Geography 360
Principles of Cartography

April 24, 2006

Outlines

1. Principles of color
   - Color as physical phenomenon
   - Color as physiological phenomenon
2. How is color specified? (color model)
   - Hardware-oriented
   - User-oriented
3. How do we effectively use color in map design?

1. Principles of color

- Color as physical phenomenon
  - Electromagnetic energy
  - Spectral reflectance curve
- Color as physiological phenomenon
  - Human vision
  - Theories of color perception

Color as physical phenomenon

- Perceiving color requires three elements: light source, object, and eye-brain system of the viewer
- When light strikes the map some of that light is reflected back to the eye of the map reader
- Color is the physical phenomenon of light, perceived by human eyes, associated with various wavelengths in the electromagnetic spectrum

Different color hues have difference spectral reflectance curves across wavelength

Spectral reflectance curves

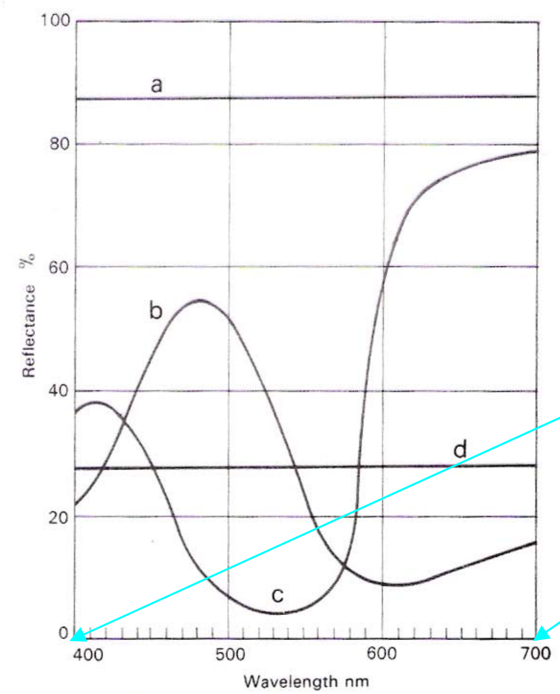
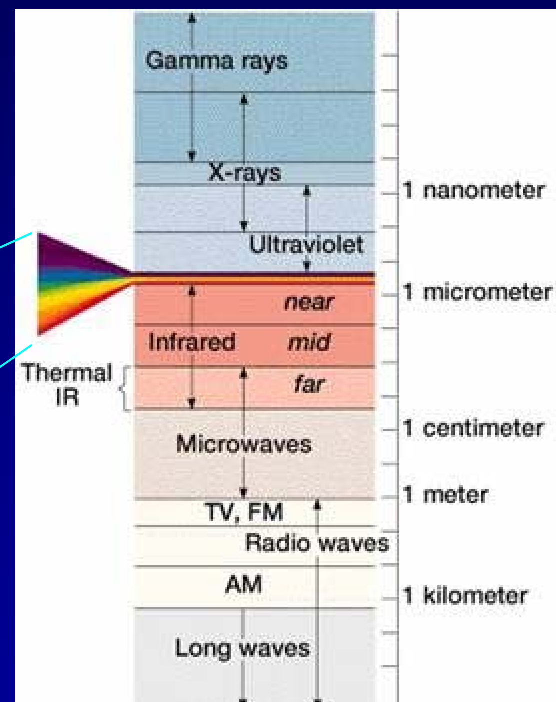


FIGURE 8.2 Four spectral reflectance curves: (A) a white surface; (B) a "greenish blue" ink; (C) a "red-purple" ink; and (D) a dark gray surface. (Curves B and C after Nimeroff.)

Electromagnetic energy

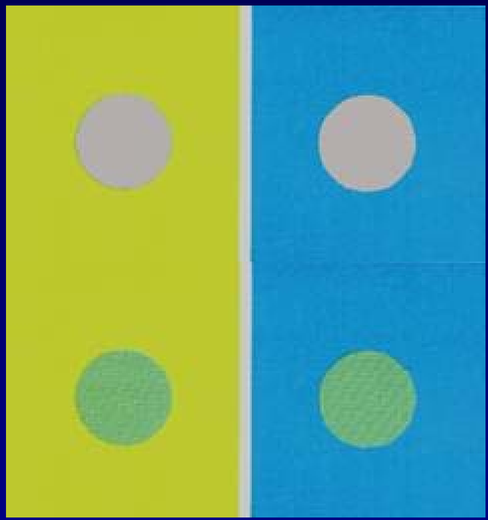


See Figure 10.2

Color as physiological phenomenon Theories of color perception

- Trichromatic theory
  - Three kinds of cones (in retina) sensitive to particular wavelengths: short (blue), medium (green), and long (red) (see Figure 10.3, 10.5)
  - Color perception is a function of the relative stimulation of the three types of cones
- Opponent-process theory
  - Color perception is based on a lightness-darkness channel and two opponent color channels: red-green and blue-yellow (see Figure 10.6)
  - We do not perceive mixtures of red and green or blue and yellow, but rather red and blue or red and yellow

Simultaneous contrast



See Figure 10.7

- The appearance of any color in a display depends on the colors that surround it
- This is an artifact of the way our brain interprets color, thus cannot be photographed
- Apparent color of an area will tend to shift toward the opponent color of the surrounding color
  - When the surround is green, the gray tone appears reddish; in contrast, when the surround is blue, the gray tone appears yellowish
- Physiological limitations of human vision
  - Any implication for map design?

2. How is color specified?

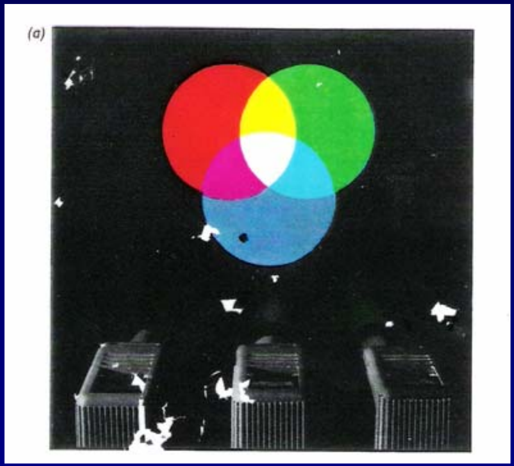
- Hardware-oriented
  - How color is produced
  - RGB model
  - CMYK model

- User-oriented
  - How color is perceived
  - HSV model
  - Munsell model

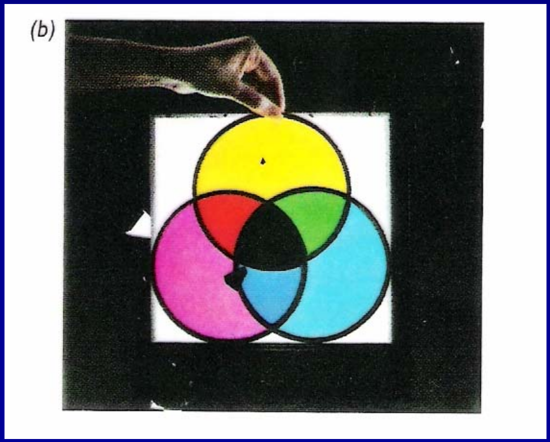
How is color produced?

See color plate 10.1

- Color additive process
  - Operative when *lights* of different colors are superimposed
  - Soft-copy color maps



- Color subtractive process
  - Operative when *dyes* of different colors are superimposed
  - Hard-copy color maps



The RGB model

- Colors are specified based on the intensity of red, green, and blue color guns
- See Figure 10.16 (p. 192)
- Related to the method of softcopy color production (see Figure 10.10 and 10.15: computer monitors use RGB guns or subpixels)
- Common notions of hue, saturation, and lightness are not inherent to the model
- Equal steps in the RGB color space do not correspond to equal visual steps

The CMYK model

- Colors are specified based on the portion of cyan, magenta, yellow, and black dyes
- Related to hardcopy color production
- Shares the same limitation as the RGB model (i.e. lack of direct linkage to human perception of color)

How color is perceived
Psychological dimensions of color

- Desert island experiment: let's classify the pebbles by color
  - green, yellow, gray, white, dark blue, light blue, brilliant blue, dusky blue…
- Human perception of color consists of hue, saturation (chroma), and value (lightness)
- **Hue**: names for psychological experiences of particular electromagnetic wavelengths
- **Saturation**: addition of a neutral gray to a hue
- **Value**: addition of white or black to a hue

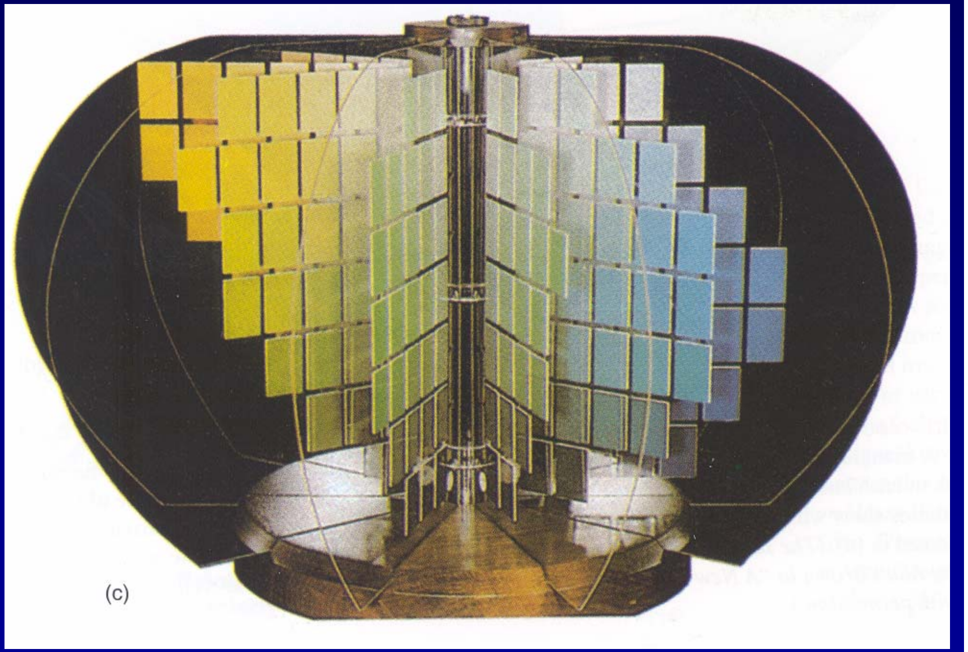
The HSV model

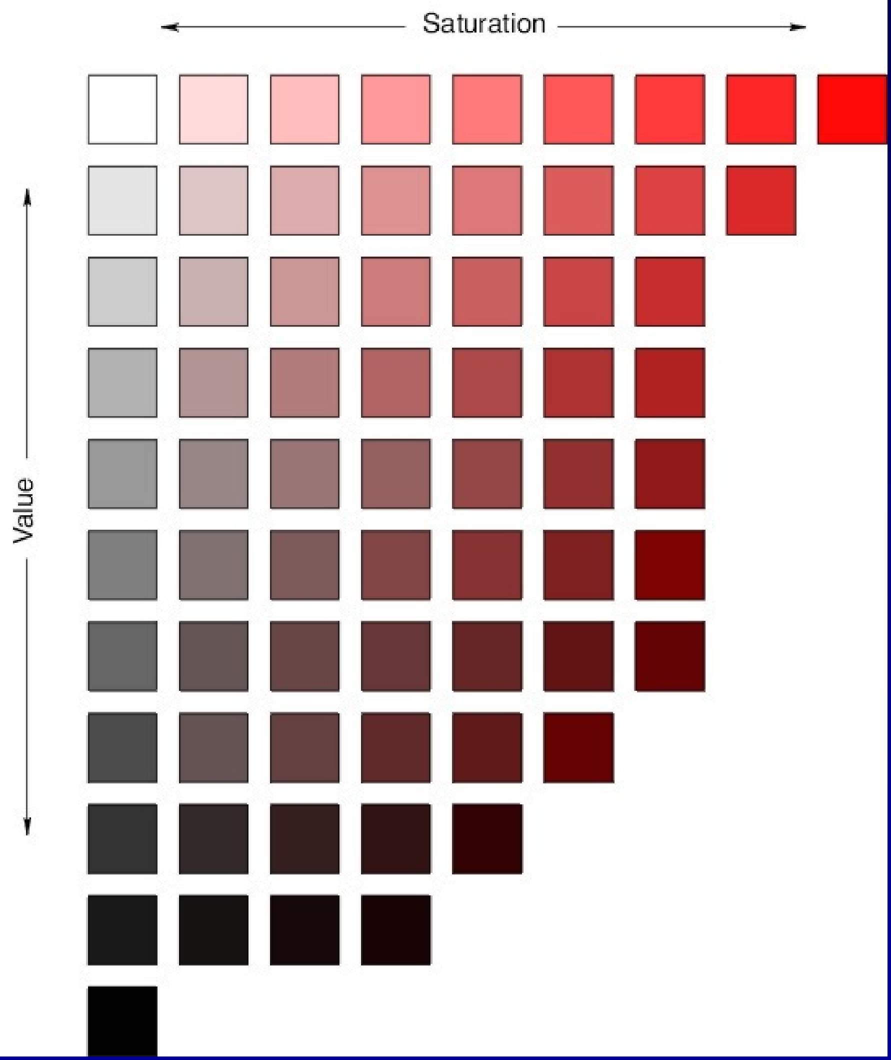
- Figure 10.17 shows how HSV is organized
- Hue at the base of the hexcone
- Saturation changes occur as you move from the center (lowest; grayscale) to the edge of the cone (highest; most saturated; pure)
- Value changes occur as you move from the base of the cone (highest; white) to the apex of the cone (lowest; black) along the vertical axis
- Color perception does not take a symmetric form as suggested by the HSV model (e.g. is the value of the lightest possible green equal to that of the lightest possible red as suggested by the model?) In other words, the HSV does not adopt perceptual scaling

The Munsell model

- See Color plate 10.3, Figure 10.18, 10.19
- Similar to the HSV model in that it consists of hue, saturation, and value
- Different from the HSV model in that it is asymmetrical (because it is perceptual based)

The Munsell model is perceptual based





The Munsell model

	Hue	Value	Saturation (Chroma)
Dimen sion	Plane of color wheel	Vertical axis	Horizontal axis
Scaling	10 letter designation 10 number division within each letter designation (e.g. 1R, 5G)	0 to 10 (darkest to lightest) upward	0 to 16 (lest to most saturated) outward
Figure	Figure 10.19	Figure 10.18	Figure 10.18

- Notation: H V/C 5R 5/14

3. Color use in map design

- Color that reflects intellectual hierarchy
- Color that reflects data measurement
- Color that makes the use of its symbolic connotations and conventions
- Color that takes into account human limitations of color perception
- Color that takes into account preferences, age, and vision impairment

Color that reflects intellectual hierarchy

- Organize map elements hierarchically by visually rendering relative importance of map elements
- Choose a set of distinctive colors corresponding to map elements with varying intellectual hierarchies
- The distinctive color will be distant from other colors along three dimensions of color models
- Good use of color for enhancing visual hierarchy
  - Most saturated vs. least saturated (blue and white)
- Poor use of color for enhancing visual hierarchy
  - Similar hue with the same level of saturation (pink and red)

Color for visual hierarchy

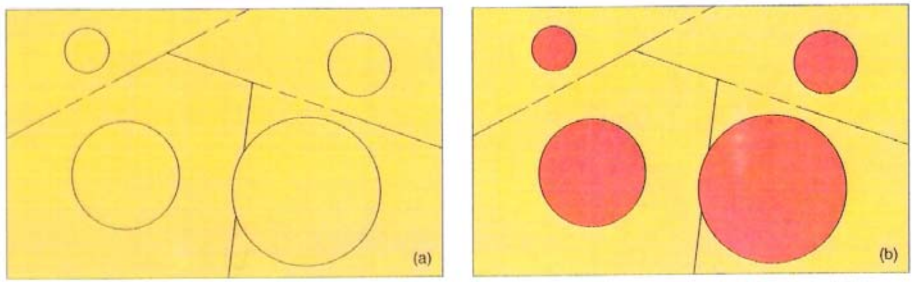
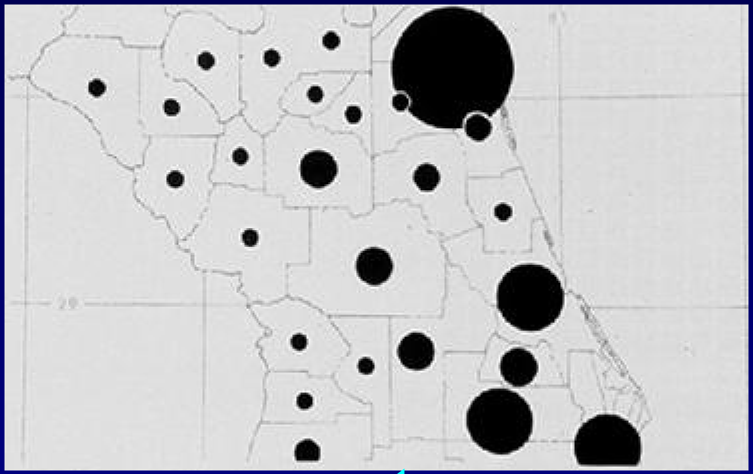


Plate 5 Color and figure-ground development.
Effective use of hue differences can enhance the figure-ground relationship on maps. In the example shown, the proportional symbols in (b) are clearly more visually dominant than those in (a).



- Using the same color hue for figure and ground does not render varying intellectual hierarchy
- Using the different color hue for figure and ground renders varying intellectual hierarchy where the color for figure is visually more dominant
- Using the different color value for figure and ground helps map readers separate figure from ground

Color for visual hierarchy

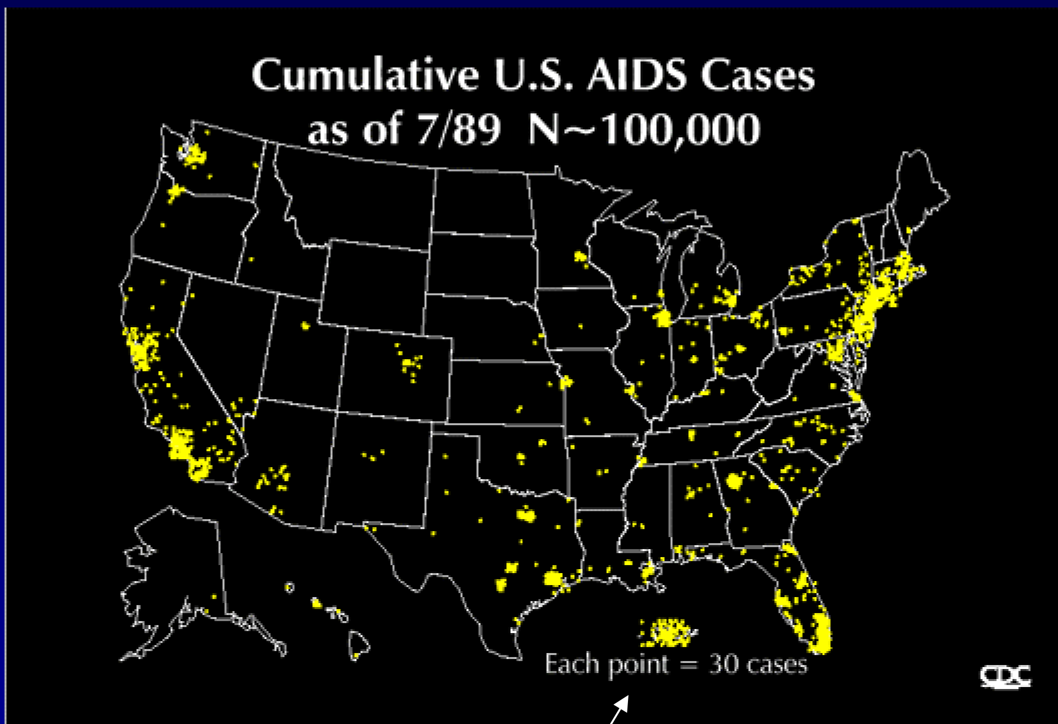


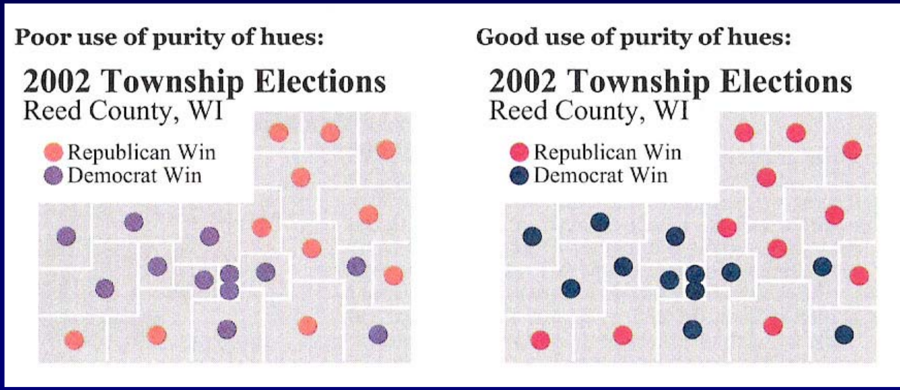
Table 16.4 Color Combinations Useful in Developing Figure and Ground Organization on the Thematic Map

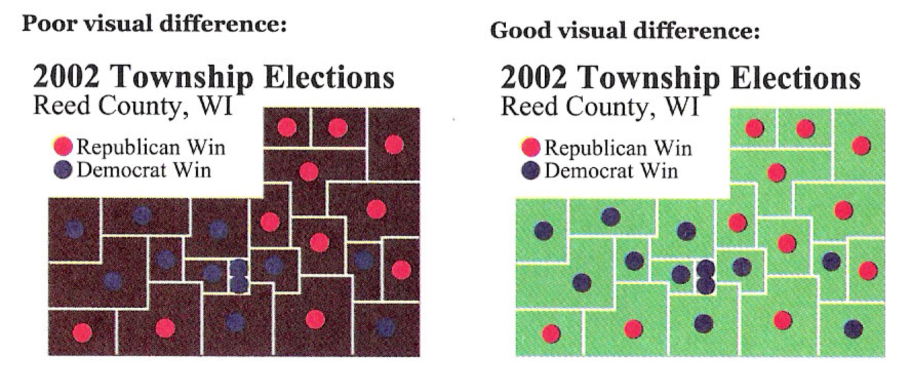
Figure Colors		Ground Colors
Yellow	Best	Black
White		Blue
Black		Orange
Black		Yellow
Orange		Black
Black		White
White		Red
Red		Yellow
Green		White
Orange		White
Red	Worst	Green

Source: Deborah Sharpe, *The Psychology of Color and Design* (Chicago: Nelson-Hall, 1974), p. 107.

- Using the different color saturation for figure and ground helps map readers separate figure from ground
- See table 15.3 in Dent (p. 299)

Color for visual hierarchy



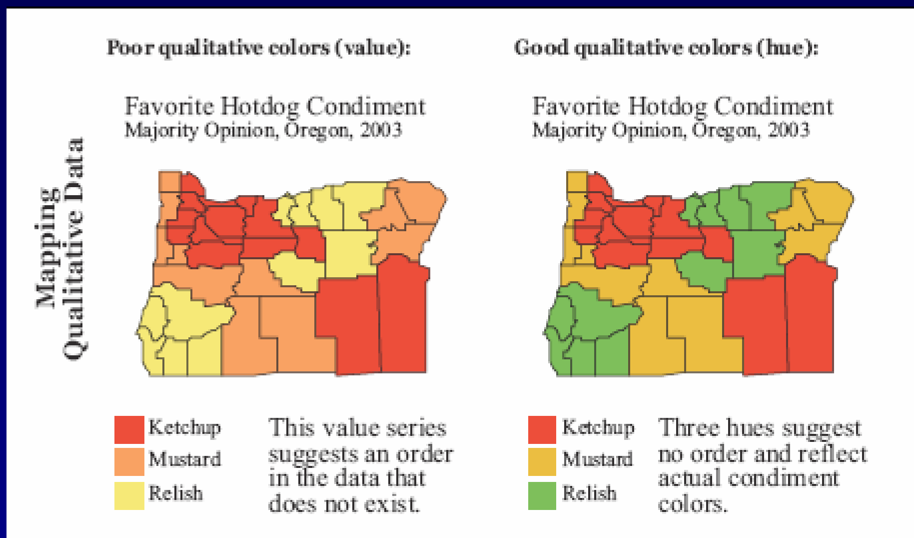


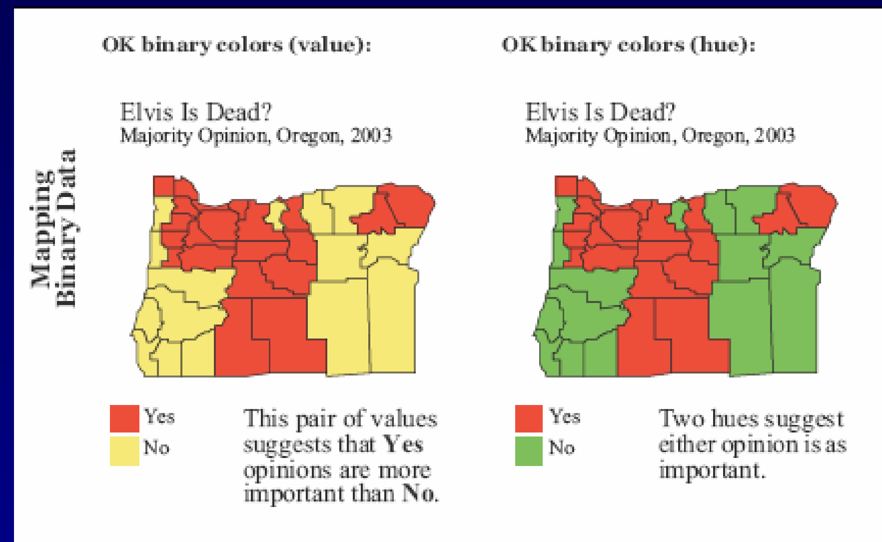
- Some hues look pure, while other hues look like mixtures; Consider the purity of hues when combining colors on a map to imply distinctive differences
- It is easier to see the colors of map elements when the map background is monochromatic (one hue) than mixtures (such as brown)

Color that reflects data measurement

- Appropriate color scheme should reflect data measurement
- Qualitative schemes: different hue can be used to trigger nominal differences
- Quantitative schemes: same hue with different value or saturation, or similar hues with different value or saturation
  - Sequential scheme for unipolar data
  - Diverging scheme for bipolar data

Color for data measurement - qualitative scheme -



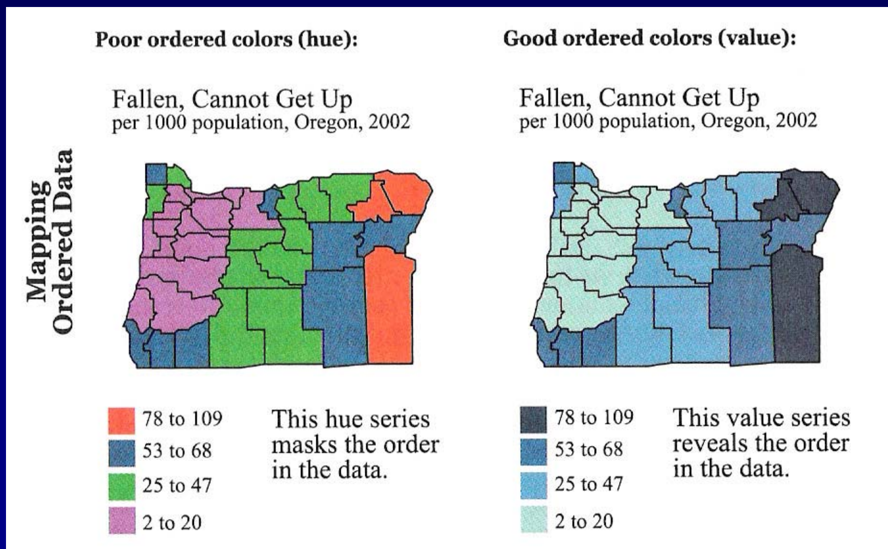


- Hue does not suggest order, thus appropriate to render nominal differences
- If nominal differences carry the same weight, use distinct hues with similar value and saturation

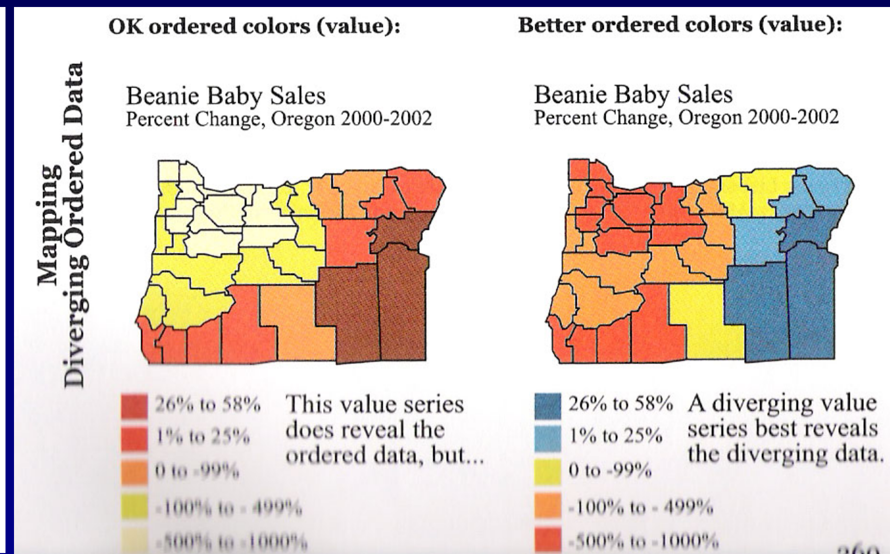
Image source: Krygier and Wood 2004

Color for data measurement
- quantitative scheme -

Sequential

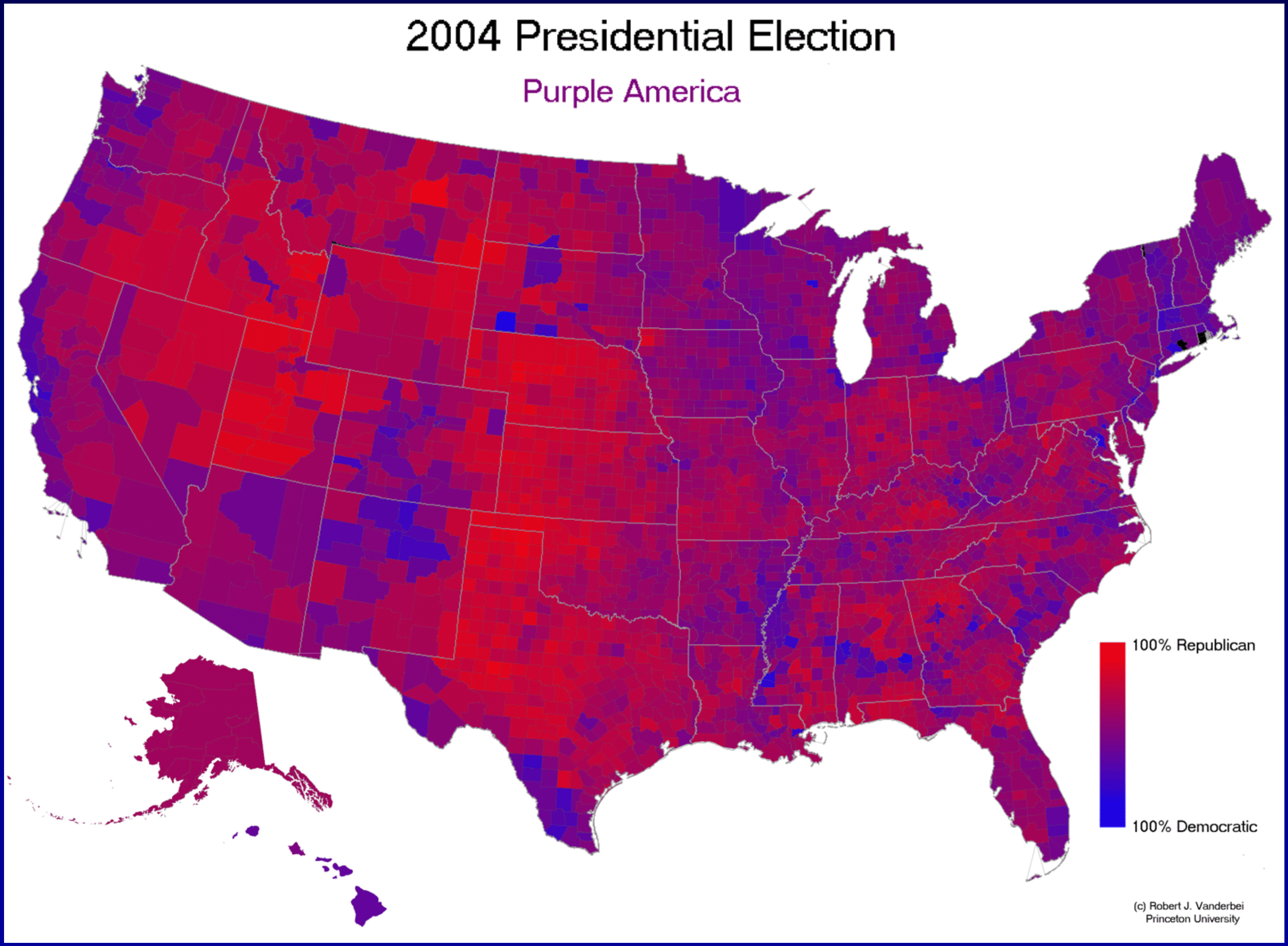


Diverging

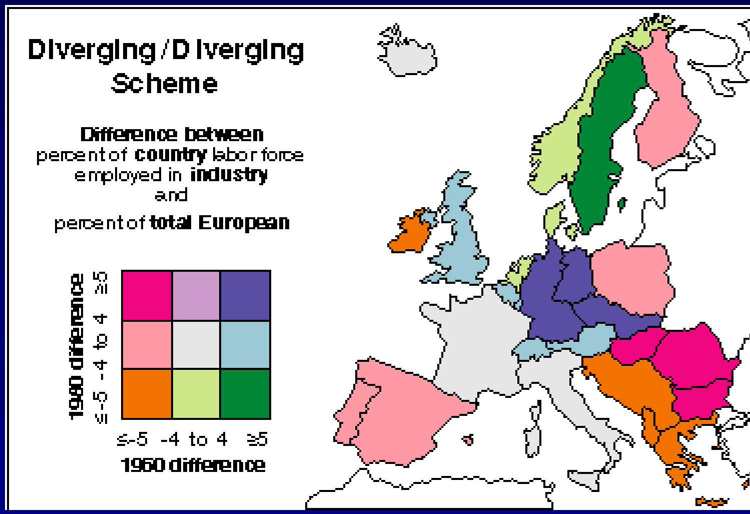


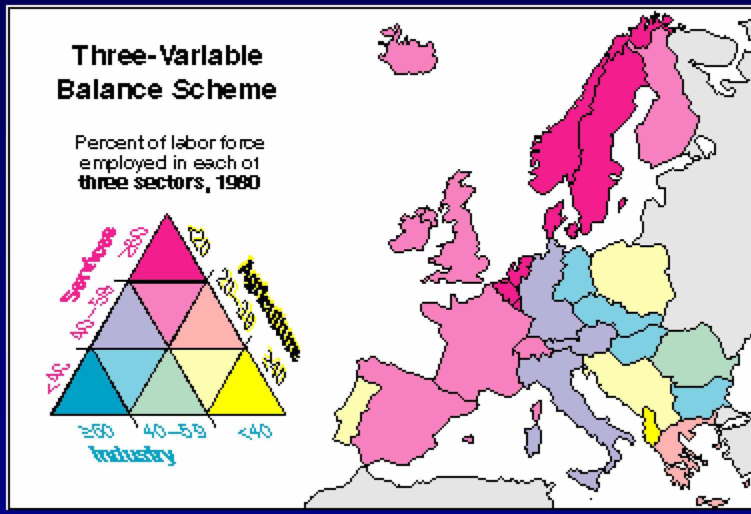
- Value or saturation suggest order, thus appropriate to render progression in magnitudes
- If data has a natural dividing point, use diverging scheme

Color scheme for balanced data



Color for data measurement
- multivariate data -





- Combine two or more variables where each variable is represented by hue, progression in magnitude within each variables is represented by value or saturation

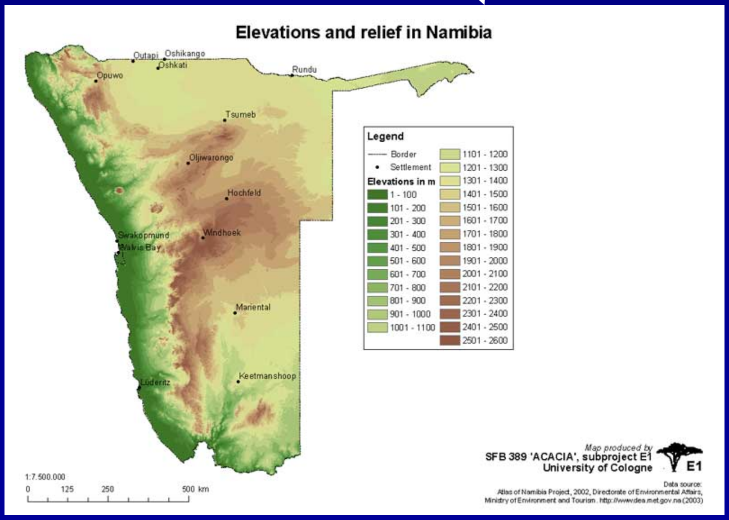
Image source: Brewer’s color guideline

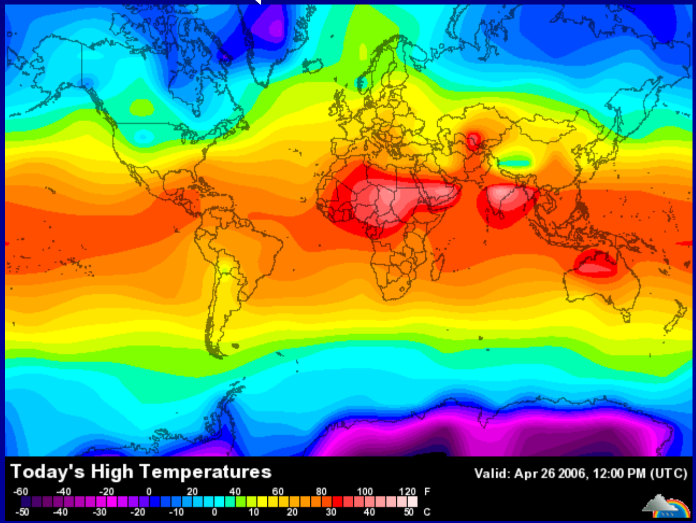
Color connotations

- We commonly associate hues with different physical phenomena, sensations, and emotions
- Landscape metaphor
  - Blue for wetness and coldness, Tan for dryness, Green for lushness, Red for warmth
- Color relates to concepts
  - Red for communism, blue for blue-collar occupation
- Map borrows from familiar concepts
  - Traffic light color used for hazard mapping
- Color can reinforce the meaning of pictorial symbols
  - Yellow dollar sign, symmetric red crosses on ambulances, vertical black crosses for cemeteries or churches

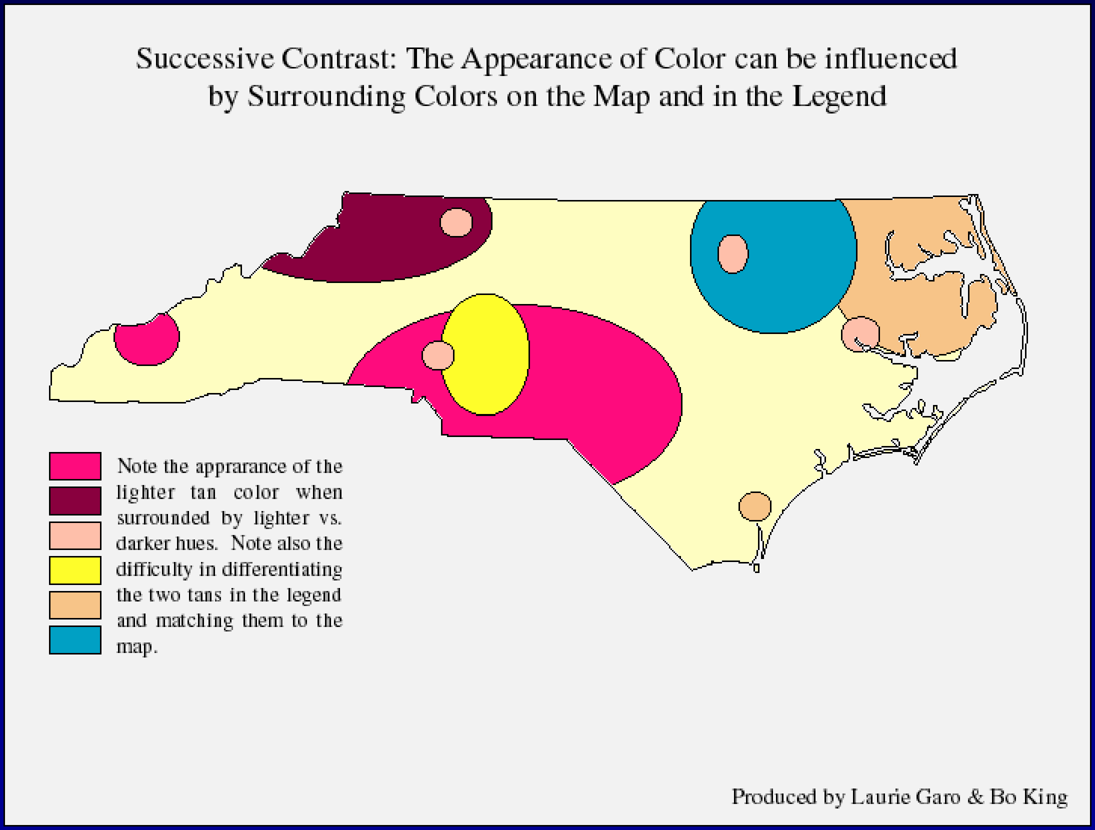
Color conventions

- Some color schemes follow conventions such as hypsometric tint or spectral color scheme (color plate 14.1)
- Color conventions do not necessarily conform to principles of map symbolization
- Color conventions do not necessarily coincide with color connotations





Color & human limitation



- The same hue may appear differently if surrounded by different colors
- For example, choose color pairs that are not affected by simultaneous contrast for diverging scheme because they should not be confused (see the 4th column of Table 13.2)

Other considerations

- Preferences for color
  - Apart from logics of map design, a particular map design can be preferred due to individual differences in color preference
  - Also consider cultural differences
- Age
  - Older map viewers have difficulty seeing colors and need more saturated colors
  - Kids are not familiar with color conventions for map
- Color-blind map viewers
  - In the U.S., 3% of females and 8% of males are color-blind, not distinguishing between reds and greens
  - Consider using reds and blues or greens and blues instead (see the third column of Table 13.2)

Functions of color in map

- Structure: color can organize map elements, and structure the message communicated
  - Visual hierarchy, data measurement
- Legibility: can enhance clarity
  - Visual contrast, human limitations of color perception
- Overtone: can elicit subjective reactions to the map
  - Color connotations