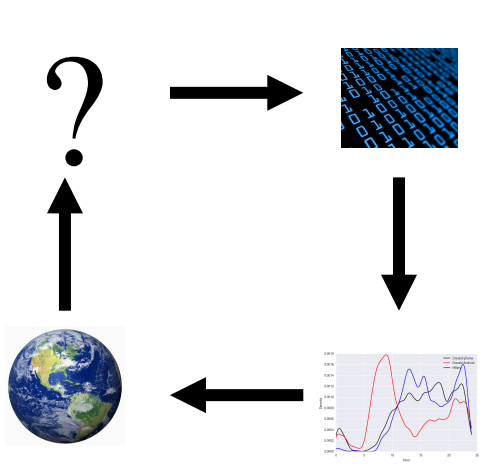


# DS100

## Lecture 6: *Visualization*


Slides by:

**Deborah Nolan**

deborah_nolan@berkeley.edu

# Why is Graphics a topic in this course?

- Visualization belongs in every stage of the data life cycle
- Plots can uncover structure in data that can't be detected from numerical summaries
- Visualization is an important communication skill

# Goals of this lecture

- Guidelines and general philosophy
  - Reveal the data
  - Facilitate Comparisons
  - Add information
  - Iterate
- Techniques for following guidelines
  - Scale
  - Conditioning
  - Perception
  - Transformations
  - Adding context
  - Smoothing & other large data considerations

# Good Starting Place – Know your data type

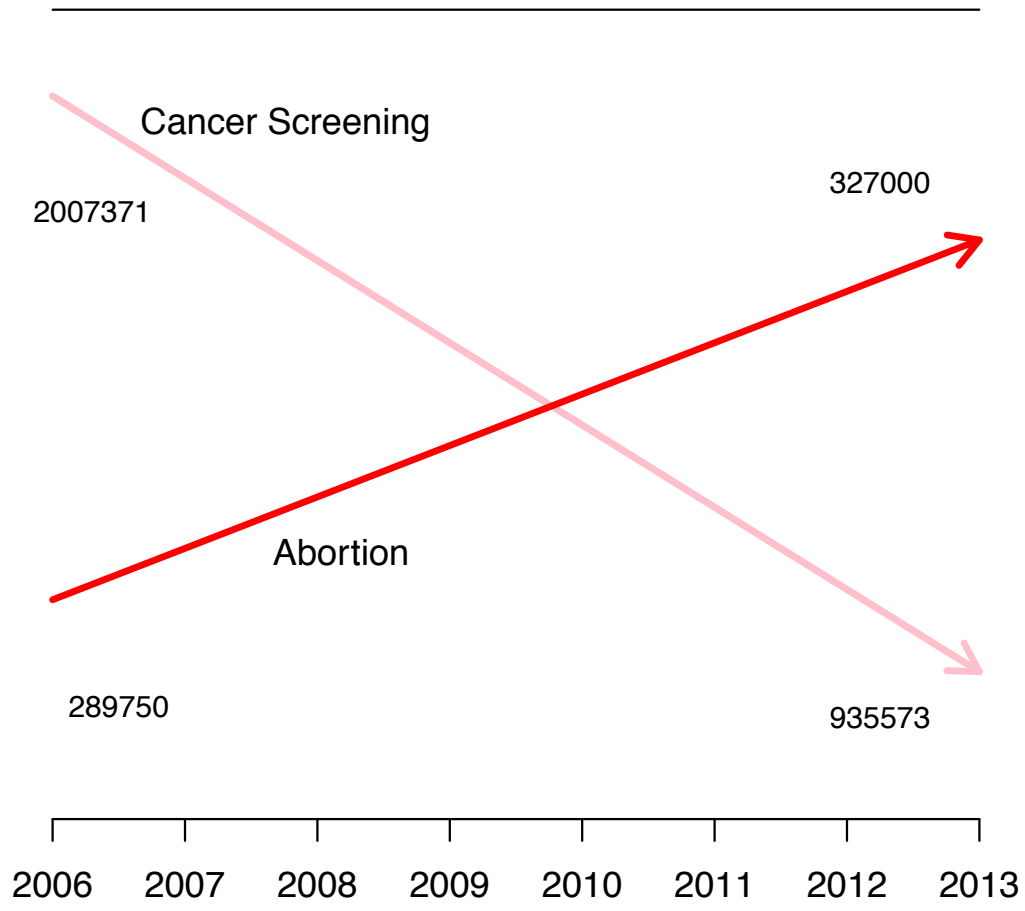
- Quantitative (Numeric)
  - Continuous (e.g., health care expenditure)
  - Discrete  (e.g., number of siblings)
- Qualitative (Categorical)
  - Nominal (e.g., lane of traffic, country)
  - Ordinal (e.g., Yelp rating, education level)
- See table that maps data types to plot types at end of slides

# 4 Examples

# 2015 Congressional Hearing: Planned Parenthood

- Congressman Chaffetz (R-UT), chair US House Oversight Committee
- Investigation of federal funding of Planned Parenthood
- Chaffetz showed a plot which originally appeared in a report by Americans United for Life (http://www.aul.org/).
- Report available at https://oversight.house.gov/interactivepage/plannedparenthood/

# Planned Parenthood Procedures




- Procedures:
  - Cancer screenings
  - Abortion
- Time: 2006 to 2013
- How many data points are in this plot?
- What's suspicious about this plot?

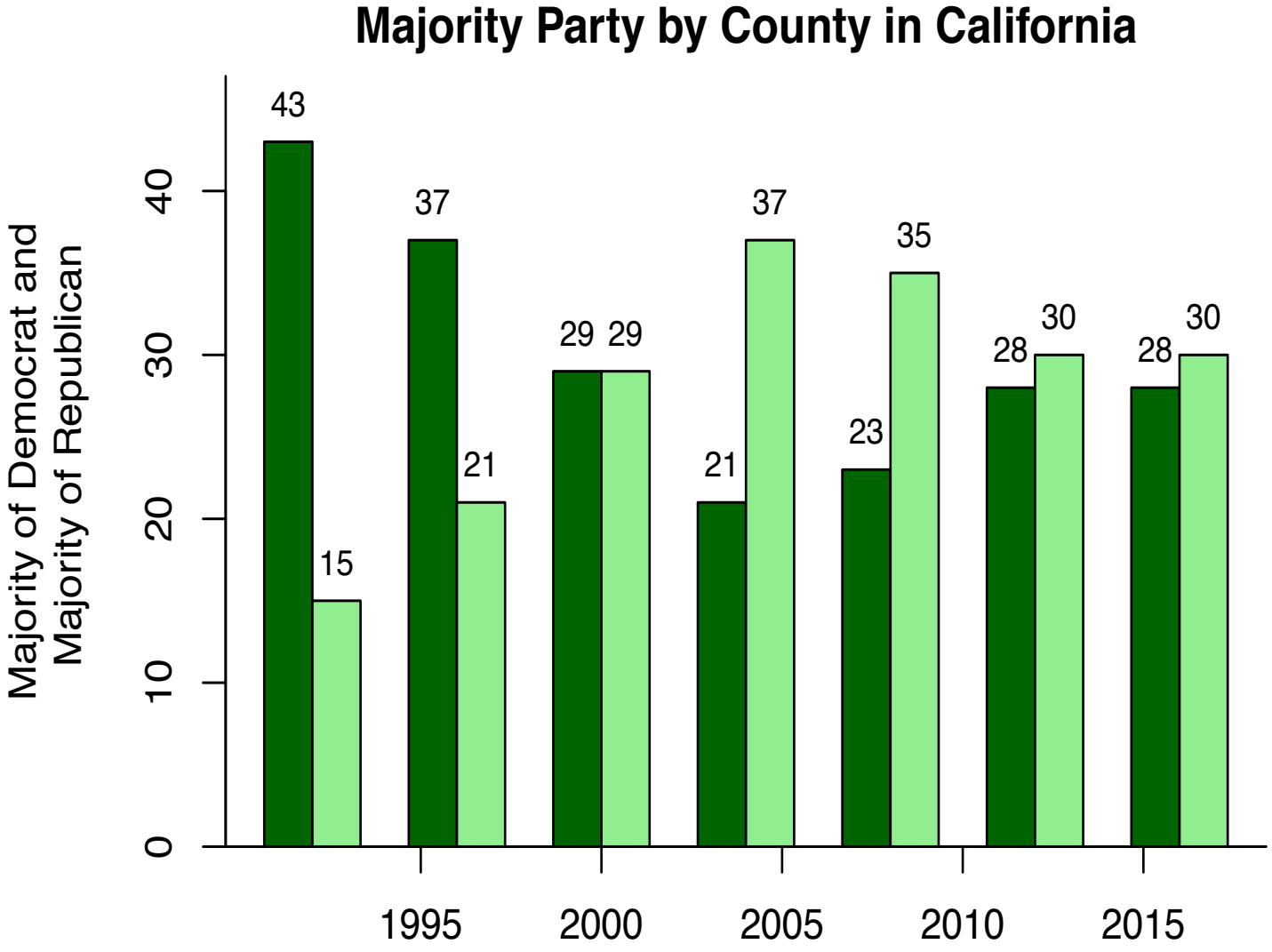
# Voter Registration Trends in California

- State of California publishes voter registration summaries

http://www.sos.ca.gov/elections/ror/60day presprim/hist reg stats.pdf

- Historical registration counts available for presidential election years

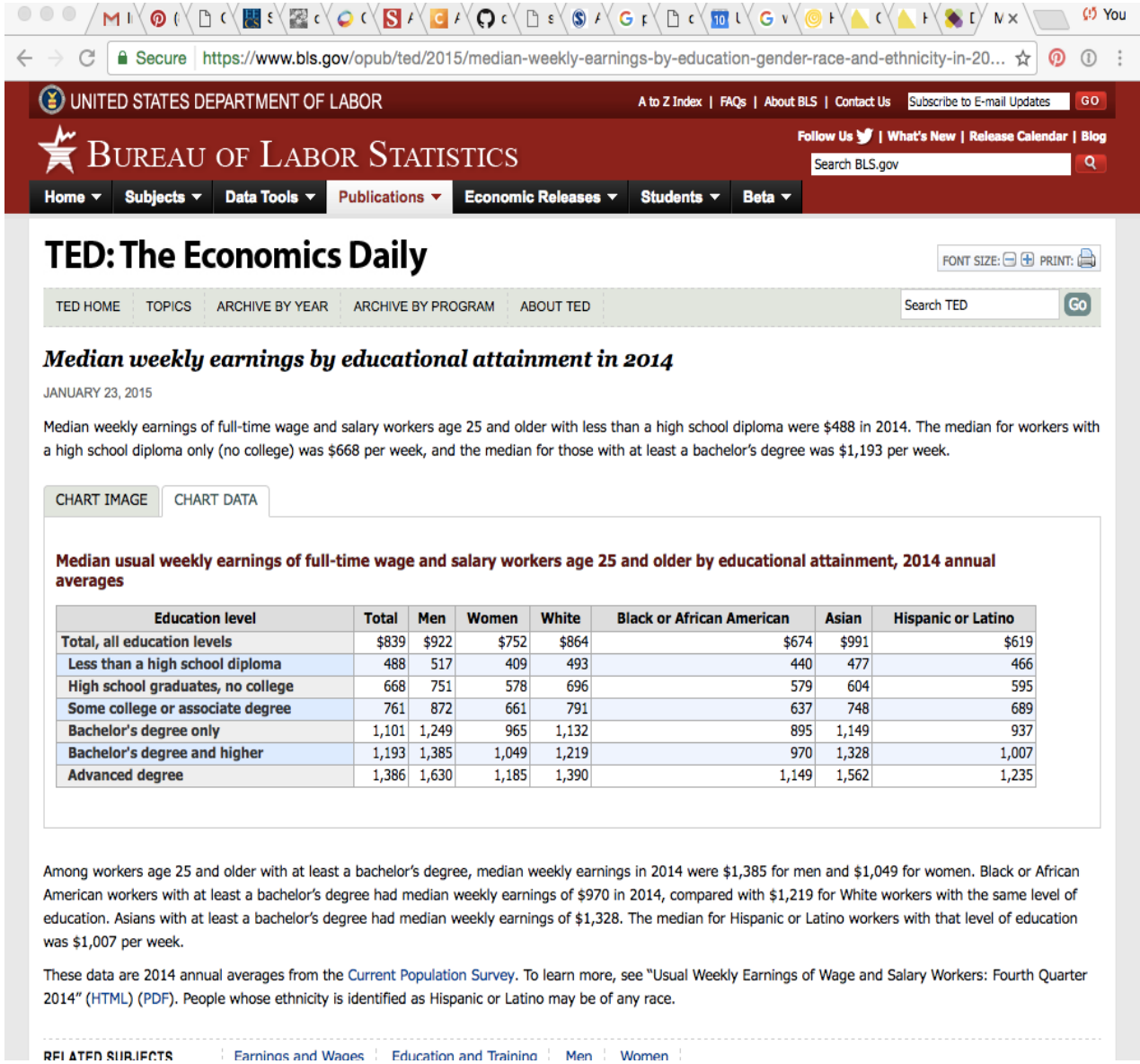
# Voter Registration Trends in California




What's confusing or annoying about this plot?

# Earnings

- Bureau of Labor Statistics
  - Oversees scientific surveys related to economic health of the country
- Current Population Survey
  - Collects data on the earnings
  - www.bls.gov - Web interface to a report generating app



Secure https://www.bls.gov/opub/ted/2015/median-weekly-earnings-by-education-gender-race-and-ethnicity-in-20...

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FONT SIZE: PRINT:

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### *Median weekly earnings by educational attainment in 2014*

JANUARY 23, 2015

Median weekly earnings of full-time wage and salary workers age 25 and older with less than a high school diploma were $488 in 2014. The median for workers with a high school diploma only (no college) was $668 per week, and the median for those with at least a bachelor's degree was $1,193 per week.

CHART IMAGE | CHART DATA

**Median usual weekly earnings of full-time wage and salary workers age 25 and older by educational attainment, 2014 annual averages**

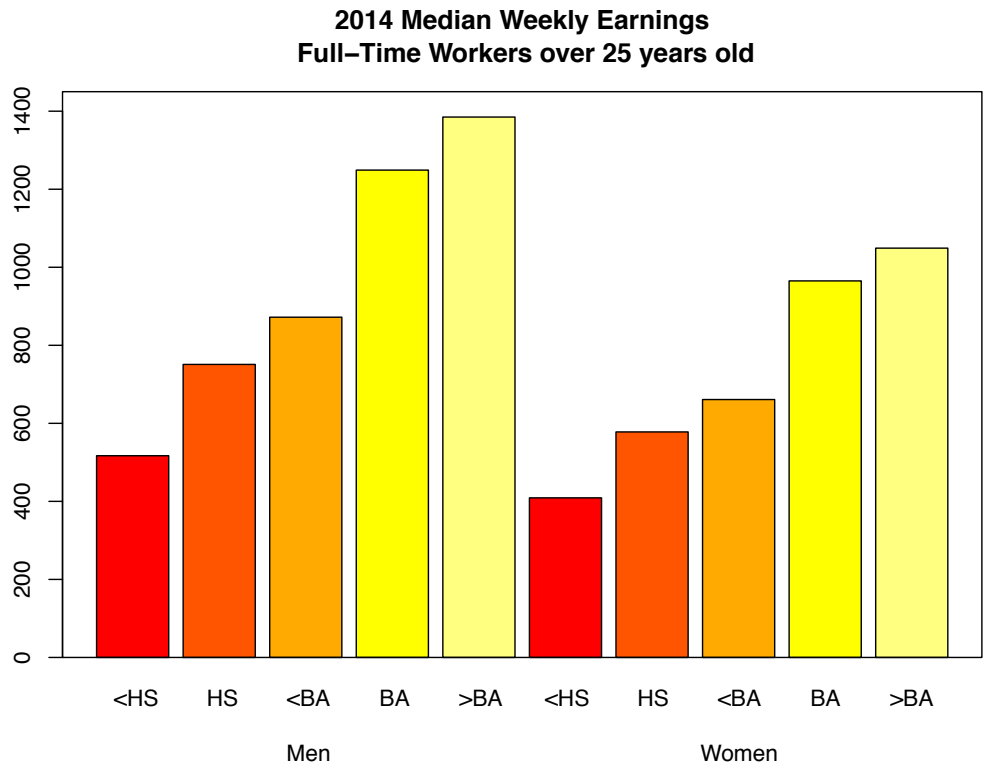
| Education level | Total | Men | Women | White | Black or African American | Asian | Hispanic or Latino |
|---|---|---|---|---|---|---|---|
| Total, all education levels | $839 | $922 | $752 | $864 | $674 | $991 | $619 |
| Less than a high school diploma | 488 | 517 | 409 | 493 | 440 | 477 | 466 |
| High school graduates, no college | 668 | 751 | 578 | 696 | 579 | 604 | 595 |
| Some college or associate degree | 761 | 872 | 661 | 791 | 637 | 748 | 689 |
| Bachelor's degree only | 1,101 | 1,249 | 965 | 1,132 | 895 | 1,149 | 937 |
| Bachelor's degree and higher | 1,193 | 1,385 | 1,049 | 1,219 | 970 | 1,328 | 1,007 |
| Advanced degree | 1,386 | 1,630 | 1,185 | 1,390 | 1,149 | 1,562 | 1,235 |

Among workers age 25 and older with at least a bachelor's degree, median weekly earnings in 2014 were $1,385 for men and $1,049 for women. Black or African American workers with at least a bachelor's degree had median weekly earnings of $970 in 2014, compared with $1,219 for White workers with the same level of education. Asians with at least a bachelor's degree had median weekly earnings of $1,328. The median for Hispanic or Latino workers with that level of education was $1,007 per week.

These data are 2014 annual averages from the Current Population Survey. To learn more, see "Usual Weekly Earnings of Wage and Salary Workers: Fourth Quarter 2014" (HTML) (PDF). People whose ethnicity is identified as Hispanic or Latino may be of any race.

RELATED SUBJECTS | Earnings and Wages | Education and Training | Men | Women

# Earnings

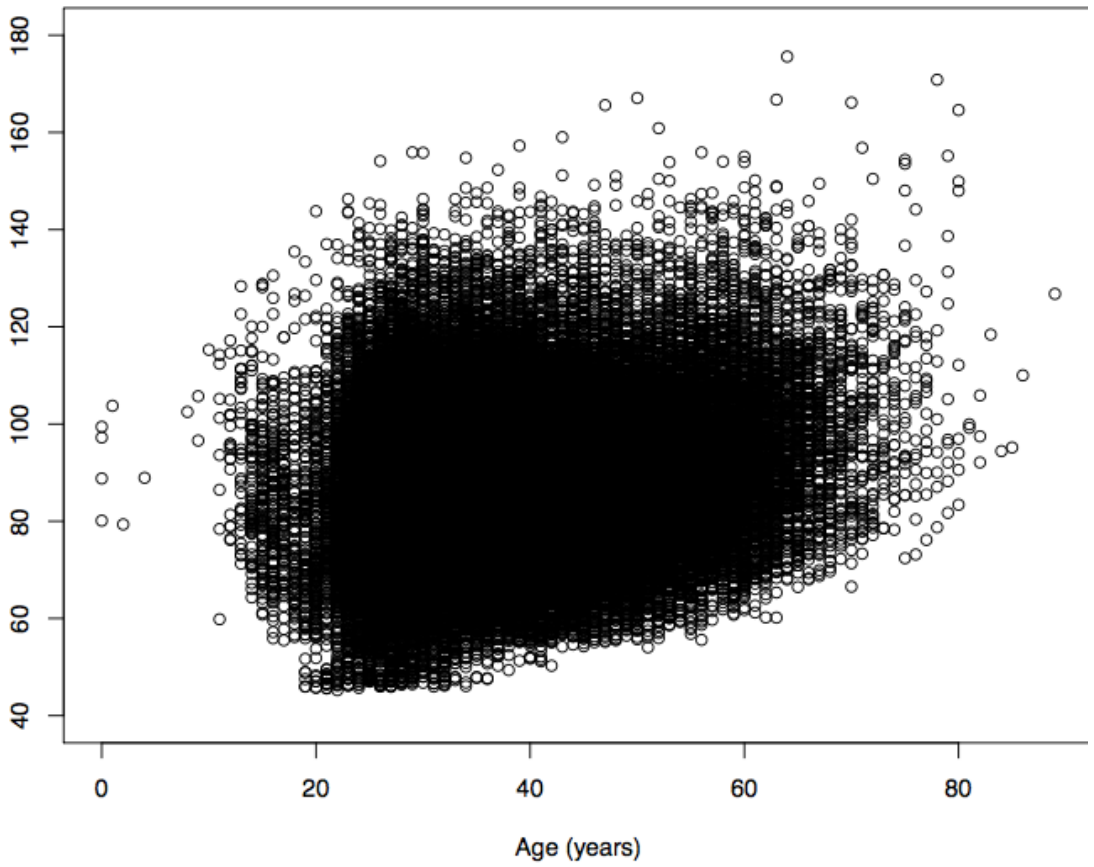



Which comparisons can be easily made with this plot?

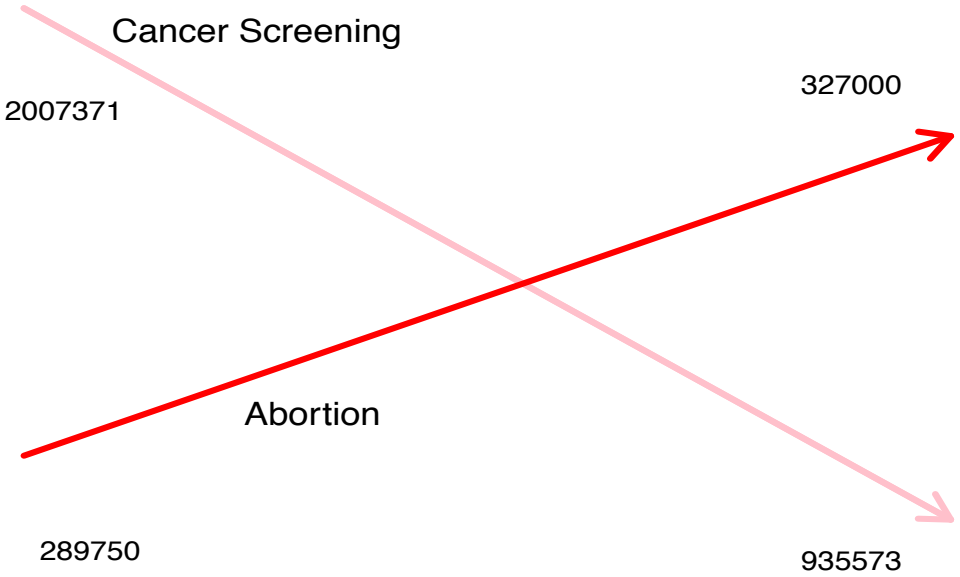
# Cherry Blossom Run

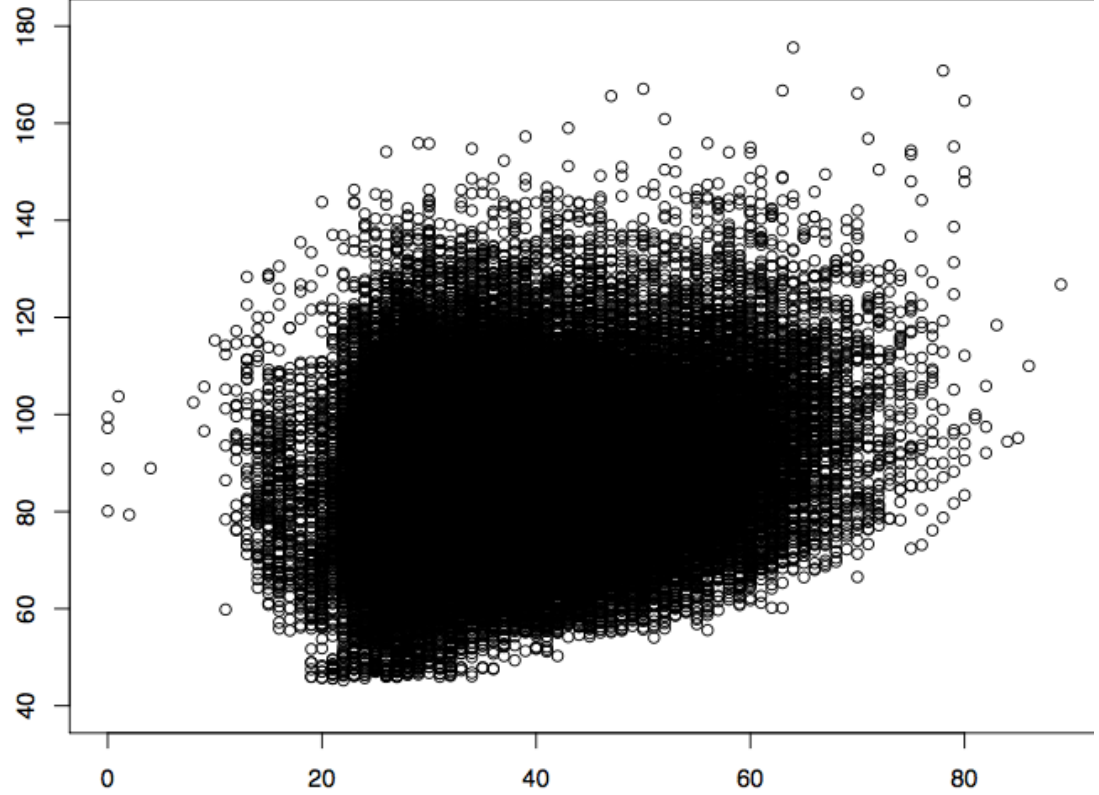
- 10 mile run in Washington DC each April
- Race organizers make results available on Web
  - Runner name, age, gender, address, hometown, time
  - Race results from 1999 to 2016
  - In 2012 nearly 17,000 runners ranging in age from 9 to 89 participated
  - http://www.cherryblossom.org/

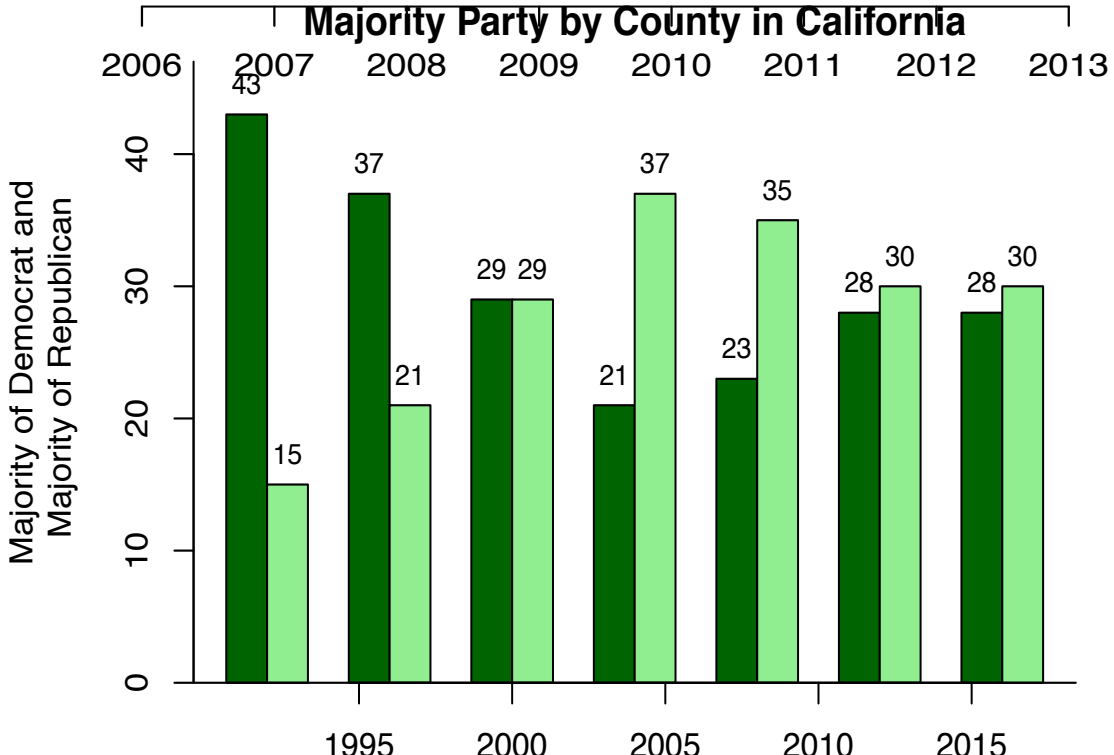
# Cherry Blossom Run

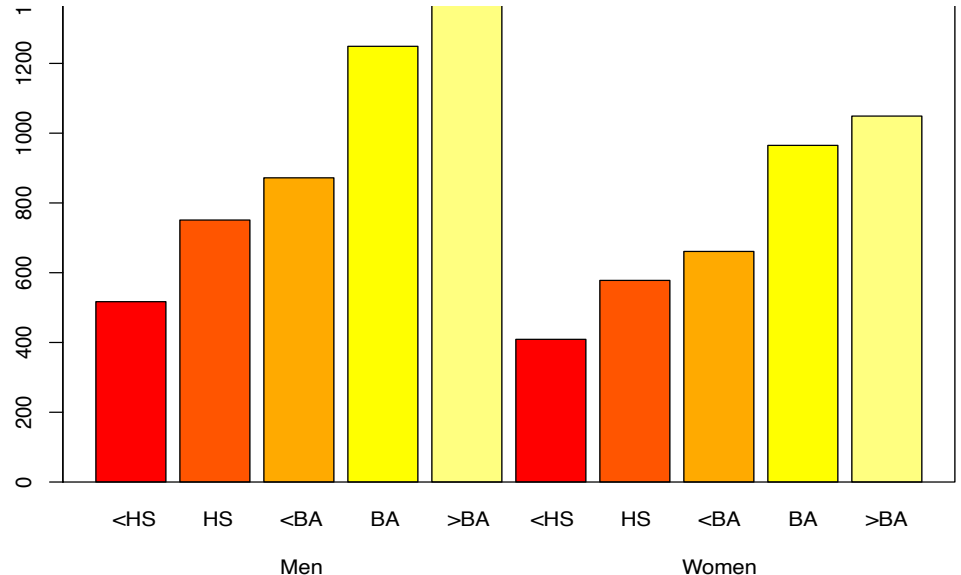



- Scatter plot of run time (minutes) by age (years)
- 70,000 points in this plot.
- What's the relationship between run time and age?


Cancer Screening
2007371
327000
Abortion
289750
935573

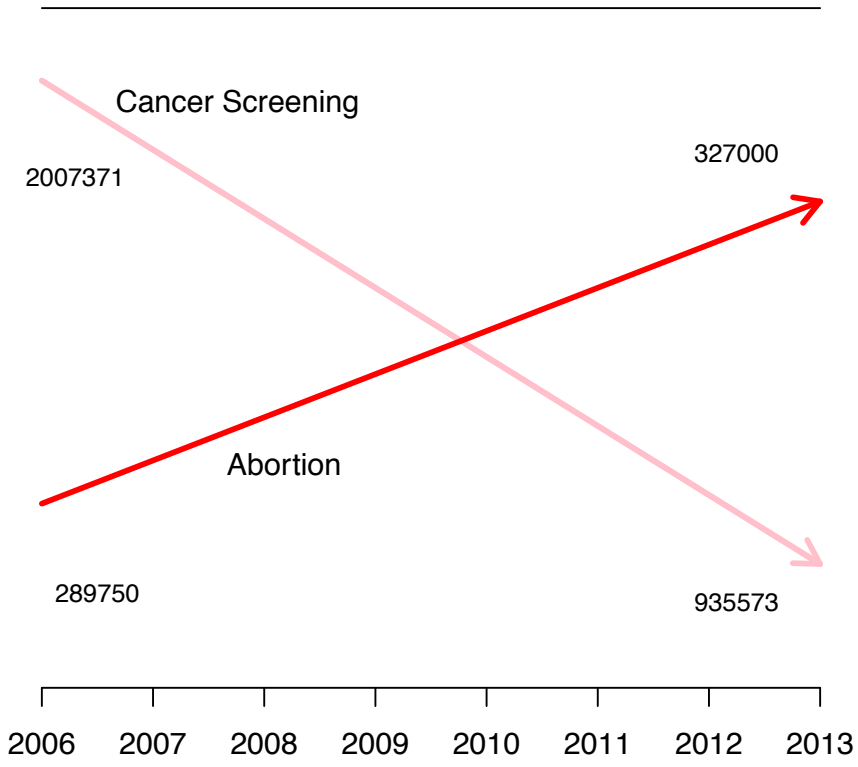

180
160
140
120
100
80
60
40
0
20
40
60
80
Age (years)

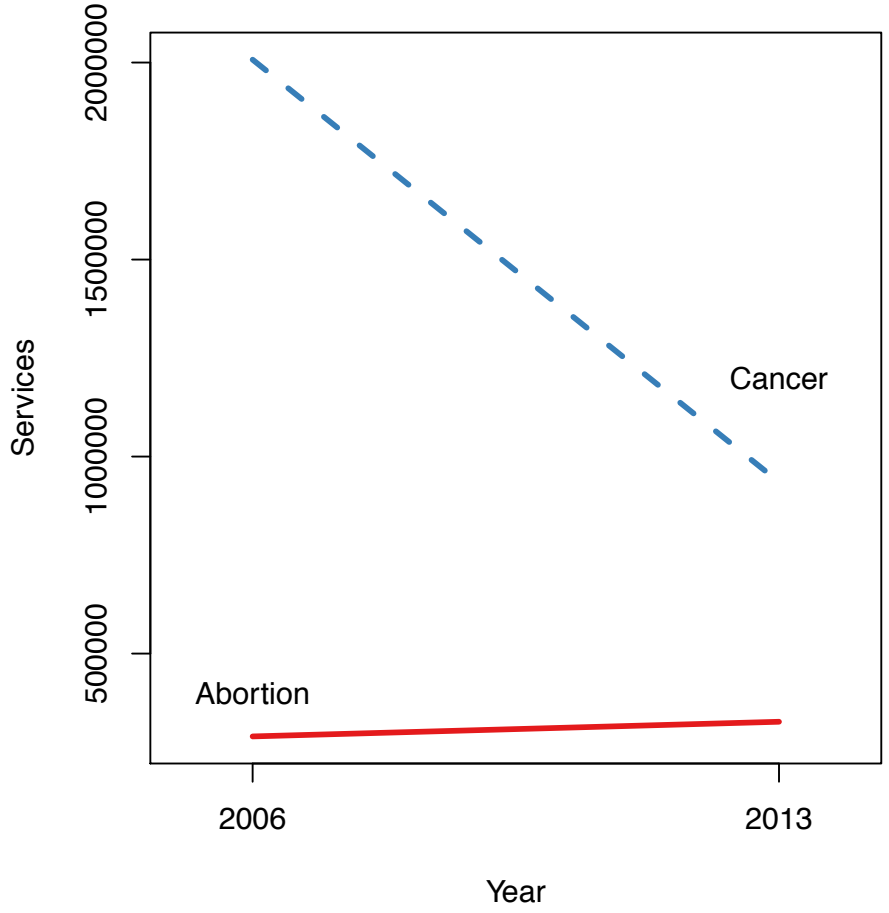

Majority Party by County in California
2006
2007
2008
2009
2010
2011
2012
2013
Majority of Democrat and
Majority of Republican
0
10
20
30
40
43
15
37
21
29
29
21
37
23
35
28
30
28
30
1995
2000
2005
2010
2015


0
200
400
600
800
1000
1200
<HS
HS
<BA
BA
>BA
<HS
HS
<BA
BA
>BA
Men
Women

# Techniques

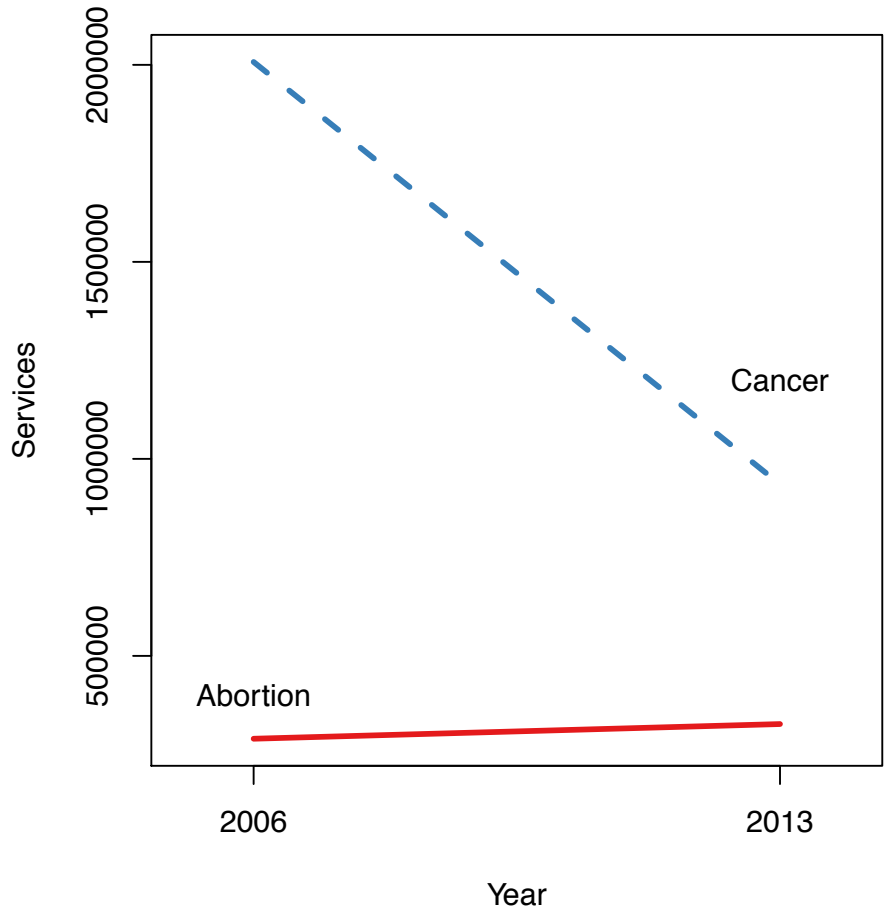
# Planned Parenthood Procedures



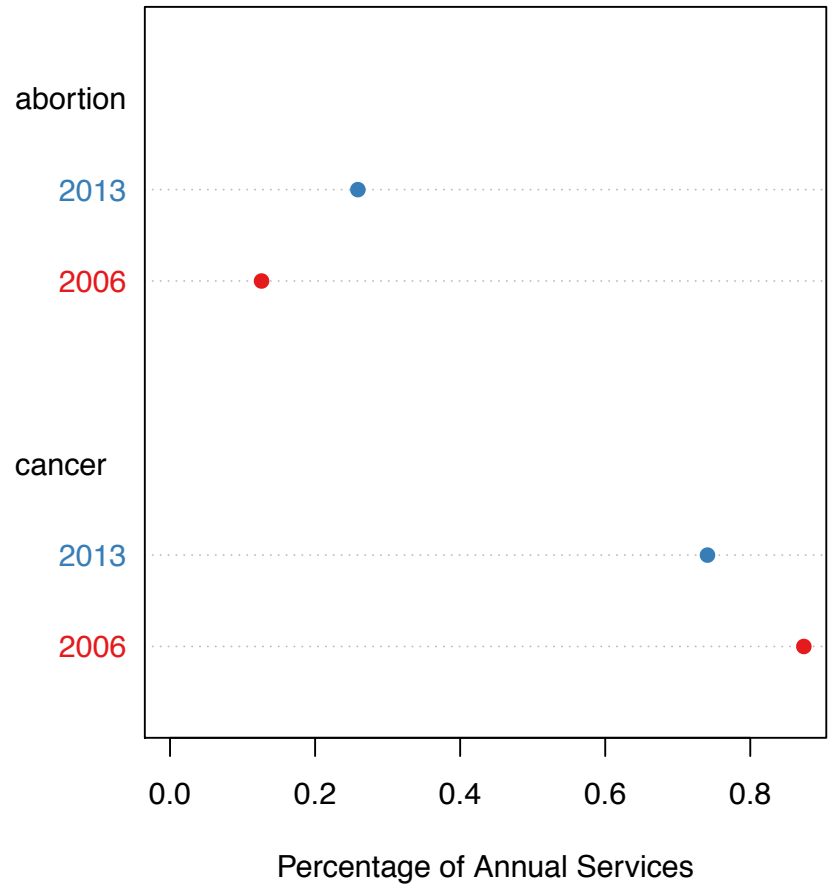
# Scale

# Planned Parenthood Procedures




- All points and lines are on the same scale
- How does this plot change the perception of the information?
- There has been a dramatic decrease in cancer screenings which dominates this plot
- The scales of the two procedures are very different – consider representing as percentages instead

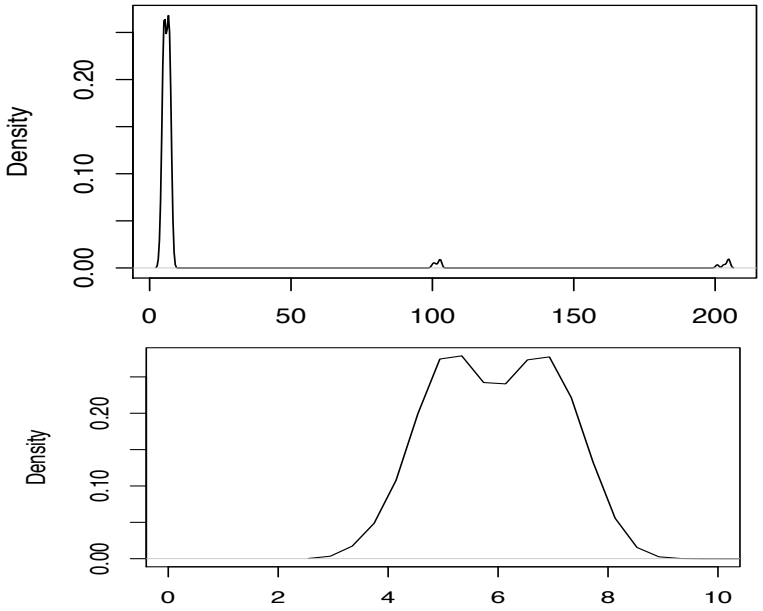
# Planned Parenthood Procedures



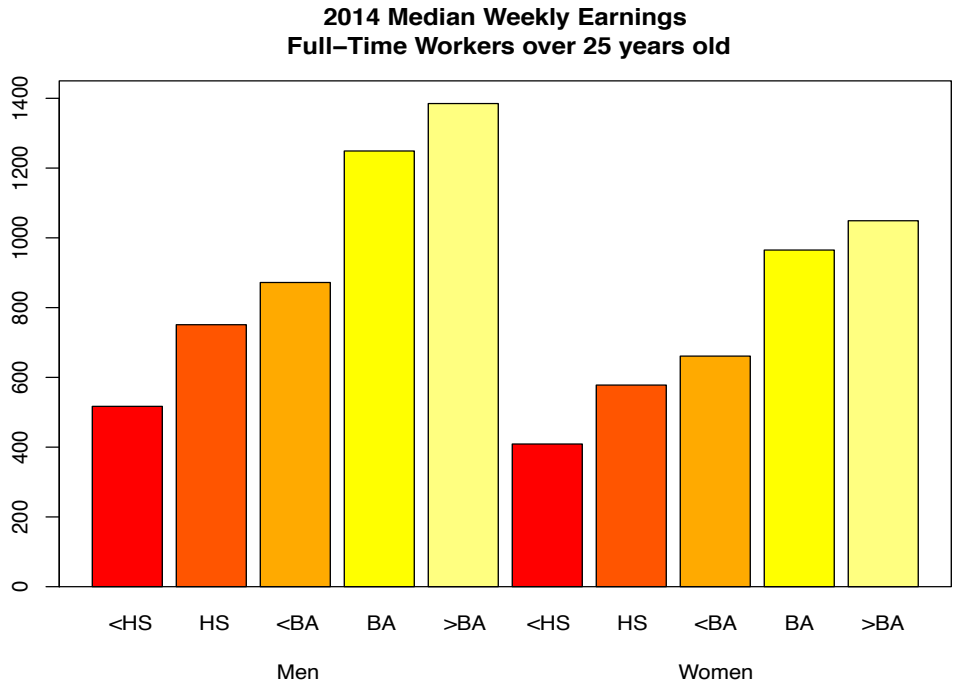

- Procedures in 2006 and 2013 as a percentage
- Abortions increased from 13% to 26% of total procedures
- May want to plot the percent change, screenings fell 50%

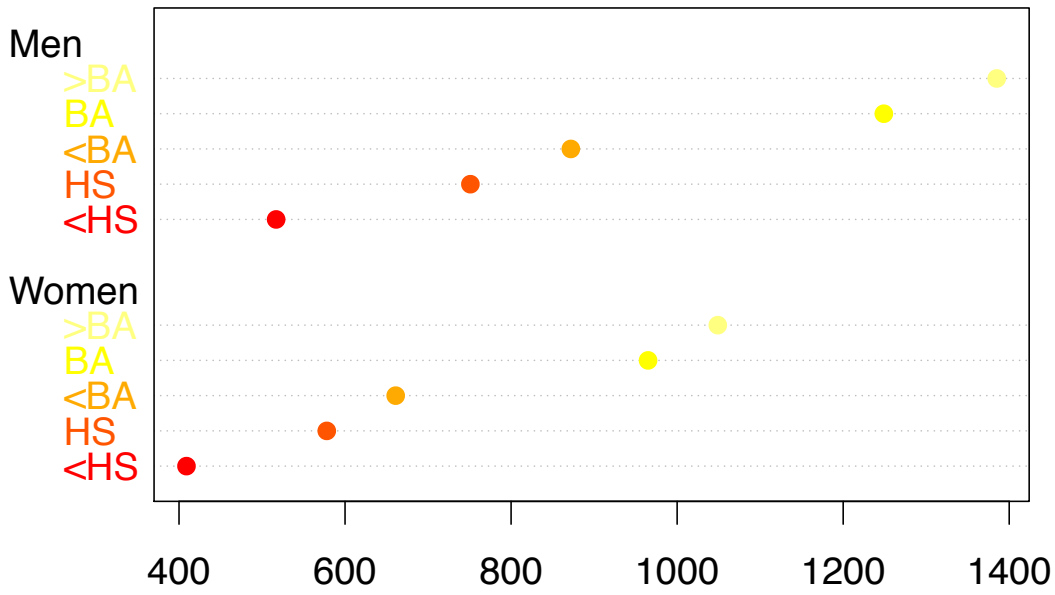
# Choosing the Scale

- Choose axis limit to fill the plotting region
- In necessary,
  - Zoom in to focus on region with bulk of data
  - Make multiple plots of different regions
  - Transform data to improve resolution (TBC)
- Don't change scale mid-axis
- Don't use two different scales for the same axis



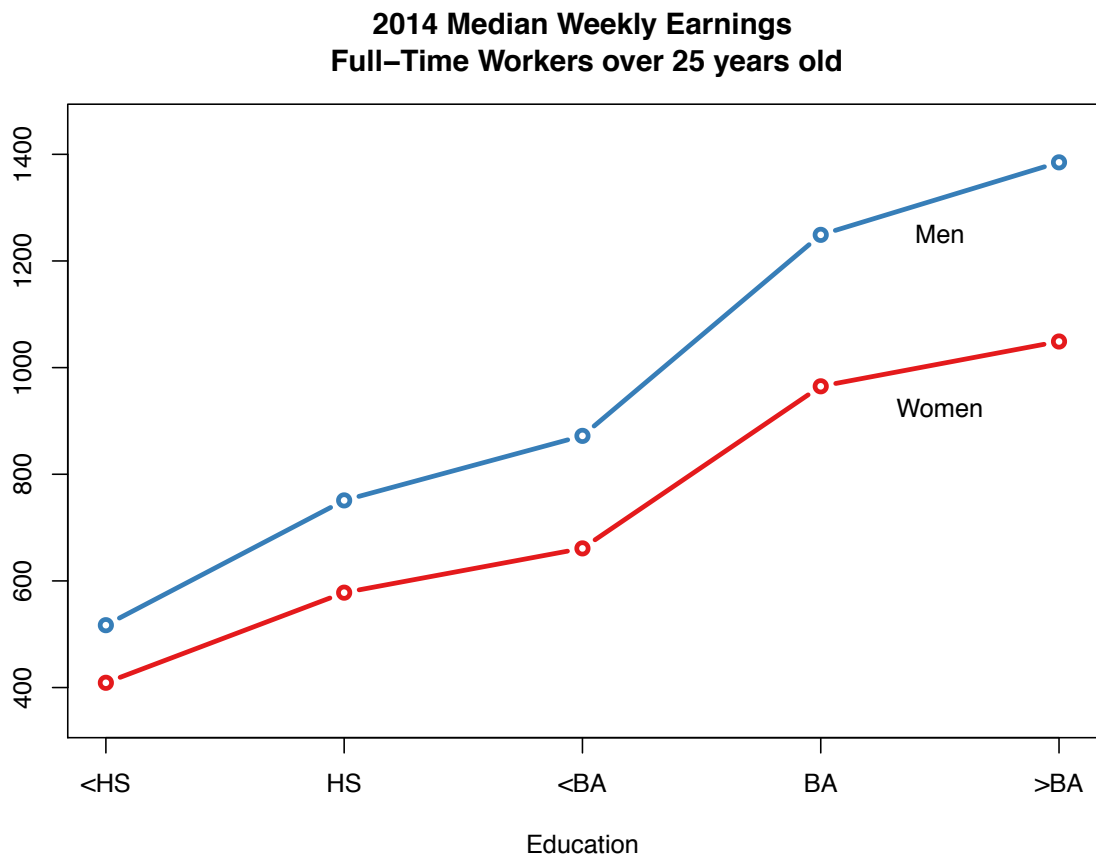
# Earnings


2014 Median Weekly Earnings
Full–Time Workers over 25 years old
0
200
400
600
800
1000
1200
1400
<HS
HS
<BA
BA
>BA
<HS
HS
<BA
BA
>BA
Men
Women


Men
>BA
BA
<BA
HS
<HS
Women
>BA
BA
<BA
HS
<HS
400
600
800
1000
1200
1400

# Conditioning

# Earnings




- Emphasize the important difference –
- Lines make it easier to see growth in gap
- Placement of one point above the other makes it easier to compare males & females

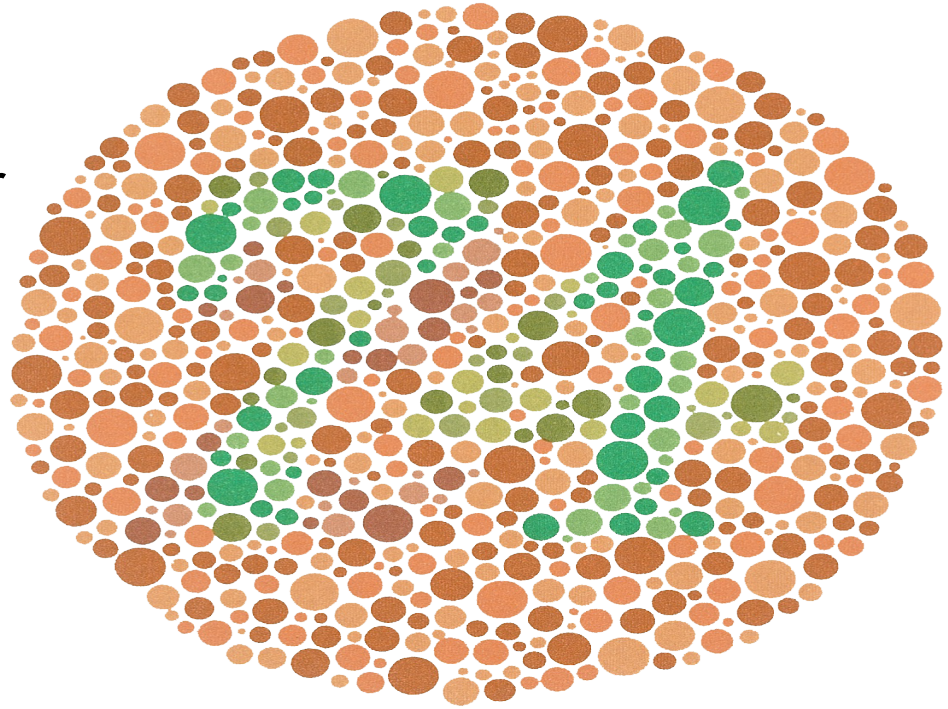
# Conditioning – Distributions & Relationships in subgroups

- Superpose density curves, fitted curves and lines from different subgroups
- Juxtapose scatter plots, histograms & keep x and y scales the same across plots to facilitate comparison
- Use color and plotting symbols to represent additional variables

# Perception - Color

# Color Guidelines

- Choosing a set of colors which work well together is a challenging task for anyone who does not have an intuitive gift for color
- 7-10% of males are red-green color blind.

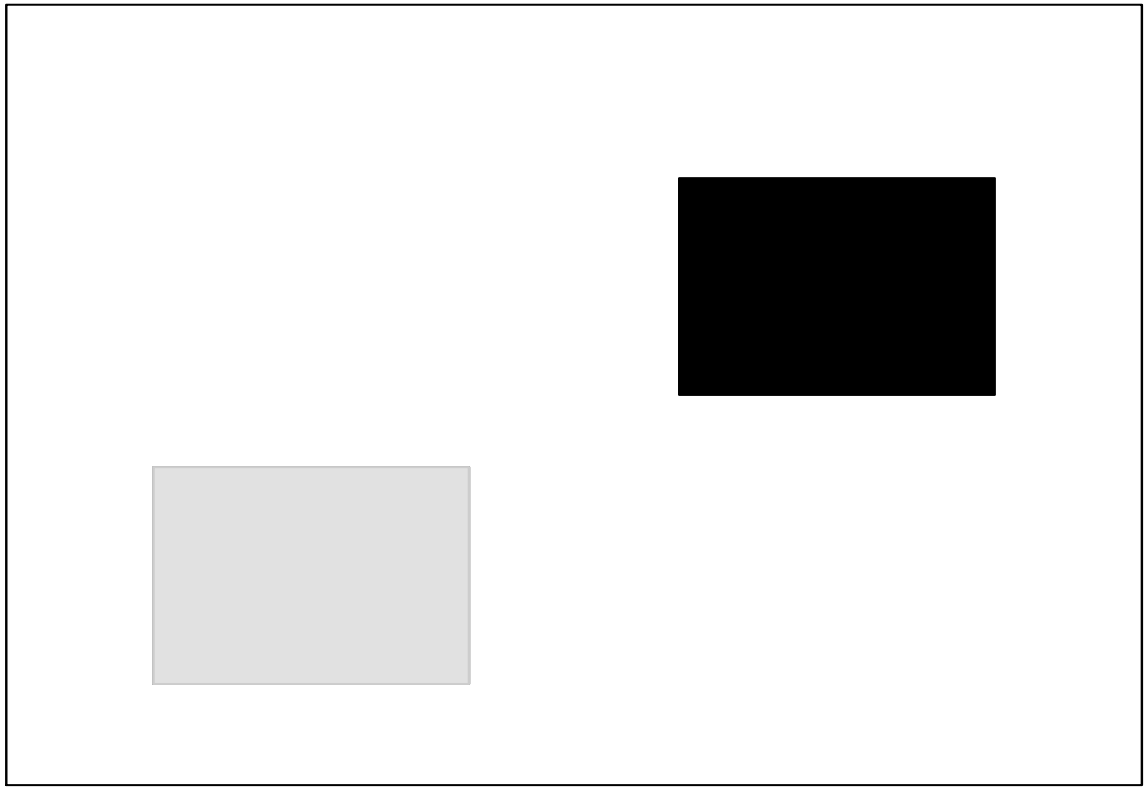


# Colorfulness

- Saturated/colorful colors are hard to look at for a long time.
- They tend to produce an after-image effect which can be distracting.

# Luminance

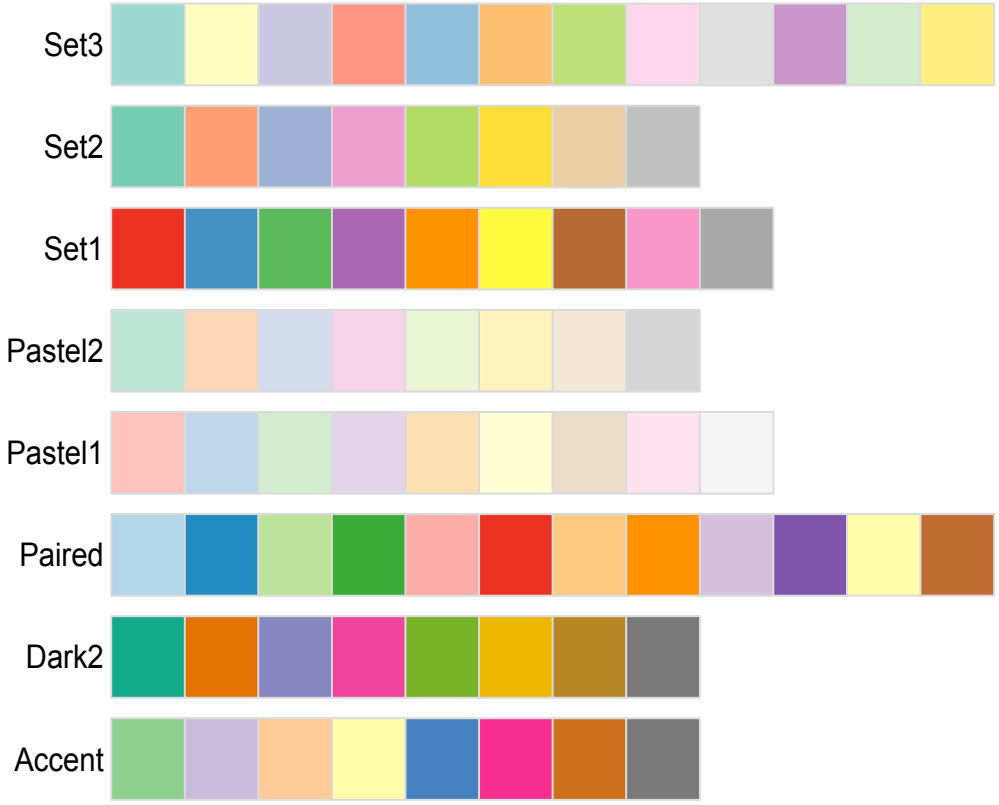
- Areas should be rendered with colors of similar luminance (brightness).
- Lighter colors tend to make areas look larger than darker colors



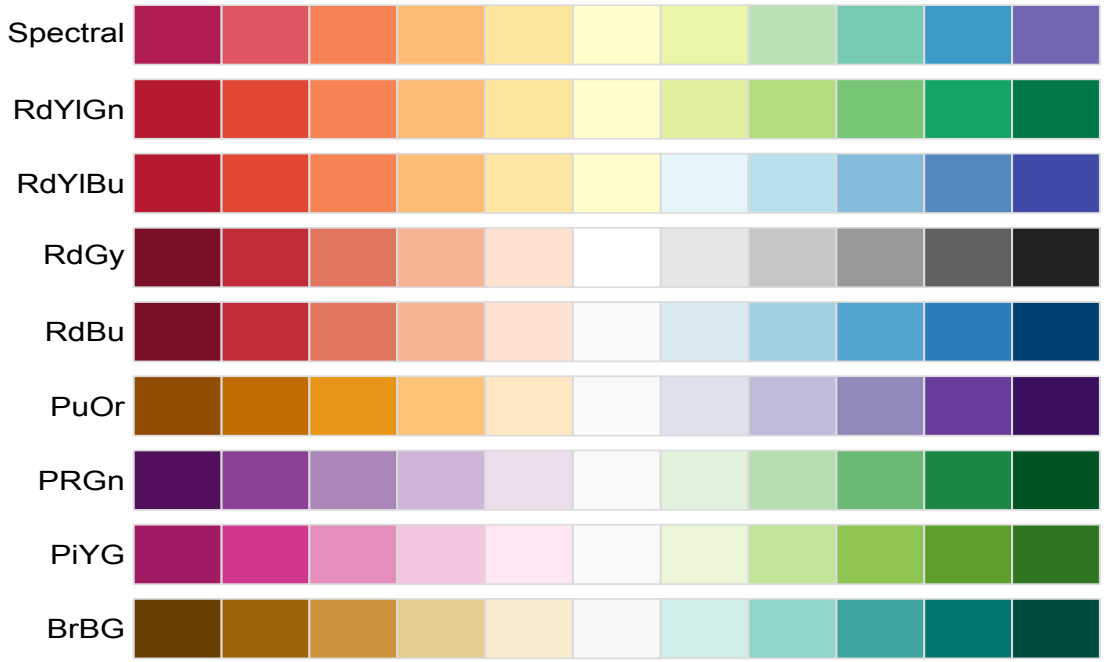
# Data Type and Color

- Qualitative – Choose a **qualitative** scheme that makes it easy to distinguish between categories
- Quantitative – Choose a color scheme that implies magnitude.
  - Does the data progress from low to high? Use a **sequential** scheme where light colors are for low values
  - Do both low and high value deserve equal emphasis? Use a **diverging** scheme where light colors represent middle values

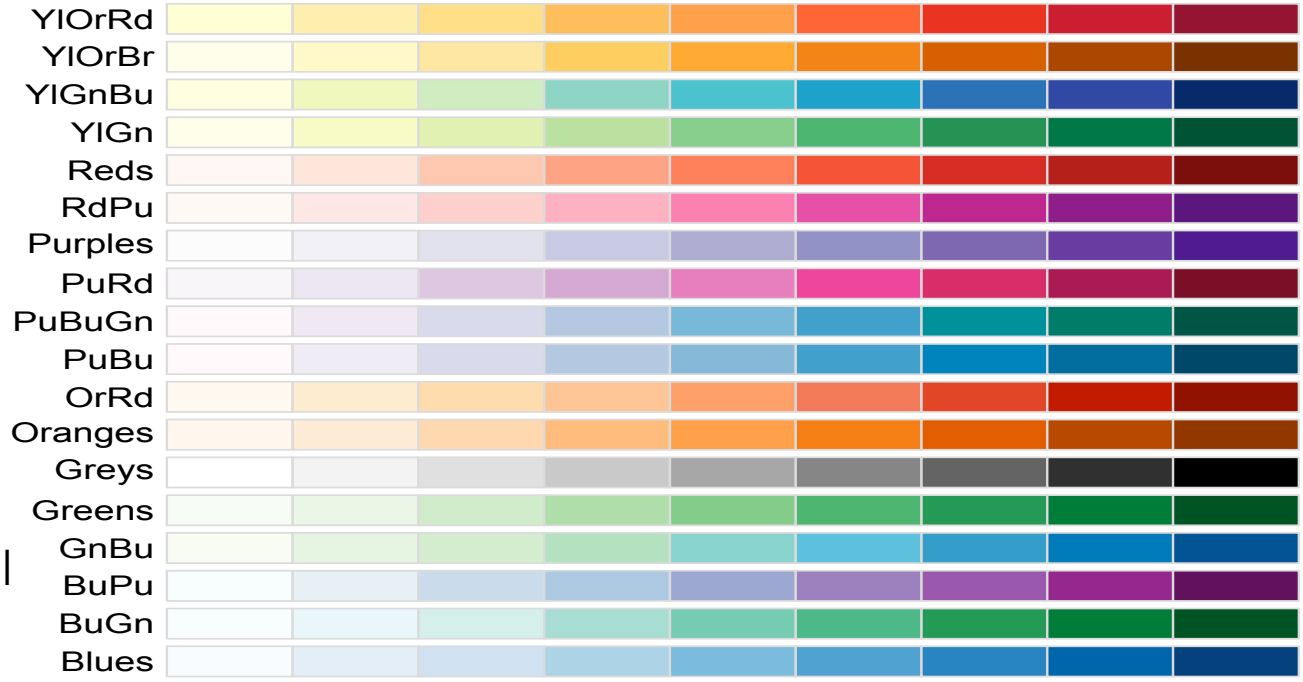
# Examples of Palettes




Qualitative




Diverging



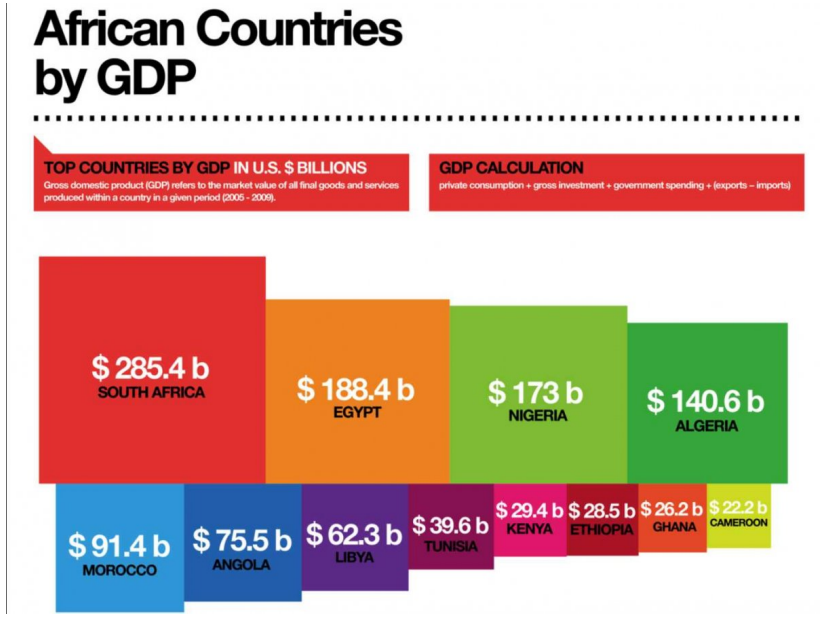

Sequential

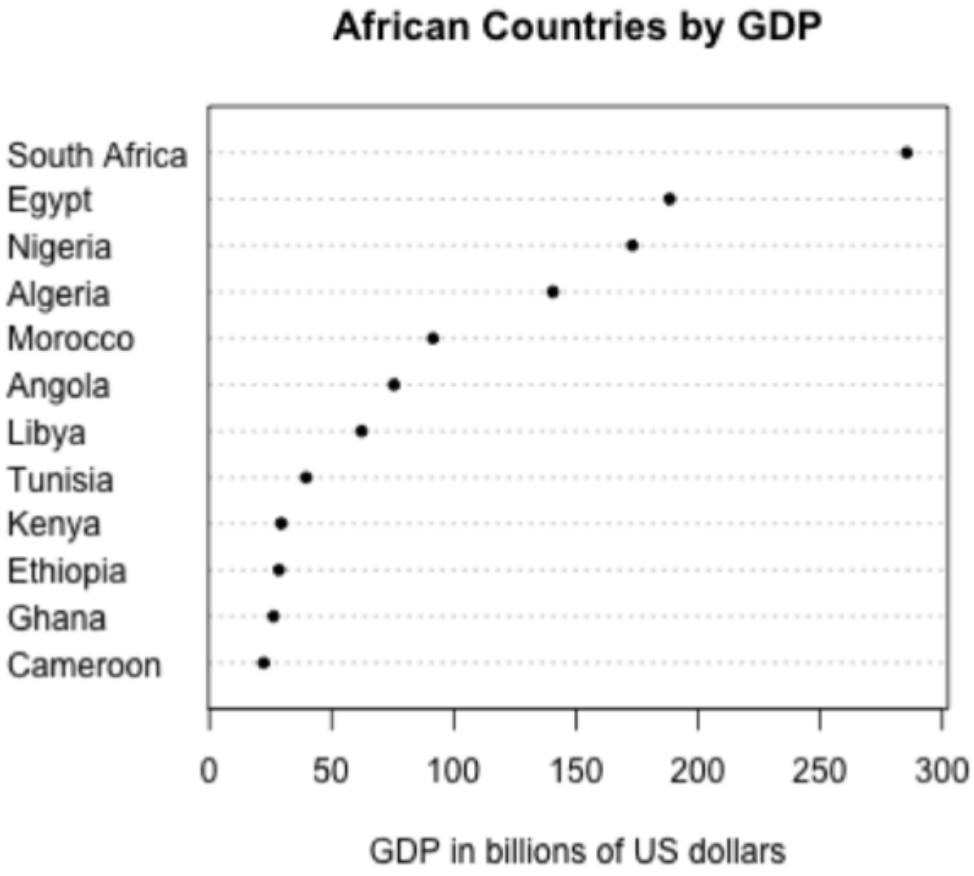
| Scale | Conditioning | Perception | Transformation | Context | Smoothing | Philosophy |
|---|---|---|---|---|---|---|

# Perception - Length

# Bar plot, Pie chart, Dot chart

- Experiments found that angle judgments based on pie charts are less accurate than length judgments from bar charts
- Length is easier to compare than area or volume
- Lengths that fall on a line are easier to compare than lengths on parallel lines, i.e., judgments based on dot charts are easier to make than judgments based on bar plots


African Countries by GDP
TOP COUNTRIES BY GDP IN U.S. $ BILLIONS
Gross domestic product (GDP) refers to the market value of all final goods and services produced within a country in a given period (2005 - 2009).
GDP CALCULATION
private consumption + gross investment + government spending + (exports – imports)
$ 285.4 b
SOUTH AFRICA
$ 188.4 b
EGYPT
$ 173 b
NIGERIA
$ 140.6 b
ALGERIA
$ 91.4 b
MOROCCO
$ 75.5 b
ANGOLA
$ 62.3 b
LIBYA
$ 39.6 b
TUNISIA
$ 29.4 b
KENYA
$ 28.5 b
ETHIOPIA
$ 26.2 b
GHANA
$ 22.2 b
CAMEROON


African Countries by GDP
South Africa
Egypt
Nigeria
Algeria
Morocco
Angola
Libya
Tunisia
Kenya
Ethiopia
Ghana
Cameroon
0
50
100
150
200
250
300
GDP in billions of US dollars

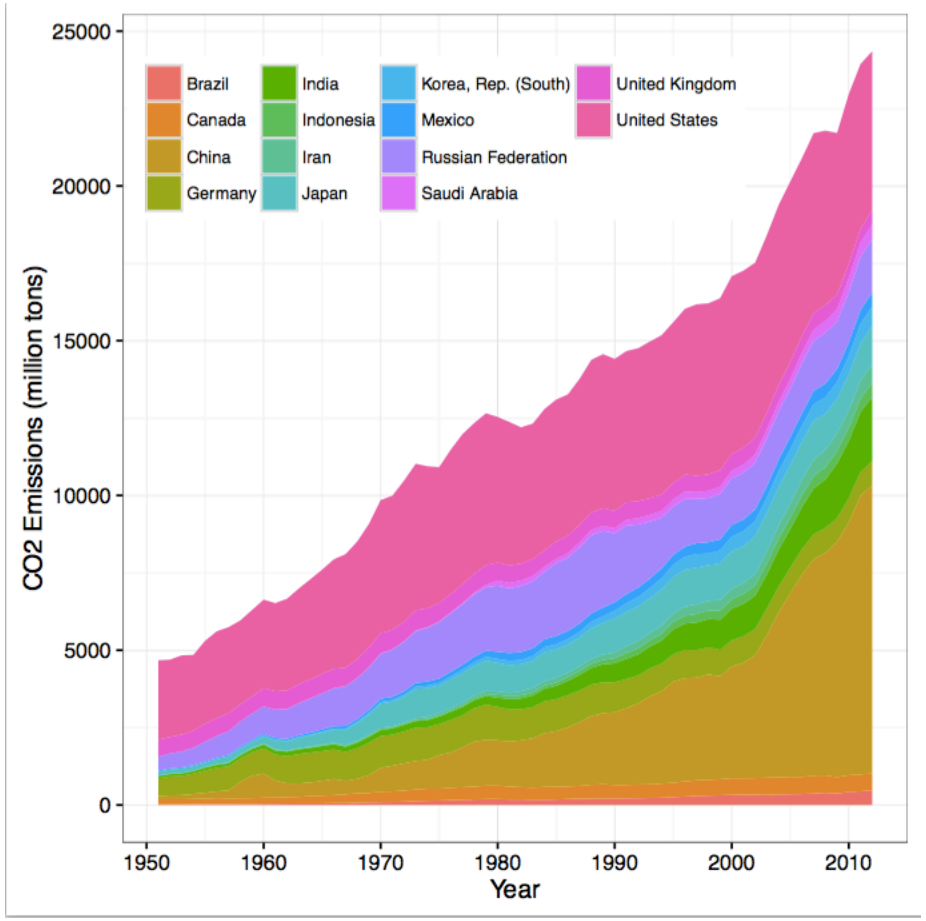
# Stacking and Jiggling

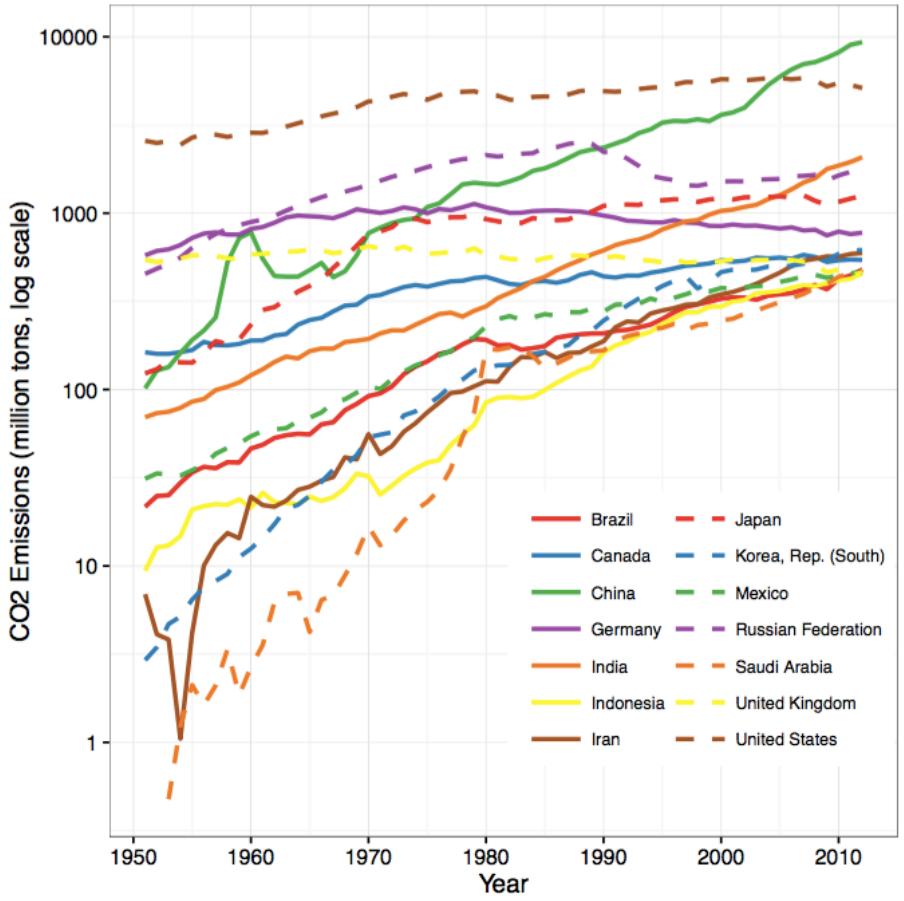
- Stacked bar plots and histograms are difficult to read because the base line moves from one bar to the next
- Line plots where the area between successive lines represent the measurement are very difficult to read because the base line jiggles up and down.

# CO2 Emissions from Fuel Consumption

- Data on historical carbon dioxide (CO2) emissions from fuel combustion (http://cait.wri.org)
- Country annual CO2 emissions date back to 1850
- Typical report on trends since 1950 for the 14 countries that emitted the greatest amount of CO2 in 2012
- World Resources Institute (http://www.wri.org/)

# CO2 Emissions



# Transformations

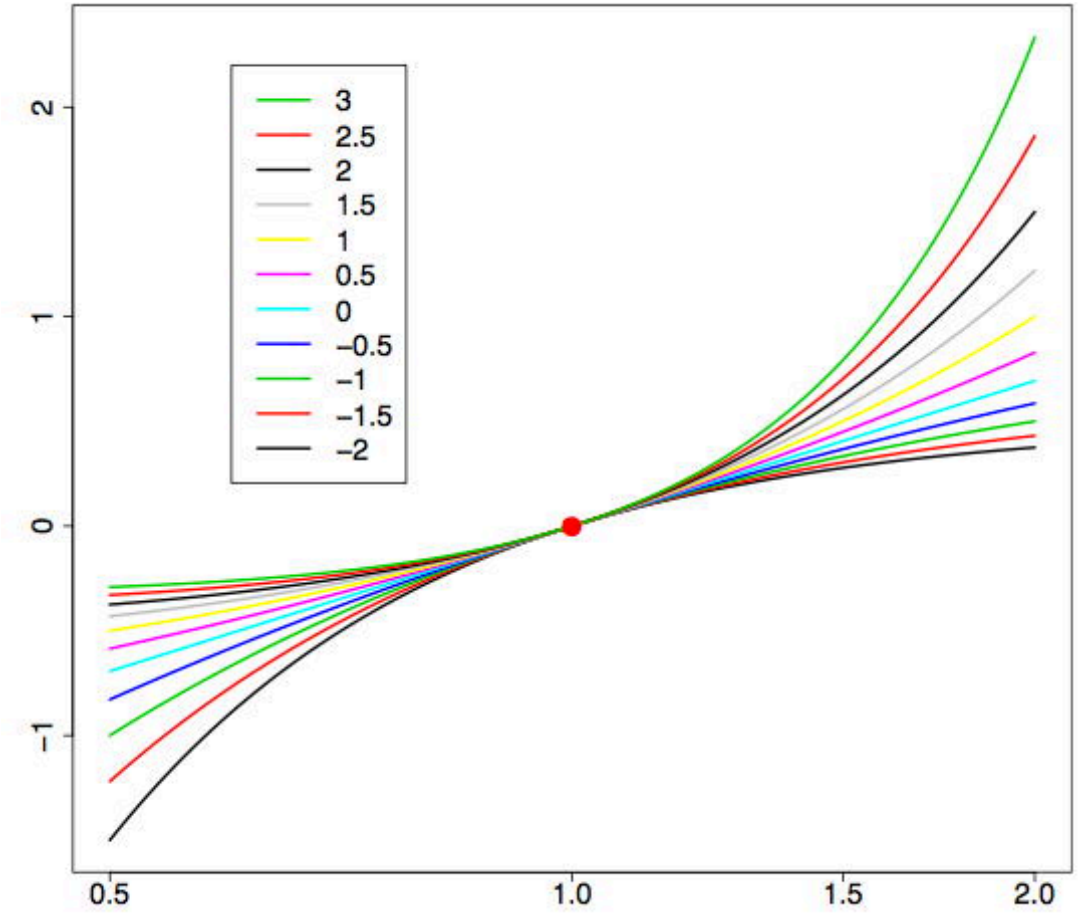
# Why Transform Variables?

- Reveal distribution of most of the observations (otherwise much of the data is squashed in a small region)
- Numerical summaries of a transformed data are better summaries of a symmetric distribution
- Choose a transformation that's simple and easily interpreted in the context of the problem, e.g., a power of 2, 3, ½, 0 (log), -1

# Power Transformation

$$x^{(p)} = \frac{x^p - 1}{p}$$

Box-Cox Transformation




Preserve order of values

Effective when max / min > 5

Sometimes add a shift before transform

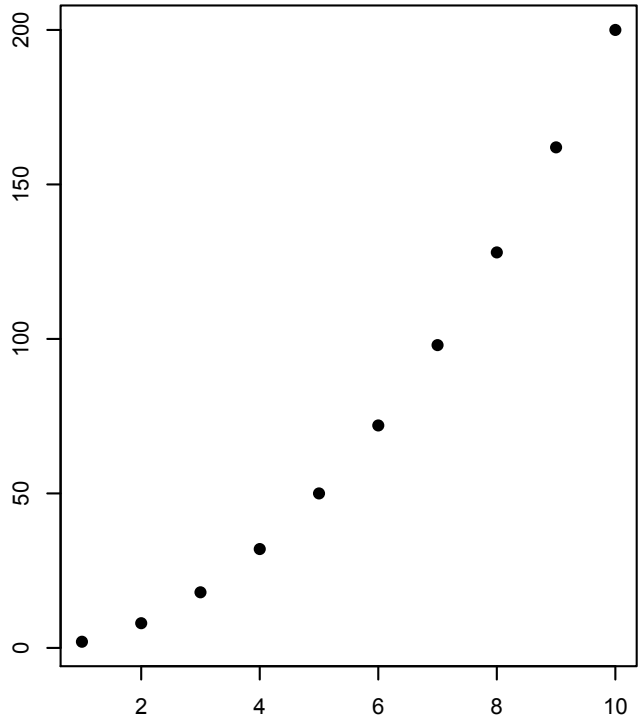
Ratio of hinges can help select a transformation

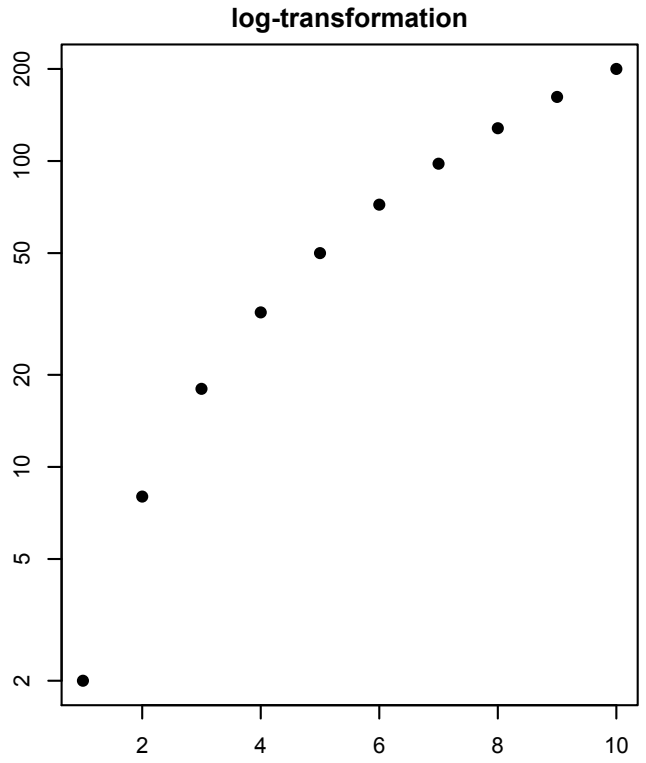
$$\frac{Upper\ Quartile - Median}{Median - Lower\ Quartile} \approx 1$$

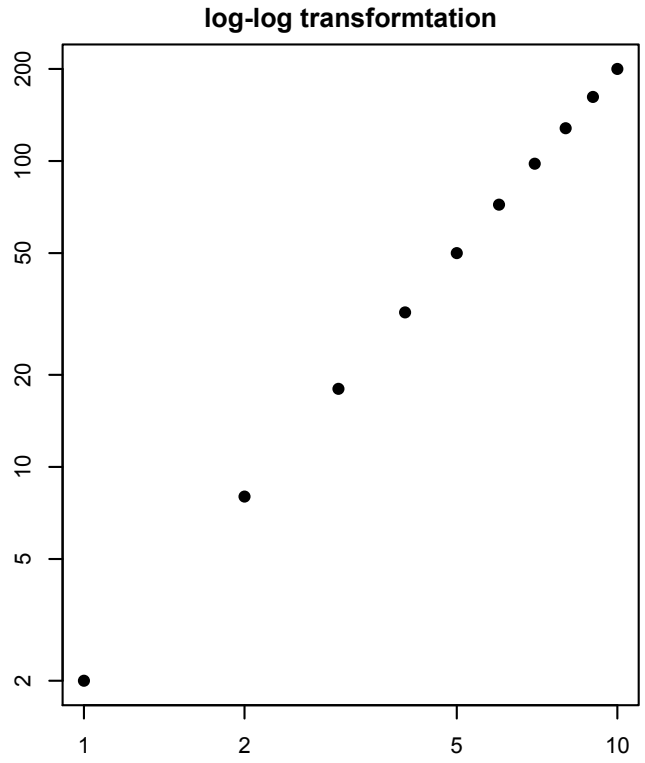
# Why Straighten Relationships?

- Easier to uncover the form of the relationship if we can transform it to linear relationship; we see what transformation used to make it linear
- Linear relationships are particularly simple to interpret & fit
- Choose a transformation that's simple and easily interpreted in the context of the problem, e.g., a power of 2, 3, ½, 0 (log), -1

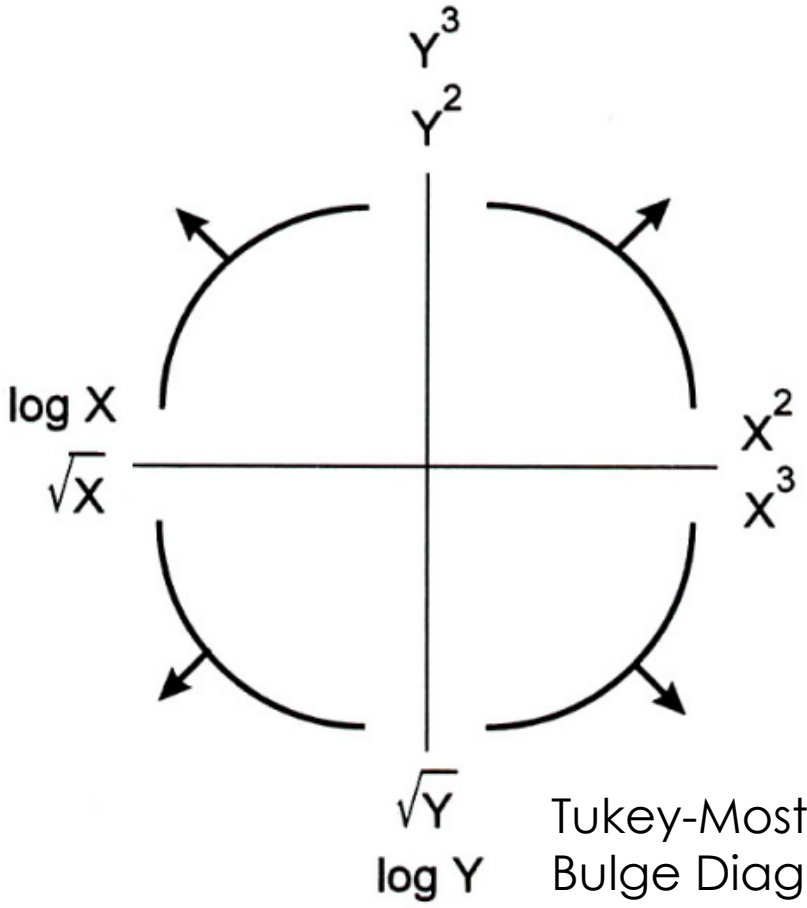
# Straighten Relationships with Transformations



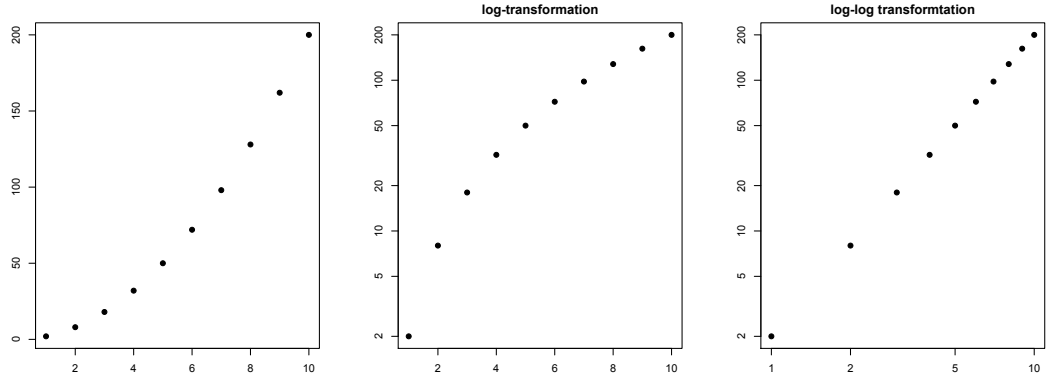



# Straighten Relationships with Transformations




Tukey-Mosteller Bulge Diagram

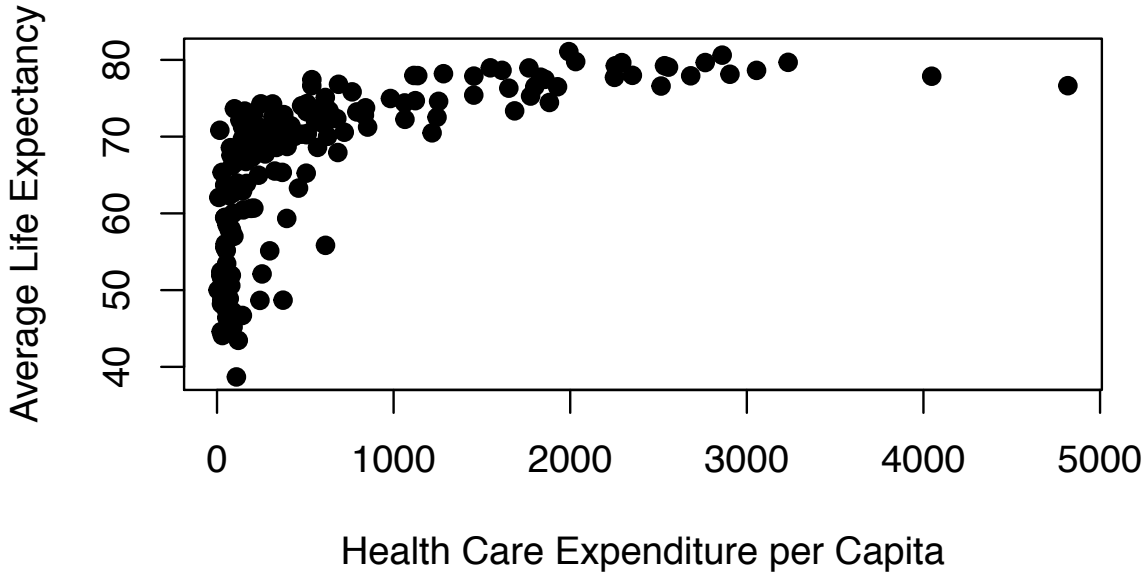


# World Bank Country Statistics

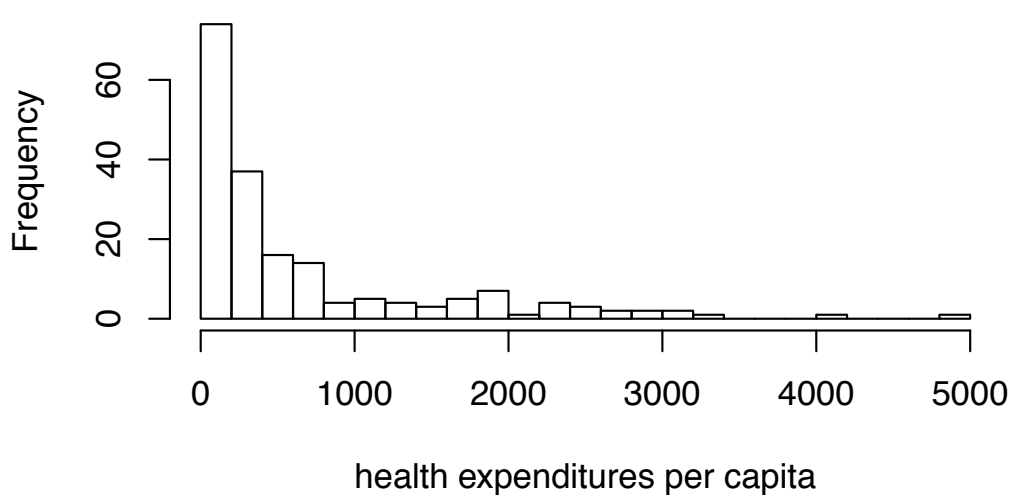
- World Bank provides financial and technical assistance to developing countries.
- In 2010, the World Bank launched an Open Data Website that provides access to data from their reports on topics such as GDP, education, health, and the environment.
- We are interested in the relationship between life expectancy and health expenditures
- These variables are measured at the country level

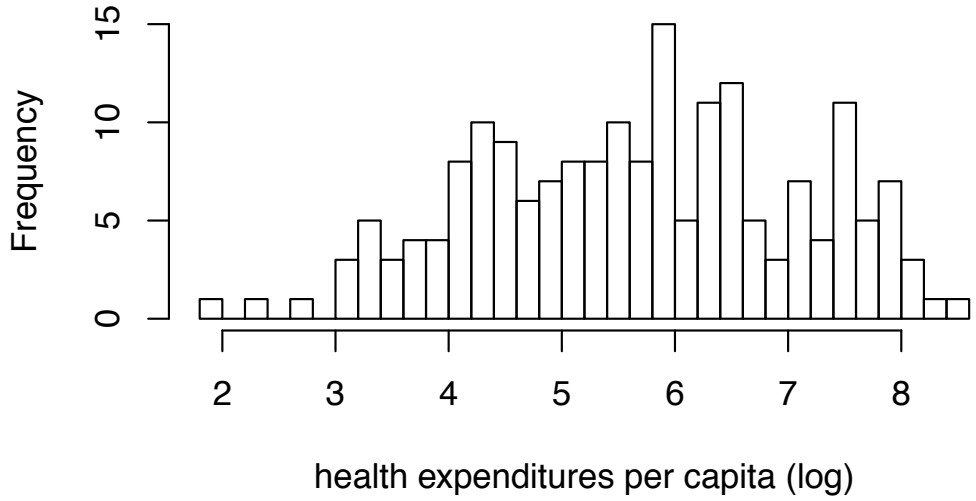
# Healthcare Costs & Life Expectancy

What does the bulge diagram tell us?

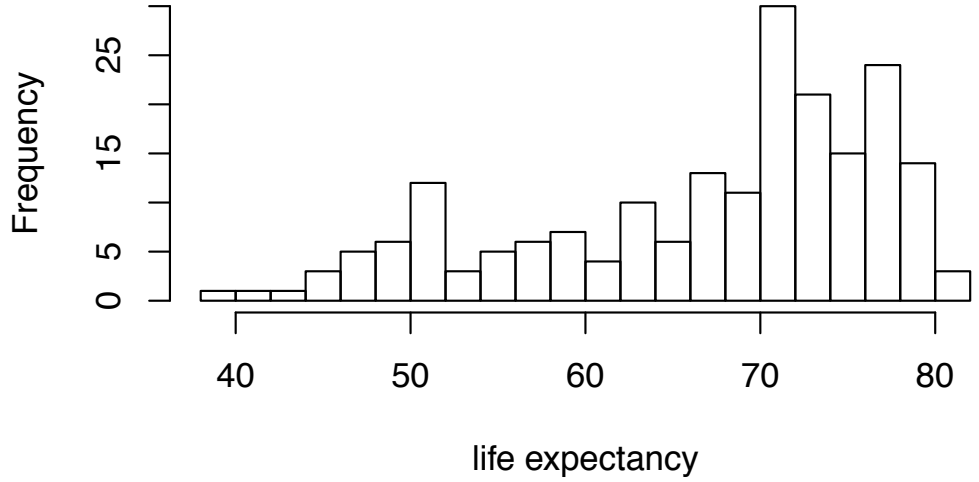


# Healthcare Costs



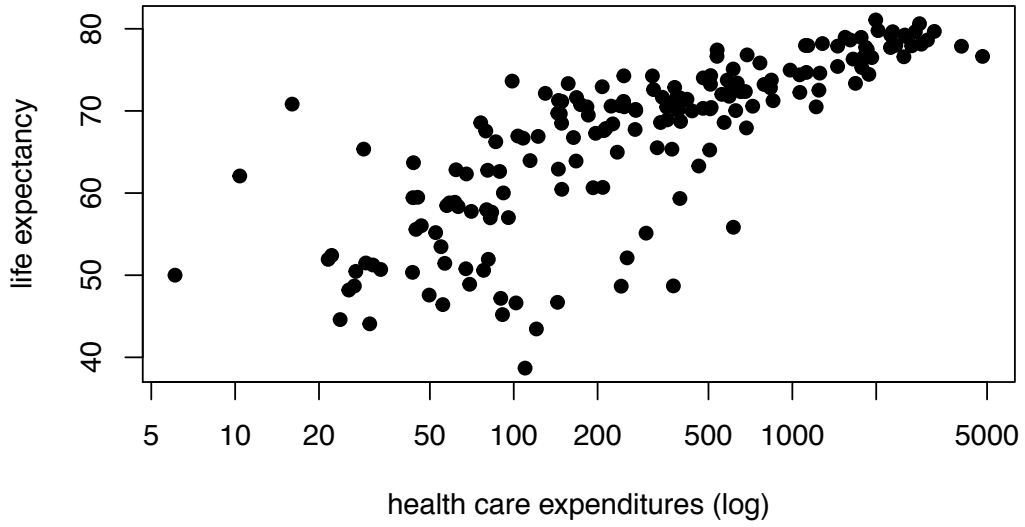



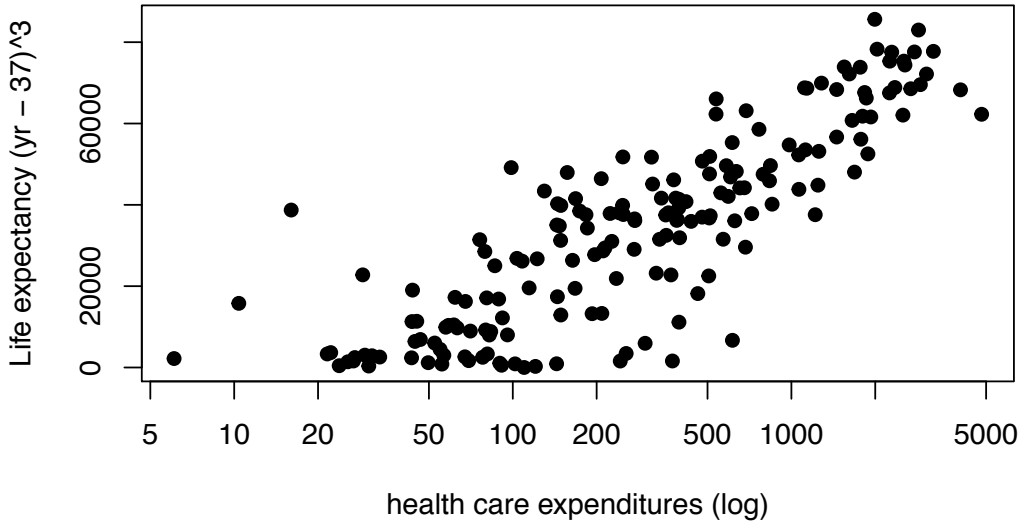
# Life Expectancy




- Unusual feature – left skew. Upper bound on life expectancy
- What transformation?
  - Range is factor of 2 so shift first
  - Pull up the low end with a square or cube transformation

# Healthcare Costs & Life Expectancy




Issues remaining:
3 unusual countries
Complexity of cube model

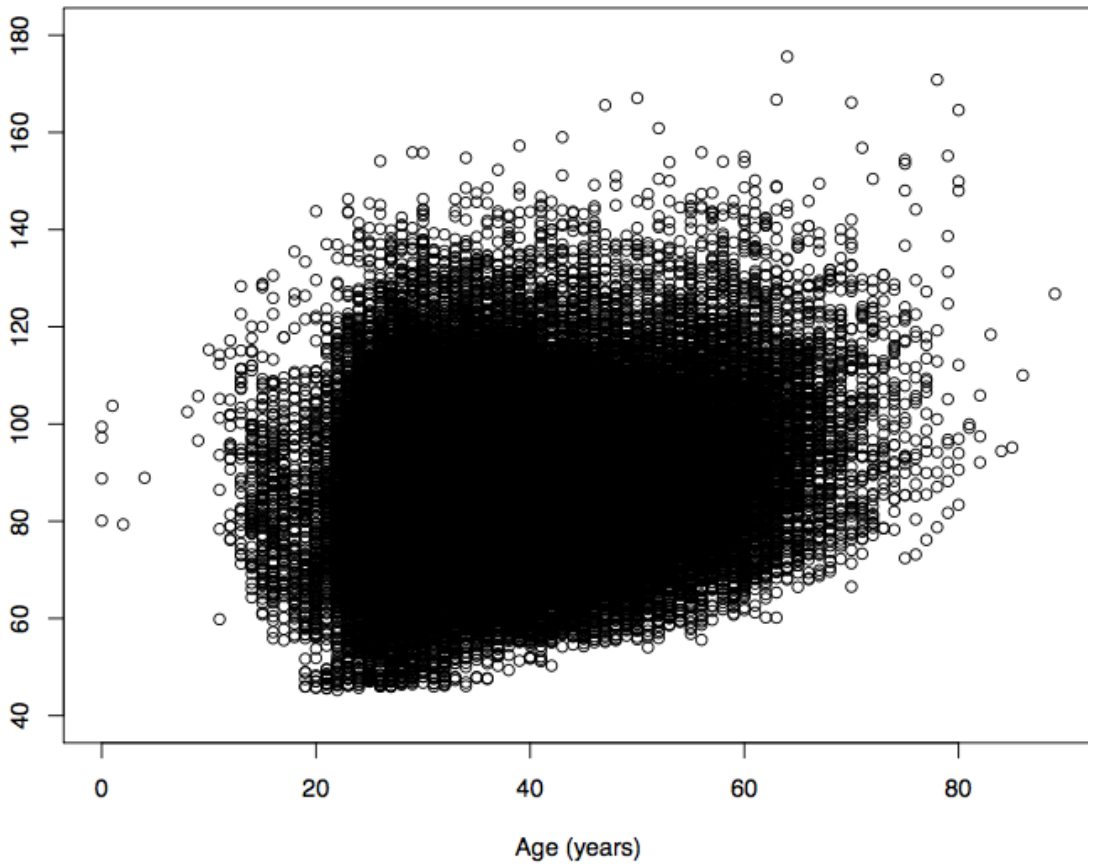
# Add Context

# Add Context

- Label axes, including units
- Add Reference lines and markers for important values
- Label points of unusual/interesting observations
- Include captions that describe data, how plotted, and describe important features

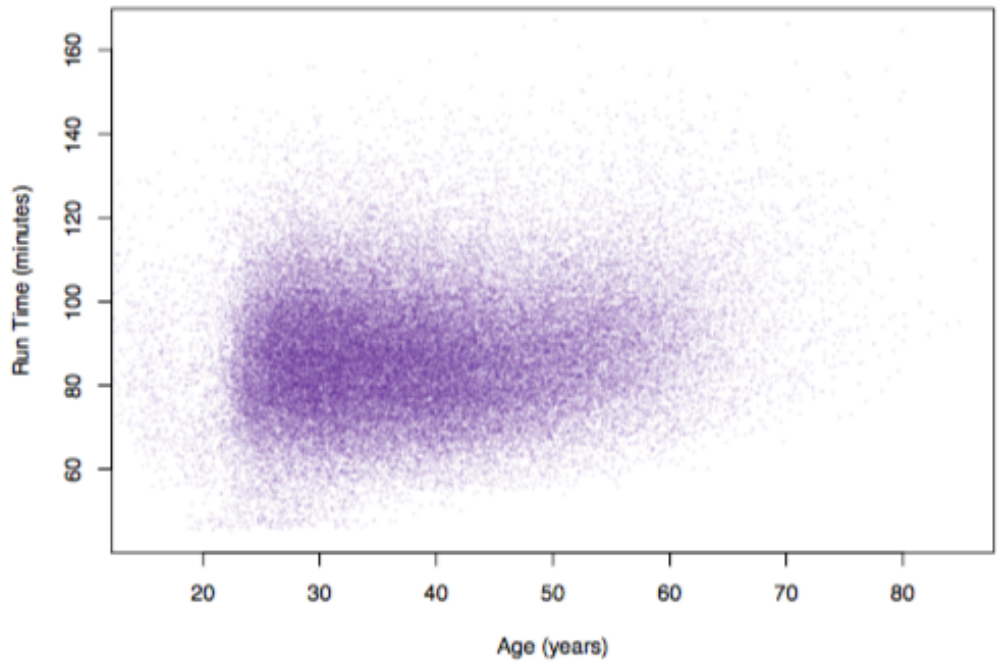
# Large n (records)

# Cherry Blossom Run




- 3-dimensional histogram is needed, but hard to come by
- Use heat map or hexbin plot or transparency
- Add smooth curve that takes local averages to see the conditional center, i.e., average y in a neighborhood of x

# Cherry Blossom Run



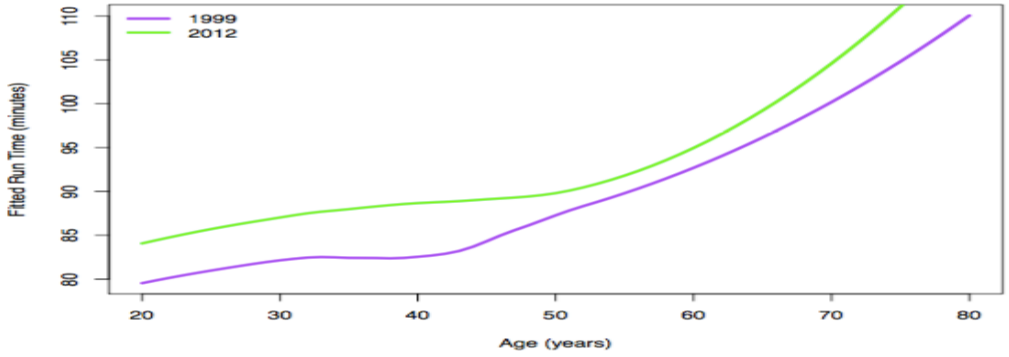

Slightly transparent points

Local Smoothing helps us see the center

Control for year – race popularity

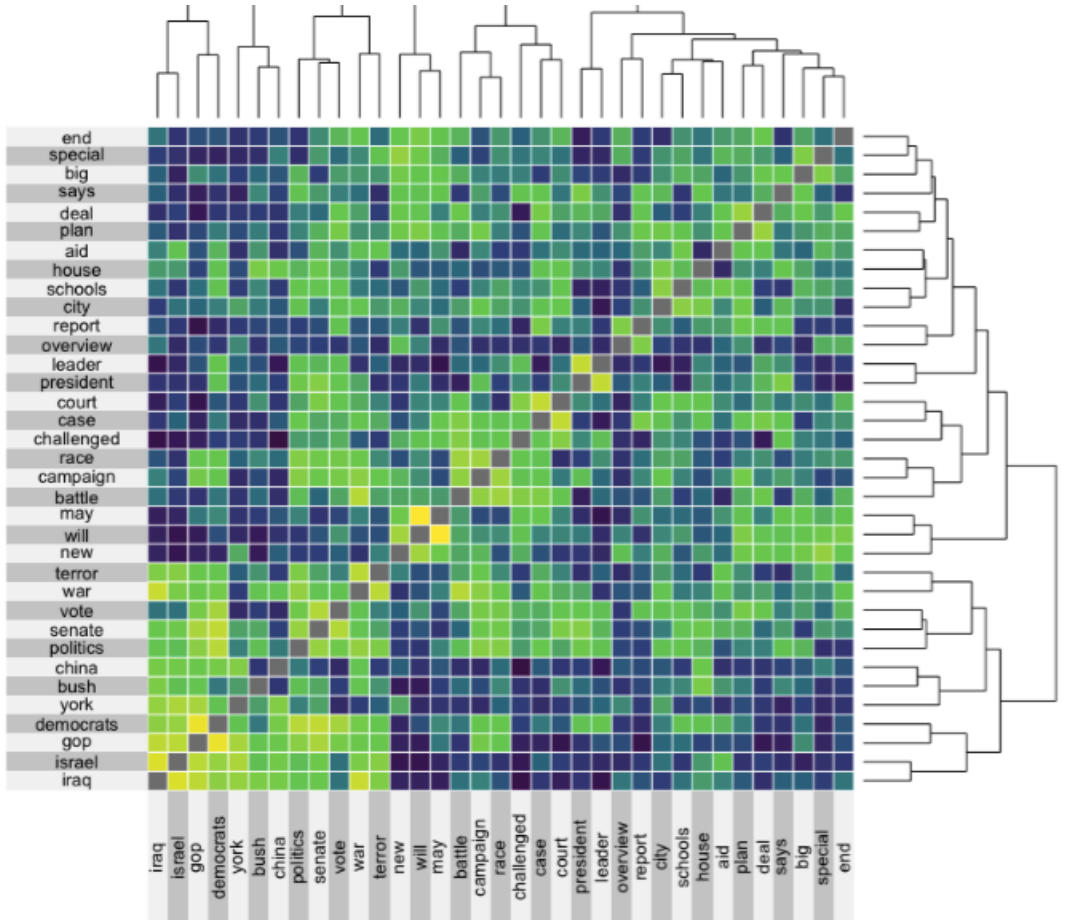
Observational data – snapshot in time

Not Longitudinal – follow same people in time



# Large p (variables)

# Heat map




Documents – records

Words counts – variables

Hierarchical clustering groups documents that have similar distributions of words

Heat Map - Color is used to denote closeness

# Philosophy

# Reveal the Data

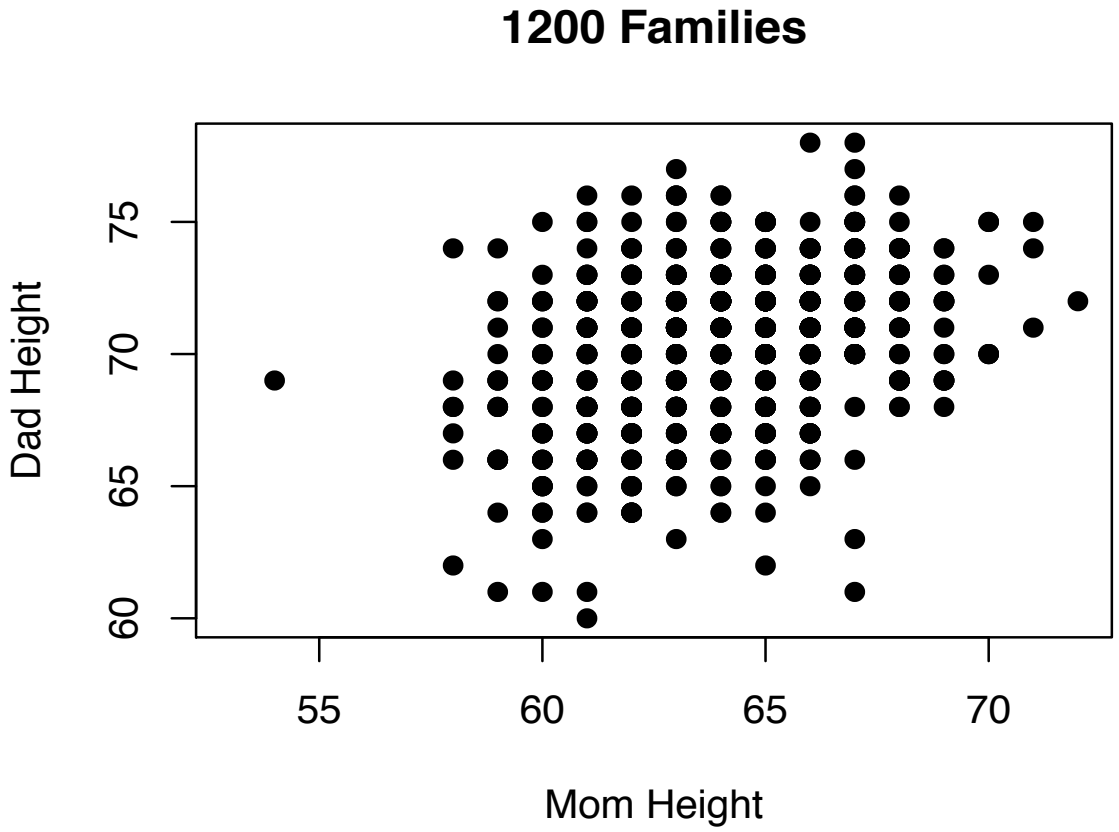
- Choose scale appropriately
- Avoid having other graph elements interfere with data
- Use visually prominent symbols
- Eliminate superfluous material, aka chart junk
- Avoid over-plotting

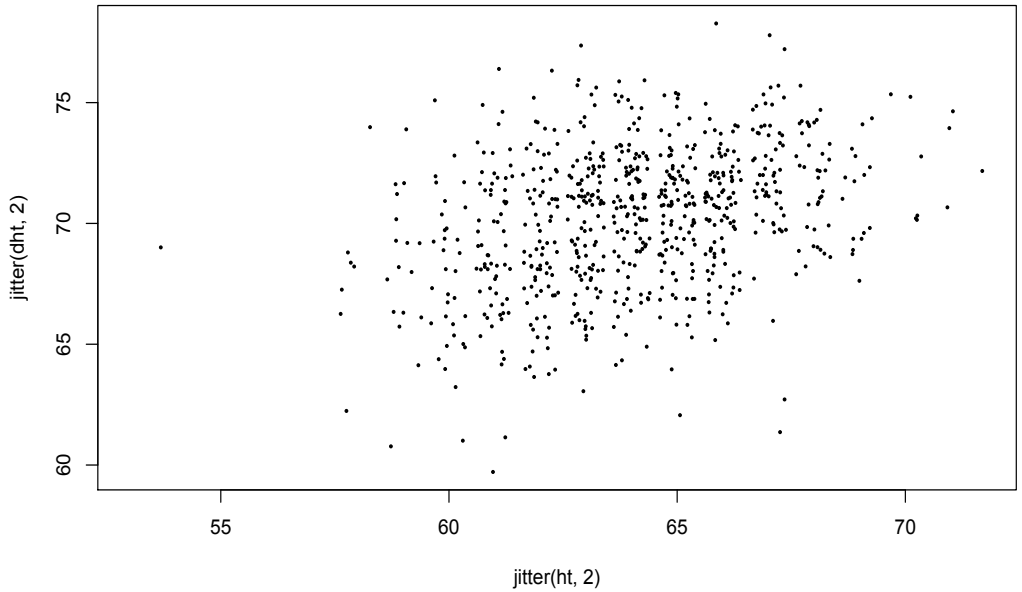
# Avoid over-plotting

## Why are there so few data points?

Jitter: Add random noise so the values aren't plotted on top of each other

Shrink the plotting symbol so they don't plot on top of each other



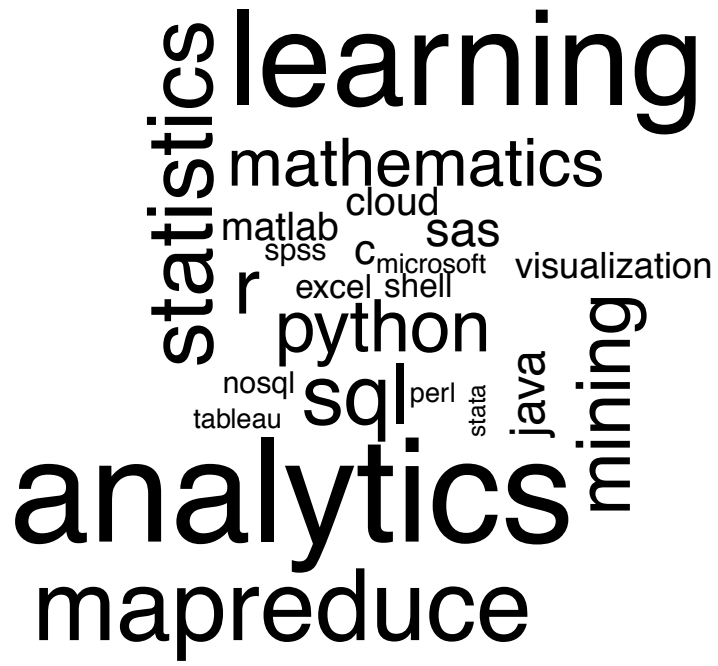
# Facilitate Comparisons

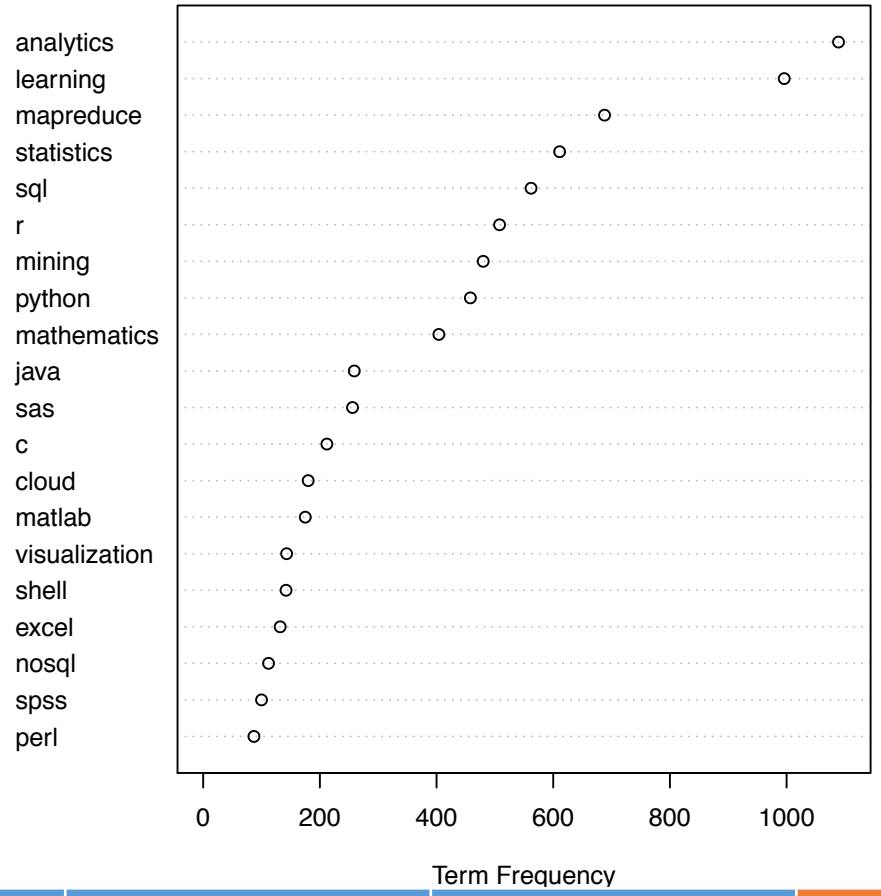
- Put Juxtaposed plots on same scale
- Make it easy to distinguish elements of *superposed* plots, e.g. color, line type
- Avoid Stacking and Jiggling the baseline
- Avoid angles, extra dimensions (e.g., areas rather than lines)
- Don't break the visual metaphor, i.e., if use rectangles, then area should correspond to value

# Comparison: area vs length

Order of words/counts is random – makes it difficult to compare

Broken Visual metaphor – count is represented by height of word, not area



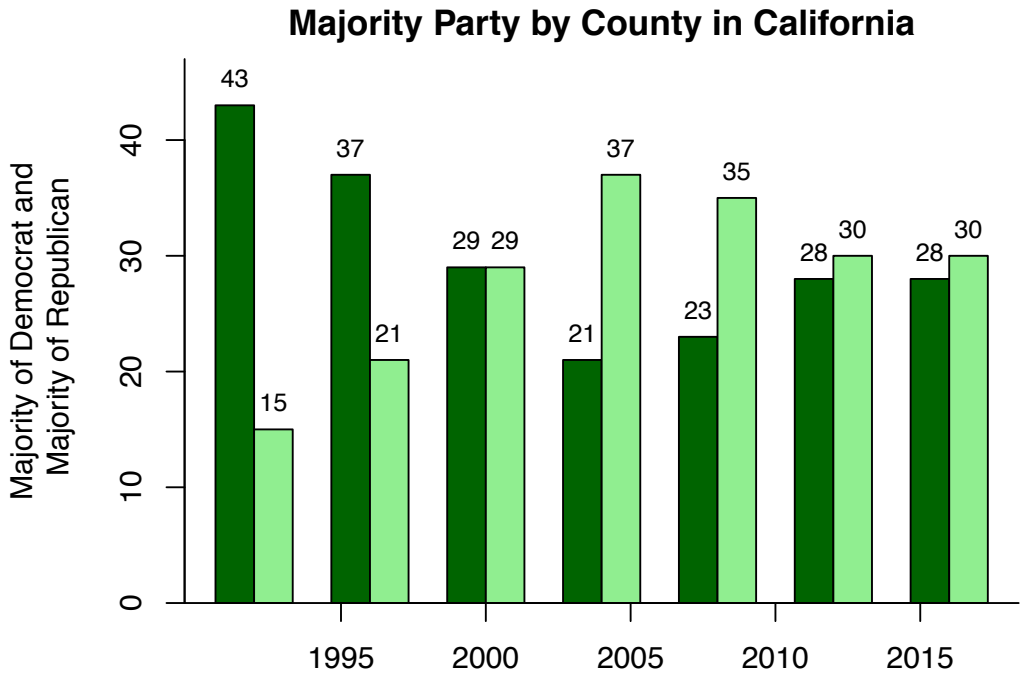
# Make a plot information rich

- Describe what you see in the Caption
- Add context with Reference Markers (lines and points) including text
- Add Legends and Labels
- Use color and plotting symbols to add more information
- Plot the same thing more than once in different ways/scales
- Reduce clutter

# Captions

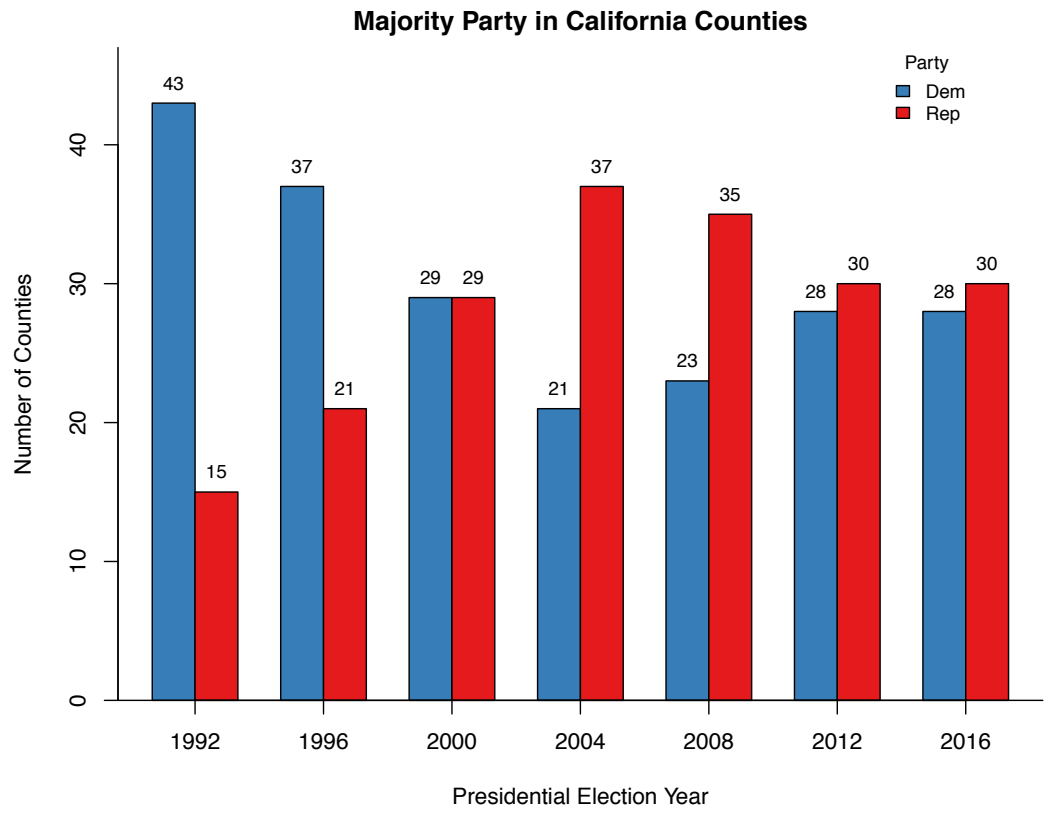
- Captions should be comprehensive
- Self-contained
- Captions should:
  - Describe what has been graphed
  - Draw attention to important features
  - Describe conclusions drawn from graph

# Iterate – Example Voter Registration



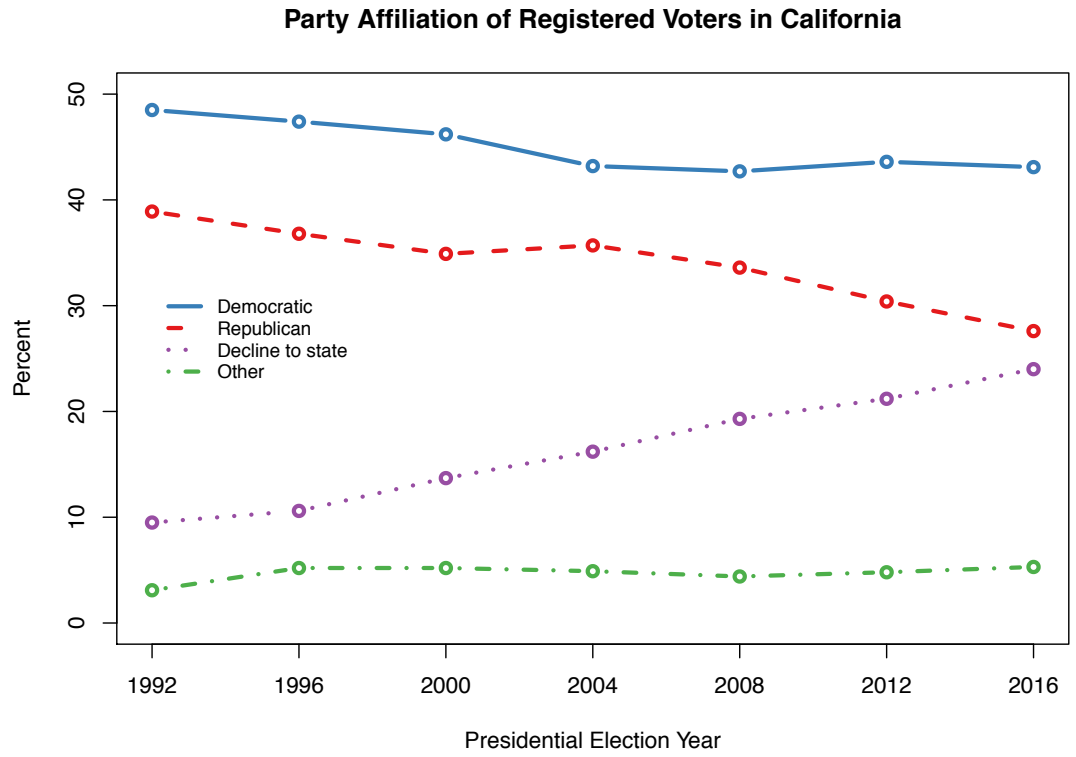

- Location of tick marks under bars
- Color of bars – indicate party
- Title confusing
- Y-axis label confusing
- X-axis label missing

# Voter Registration Trends




- Check data for understanding of how plot is made
- Observation? People vote, not counties
- Lurking variable? County size - small counties tend to be rural and conservative

# Voter Registration Trends

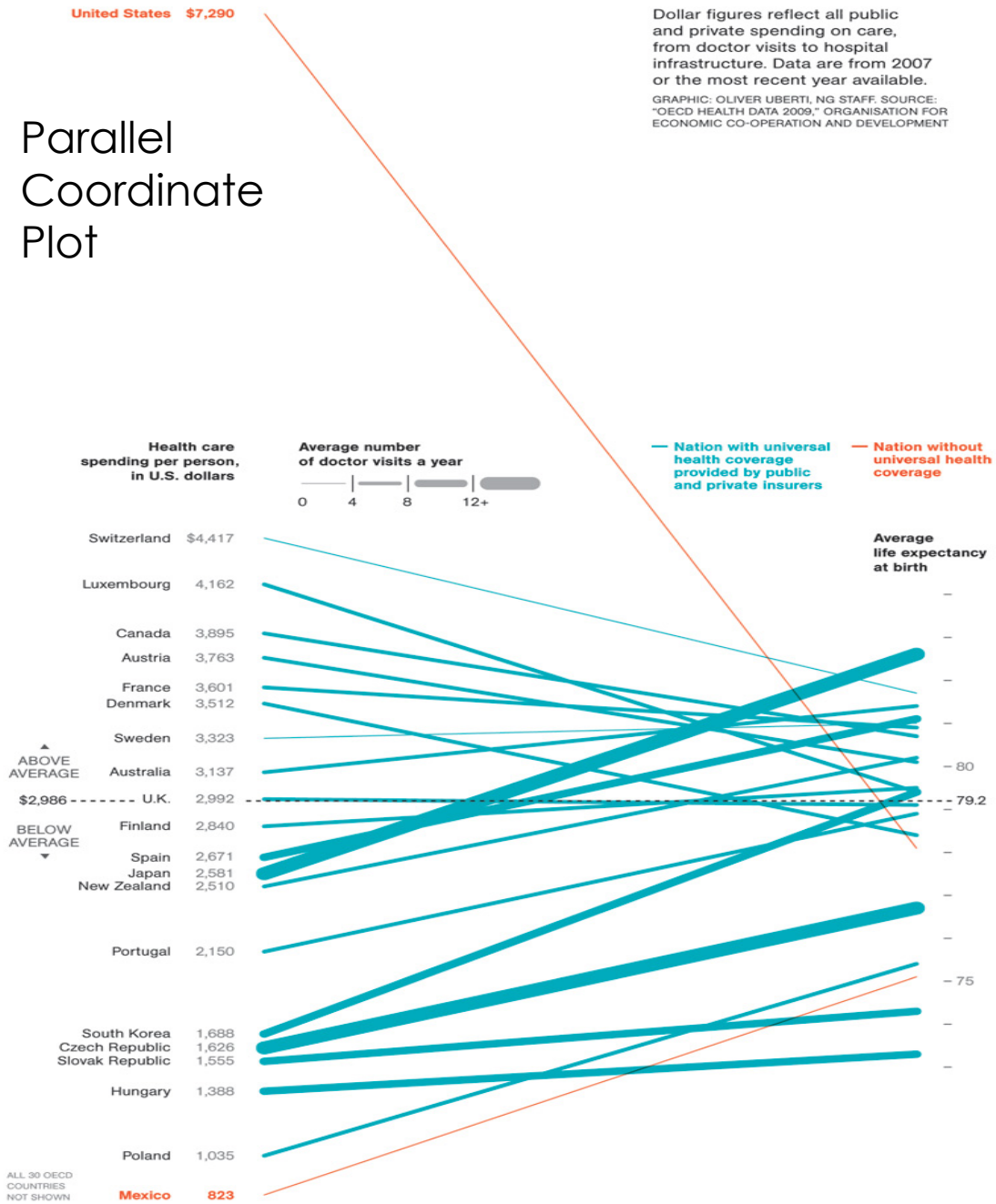



- What is the message?
- Can we improve it?
- Collect better/more data
  - Decline to state and other parties are missing
  - Voter registration totals may be more useful

# Good Plot Making Practice

- Put major conclusions in graphical form
- Provide reference information
- Proof read for clarity and consistency
- Graphing is an iterative process
- Multiplicity is OK, i.e., two plots of the same variable may provide different messages
- Make plots data rich

# Parallel Coordinate Plot




# Univariate Displays

| Type | Plot |
| --- | --- |
| Numeric – | few observations<br>Histogram, Density curve<br>Box plot, Violin plot<br>Normal quantile plot<br>Few Observations - Rug plot, Dot plot<br>Caution if discrete: density curves and box plots may be misleading |
| Categorical –<br>Counts of categories | Dot chart<br>Bar chart<br>Pie chart (avoid!)<br>Caution if ordinal –order of bars, dots, etc. should reflect category order |

# Bivariate Displays

| | Numeric | Categorical |
|---|---|---|
| Numeric | Scatter plot<br>Smooth scatter<br>Smooth lines and curves | Multiple histograms,<br>density curves,<br>Avoid jiggling! |
| Categorical | | Side-by-side bar plot<br>Overlaid Lines plot<br>Side-by-side dot chart<br>Mosaic plot<br>Avoid stacking! |