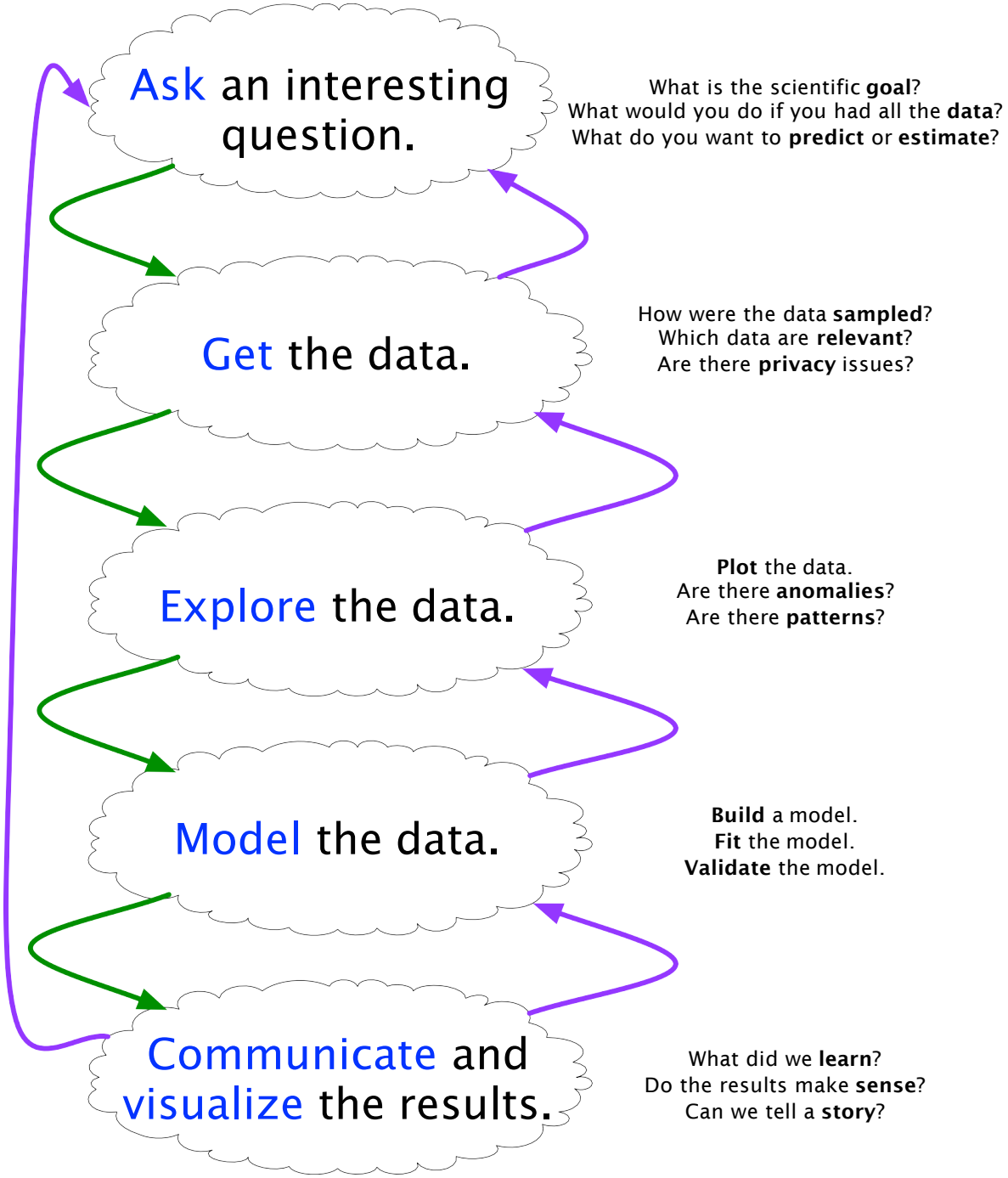
Statistical Data Exploration and Visualization

Data Exploration

Not always sure what we are looking for (until we find it)


Ask an interesting question.
What is the scientific goal?
What would you do if you had all the data?
What do you want to predict or estimate?
Get the data.
How were the data sampled?
Which data are relevant?
Are there privacy issues?
Explore the data.
Plot the data.
Are there anomalies?
Are there patterns?
Model the data.
Build a model.
Fit the model.
Validate the model.
Communicate and visualize the results.
What did we learn?
Do the results make sense?
Can we tell a story?

Visualization

- Visualization is the conversion of data into a visual or tabular format.
- Visualization helps understand the characteristics of the data and the relationships among data items or attributes can be analyzed or reported.
- Visualization of data is one of the most powerful and appealing techniques for data exploration.
  - Humans have a well developed ability to analyze large amounts of information that is presented visually
  - Can detect general patterns and trends
  - Can detect outliers and unusual patterns

What is Data?

- Collection of data objects and their attributes

- An attribute is a property or characteristic of an object
  - Examples: eye color of a person, temperature, etc.
  - Attribute is also known as variable, field, characteristic, or feature
- A collection of attributes describe an object
  - Object is also known as record, point, case, sample, entity, or instance

Attributes

Objects

Tid	Refund	Marital Status	Taxable Income	Cheat
1	Yes	Single	125K	No
2	No	Married	100K	No
3	No	Single	70K	No
4	Yes	Married	120K	No
5	No	Divorced	95K	Yes
6	No	Married	60K	No
7	Yes	Divorced	220K	No
8	No	Single	85K	Yes
9	No	Married	75K	No
10	No	Single	90K	Yes

Type of variables (attributes)

- **Descriptive (categorical) variables**
  - **Nominal** variables (no order between values): gender, eye color, race group, ...
  - **Ordinal** variables (inherent order among values): response to treatment: none, slow, moderate, fast
- **Measurement variables**
  - **Continuous measurement** variable: height, weight, blood pressure ...
  - **Discrete measurement** variable (values are integers): number of siblings, the number of times a person has been admitted to a hospital ...

Properties of Attribute Values

- The type of an attribute depends on which of the following properties it possesses:
  - Distinctness: = ≠
  - Order: < >
  - Addition: + -
  - Multiplication: * /

  - Nominal attribute: distinctness
  - Ordinal attribute: distinctness & order
  - Interval attribute: distinctness, order & addition
  - Ratio attribute: all 4 properties

The Trouble with Summary Stats

Set A		Set B		Set C		Set D	
X	Y	X	Y	X	Y	X	Y
10	8.04	10	9.14	10	7.46	8	6.58
8	6.95	8	8.14	8	6.77	8	5.76
13	7.58	13	8.74	13	12.74	8	7.71
9	8.81	9	8.77	9	7.11	8	8.84
11	8.33	11	9.26	11	7.81	8	8.47
14	9.96	14	8.1	14	8.84	8	7.04
6	7.24	6	6.13	6	6.08	8	5.25
4	4.26	4	3.1	4	5.39	19	12.5
12	10.84	12	9.11	12	8.15	8	5.56
7	4.82	7	7.26	7	6.42	8	7.91
5	5.68	5	4.74	5	5.73	8	6.89

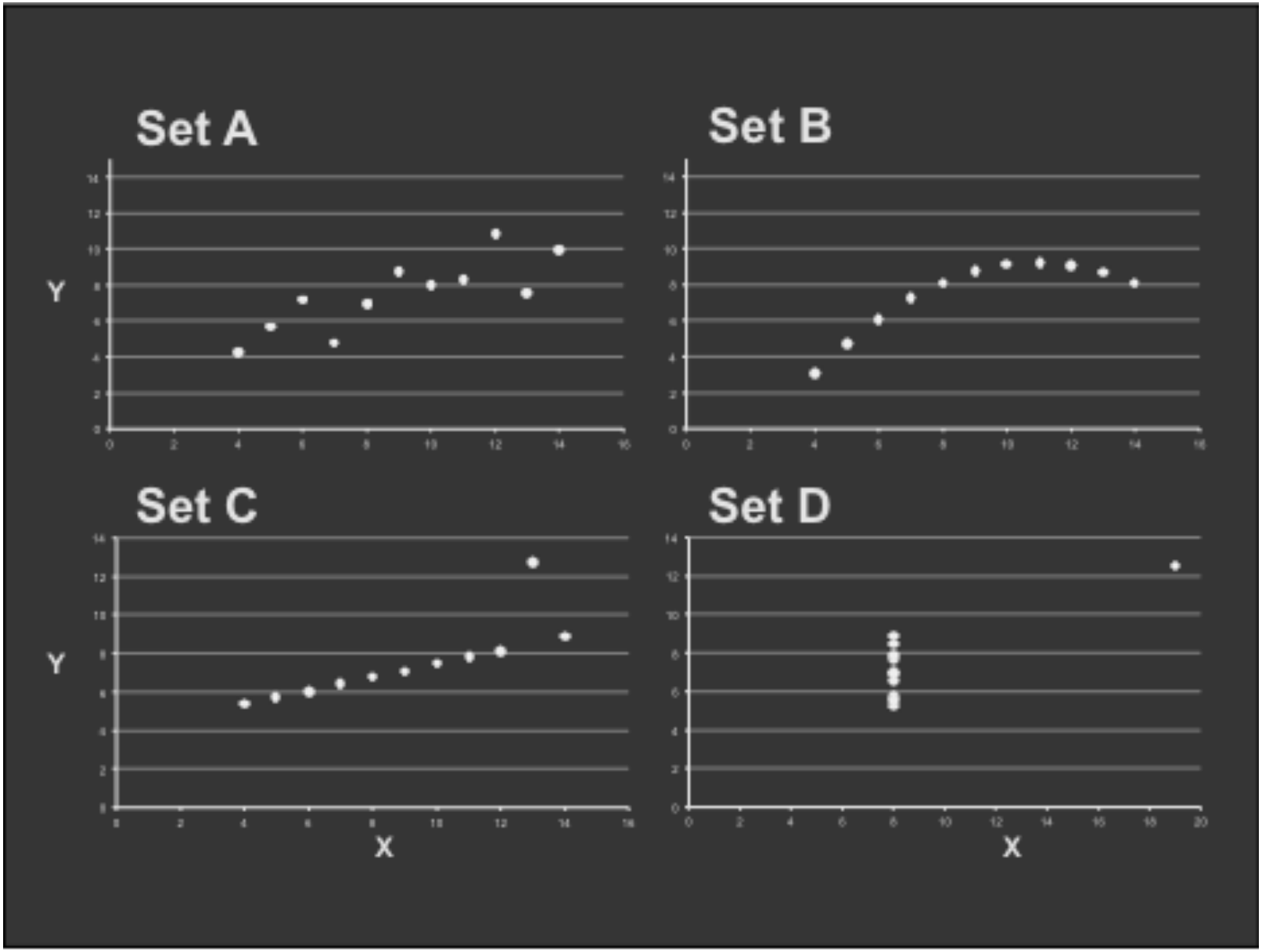
Summary Statistics Linear Regression

$u_X = 9.0$ $\sigma_X = 3.317$ $Y = 3 + 0.5\ X$

$u_Y = 7.5$ $\sigma_Y = 2.03$ $R^2 = 0.67$

[Anscombe 73]

Looking at Data



Visualization in R

- plot() is the main graphing function
- Automatically produces simple plots for vectors, functions or data frames
- Many useful customization options…

Chart types

- Single variable
  - Dot plot
  - Box-and-whisker plot
  - Histogram
  - Jitter plot (dot plot with multiple data sets)
  - Error bar plot
  - Cumulative distribution function

Chart types

- Two variables
  - Bar chart
  - Scatter plot
  - Line plot
  - Log-log plot
- More than two variables
  - Stacked plots
  - Parallel coordinate plot

Sample Data

Height	Weight	Waist	Hip	bp.sys	bp.dia
172	72	87	94	127.5	80
166	91	109	107	172.5	100
174	80	95	101	123	64
176	79	93	100	117	76
166	55	70	94	100	60
163	76	96	99	160	87.5
154	84	98	118	130	80
165	90	108	101	139	80
155	66	80	96	120	70
146	59	77	96	112.5	75
164	62	76	93	130	47.5
159	59	76	96	109	69
163	69	96	99	155	100
143	73	97	117	137.5	85
. . .					

Importing Data

- How do we get data into R?
- First make sure your data is in an easy to read format such as CSV (Comma Separated Values).

- Use code:

```
> dataset<-read.table("C:/bodyfat.csv",sep=",",header=TRUE)
> summary(dataset)
```

```
     Height          Weight          Waist
Min.   :131.0   Min.   :  0.00   Min.   :  0.0
1st Qu.:153.0   1st Qu.: 55.00   1st Qu.: 74.0
Median :159.0   Median : 63.00   Median : 84.0
Mean   :159.6   Mean   : 64.78   Mean   : 84.6
3rd Qu.:166.0   3rd Qu.: 74.00   3rd Qu.: 94.0
Max.   :196.0   Max.   :135.00   Max.   :134.0
```

Plotting a Vector

- *plot(v)* will print the elements of the vector v according to their index

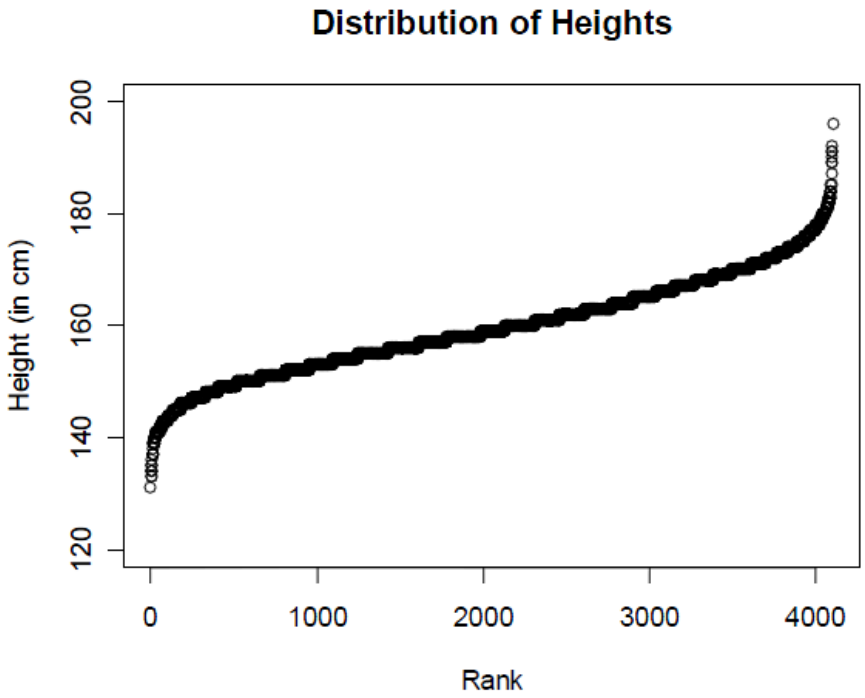
```
# Plot height for each observation
> plot(dataset$Height)

# Plot values against their ranks
> plot(sort(dataset$Height))
```

Parameters for plot()

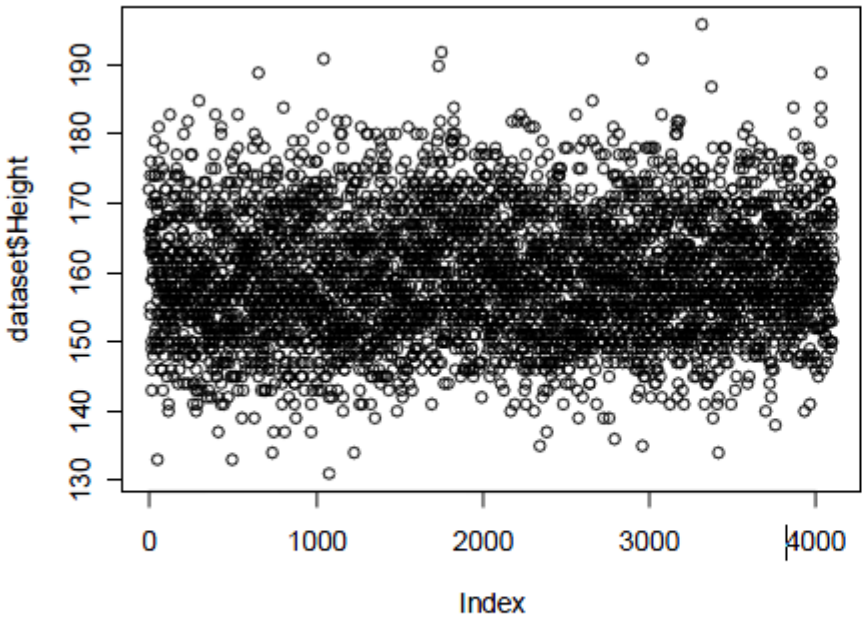
- Specifying labels:
  - main – provides a title
  - xlab – label for the x axis
  - ylab – label for the y axis

- Specifying range limits
  - ylim – 2-element vector gives range for x axis
  - xlim – 2-element vector gives range for y axis

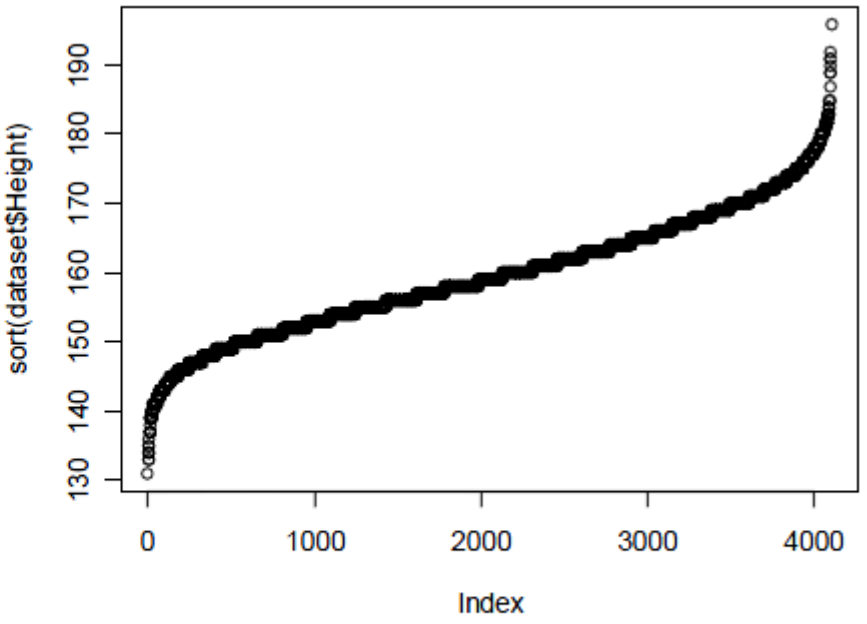



```
plot(sort(dataset$Height), ylim = c(120,200),
ylab = "Height (in cm)", xlab = "Rank", main = "Distribution of Heights")
```

Plotting a Vector



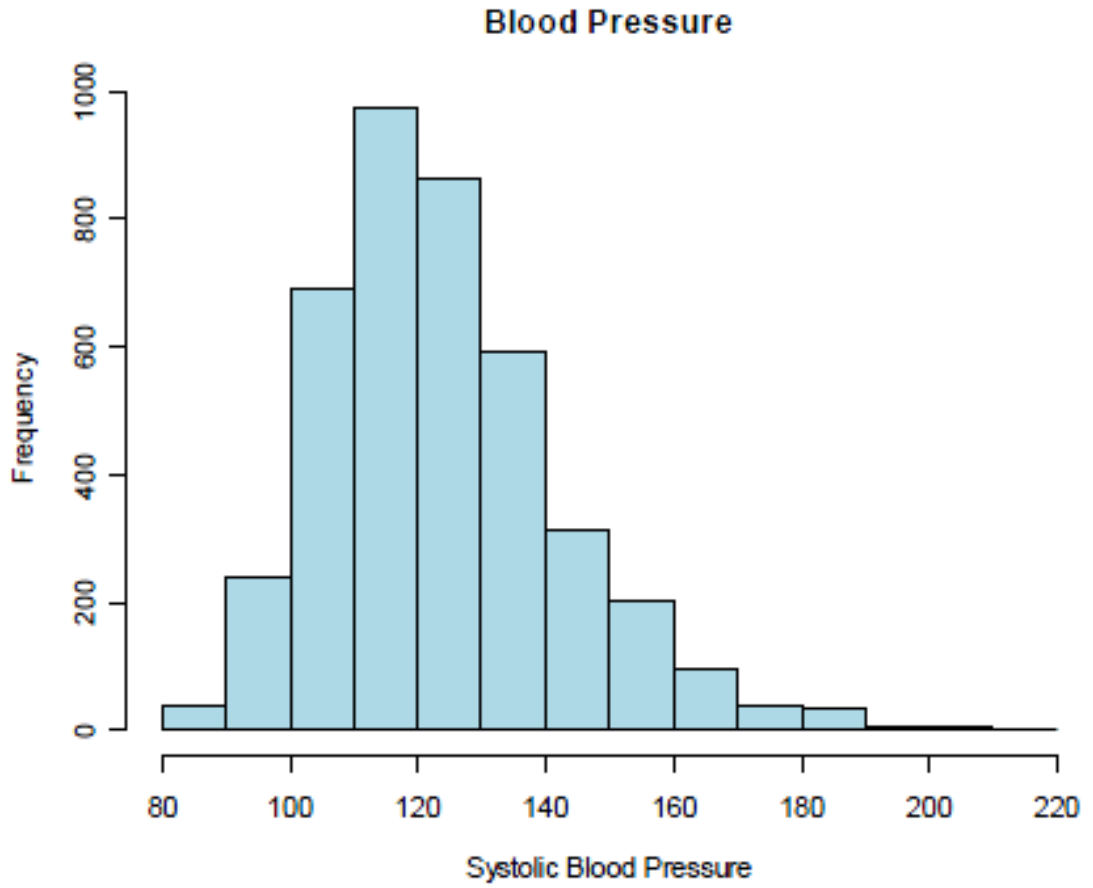

```
plot(dataset$Height)
```




```
plot(sort(dataset$Height))
```

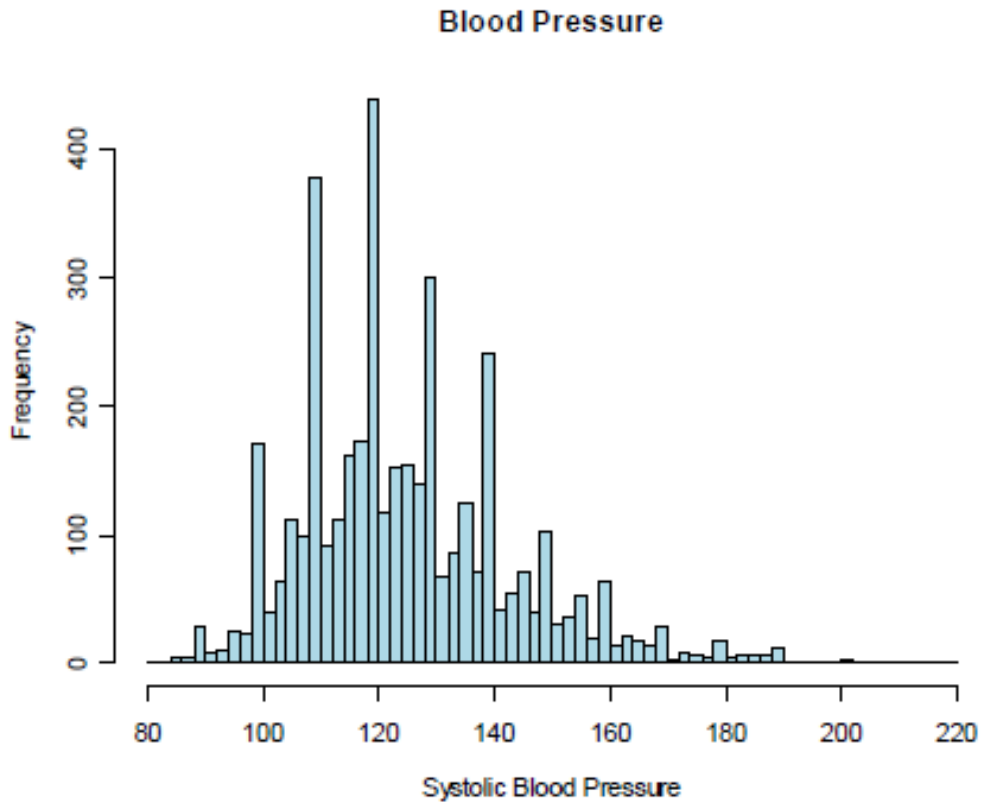
Histogram

```
hist(dataset$bp.sys, col = "lightblue",
xlab = "Systolic Blood Pressure", main = "Blood Pressure")
```



Histogram

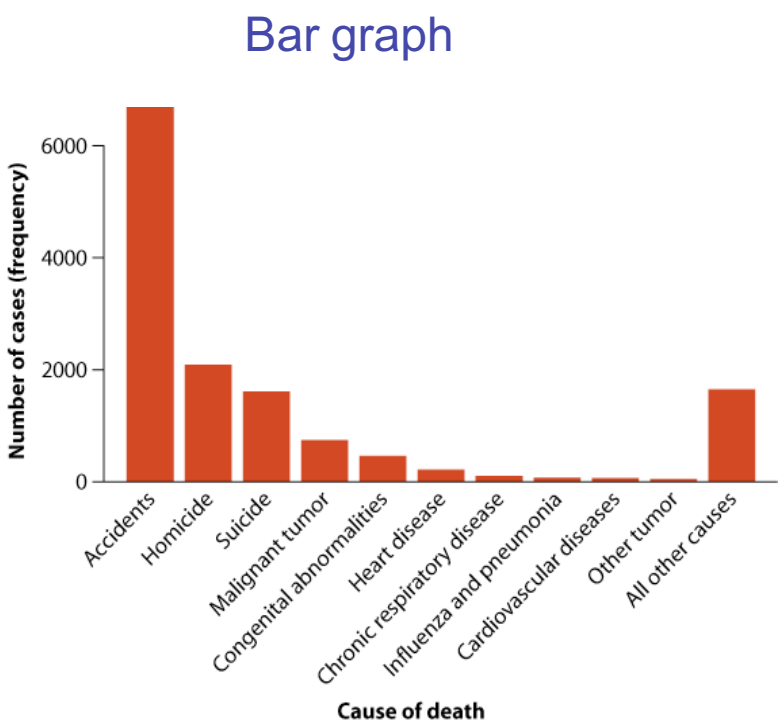
```
hist(dataset$bp.sys, col = "lightblue", breaks = seq(80,220,by=2),
     xlab = "Systolic Blood Pressure", main = "Blood Pressure")
```



Bar graph

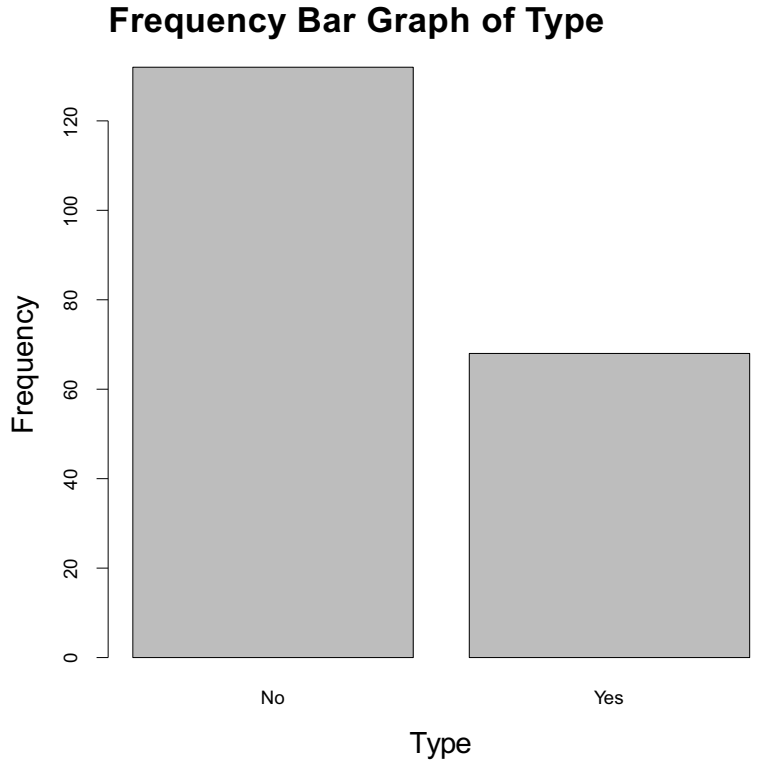
Cause of death	Frequency
Accidents	6,688
Homicide	2,093
Suicide	1,615
Malignant tumor	745
Heart disease	463
Congenital abnormalities	222
Chronic respiratory disease	107
Influenza and pneumonia	73
Cerebrovascular diseases	67
Other tumor	52
All other causes	1,653

Frequency table showing the ten most common causes of death in Americans between 15 and 19 years of age in 1999. The total number of deaths is n = 13,778.



Bar graphs and frequencies

```
> type.freq <- table(Pima.tr$type)
> barplot(type.freq, xlab = "Type", ylab = "Frequency", main = "Frequency Bar Graph of Type")
```



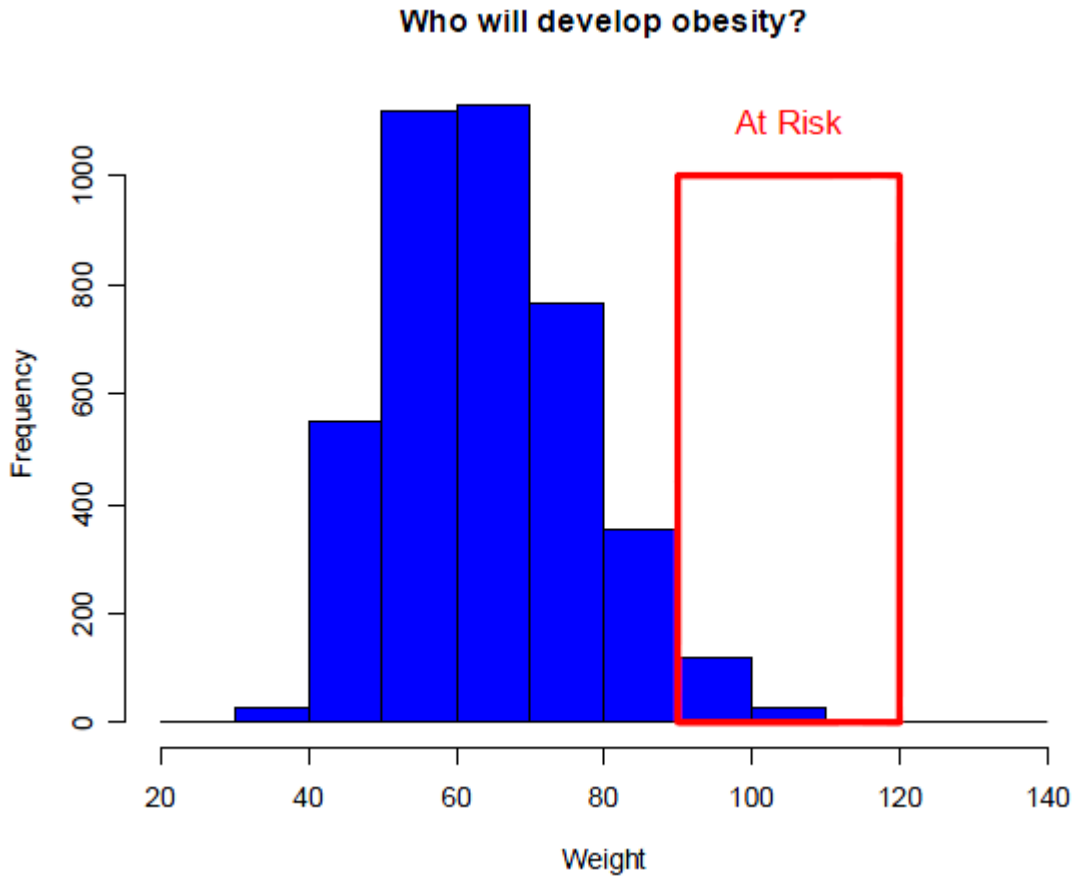
Type	Frequency
Yes	67
No	140

Adding a Label Inside a Plot

> hist(dataset$Weight, xlab = "Weight", main = "Who will develop obesity?", col = "blue")

> rect(90, 0, 120, 1000, border = "red", lwd = 4)

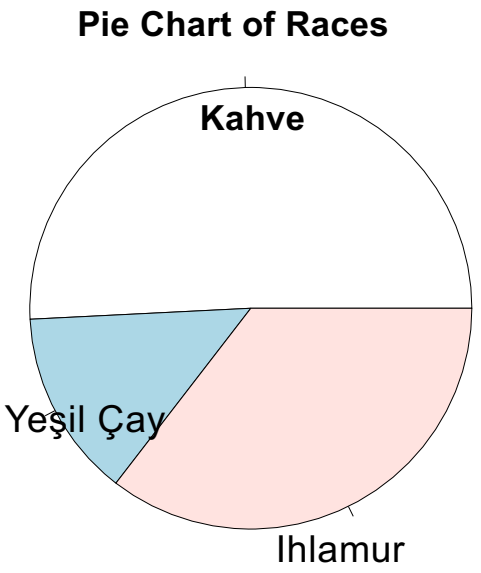
> text(105, 1100, "At Risk", col = "red", cex = 1.25)



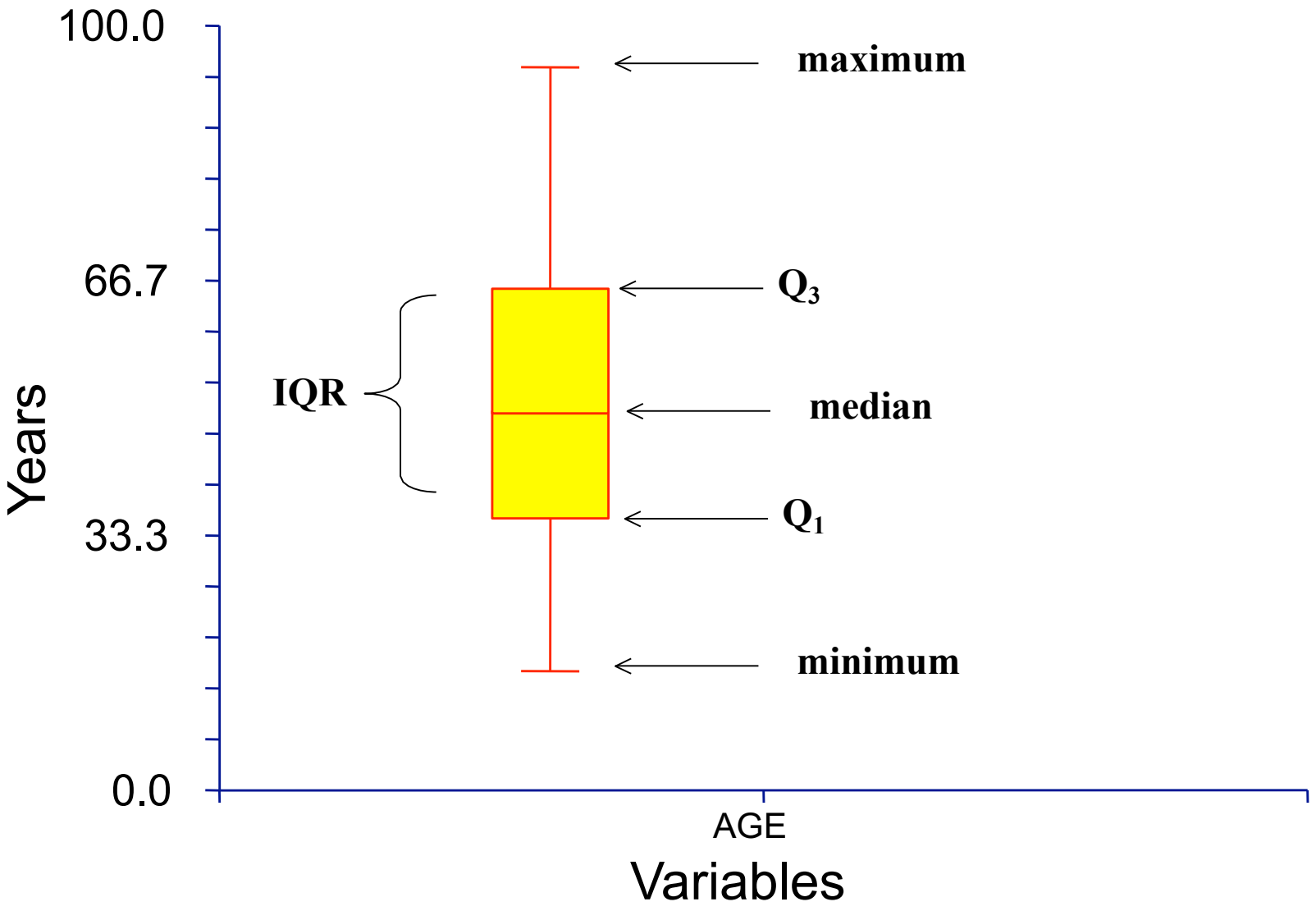
Pie chart

- We can use a `pie chart` to visualize the relative frequencies of different categories for a categorical variable.
- In a pie chart, the area of a circle is divided into sectors, each representing one of the possible categories of the variable.
- The area of each sector *c* is proportional to its frequency.

```
slices <- c(11, 4,  6)
lbls <- c(”Kahve", ”Yeşil Çay", ”Ihlamur",)
pie(slices, labels = lbls, main="Pie Chart of Races")
```

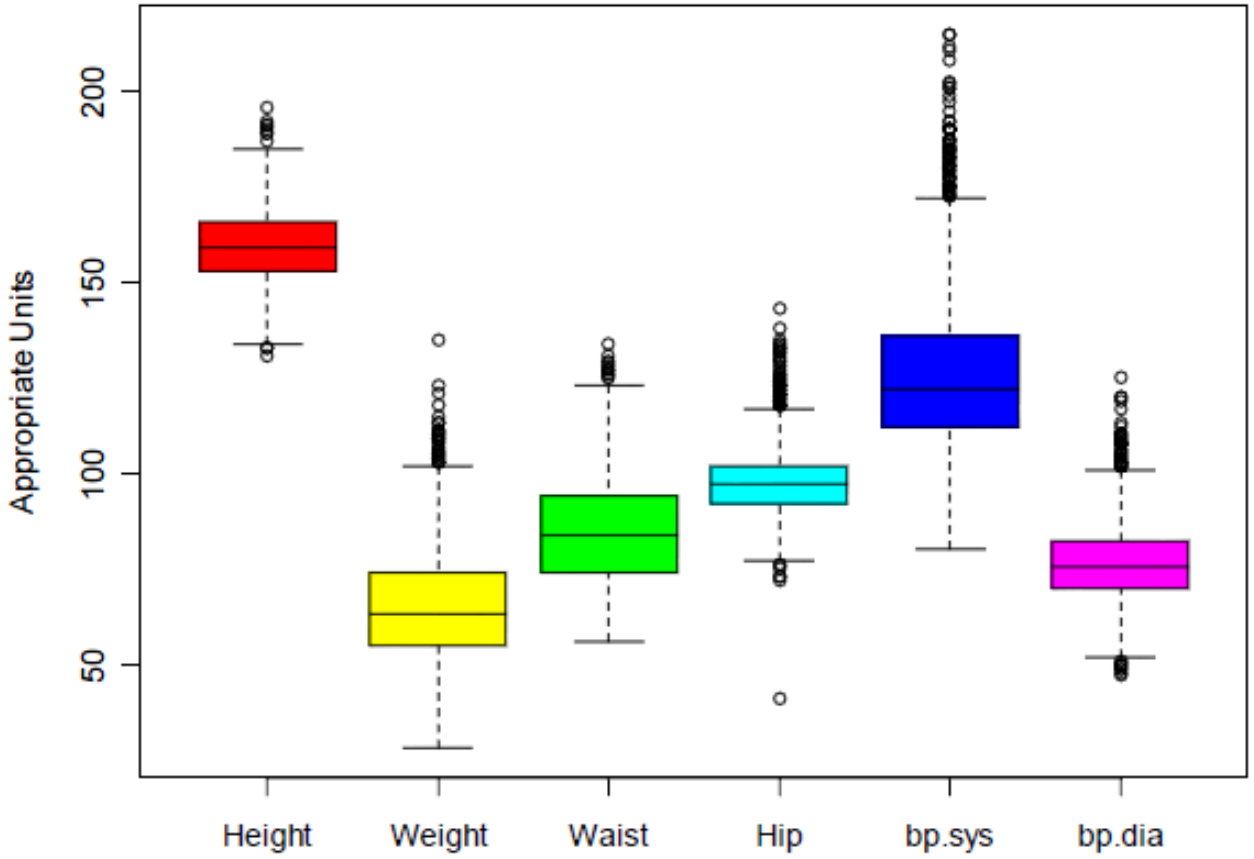


Box Plots


100.0
66.7
33.3
0.0
Years
maximum
Q_3
IQR
median
Q_1
minimum
AGE
Variables

Example of Box Plots

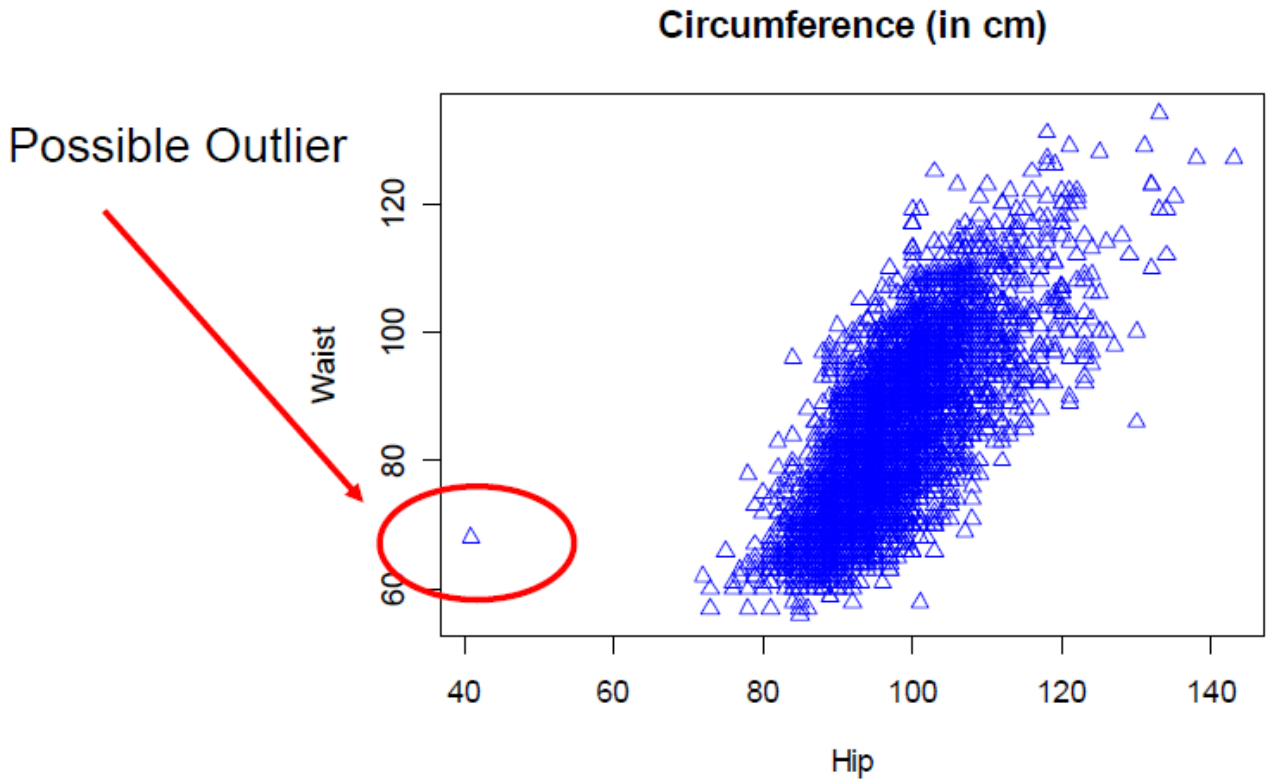
- Box plots can be used to compare attributes



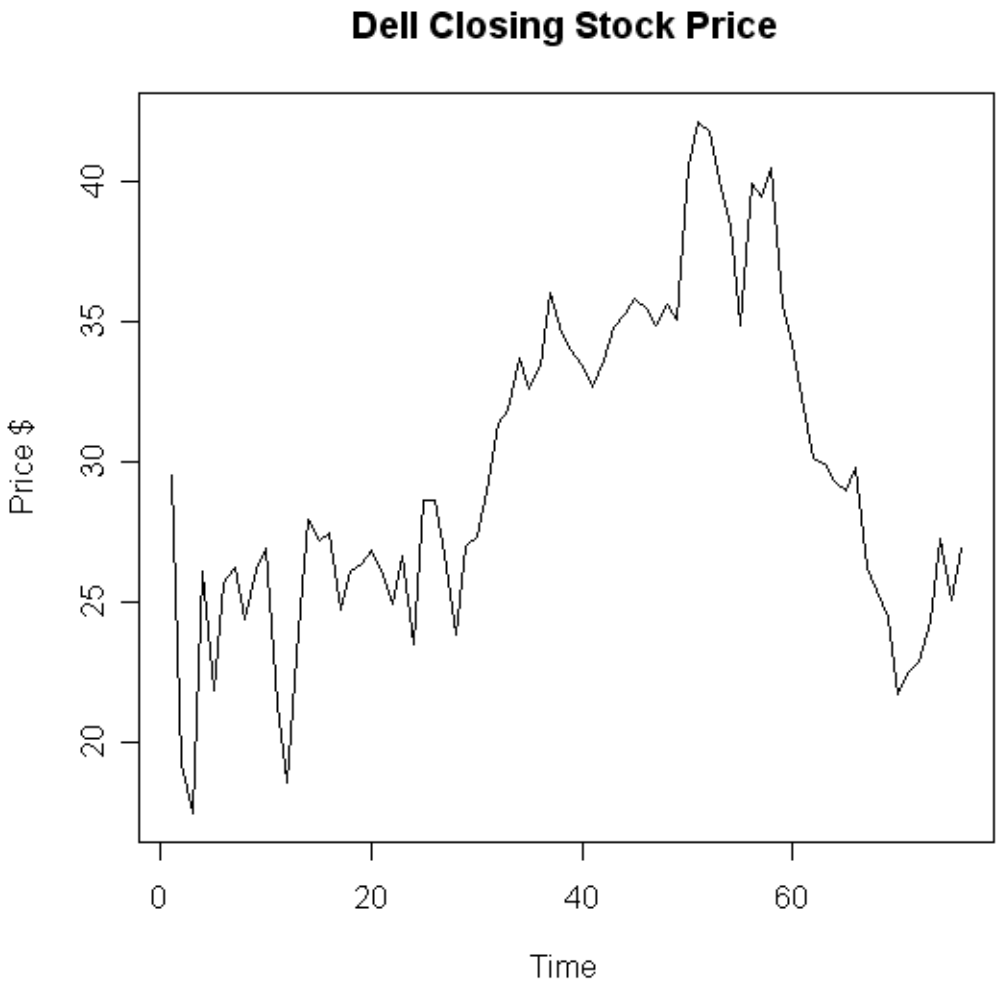

```
boxplot(dataset, col = rainbow(6), ylab = "Appropriate Units")
```

Scatter plots -Plotting Two Vectors

```
plot(dataset$Hip, dataset$Waist,
  xlab = "Hip", ylab = "Waist",
main = "Circumference (in cm)", pch = 2, col = "blue")
```

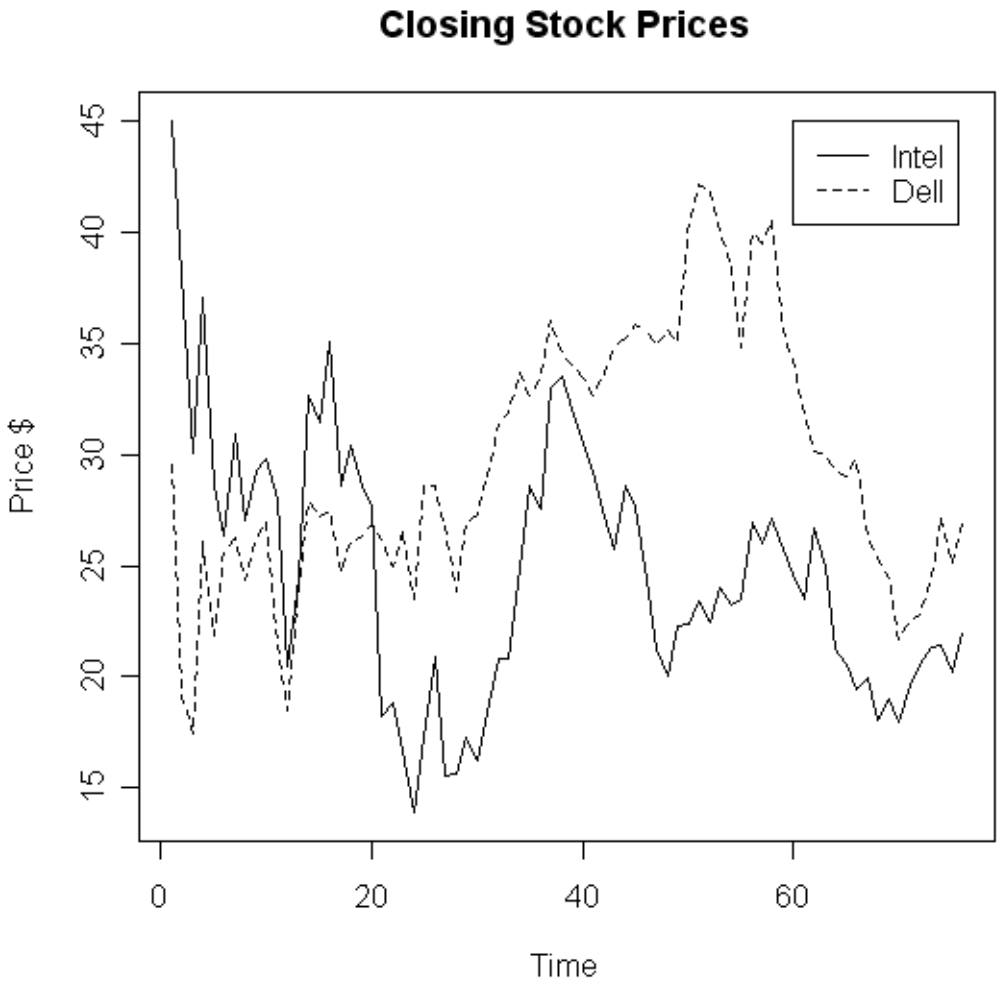


Line Plots




```
plot(t1,D2$DELL,type="l",main='Dell Closing Stock Price',
xlab='Time',ylab='Price $'))
```

Adding a Legend




```
legend(60,45,c('Intel','Dell'),lty=c(1,2))
```

Mosaic plot

Association between reproductive effort and avian malaria

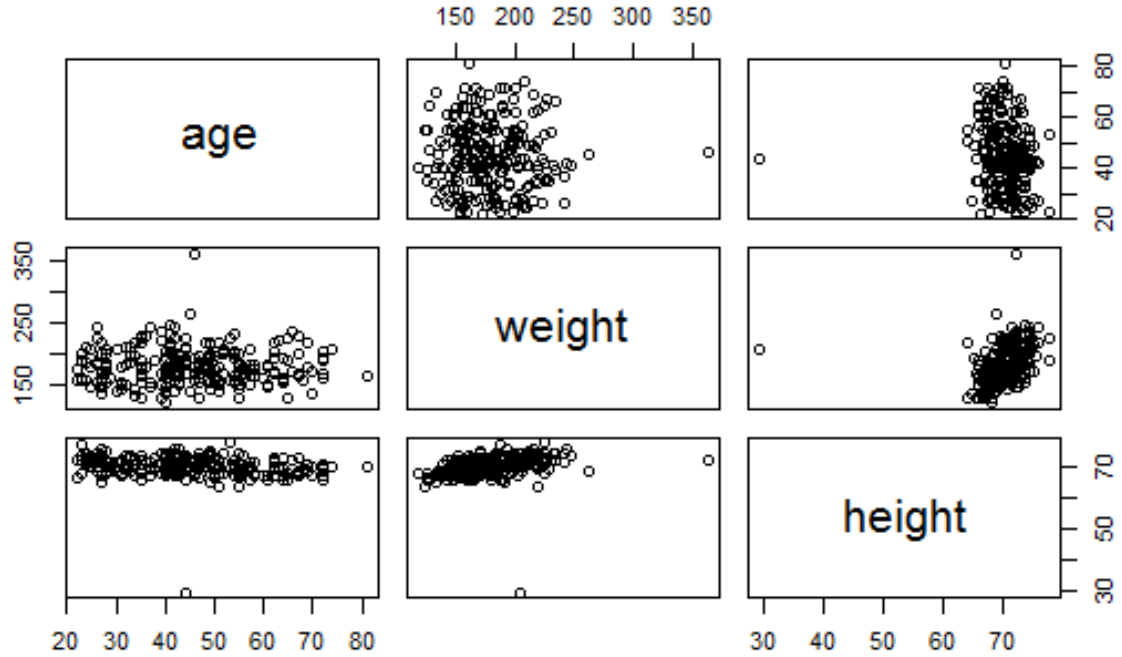
Table 2.3A. Contingency table showing incidence of malaria in female great tits subjected to experimental egg removal.

	control group	egg removal group	row total
malaria	7	15	22
no malaria	28	15	43
column total	35	30	65


```
>library(vcd)
>mosaic(HairEyeColor, shade=TRUE, legend=FALSE)
```

Plotting Contents of a Dataset as Matrix

>plot(dataset[c(5,6,7)])

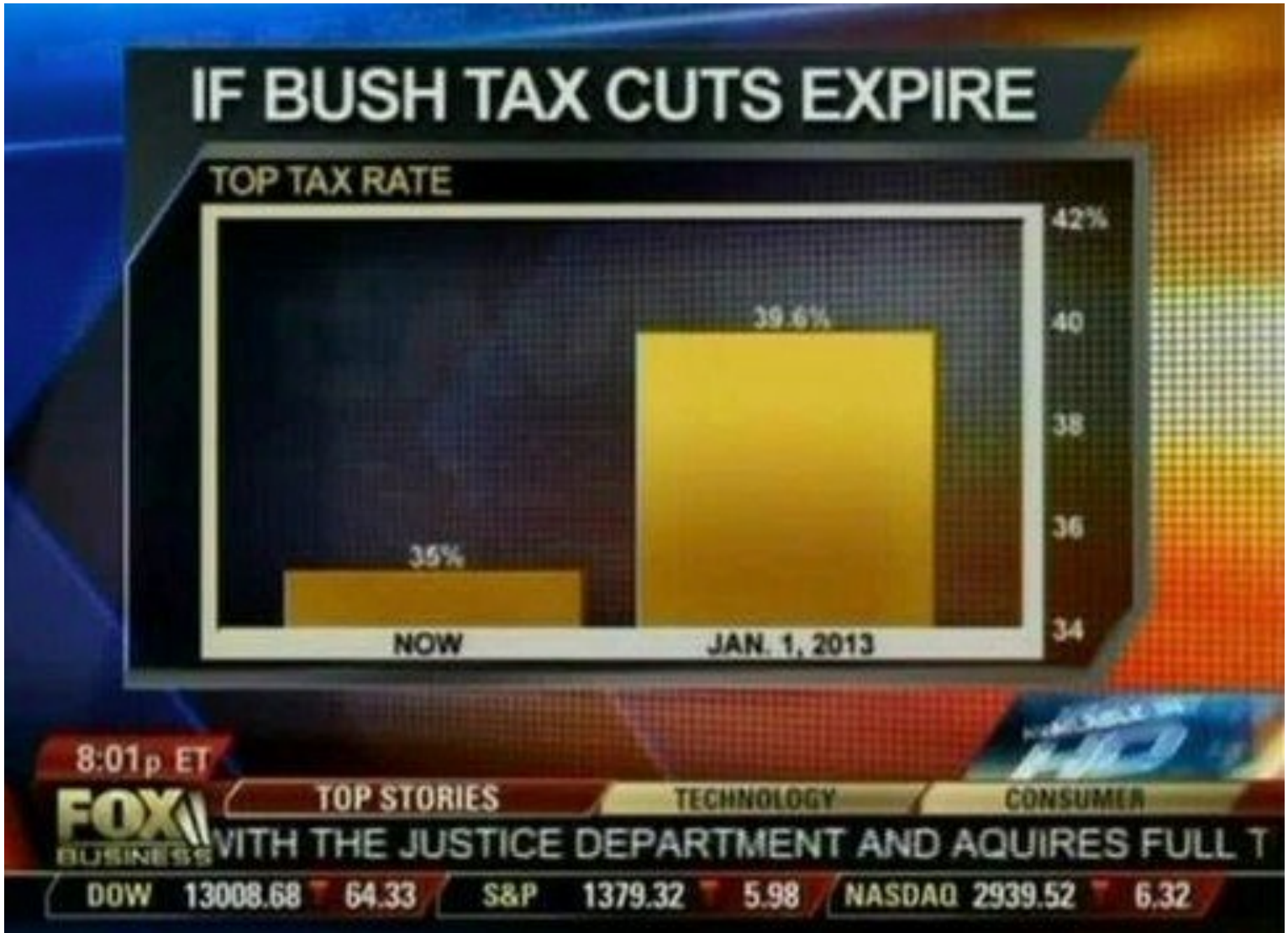


Effective Visualizations

1. Have graphical integrity
2. Keep it simple
3. Use the right display
4. Use color strategically
5. Tell a story with data

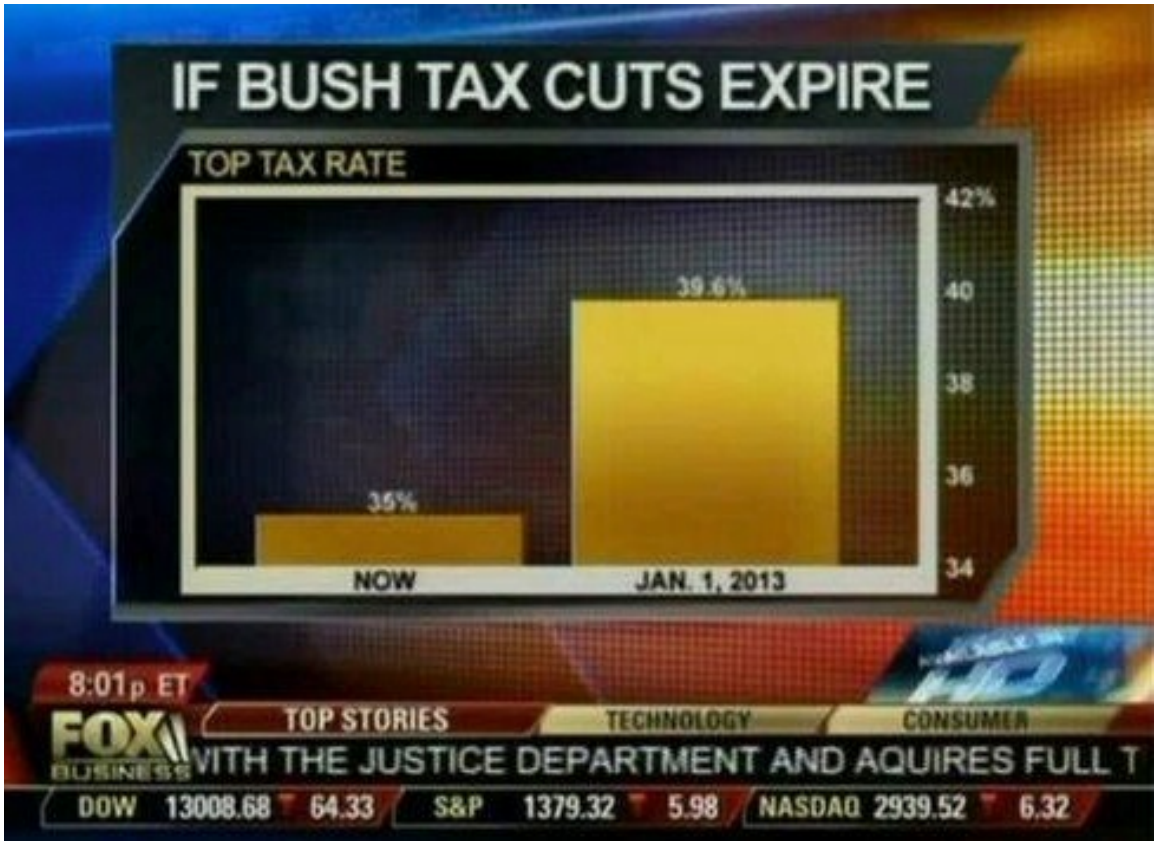
Graphical Integrity

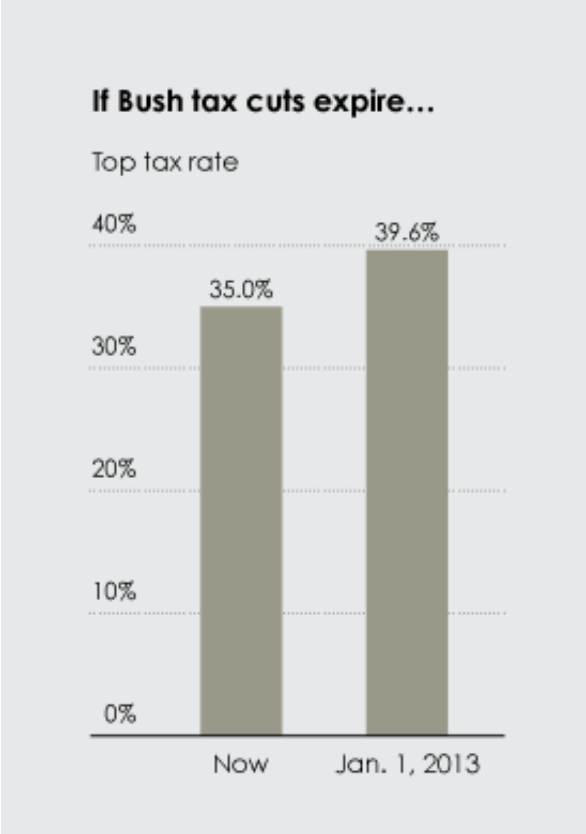
Graphical Integrity



Flowing Data

Scale Distortions



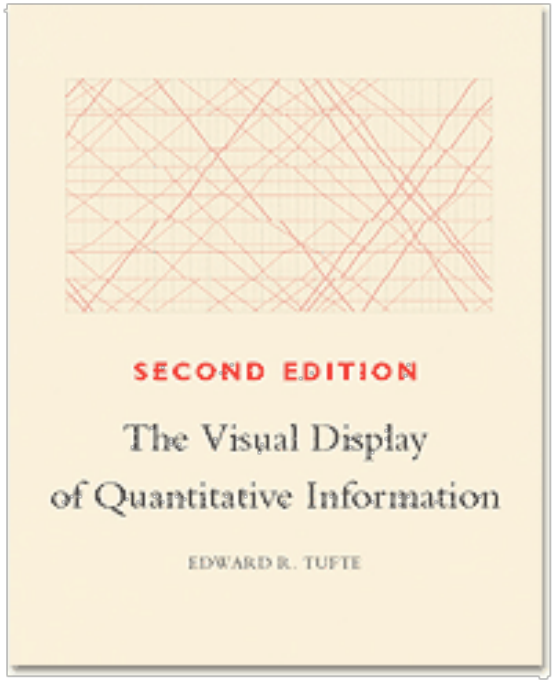


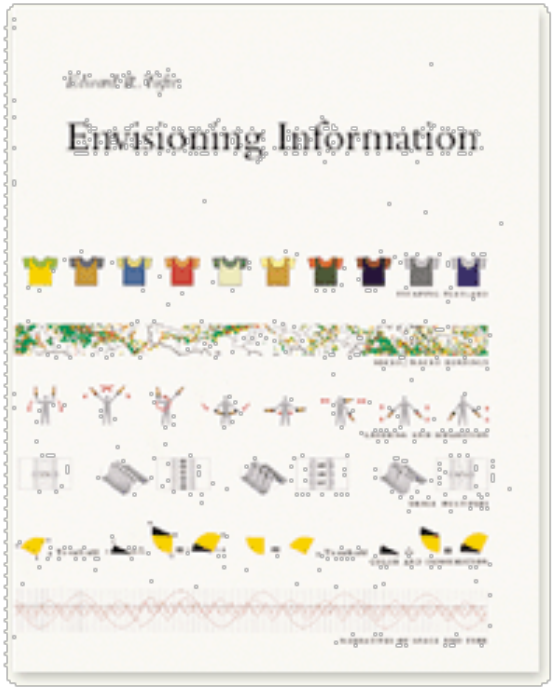

JOB LOSS BY QUARTER
15 MIL
13.5 MIL
9 MIL
7 MIL
DEC '07
SEPT '08
MARCH '09
JUNE '10
FOX NEWS .COM
SOURCE: BLS
AMERICA'S NEWSROOM

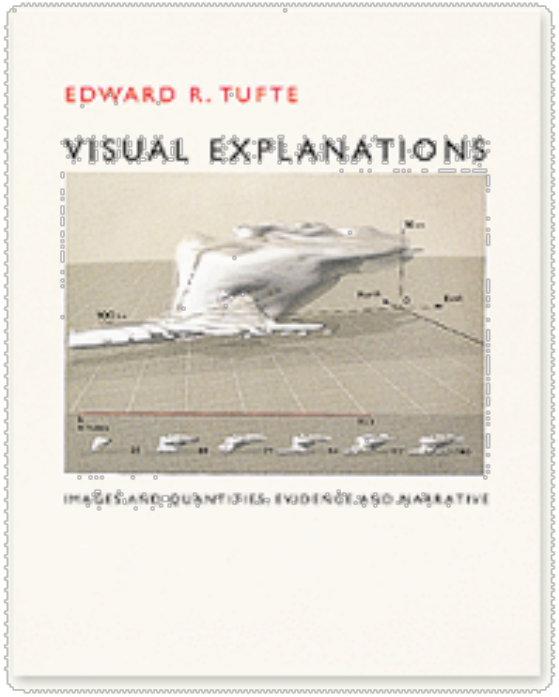
Scale Distortions

Keep It Simple

Edward Tufte

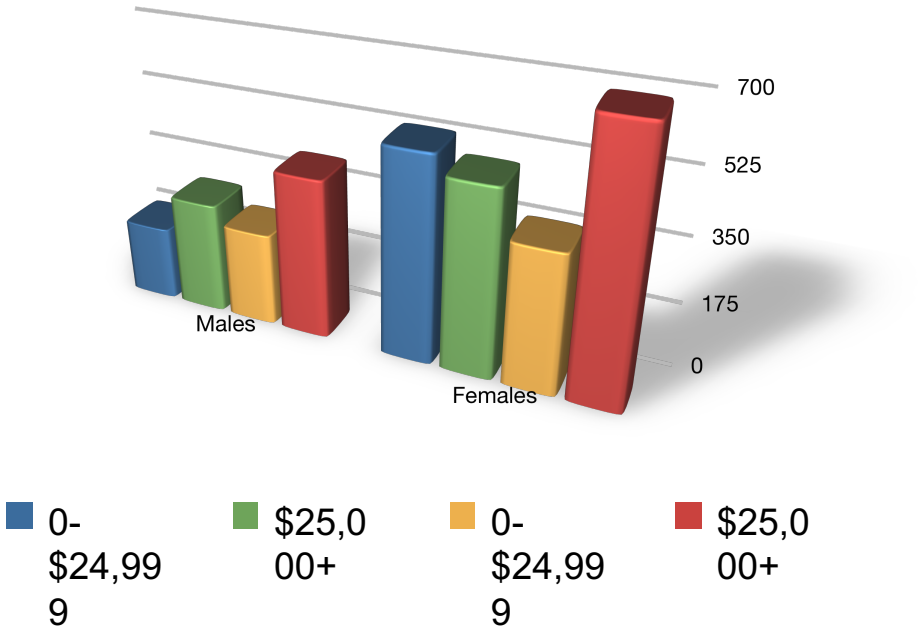






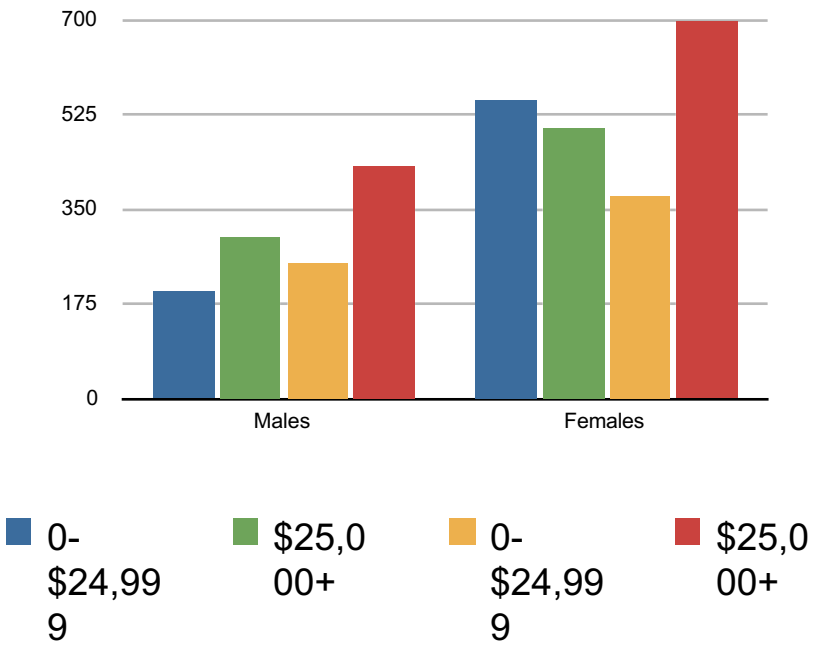
Maximize Data-Ink Ratio

$$\text{Data-Ink Ratio} = \frac{\text{Data ink}}{\text{Total ink used in graphic}}$$

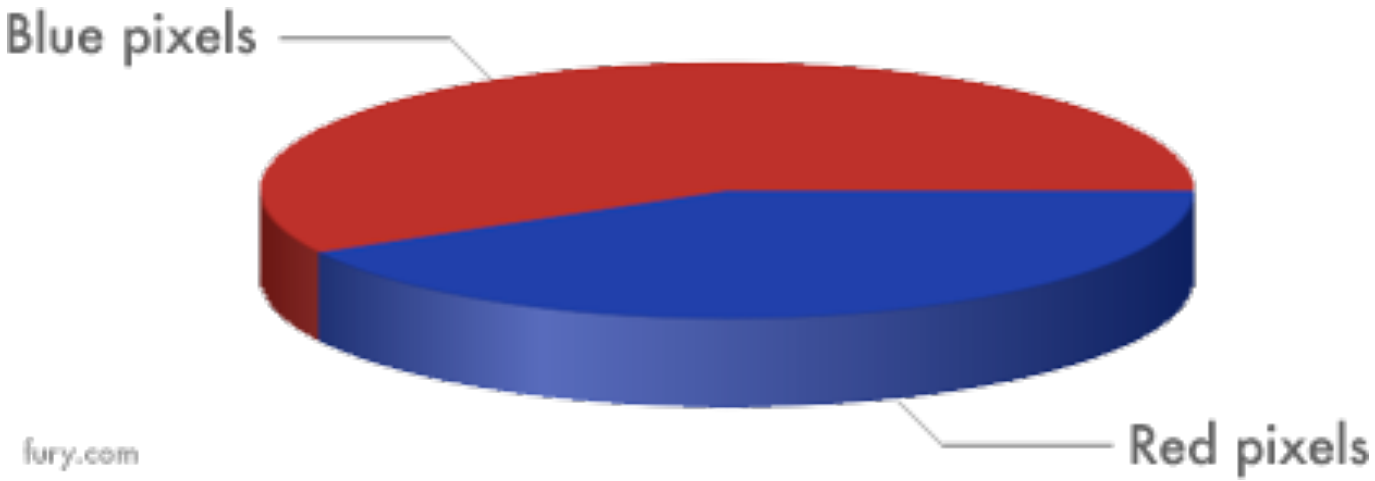


Maximize Data-Ink Ratio

$$\text{Data-Ink Ratio} = \frac{\text{Data ink}}{\text{Total ink used in graphic}}$$



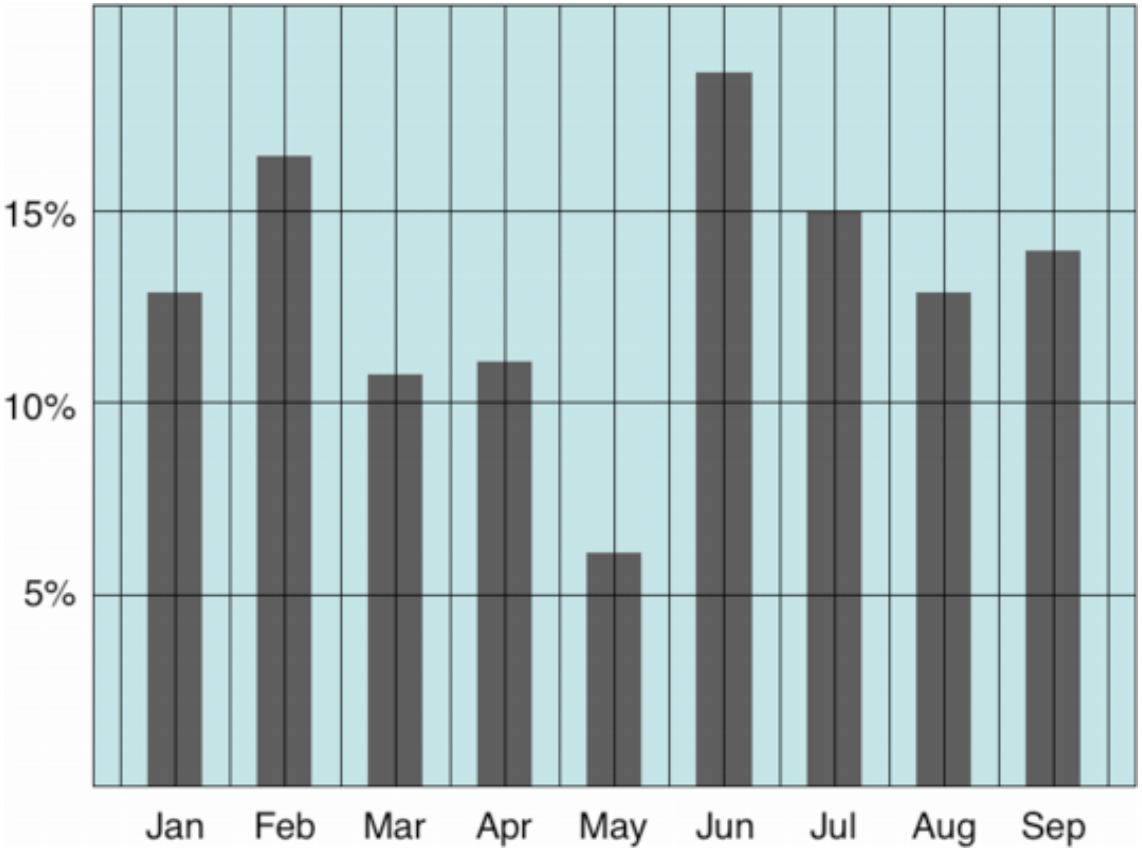
Why 3D pie charts are bad



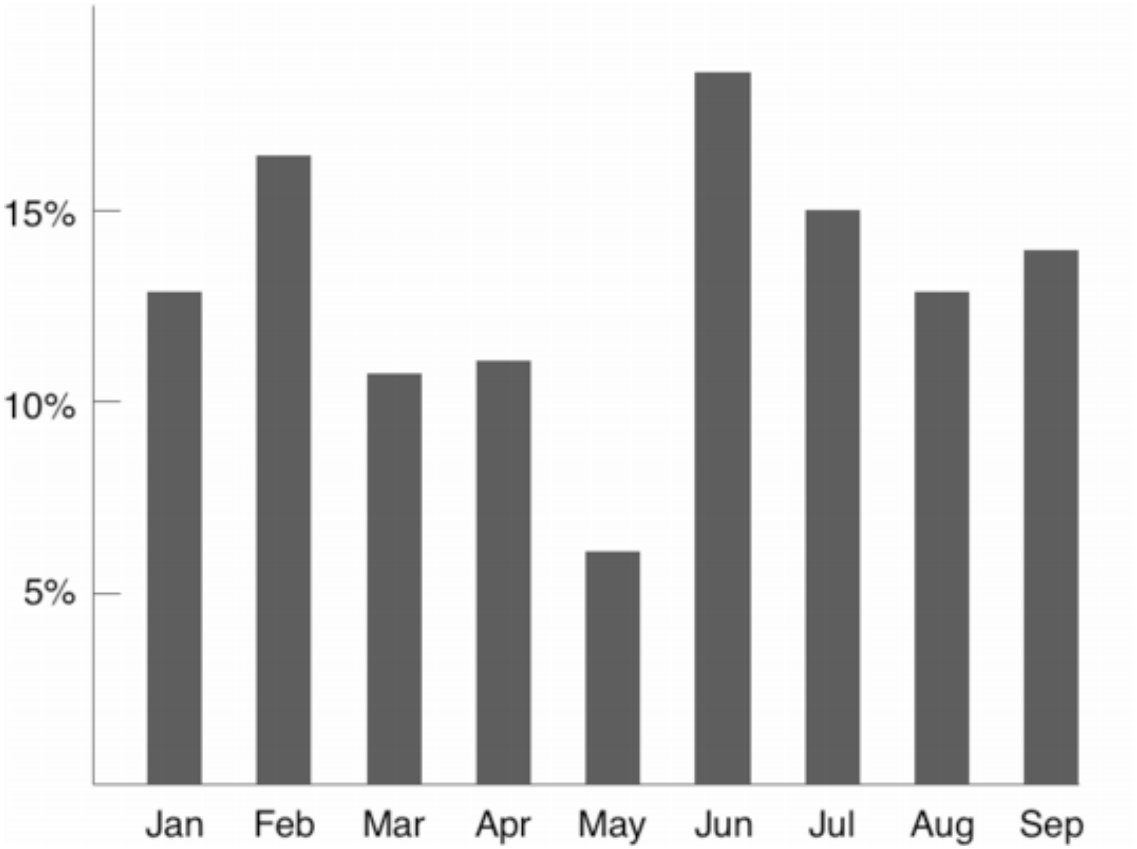
Kevin Fox

Avoid Chartjunk

Extraneous visual elements that distract from the message

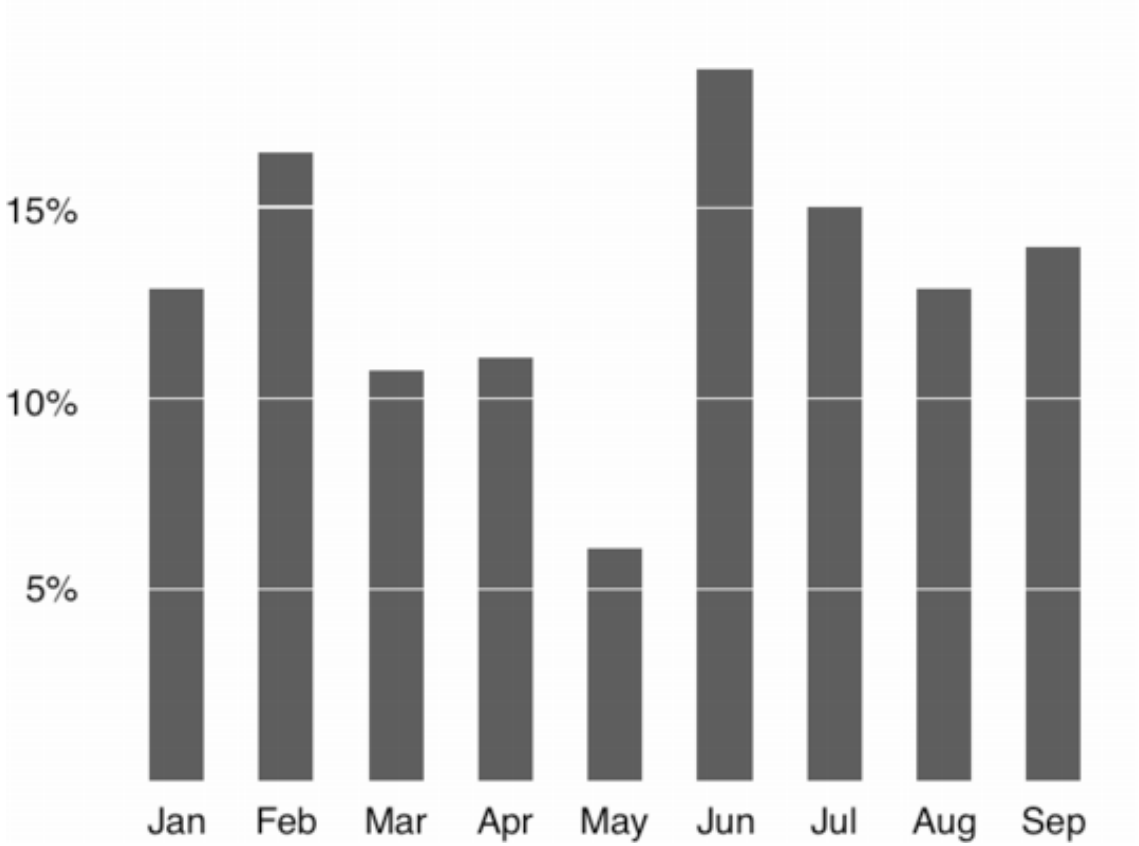


Avoid Chartjunk



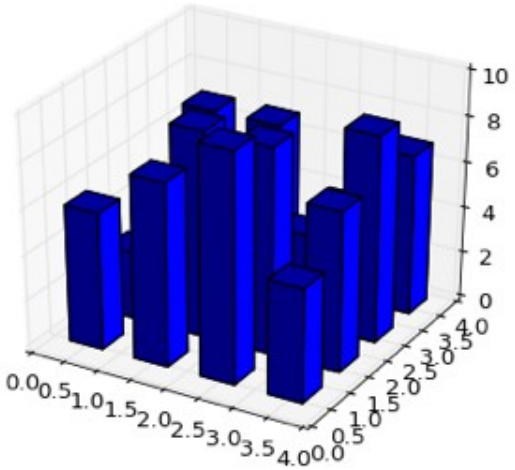
ongoing,Tim Brey

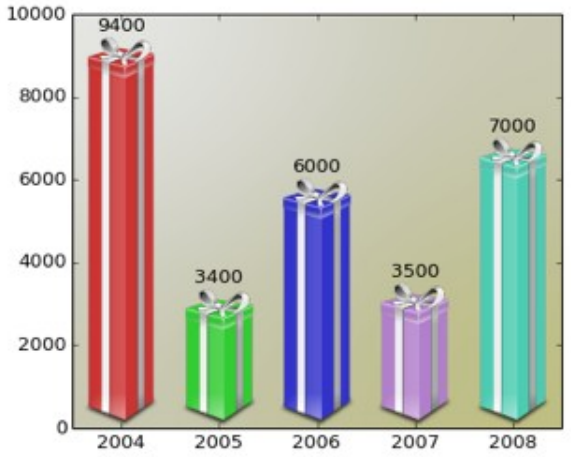
Avoid Chartjunk



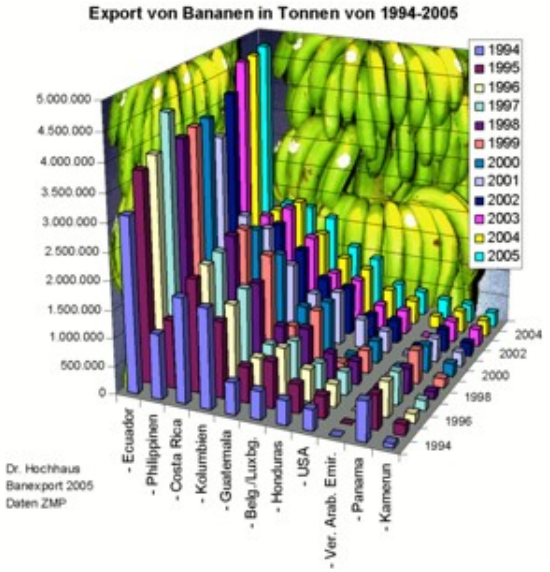
ongoing,Tim Brey

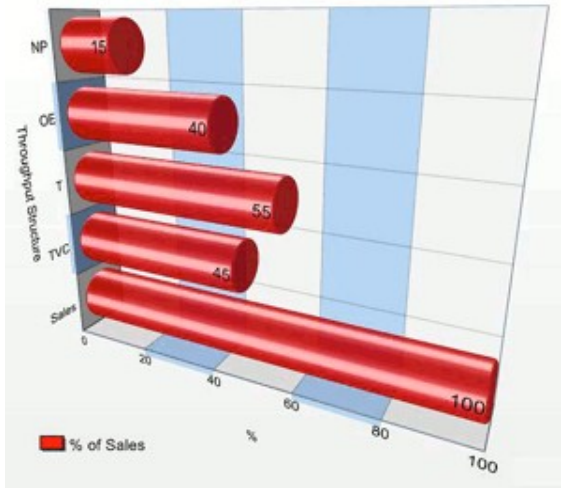
Don’t!





matplotlib gallery

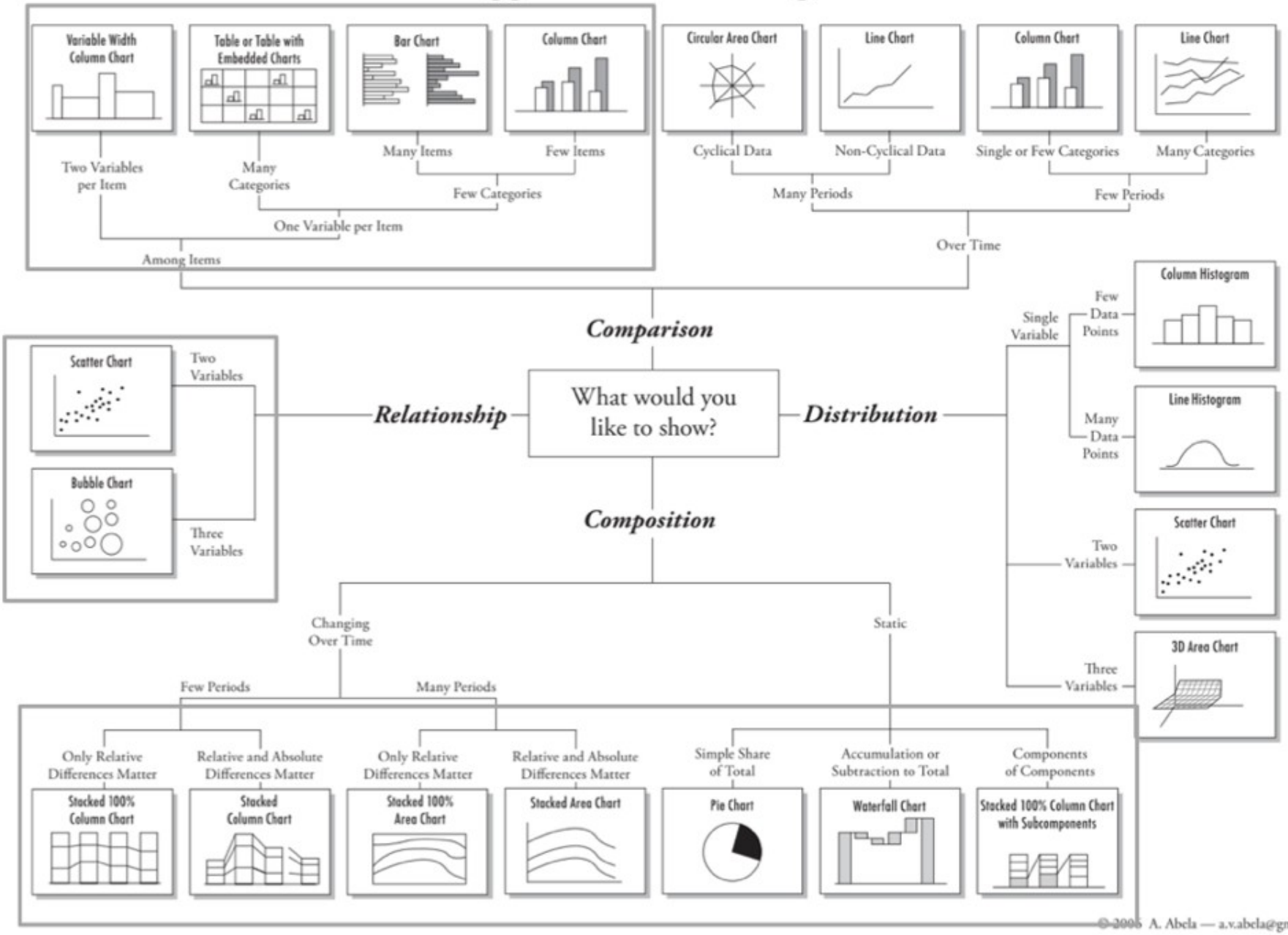




Excel Charts Blog

Use The Right Display

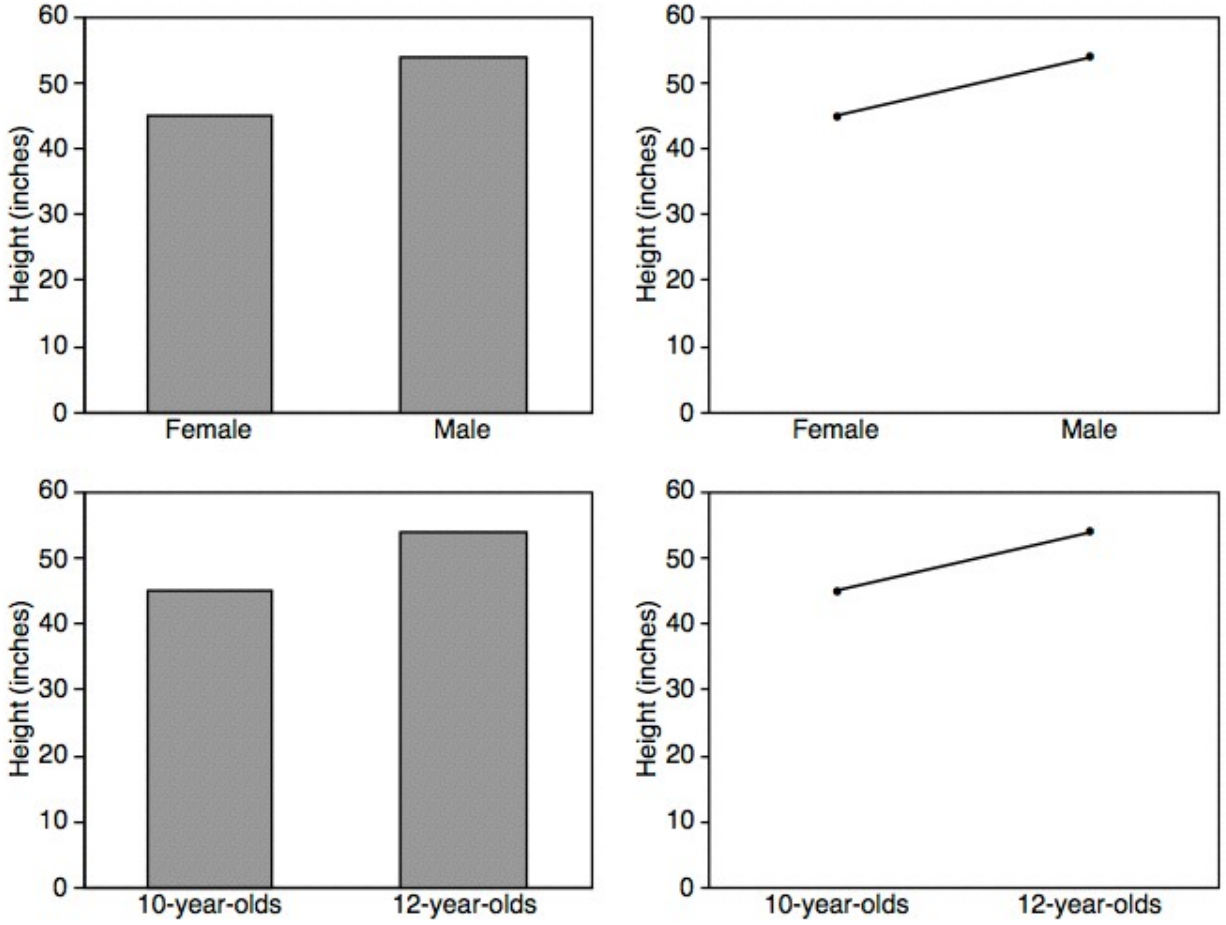
Chart Suggestions—A Thought-Starter



http://extremepresentation.typepad.com/blog/files/choosing_a_good_chart.pdf

Comparisons

Bars vs. Lines

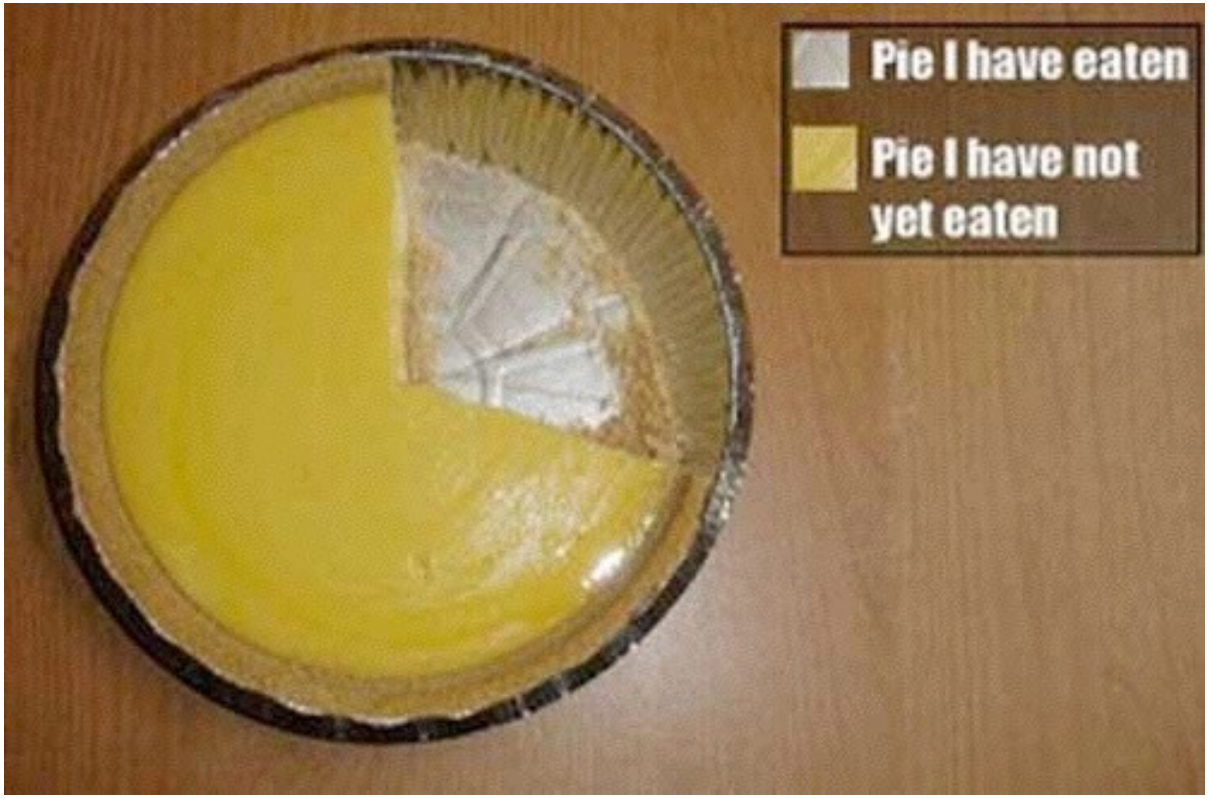


Trends

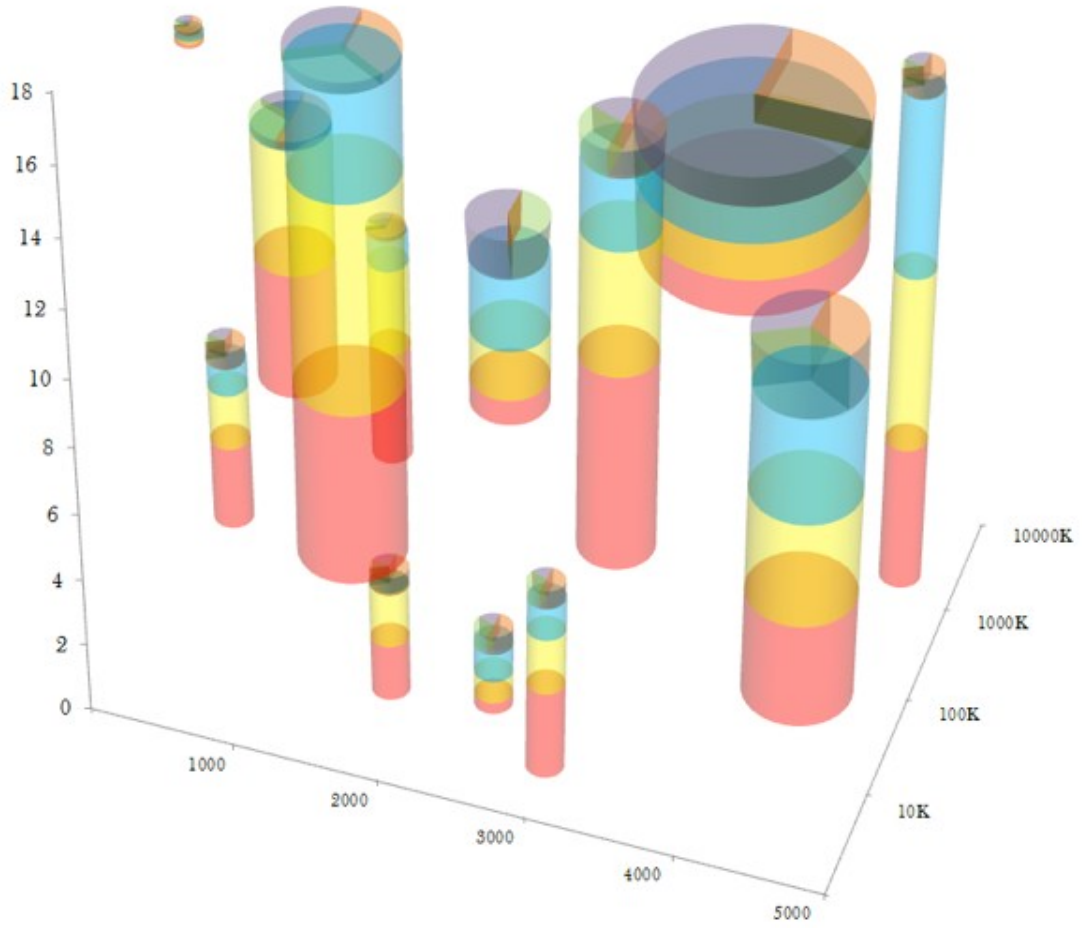
Yahoo! Finance

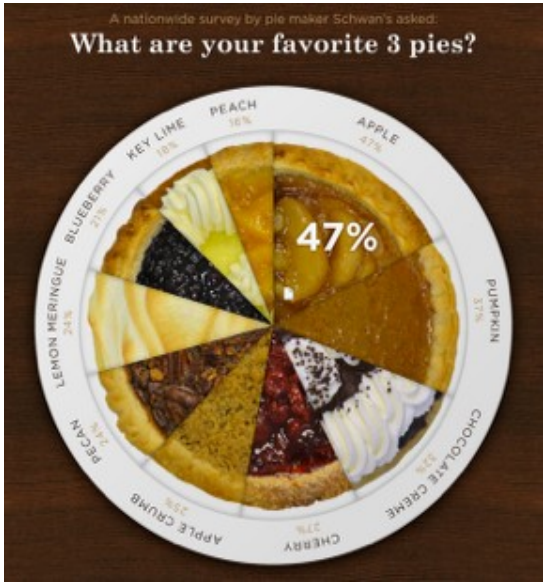
Proportions

Pie Charts

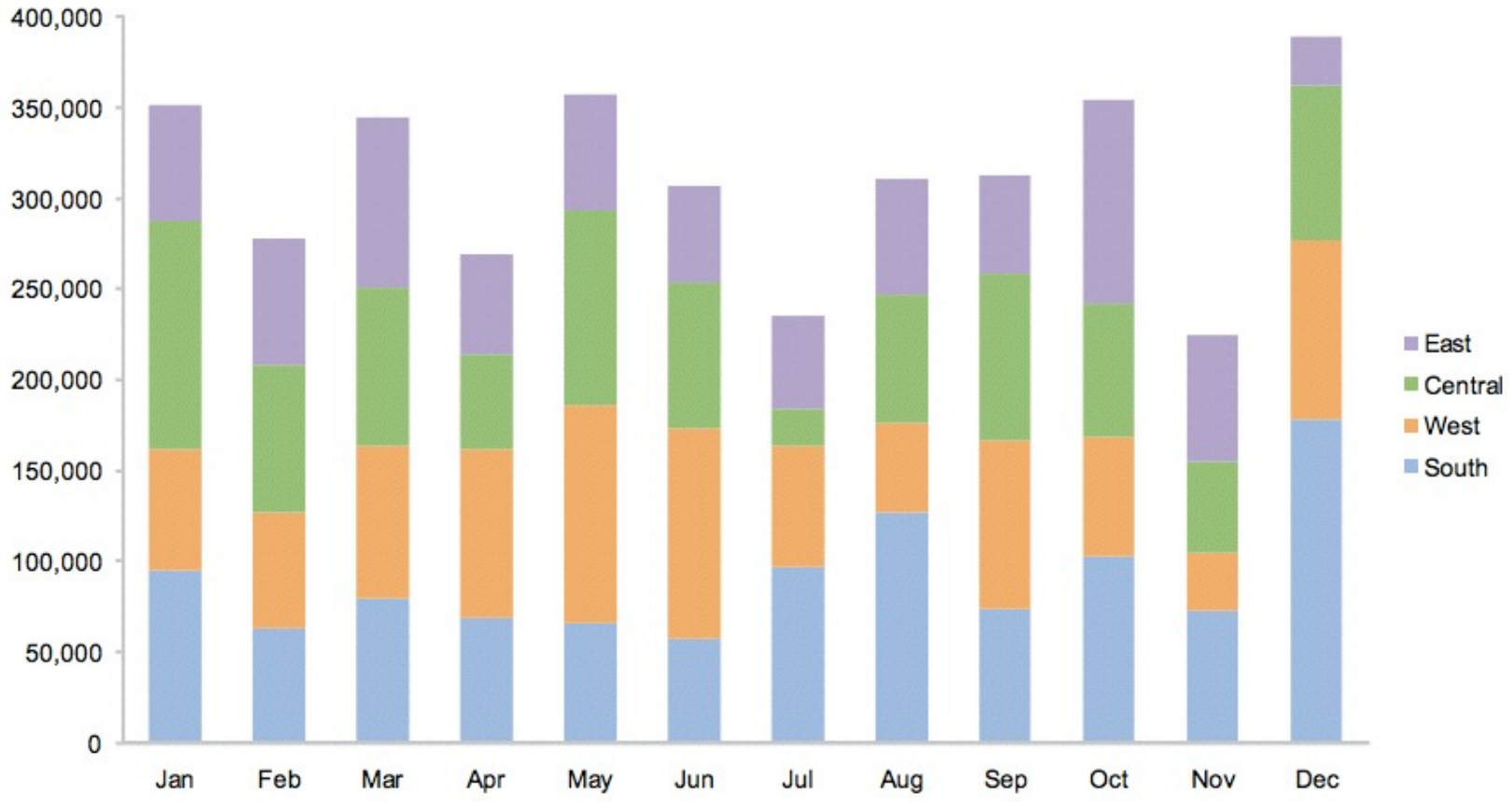


eagerpies.com



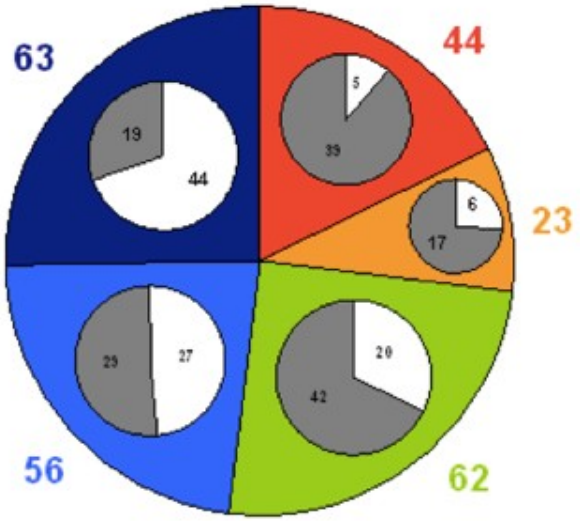


Stacked Bar Chart

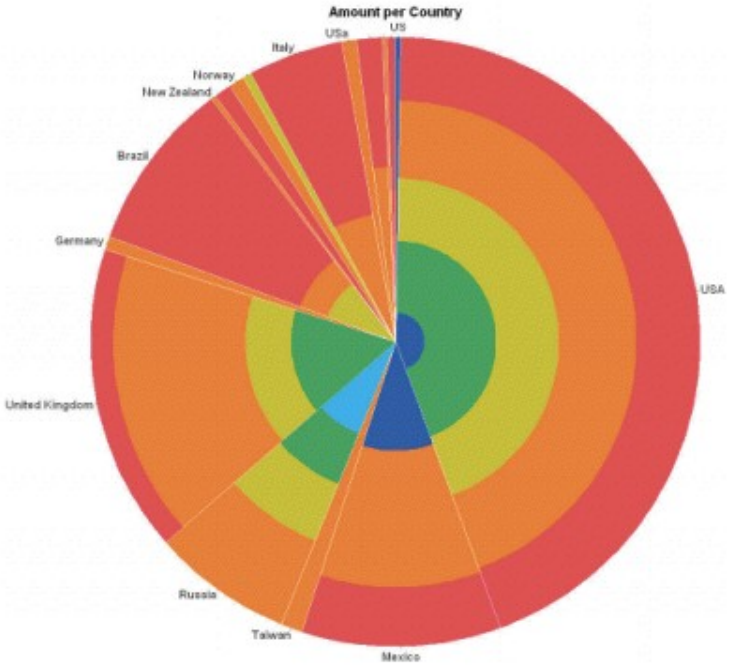


S.Few

Don't!

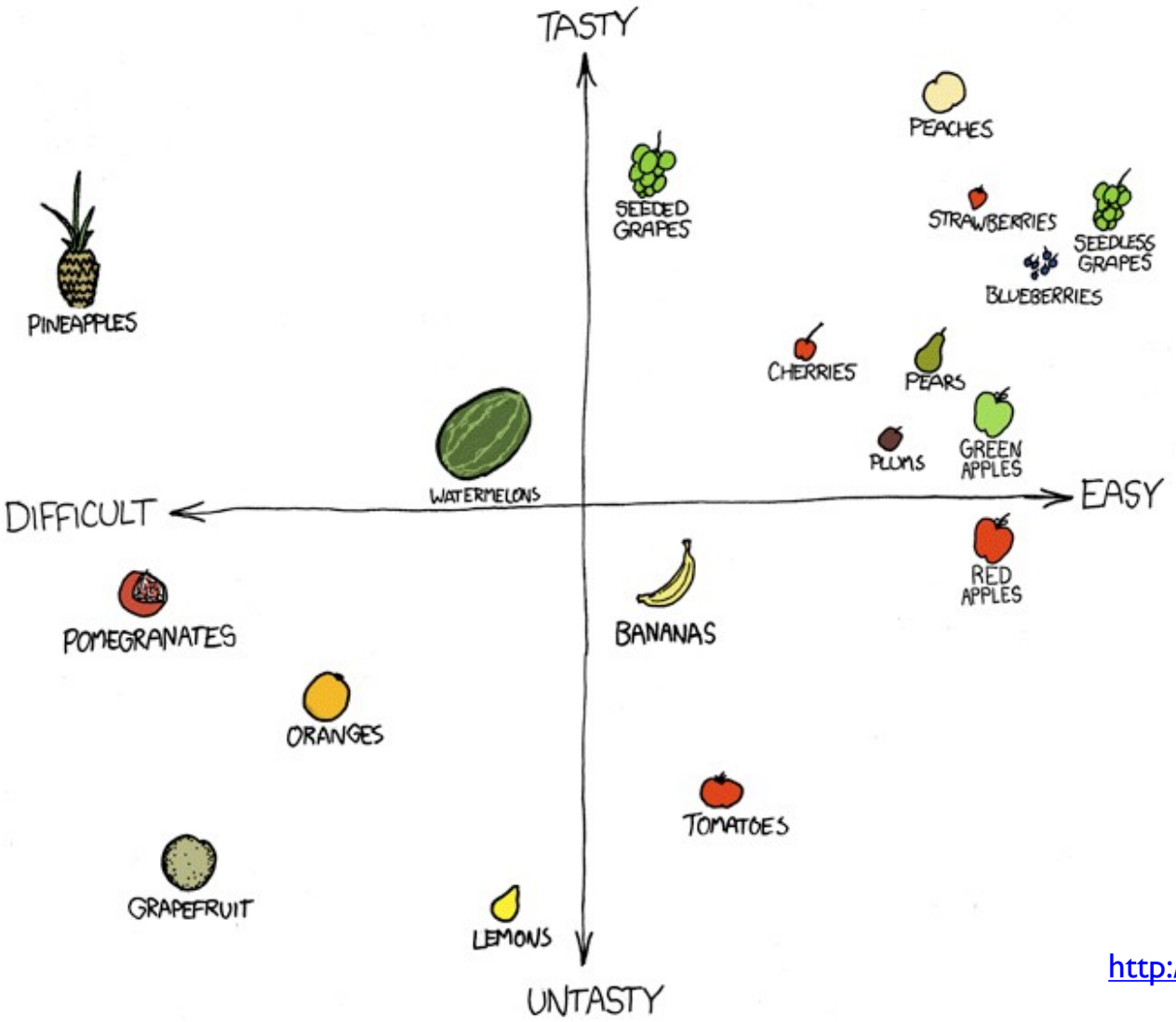

63
44
23
56
62
19
44
5
39
6
17
29
27
20
42


new folds
new folds, partial similarity
putative analogs
putative homologs
recognizable homologs
hypothesis about function
no hypothesis about function


Amount per Country
US
USa
Italy
Norway
New Zealand
Brazil
Germany
USA
United Kingdom
Russia
Taiwan
Mexico

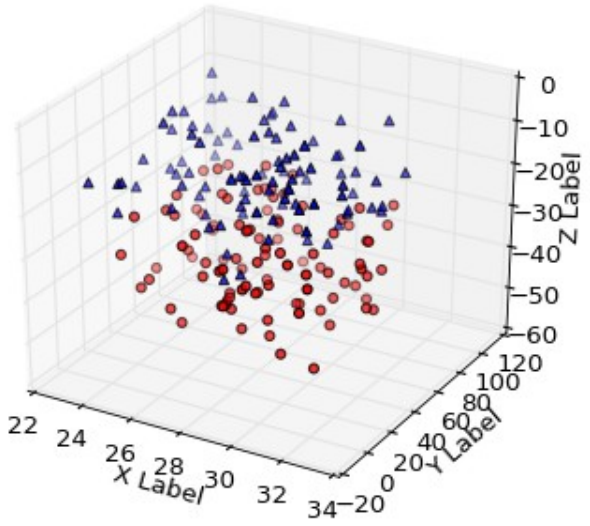
Correlations

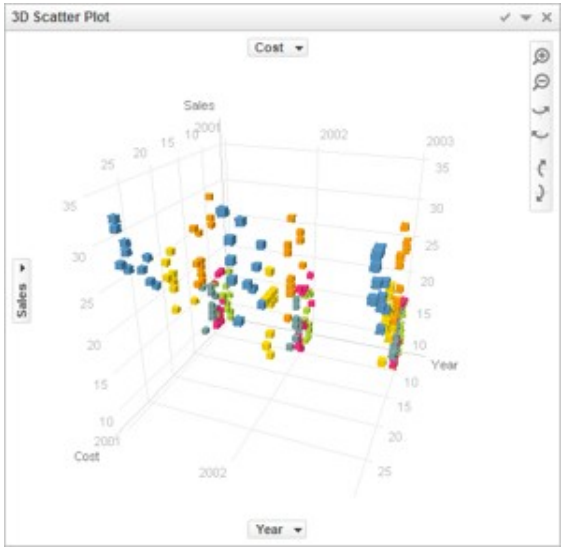
Scatterplots

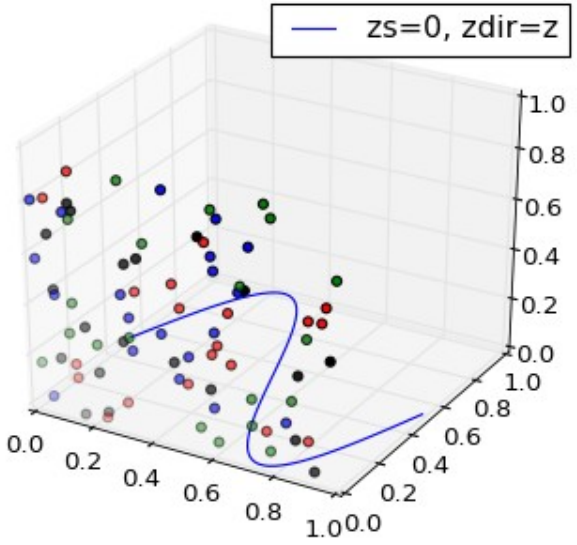


http://xkcd.com/388/

Don't!

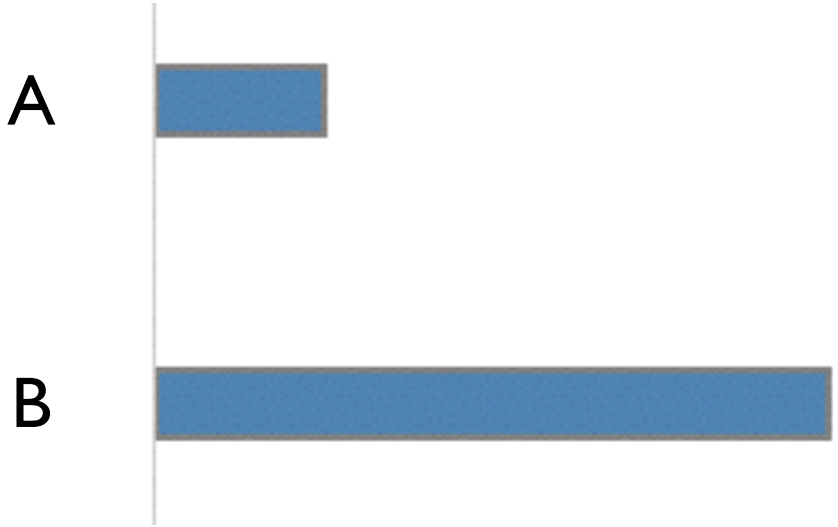

X Label
Y Label
Z Label


3D Scatter Plot
Cost
Sales
Year

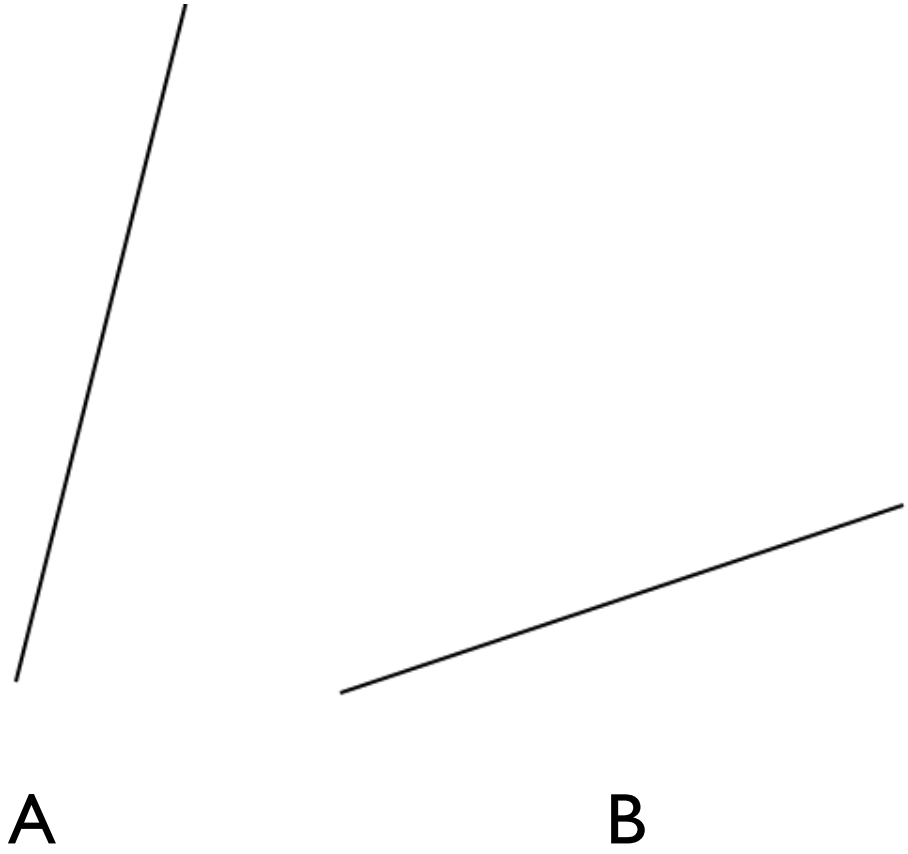

zs=0, zdir=z

Perceptual Effectiveness

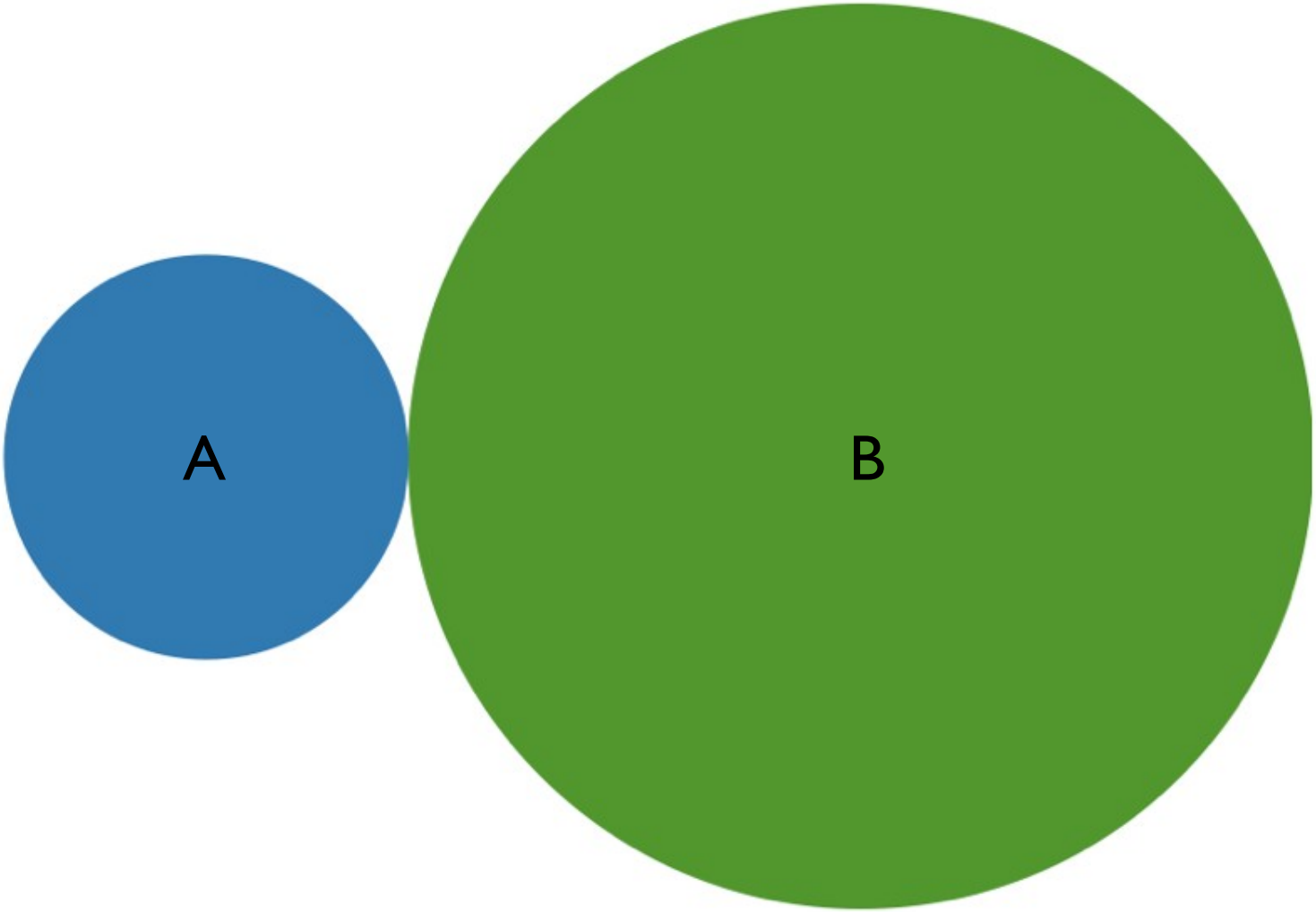
How much longer?



How much steeper slope?



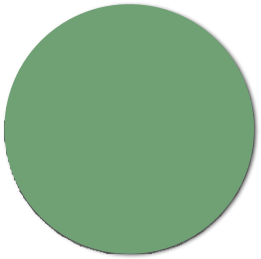
How much larger area?



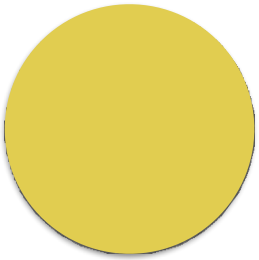
How much darker?

A B

How much bigger value?

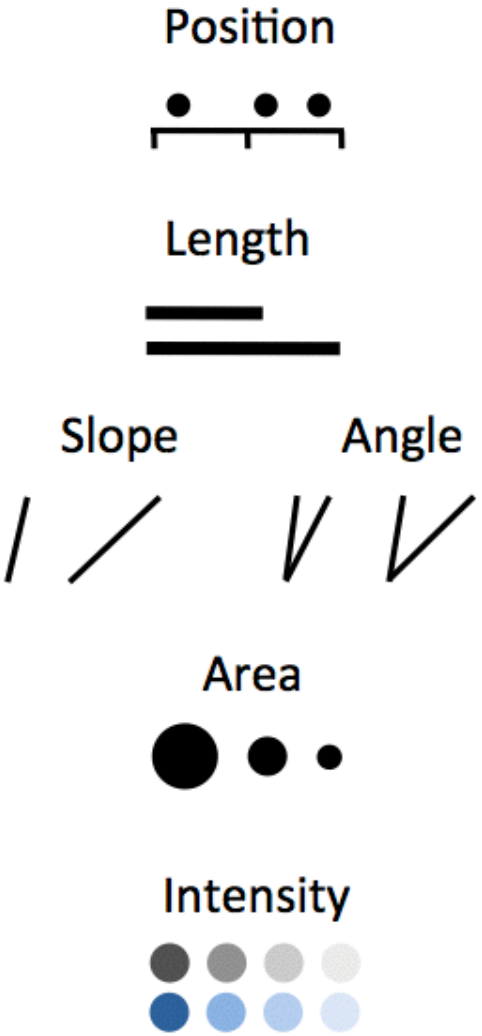


A



B

Most Efficient



Least Efficient

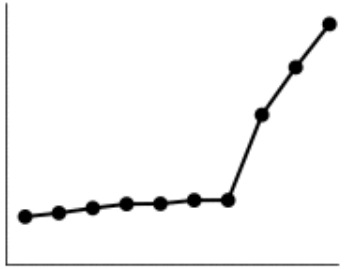
Quantitative

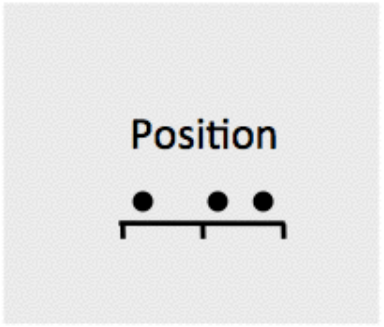
Ordered

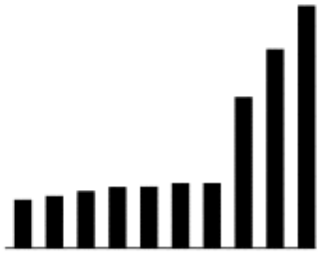
Categories

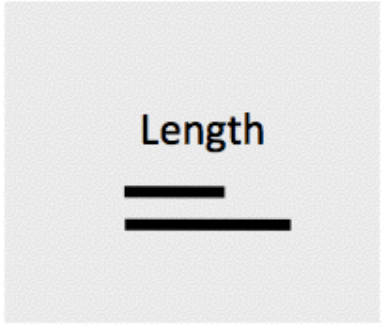
C. Mulbrandon
VisualizingEconomics.com

Most Effective

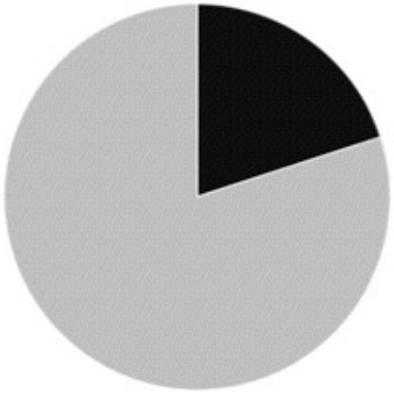


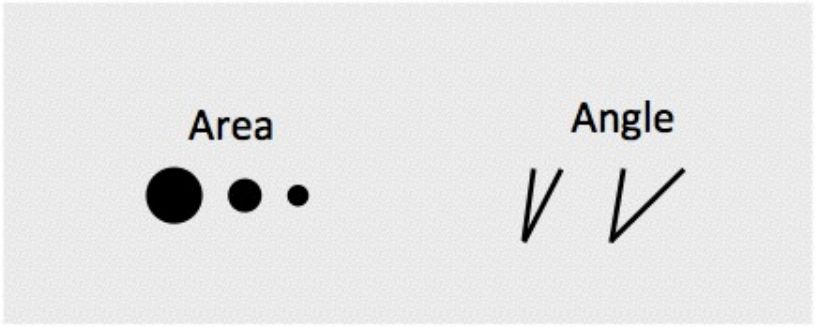


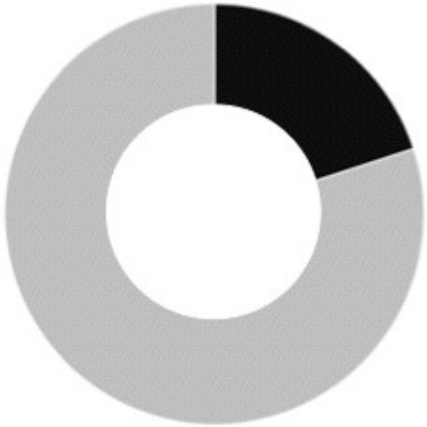


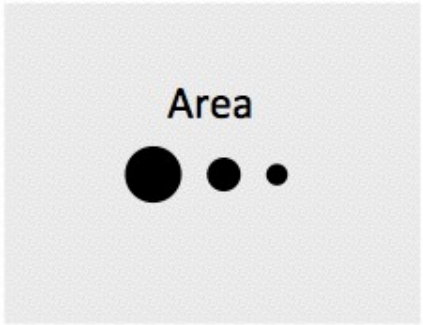


Less Effective



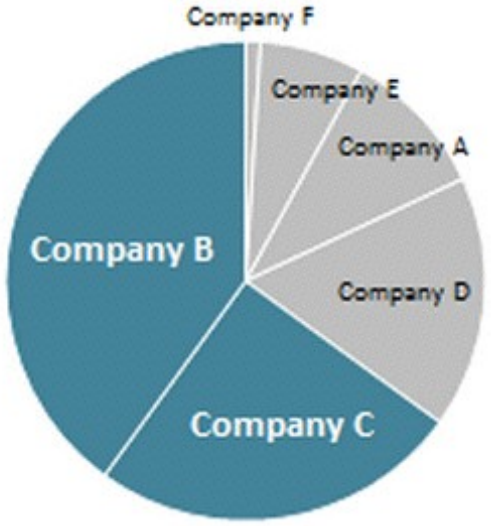


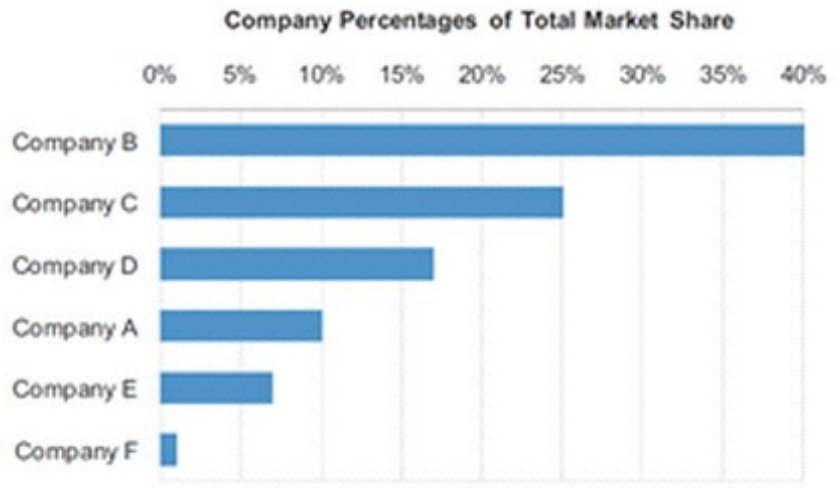




Pie vs. Bar Charts

65% of the market is controlled by companies B and C





Least Effective

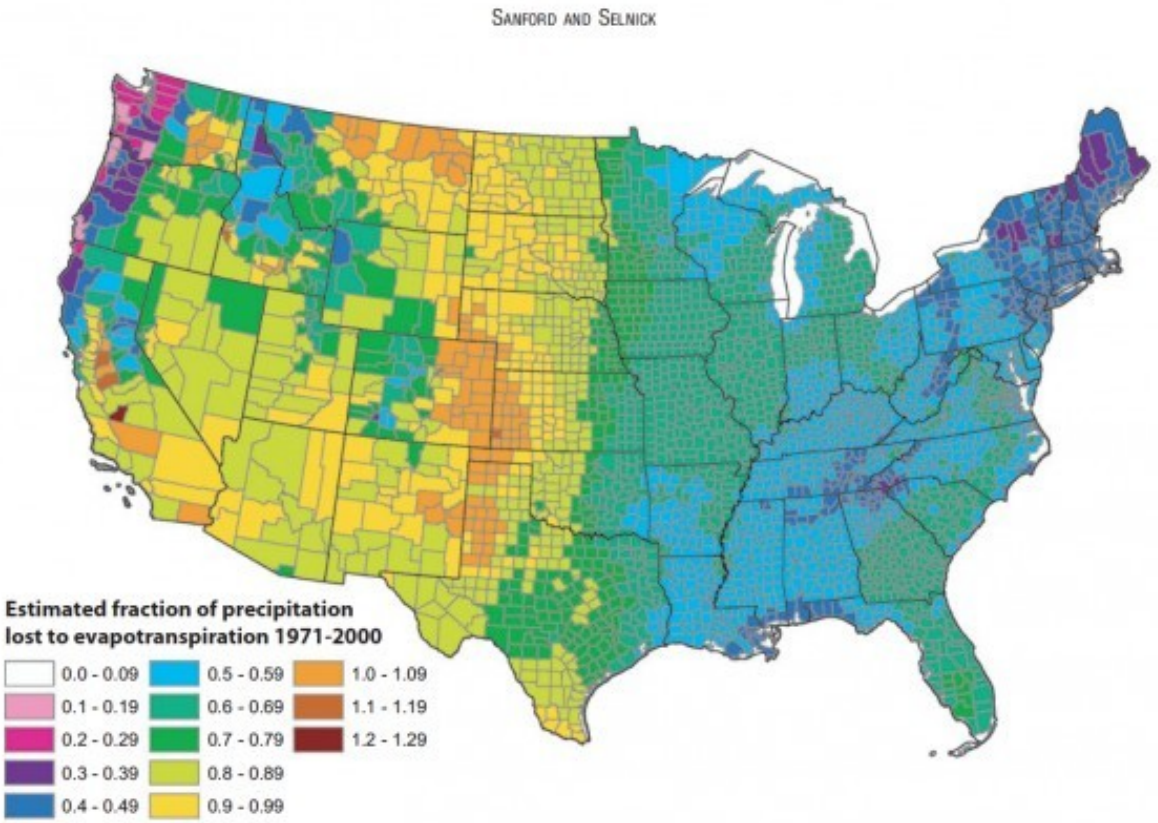
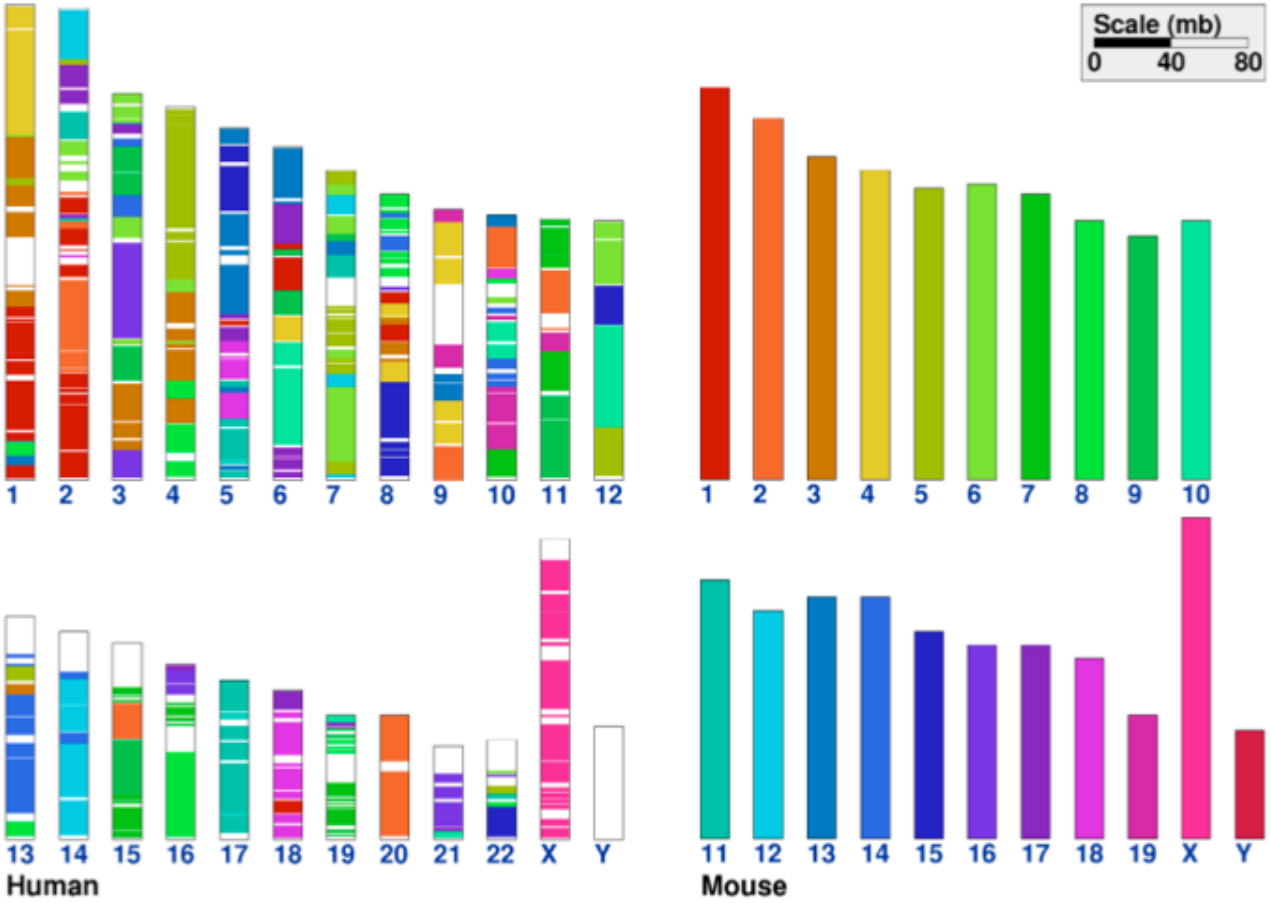


FIGURE 13. Estimated Mean Annual Ratio of Actual Evapotranspiration (ET) to Precipitation (P) for the Conterminous U.S. for the Period 1971-2000. Estimates are based on the regression equation in Table 1 that includes land cover. Calculations of ET/P were made first at the 800-m resolution of the PRISM climate data. The mean values for the counties (shown) were then calculated by averaging the 800-m values within each county. Areas with fractions >1 are agricultural counties that either import surface water or mine deep groundwater.

Cliff Mass

Use Color Strategically

Color Discriminability



Sinha 2007

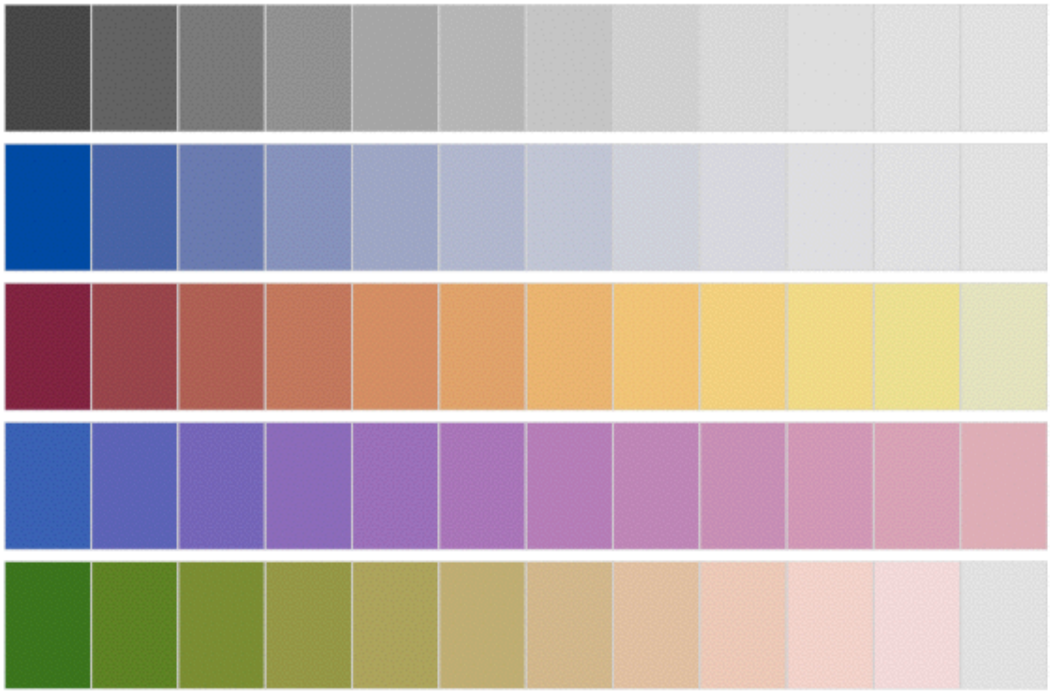
Colors for Categories

Do not use more than 5-8 colors at once

Ware, "Information Visualization"

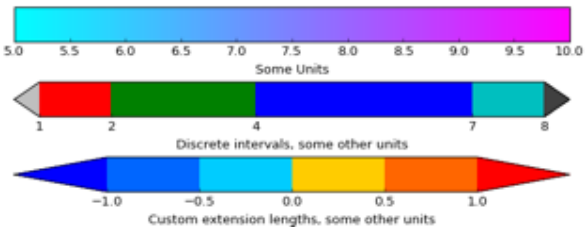
Colors for Ordinal Data

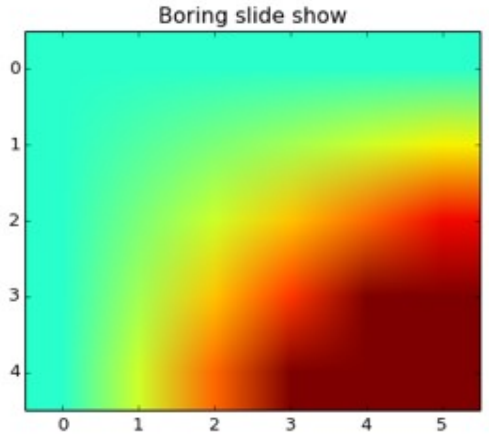
Vary luminance and saturation

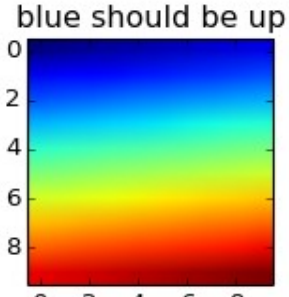


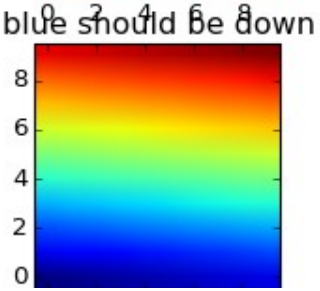
Zeilis et al, 2009, "Escaping RGBland: Selecting Colors for Statistical Graphics"

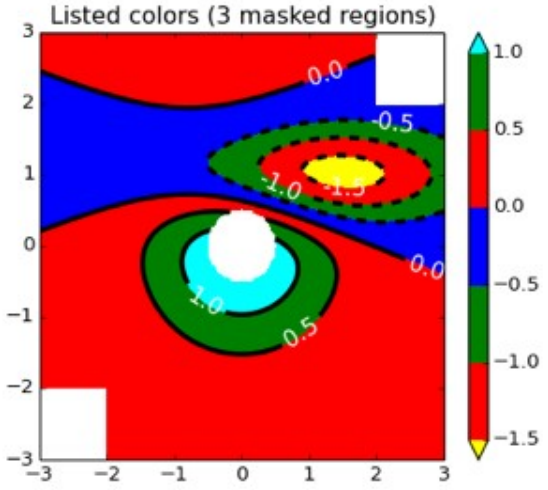
Avoid Rainbow Colors!

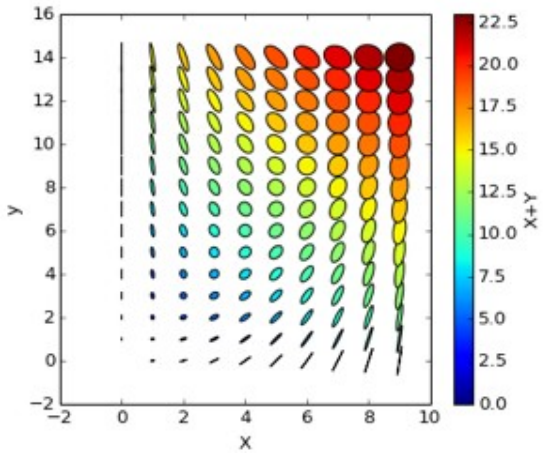


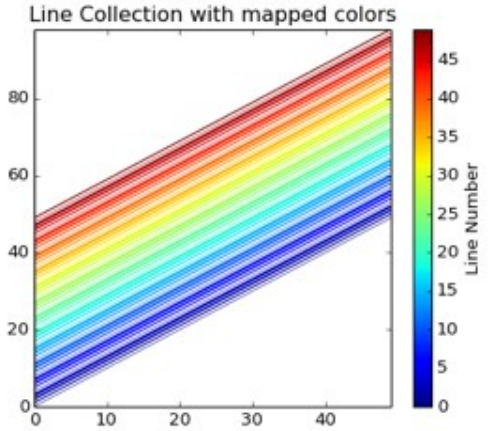








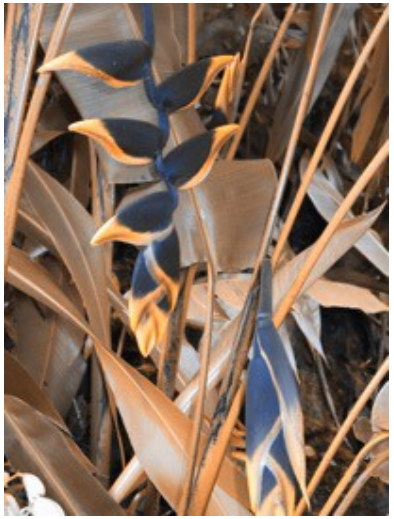




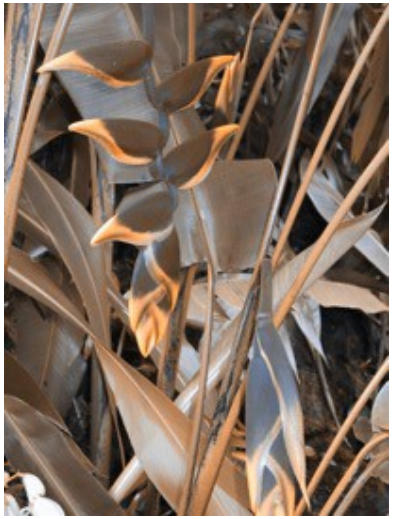
Perceptually nonlinear

matplotlib gallery

Color Blindness



Protanope



Deuteranope

Tritanope

Red / green deficiencies

Blue /Yellow deficiency

Based on slide from Stone