Topic 4: Descriptive statistics & visualization

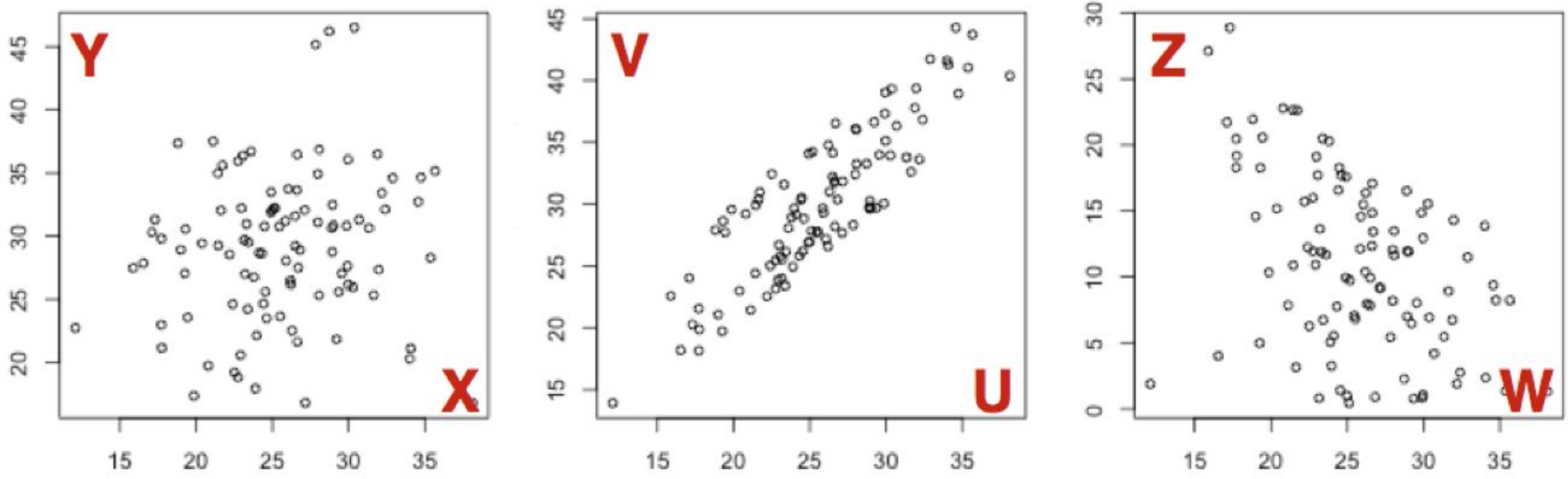
Lectures 8 & 9

- Descriptive statistics
- Spurious correlations
- Visualization challenges

Calculating correlation

Variables   Attributes / Features

x	10	8	13	9	11	14	6	4	12	7	5
y	8.04	6.95	7.58	8.81	8.33	9.96	7.24	4.26	10.84	4.82	5.68



Correlation coefficient

Pearson Correlation Coefficient

- Measures 'linear' relationship between variables.

$$r = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2}\sqrt{\sum_{i=1}^{n}(y_i - \bar{y})^2}}$$

where:

- n is the sample size
- x_i, y_i are the single samples indexed with *i*
- $\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$ (the sample mean); and analogously for $\bar{y}$

$$r = \frac{1}{n-1}\sum_{i=1}^{n}\left(\frac{x_i - \bar{x}}{s_x}\right)\left(\frac{y_i - \bar{y}}{s_y}\right)$$

Wikipedia

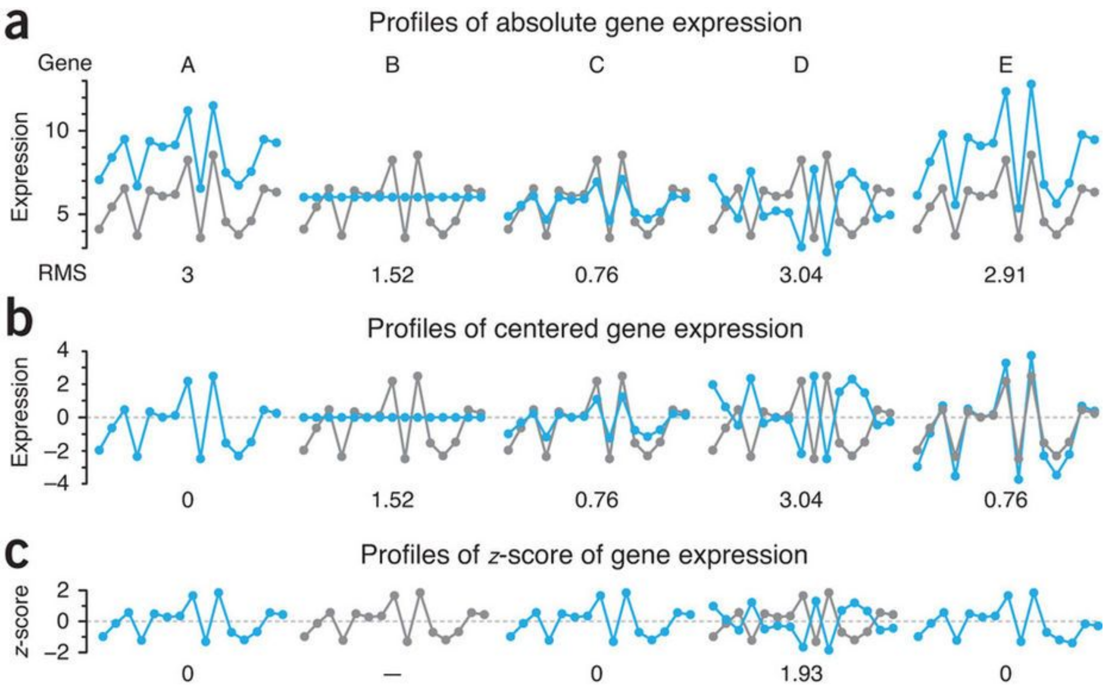
Correlation coefficient

Pearson Correlation Coefficient

- Captures the relationship between 2 vectors after centering each vector by its mean and scaling by its standard deviation.

- The final quantities for each vector are called z-scores.

$$r = \frac{1}{n-1} \sum_{i=1}^{n} \left(\frac{x_i - \bar{x}}{s_x} \right) \left(\frac{y_i - \bar{y}}{s_y} \right)$$



Altman & Krzywinski (2017) Nat. Meth.

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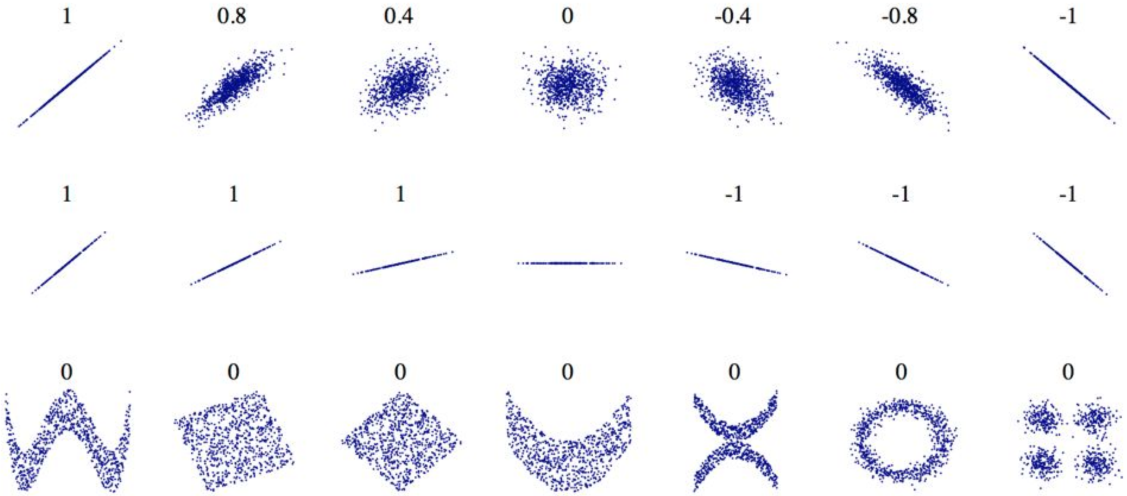


$-1 \leq r \leq +1$

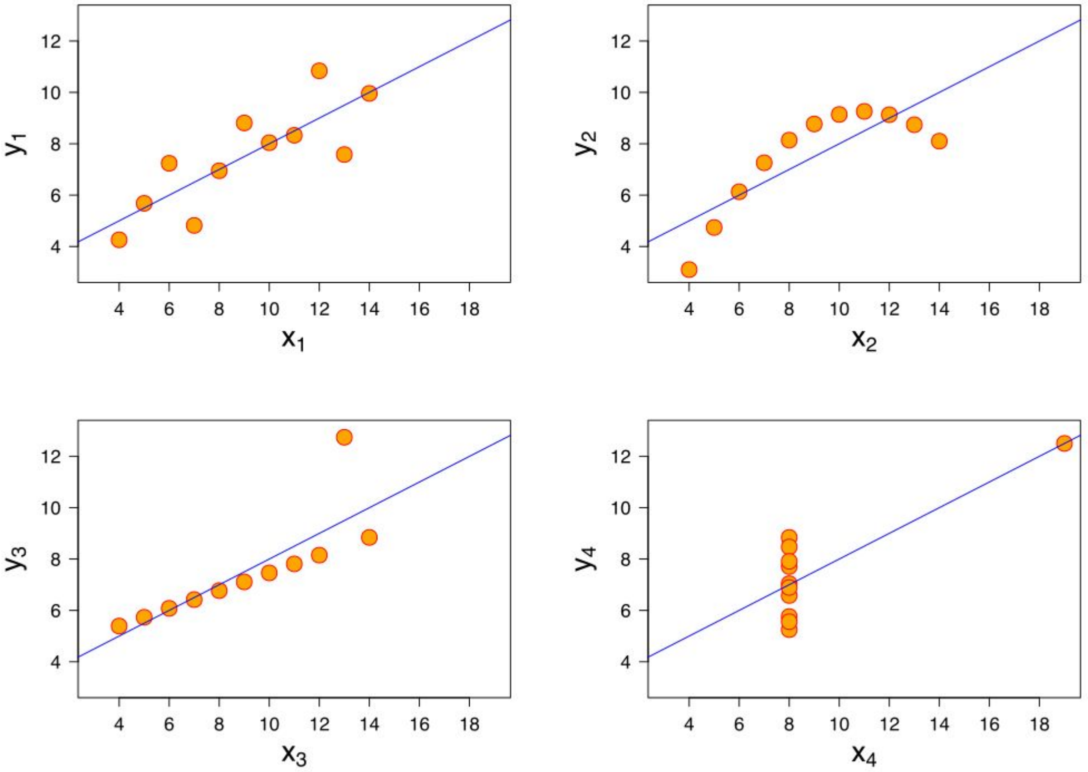
−1 is total −ve correlation | 0 is no correlation | +1 is total +ve correlation

Wikipedia

Anscombe's quartet: "calculation are exact; graphs are rough!"

11 datapoints

- Mean (x) = 9
- Var (x) = 11
- Mean (y) = 7.50
- Var (y) ~ 4.12
- Cor (x, y) = 0.816
- Linear regression line:
  - y = 3.00 + 0.500x

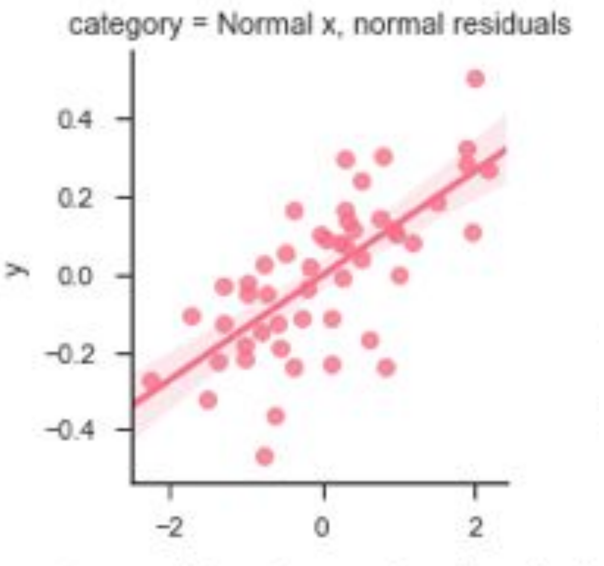


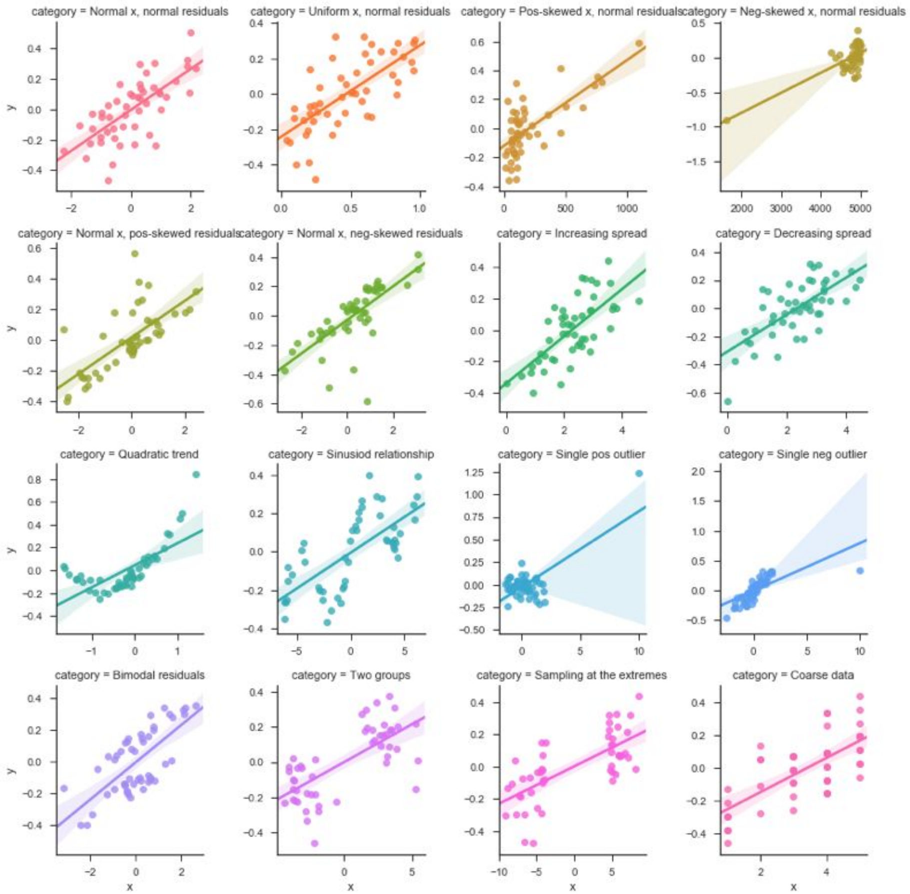
Anscombe, F. J. (1973). "Graphs in Statistical Analysis". American Statistician 27 (1): 17–21.

Wikipedia

What does a correlation coefficient tell you about the data?

Correlation = 0.7

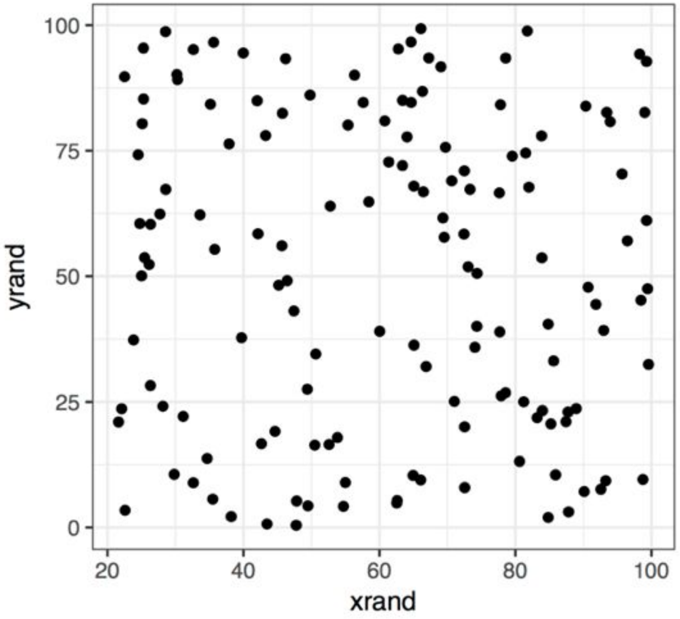




Wikipedia

What does a correlation coefficient tell you about the data?

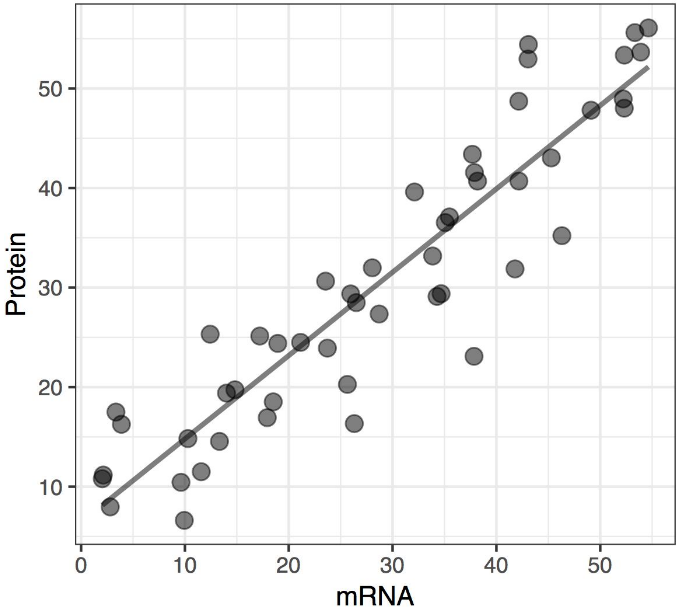
Correlation = -0.06



https://www.autodeskresearch.com/publications/samestats

What does a correlation coefficient tell you about the data?

Simpson's Paradox



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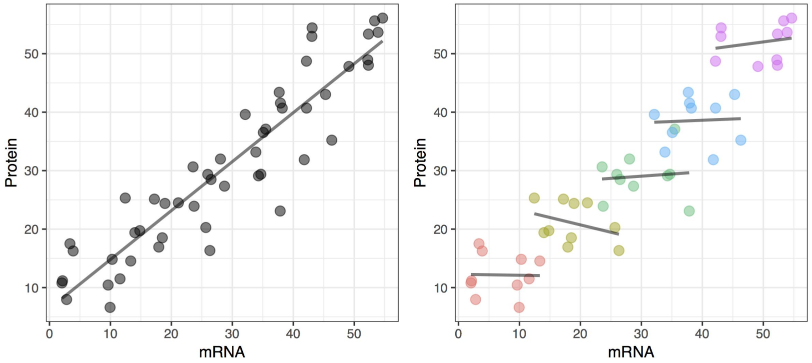
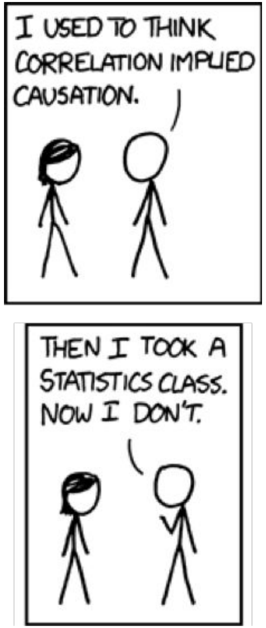
Simpson's Paradox

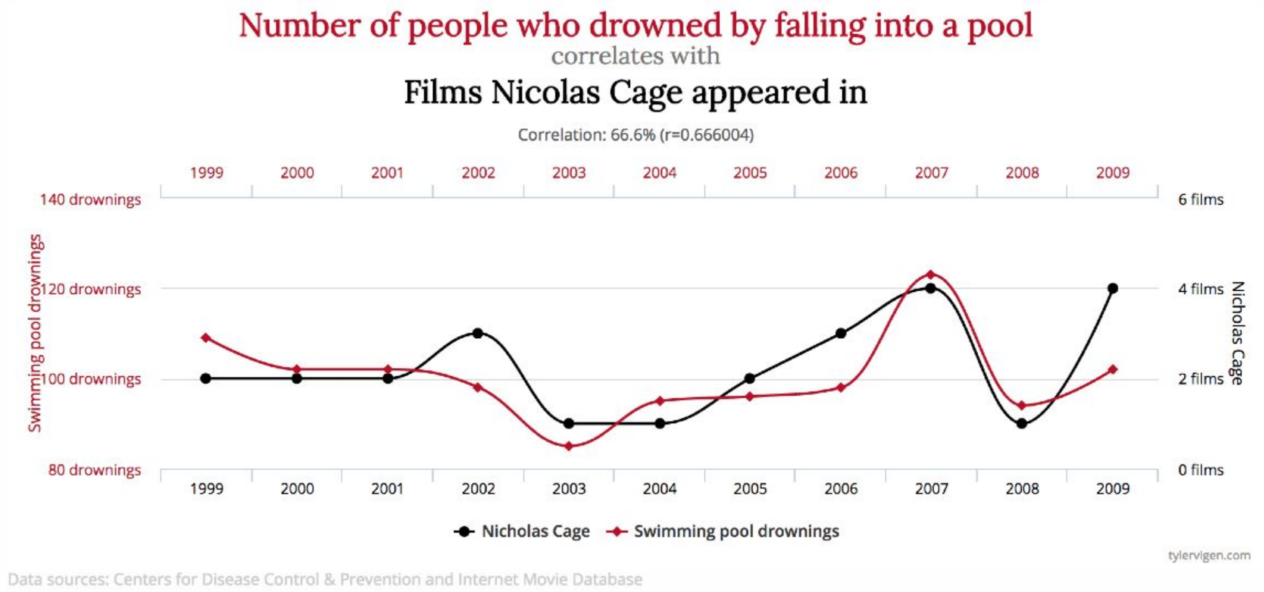


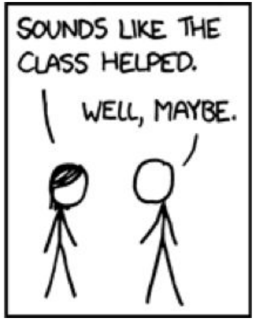
Success rates of kidney stone removal surgeries		
Treatment		**Overall**
Open surgery		78%
Percutaneous nephrolithotomy		83%

Spurious correlations

What does Nicholas Cage have to do with people drowning in swimming pools?







Checkout https://www.google.com/trends/correlate

xkcd.com/552

Spurious correlations

Simulate fluctuations in correlation coefficients

- Repeat 10,000: Calculate correlation coefficients of $n = 10$ samples of two independent normally distributed variables ($\mu = 0$, $\sigma = 1$). Plot a histogram.
- Mark statistically significant coefficients ($\alpha = 0.05$).
- Plot the samples with the three largest and smallest correlation coefficients (statistically significant).
- Vary $\sigma = \{0.1, 0.5, 1.0\}$ and vary sample size $n = \{5, 10, 50\}$.

Many correlation/distance measures

Pearson Correlation Coefficient

Spearman Rank Correlation

Euclidean Distance

Mutual Information

...

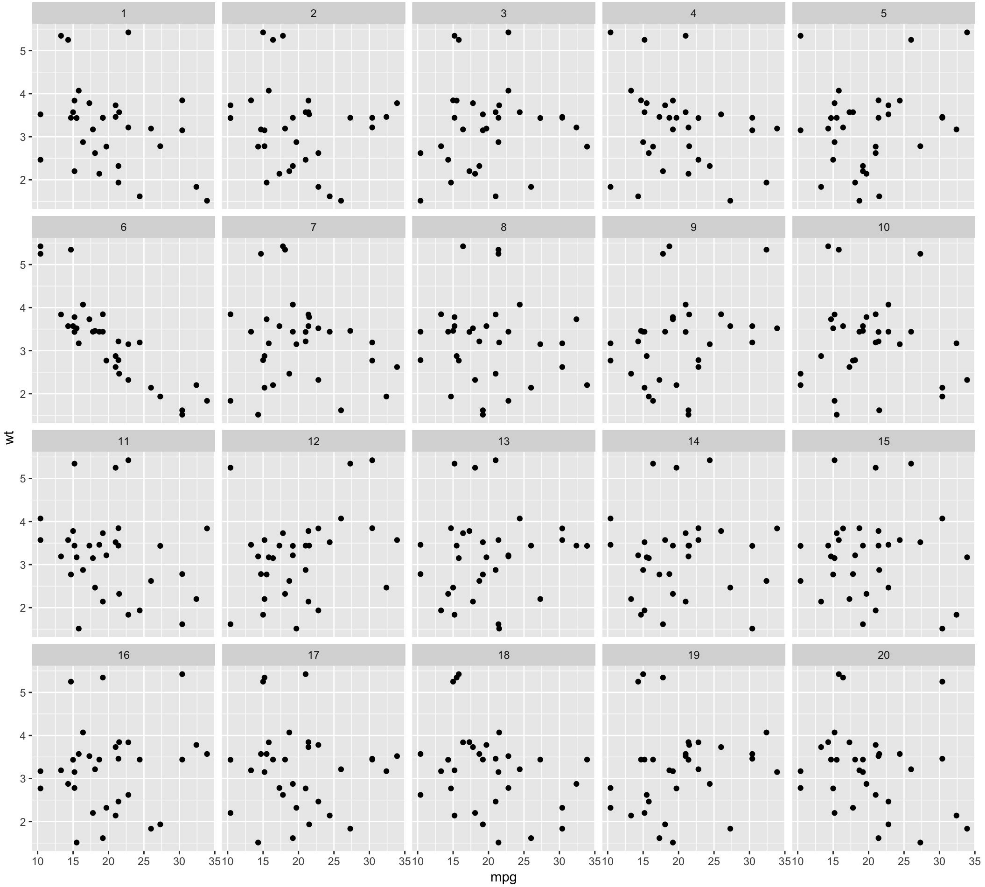
$$d = \sqrt{\sum_{i=1}^{n} (x_i - y_i)^2}$$

$$r = \frac{1}{n} \sum_{i=1}^{n} \left(\frac{x_i - \bar{x}}{\sigma_x} \right) \left(\frac{y_i - \bar{y}}{\sigma_y} \right)$$

$$\rho = 1 - \frac{6 \sum_{i=1}^{n} [rank(x_i) - rank(y_i)]}{n(n^2 - 1)}$$

Wikipedia

Spurious correlations – But it *looks* associated!

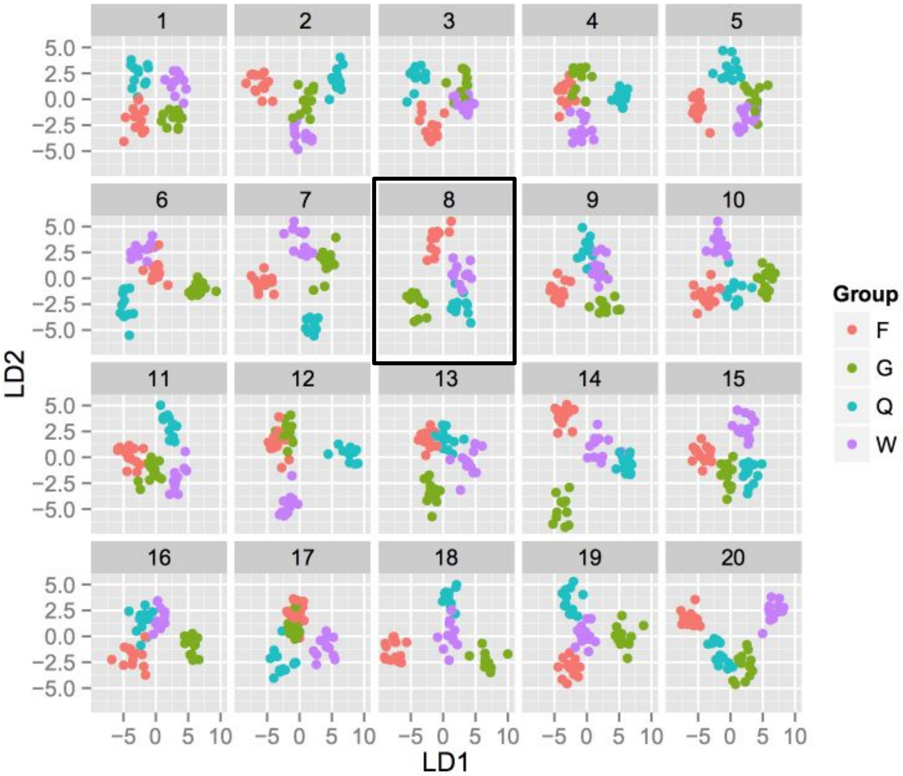


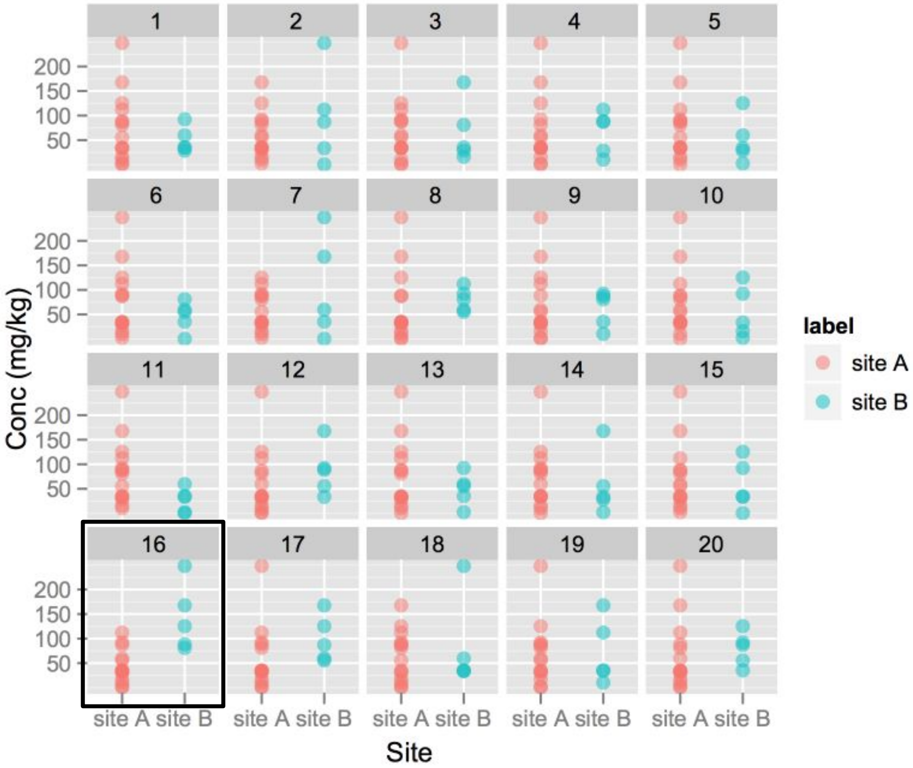
Create a <u>lineup</u> for visual inference

- Place the plot of the real data amongst a set of null plots to create a lineup; Null plots are generated in a way consistent with the null hypothesis.
- If the observer can pick the real data as different from the others, this puts weight on the statistical significance of the structure in the plot.

https://lib.dr.iastate.edu/cgi/viewcontent.cgi?article=4995&context=etd

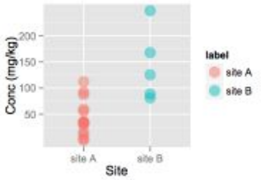
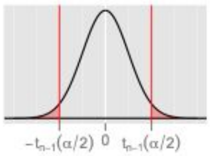
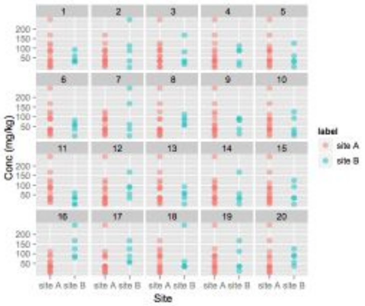
Spurious correlations – But it *looks* associated!





https://lib.dr.iastate.edu/cgi/viewcontent.cgi?article=4995&context=etd

Spurious correlations – But it *looks* associated!

	Mathematical Inference	Visual Inference
Hypothesis	$H_0 : \mu_1 = \mu_2$ vs $H_a : \mu_1 \neq \mu_2$	$H_0 : \mu_1 = \mu_2$ vs $H_a : \mu_1 \neq \mu_2$
	$\downarrow$	$\downarrow$
Test Statistic	$T(y) = \frac{\bar{y}_1 - \bar{y}_2}{s\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}}$	$T(y) =$ 
	$\downarrow$	$\downarrow$
Sampling Distribution	$f_{T(y)}(t)$; 	$f_{T(y)}(t)$; 
	$\downarrow$	$\downarrow$
Reject H_0 if	observed T is extreme	observed plot is identifiable