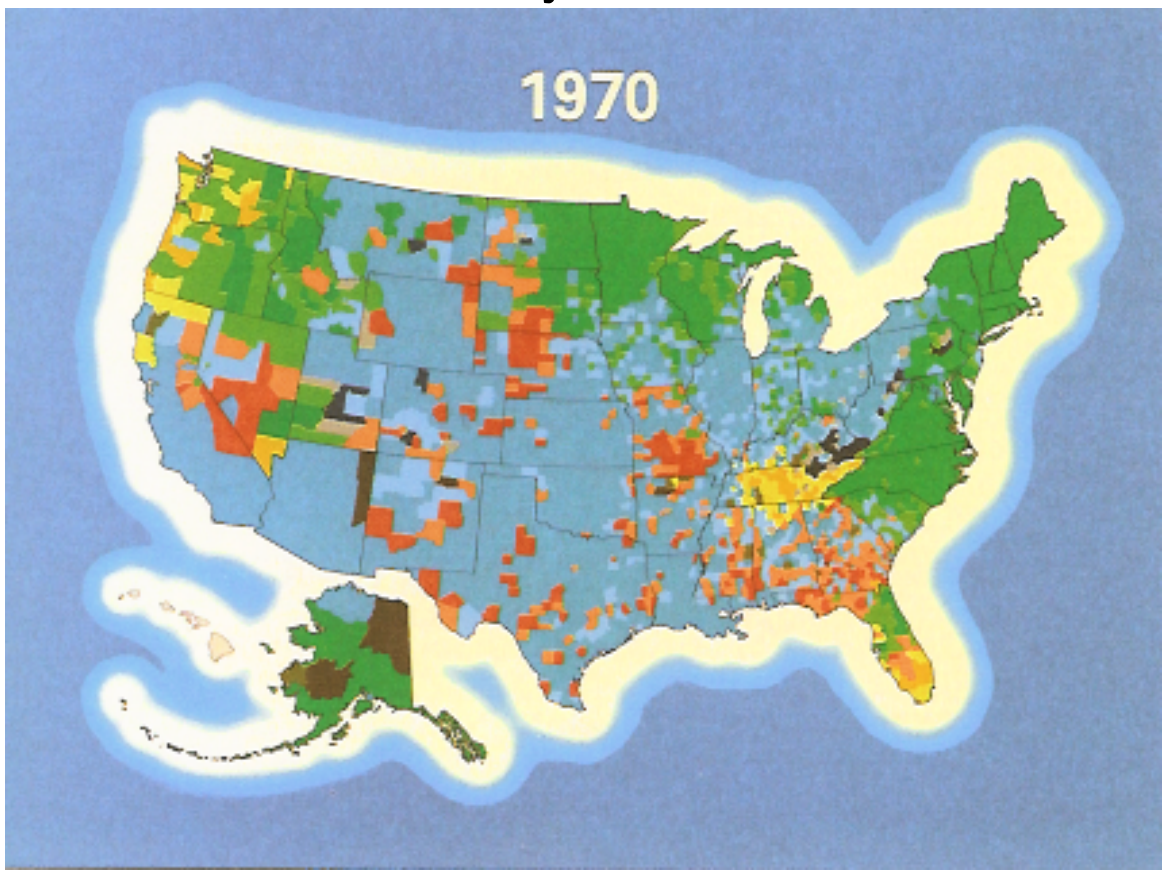


[Colin Ware, Information Visualization: Perception for Design. Morgan Kaufmann 1999. Figure 4.21]

Minimal Saturation For Large Areas

- avoid saturated color in large areas

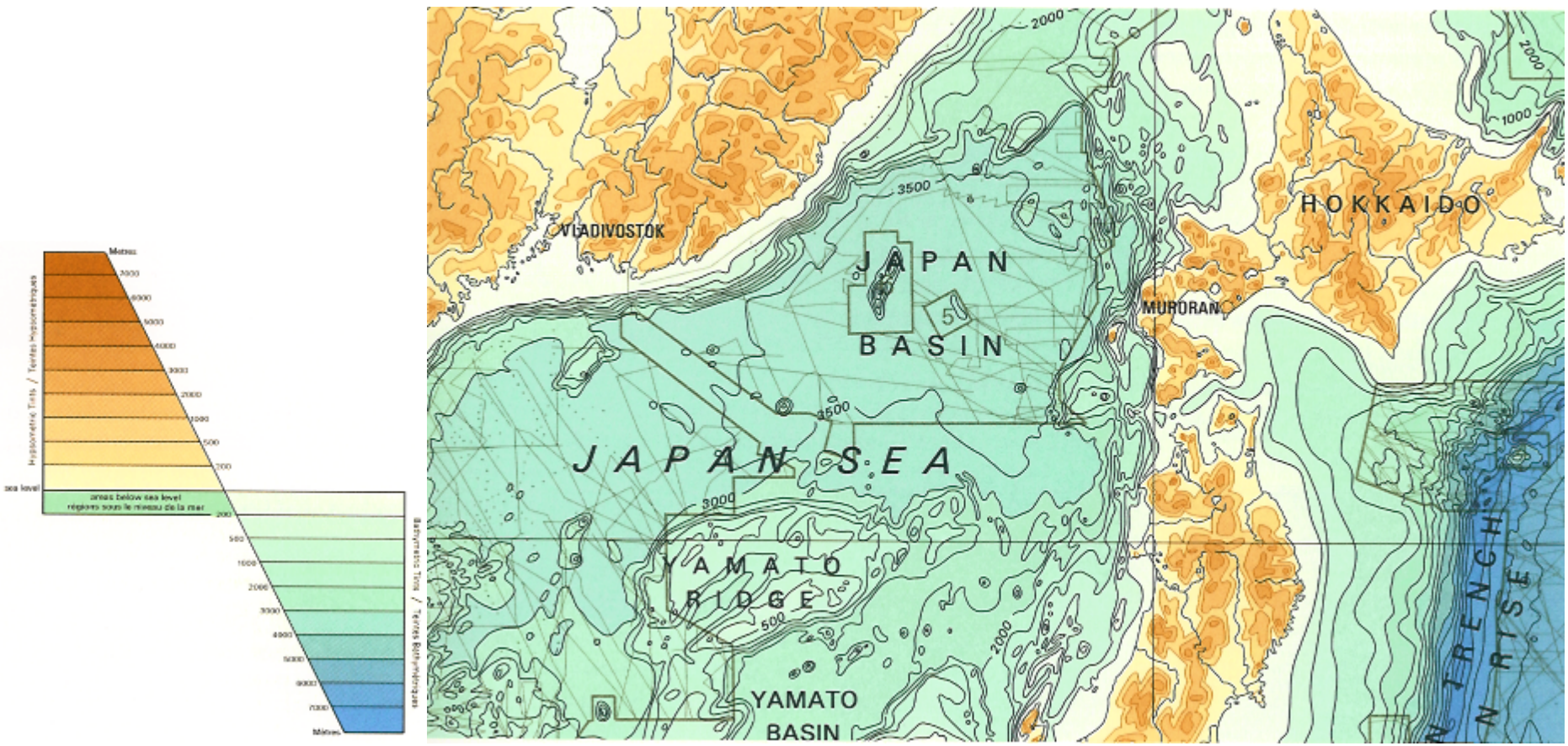
"excessively exuberant"



[Edward Tufte, Envisioning Information, p.82] [Colin Ware, Information Visualization: Perception for Design. Morgan Kaufmann 1999. Figure 4.20]

Minimal Saturation For Large Areas

- large continouous areas in pastel
  - diverging colormap (bathymetric/hypsometric)

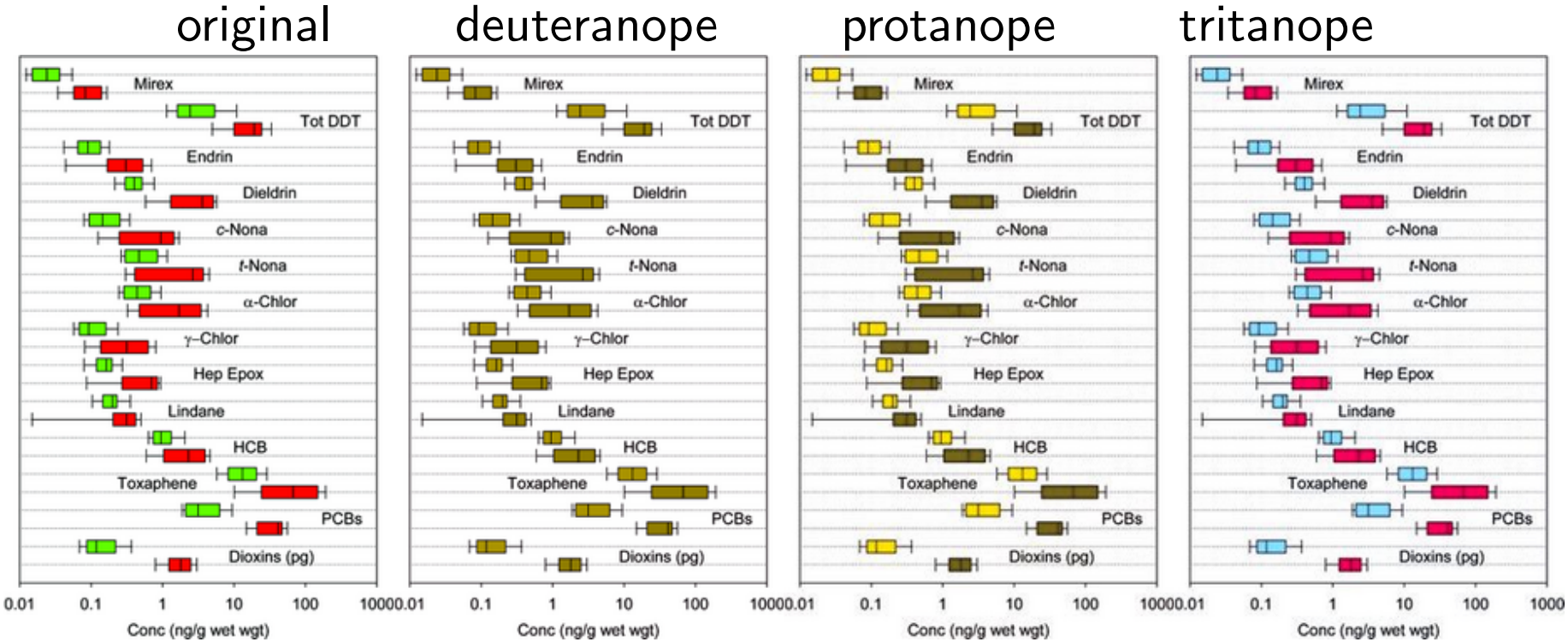


[Tufte, Envisioning Information, p. 91]

Color Deficiency

- deutanope
- protanope
  - has red/green deficit
  - 10% of males!
- tritanope
  - has yellow/blue deficit
- http://www.vischeck.com/vischeck
  - test your images
  - **use this with your final projects!**

Color Deficiency Examples: vischeck

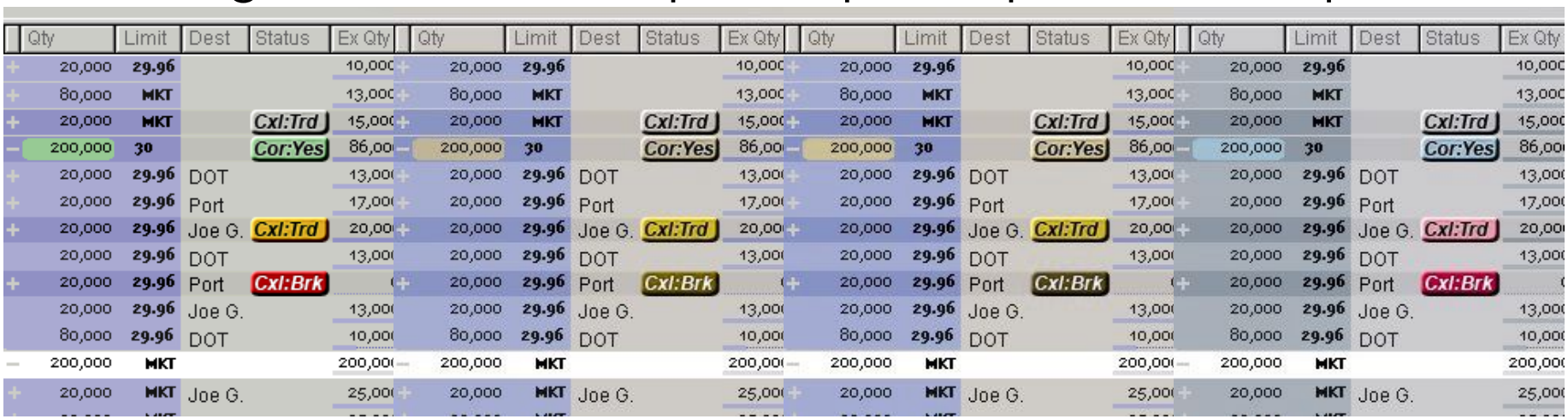


[www.cs.ubc.ca/∼tmm/courses/cpsc533c-04-spr/a1/dmitry/533a1.html, citing Global Assessment of Organic Contaminants in Farmed Salmon, Hites et al, Science 2004 303:226-229.]

Designing Around Deficiencies

- red/green could have domain meaning
- then distinguish by more then hue alone
  - redundantly encode with saturation, brightness

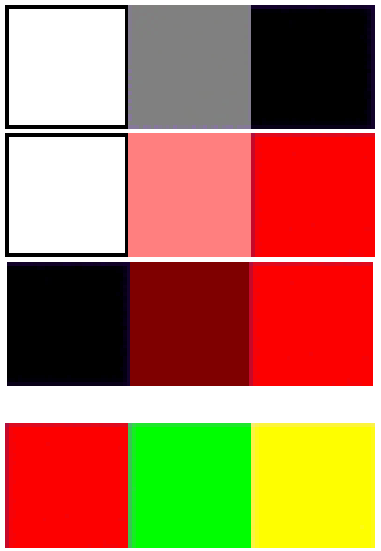
original deuteranope protanope tritanope



[Courtesy of Brad Paley]

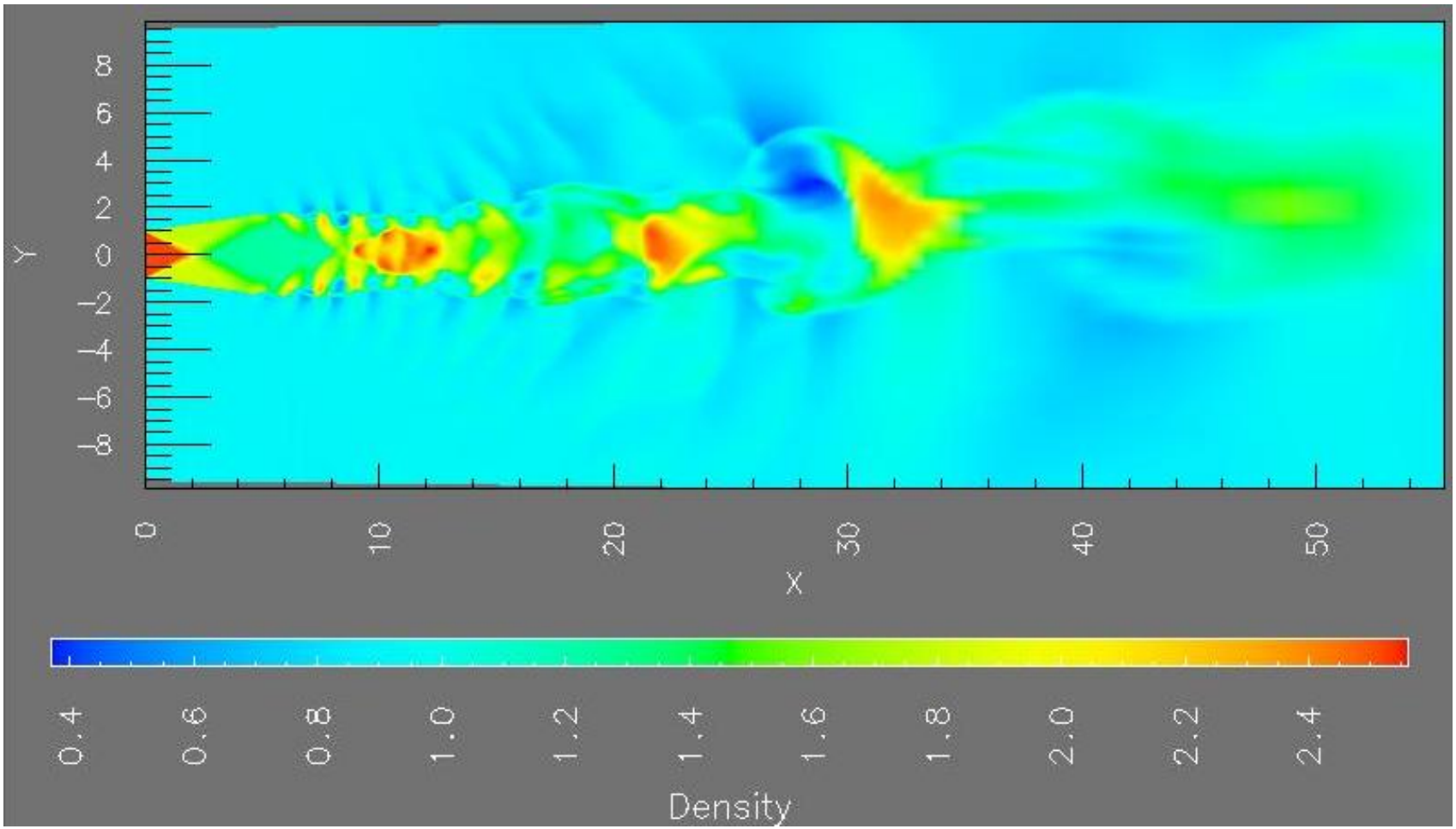
Coloring Ordered Data

- innate visual order
  - greyscale/luminance
  - saturation
  - brightness
- unclear visual order
  - hue



Rainbow Colormap Advantages

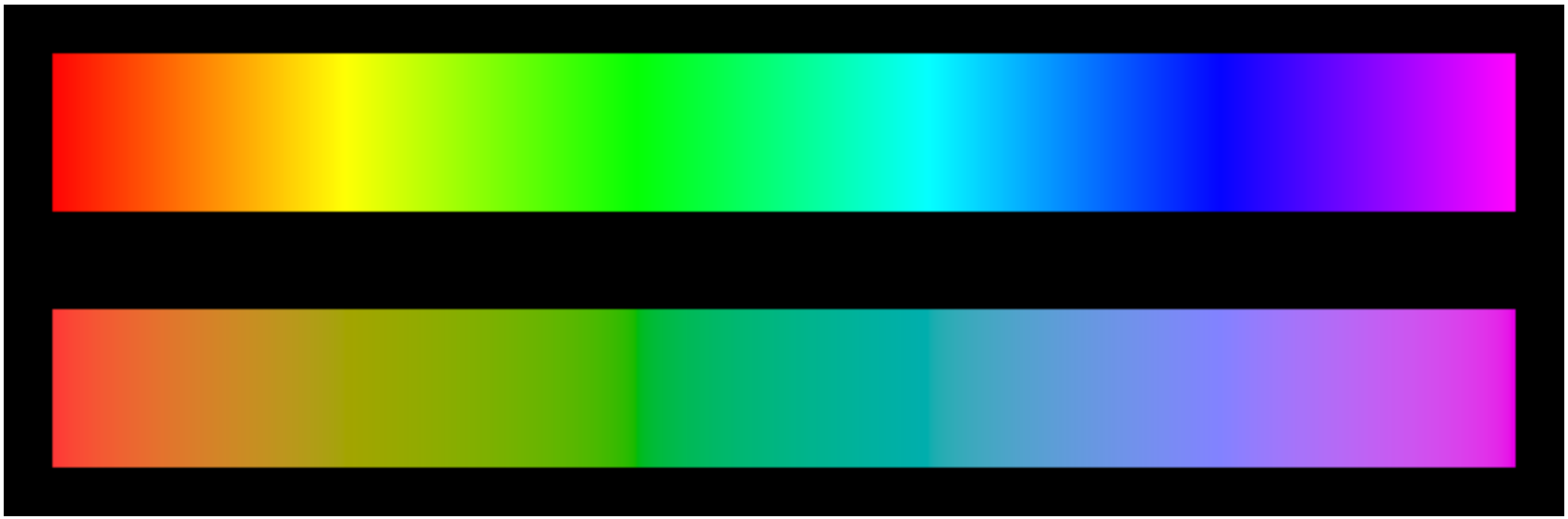
- low-frequency segmentation
  - the red part, the orange part, the green part, ...



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

Rainbow Colormap Disadvantages

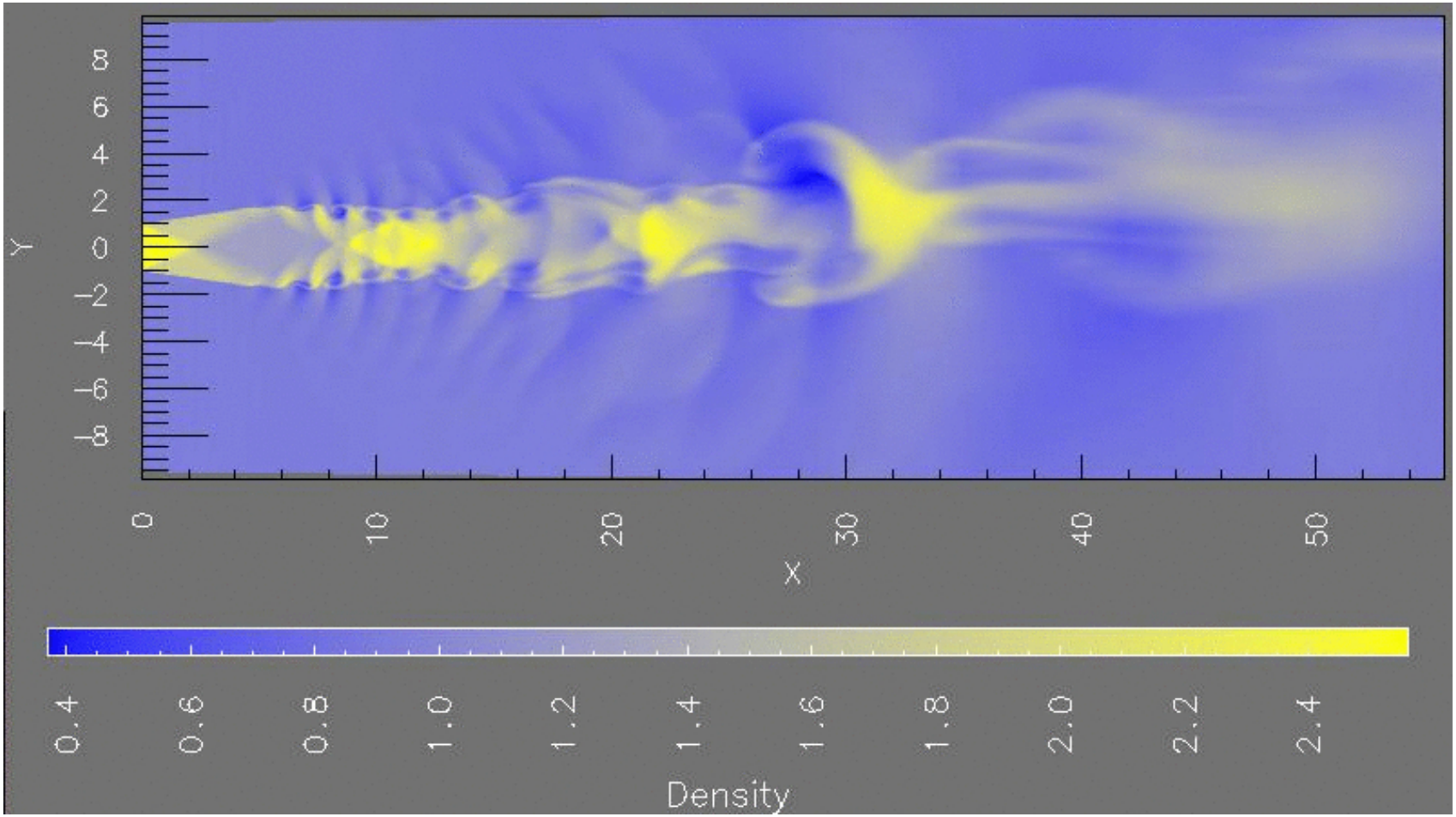
- segmentation artifacts
  - popular interpolation perceptually nonlinear!
- one solution: create perceptually linear colormap
  - but lose vibrancy



[Kindlmann, Reinhard, and Creem. Face-based Luminance Matching for Perceptual Colormap Generation. Proc. Vis 02 www.cs.utah.edu/ gk/lumFace]

Non-Rainbow Colormap Advantages

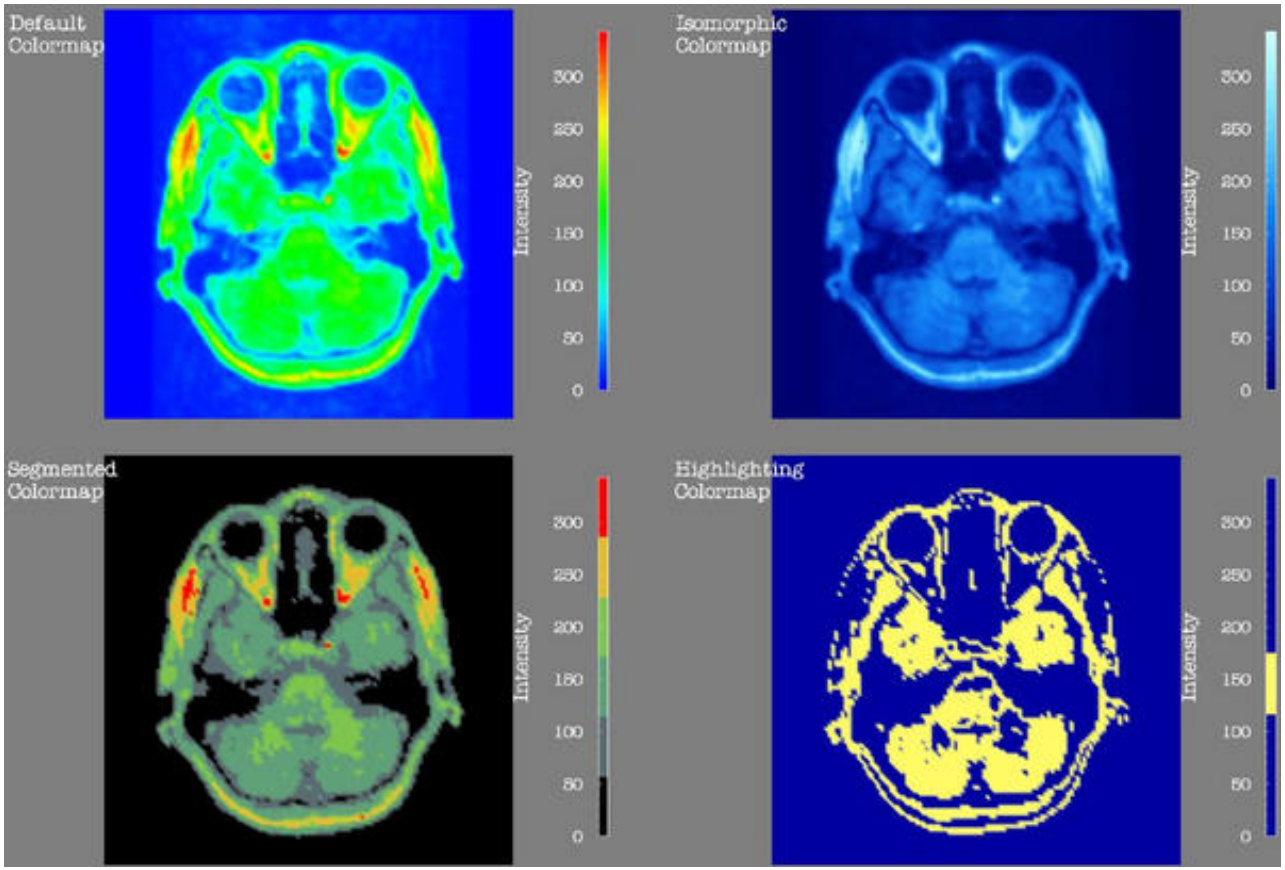
- high-frequency continuity
  - interpolating between just two hues



[Rogowitz and Treinish, How NOT to Lie with Visualization, www.research.ibm.com/dx/proceedings/pravda/truevis.htm]

Segmenting Colormaps

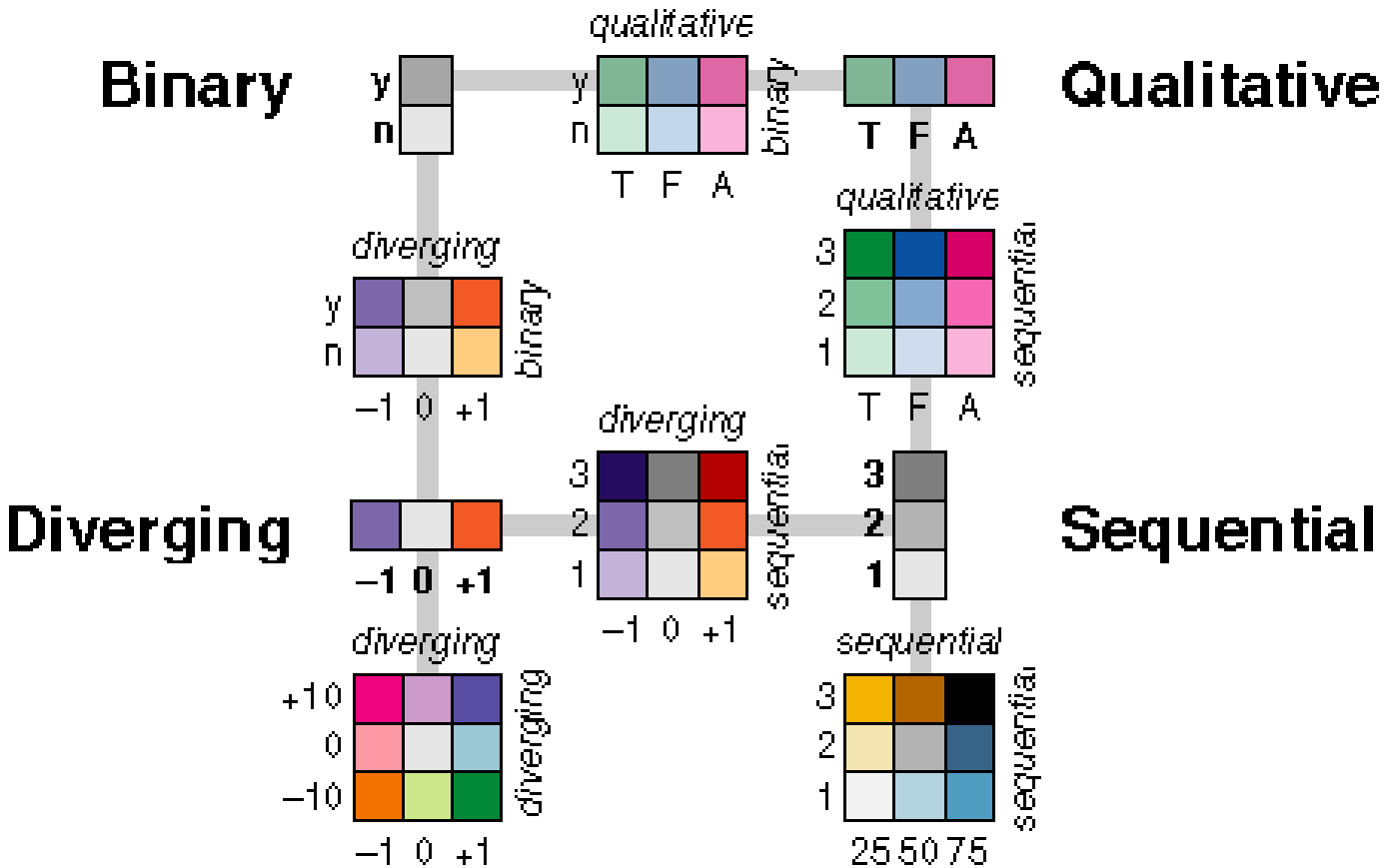
- explicit rather than implicit segmentation



[Rogowitz and Treinish, How NOT to Lie with Visualization, www.research.ibm.com/dx/proceedings/pravda/truevis.htm]

Cartographic Color Advice, Brewer

- http://www.colorbrewer.org



[Brewer, www.personal.psu.edu/faculty/c/a/cab38/ColorSch/Schemes.html]