

## Ch. 3: Correlation & Linear Regression

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## Ch. 3: Correlation & Linear Regression

- Relationships between 2 variables
- Scatterplots
- Linear Regression
- Exercise 2
- Correlation
- Race / DNA

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## Number of variables

- One variable, one dimension
- Number Line
- Frequency Distribution / Histogram
  - 2 dimensional graph of 1D data
- Difference Score
  - 1 dimension
  - 2 dimensions

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## Bivariate relationships

- “is factor A related to factor B”?
- Methods of analysis...
  - Anecdotal / Clinical
  - Numerical : simple 2x2 analysis
  - Visually -- scatterplots
  - Statistically -- correlation & regression

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## Anecdotal / Clinical

- Many interesting findings began from non-scientific approaches
- “Intuition” that something is related through experiencing multiple situations
- Pattern recognition - Good and Bad
- Problems -- faulty memory, confirmation biases, prejudice, etc...
- Next step after a “gut” feeling : design experiment and collect data.

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## Simple numerical analysis

- Simplify:
  - use categorical variables
  - or convert continuous variables to categorical
- Use extreme cases to maximize effect
- Compute percentages in a 2x2 matrix
- Do the results suggest an effect?
- Compute Chi-square statistic to judge significance

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## Dichotomous Variables

- The simplest form of categorical
- Aka “binary”
- Examples:
  - 1/0
  - yes/no
  - pass/fail
  - true/false
  - healthy/sick
  - normal/impaired
  - etc.

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## Example

- “I think there is brain dysfunction in HIV disease” as measured by neuropsychological (NP) testing
- Medical status: control vs. HIV+
- NP test results: normal vs. impaired

		Medical Status	
		Control	HIV+
NP Status	Normal	85%	52%
	Impaired	15%	48%

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## 2x2 Analysis

- Pro: easy to understand
- Con: using binary categories reduces *statistical power*
- Conclusion: other Graphical and Statistical methods should be used as well.

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## Scatterplots

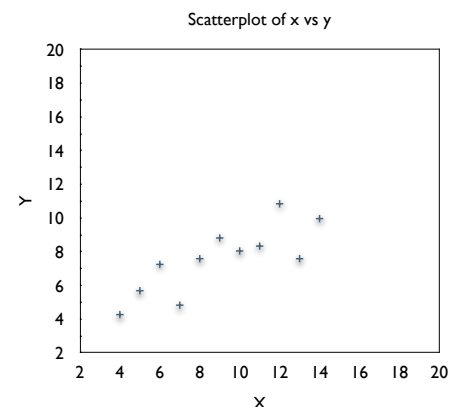
- Graph two variables in relation to each other on two-dimensional X, Y axis
- Easy to see
  - relations
  - problems
- Can't prove relationship is “significant”
- Difficult to interpret clinically or in “common sense” terms

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## Scatterplots

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



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# Linear Regression

- Assume X and Y are related
- Assume relationship is linear
- Model with single straight line
- Pick the line that best “fits” our data
- Other names: fitting a line, finding the trend, creating a trendline, best fit line...
- Residuals = difference between prediction and actual value
- Linear Regression minimizes the square of the residuals, often called “Ordinary Least Squares”

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# Why “Regression”

- Frances Galton
- Height of children vs parents.
- Tall parents have tall children (and vice versa)
- But children are closer to the mean than their parents (by a factor of ~2/3)
- Galton called this “Regression to the Mean”
- His paper fit\*\* straight lines to data points.
- The technique has been called “regression” ever since
- \*\* He never calculated the lines, he just eyeballed them

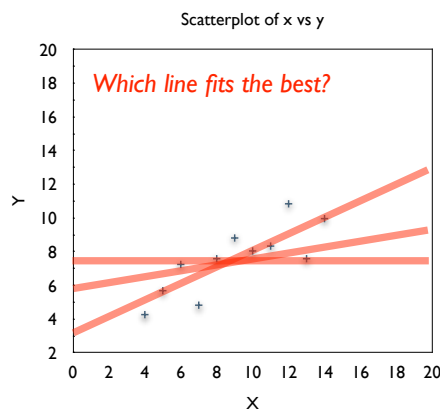
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# Linear Regression

Equation:  
 $y = 3.0 + 0.5x$

Correlation  
 $r_{x,y} = 0.816$

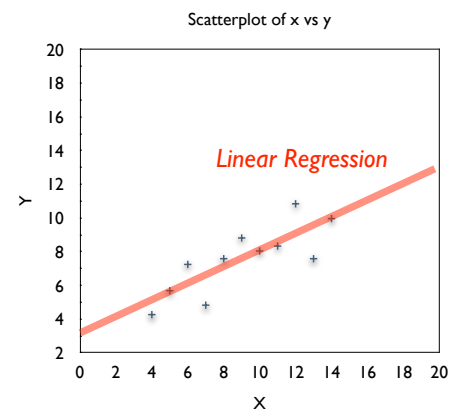


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# Anscombe's Quartet I

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

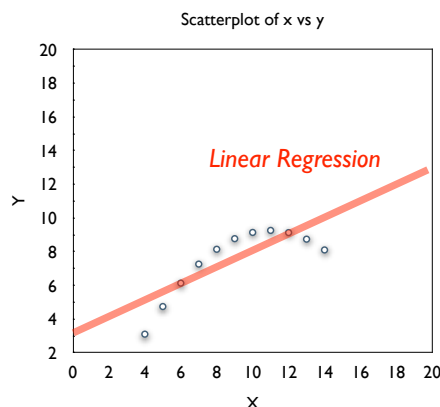


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# Anscombe's Quartet II

x	y
10	9.14
8	8.14
13	8.74
9	8.77
11	9.26
14	8.1
6	6.13
4	3.1
12	9.13
7	7.26
5	4.74

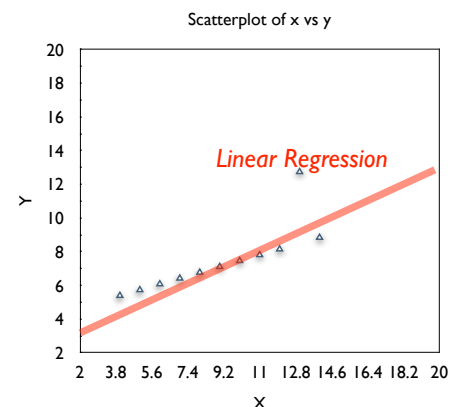


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# Anscombe's Quartet III

x	y
10	7.46
8	6.77
13	12.74
9	7.11
11	7.81
14	8.84
6	6.08
4	5.39
12	8.15
7	6.42
5	5.73

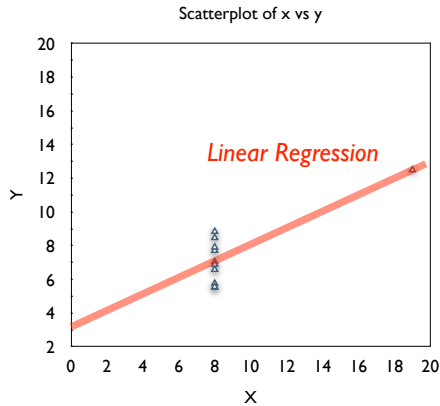


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# Anscombe's Quartet IV

x	y
8	6.58
8	5.76
8	7.71
8	8.84
8	8.47
8	7.04
8	5.52
19	12.5
8	5.56
8	7.91
8	6.89

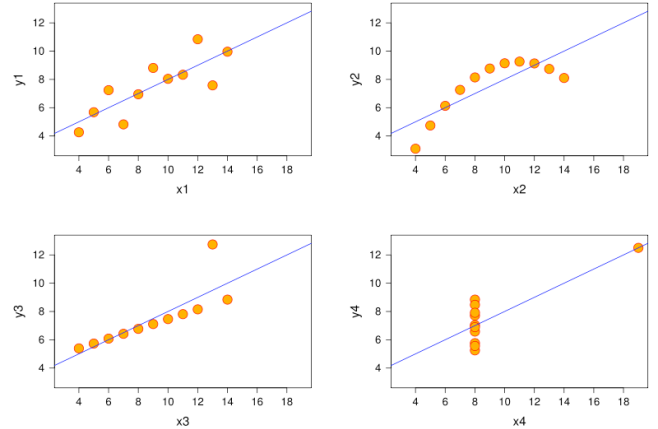


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# Anscombe's Quartet

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## Anscombe's Quartet Summary

- Each series has the same Quantitative stats:
  - linear regression equations
  - correlations
- Each one is Qualitatively different
- Each series needs special handling
- Lesson? Graph Your Data!

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## Linear Regression Equation

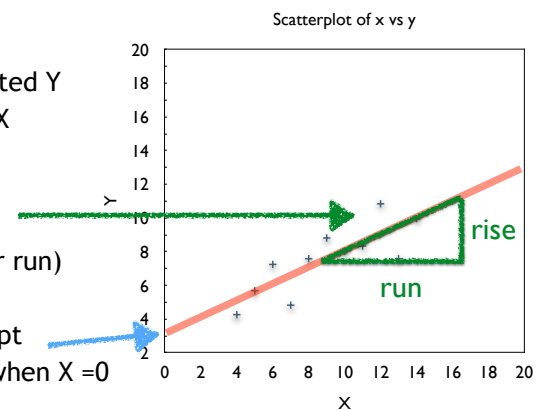
$$Y' = a + bX$$

$Y'$  = predicted Y

X = actual X

b = slope  
dY/dX  
(rise over run)

a = intercept  
Y value when X = 0



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## Residuals in Linear Regression

- $X_i$  : independent variable
- $Y_i$  : dependent variable
- Model: predict  $Y_i$  from  $X_i$
- $Y_i'$  : "Y prime" : predicted  $Y_i$
- $Y_i' = a + bX_i$
- Prediction is imperfect.
- Difference between predicted ( $Y'$ ) and actual ( $Y$ ) is called a "Residual" =  $(Y_i - Y_i')$
- Calculation of best fit line minimizes the sum of the squared residuals  $\sum(Y_i - Y_i')^2$

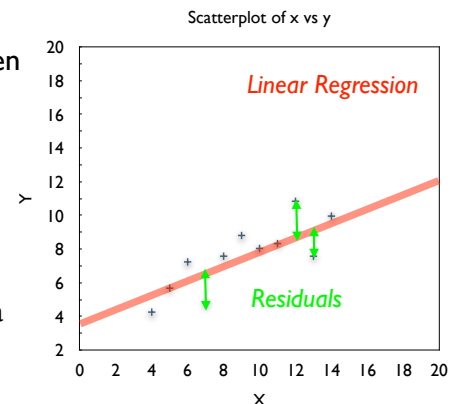
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## Residuals in Linear Regression

Residuals are difference between actual Y and predicted  $Y'$  ( $Y - Y'$ )

Graphically it is equal to how far away (vertically) a point is from the linear regression line



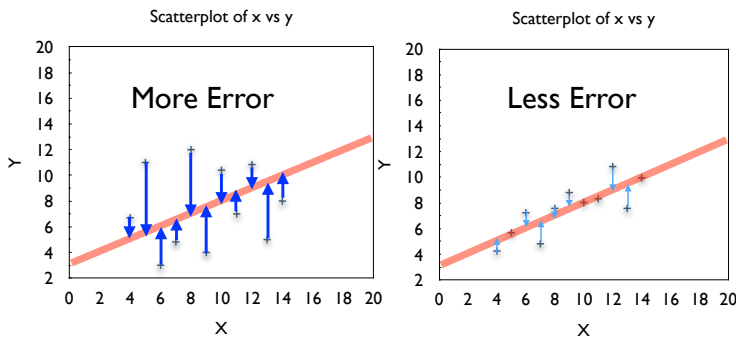
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# Residuals and Error

Residuals (error) are greater when Y values are further from prediction.



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# Residuals

$$d_i = y_i - y_i'$$

- In linear regression, the difference between the actual y and predicted y

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# Measuring “fit”

- Can we use residuals to measure how close the predicted values are vs. the actual values?
- E.g. how big are the residuals
- Similar to how we calculate Standard Deviation with a single X variable*

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# Sum of Squared Residuals

$$SSR = \sum_{i=1}^N d_i^2$$

$$SSR = \sum_{i=1}^N (y_i - y_i')^2$$

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# Sum of Squared Residuals

- Residual =  $(Y_i - Y_i')$
- Squared residual =  $(Y_i - Y_i')^2$
- SSR: Sum of squared residuals
  - Linear regression minimizes this value
- SSR is hard to interpret
- Can we standardize SSR?
- Need to compare SSR to something else

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# Sum of Squares Total

- What can we compare SSR to?
- SST
  - similar to the null hypothesis:
  - “what would SSR be if X and Y aren’t related at all?”
  - uses the mean of Y as the prediction

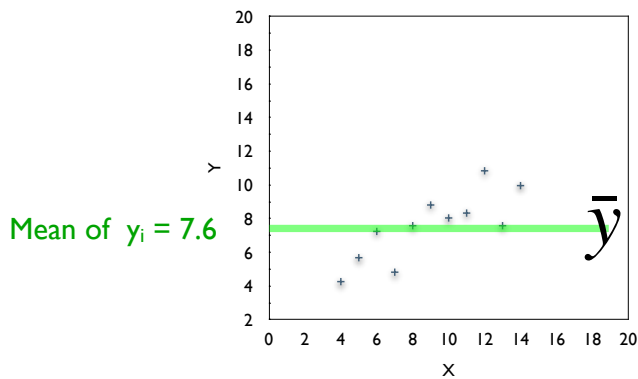
$$SST = \sum_{i=1}^N (y_i - \bar{y})^2$$

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$$SST = \sum_{i=1}^N (y_i - \bar{y})^2$$

Scatterplot of x vs y



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$R^2$

$$R^2 = 1 - \frac{SSR}{SST}$$

- $R^2 = 1 - (SSR/SST)$
- Ranges from 0 to 1 (0% to 100%)

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$R^2$

- Terminology
  - Coefficient of Determination
  - Explained Variance
  - Shared Variance
- Meaning
  - what % of variation in Y values can we predict from the variation in X values
- Careful: *Correlation* is not causation

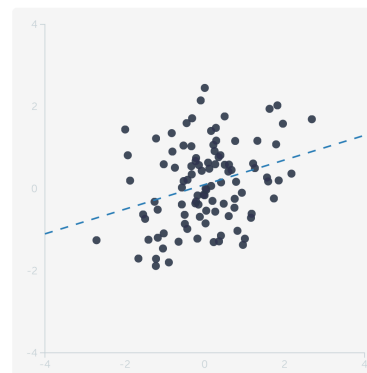
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## Interactive Correlation Demo

- <http://rpsychologist.com/d3/correlation/>

Slide me

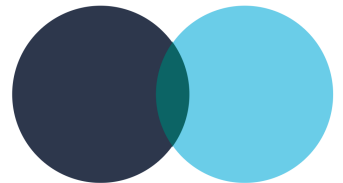


Correlation: 0.3

Sample size 100

New sample

Shared variance: 9%



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## Ch. 3 - Part 2

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## Review

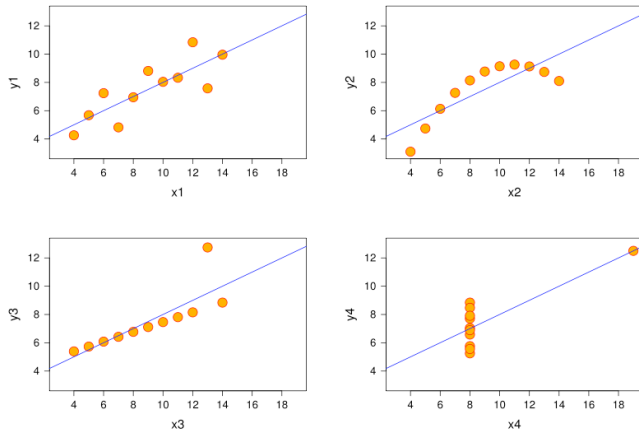
- # of variables / dimensions
  - 1 Mean (SD)
  - 2 Linear Regression

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## Anscombe's Quartet

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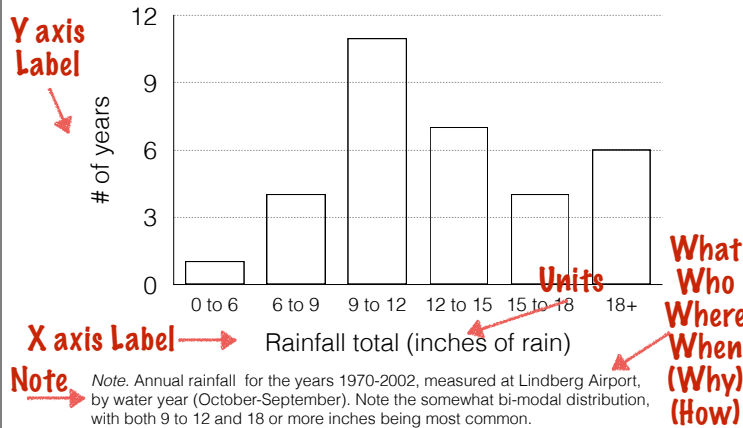
## Exercise 2 - GraphPad Prism

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### Example of APA-7 style Histogram

**Figure 1**  
Frequency Distribution of Annual Rainfall in San Diego



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### APA-7 Figure Example

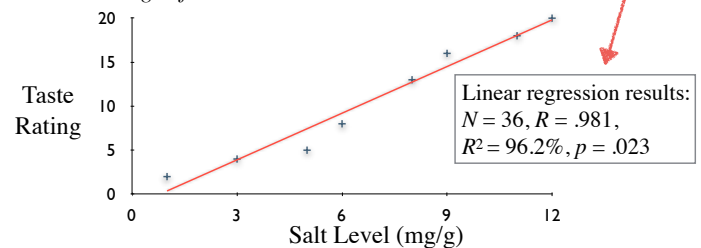
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Title is above the figure

Legend is within the figure

**Figure 1**

Taste Ratings of a Cracker in Relation to Salt Amount



Note. Subjects ( $N=36$ ) ate a single dry cracker which varied in the amount of salt (milligrams per gram) and rated the taste on a 20 point scale. Note the very strong correlation, suggesting higher salt levels are strongly related to taste ratings.

Note is below the figure

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## Ch. 3 - Part 3

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## Review

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## Standard Error of Estimate

- Residual =  $(Y - Y')$
- Standard Deviation of residuals
  - measure of “average” error
  - aka “Standard Error of Estimate”
  - In Prism:  $S_{y,x}$

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## Correlation : Pearson's r

- Pearson's Product-Moment Correlation
- Measures the strength of the linear relationship between two variables
- Ranges between -1.0 and +1.0
- Is a special case of linear regression, when both X and Y have been turned into Z scores.
- r is **transitive commutative** (correlation between X and Y is same as correlation between Y and X)
- $R^2$  = “explained variance” is the proportion of variation in the data explained by the model.
- $R^2$  ranges from 0 to 1.0 (0% to 100%)

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## Regression vs. Correlation

	Linear Regression	Correlation
<b>Scores</b>	Raw	Z
<b>Mean, Std Dev</b>	sample means sample Std Dev	0 1
<b>Equation</b>	$Y' = a + bX$	$Y' = rX$
<b>Slope</b>	b = change in Y per change in X	r = correlation coefficient
<b>Slope<sup>2</sup></b>	meaningless	$R^2$ = % variance explained
<b>Commutative ?</b>	no	yes, $R_{xy} = R_{yx}$

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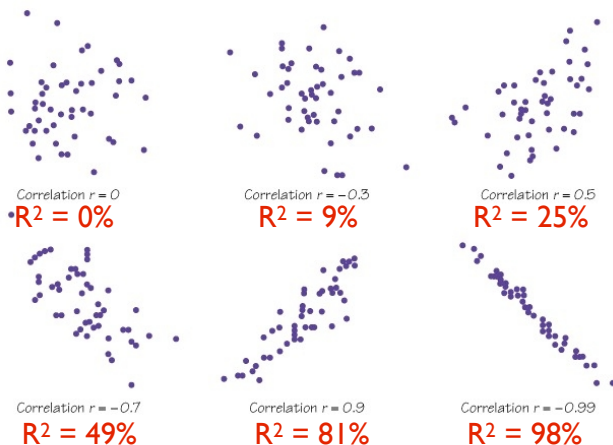
## R vs R<sup>2</sup>

	R	R <sup>2</sup>
<b>Minimum</b>	-1.0	0.0 (0%)
<b>Maximum</b>	1.0	1.0 (100%)
<b>Meaning</b>	correlation between X and Y	% of variance in Y explained by X
<b>AKA</b>	“correlation”, “correlation coefficient”	shared variance, explained variance, coefficient of determination
<b>Notes</b>	can be positive or negative	always positive (since it's squared)

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## Correlations



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## Interactive Correlation Example

- <http://rpsychologist.com/d3/correlation/>
- $R^2$  or “Explained Variance” is sometimes called “Shared Variance”

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## Other Correlation Coefficients

- Continuous (interval & ratio): Pearson's  $r$
- Ordinal (Ranked): A B C D... 1st, 2nd, 3rd...
  - Spearman's Rho: correlation between two ordinal / ranked variables.
- Dichotomous (yes/no, one/zero, T/F, Male/Female, Pass/Fail...)
  - True vs. Artificial?

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## Continuous vs. Dichotomous

Type of X / Type of Y	Continuous	Artificial Dichotomous	True Dichotomous
Continuous	Pearson $r$	Biserial $r$	Point biserial $r$
Artificial Dichotomous	Biserial $r$	Tetrachoric $r$	Phi
True Dichotomous	Point biserial $r$	Phi	Phi

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## Correlation : Issues

- Technical / Calculation :
  - Non-normal distribution
  - Non-linear data and relationships
  - Outliers, data errors
  - Restricted Range
- Interpretation:
  - Correlation  $\neq$  Causation
  - Third variable explanations

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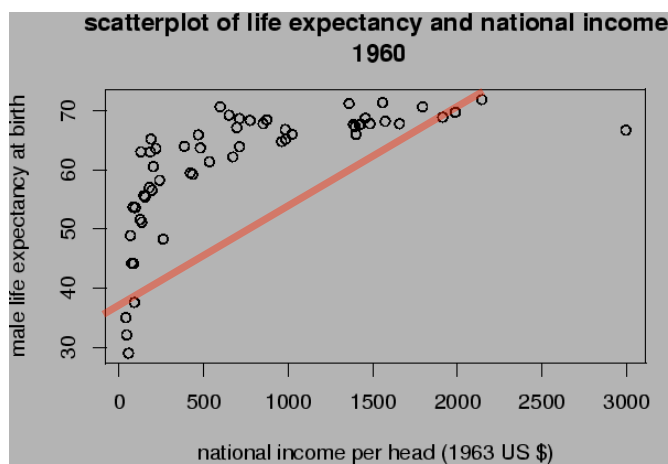
## Non-linearity

- Linear Regression & Correlation assume a linear relationship between X and Y
- When it's not linear:
  - Restrict the range of X
  - Transform (log, square root, etc.)
  - other statistical analyses (Spearman's Rho...)

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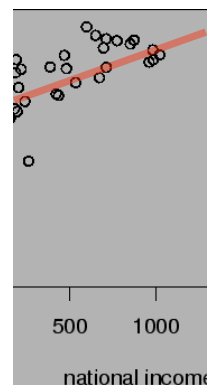
## Life expectancy / national income



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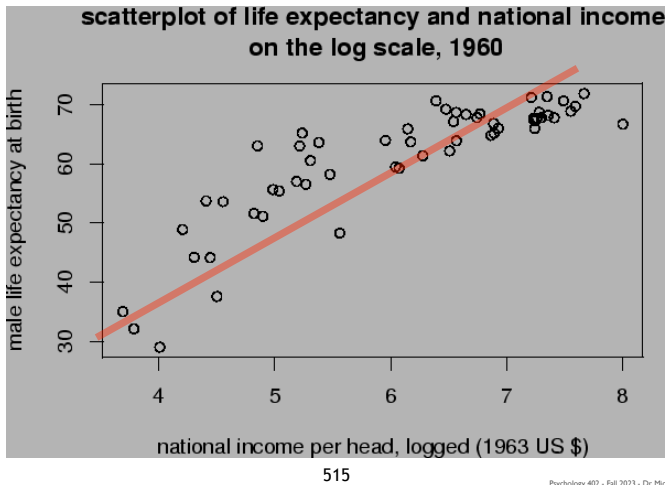
## Restrict range of X



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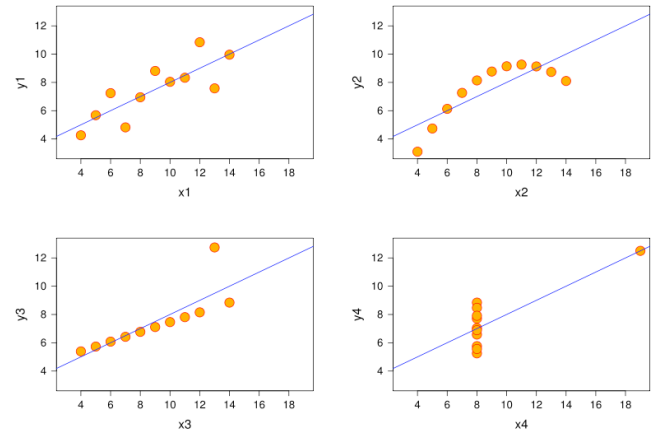
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## log transform X (or Y)



## Outliers & Data Errors?

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## Correlation = Causation?

- A relationship (linear or otherwise) between X and Y tells us nothing about whether X causes Y
- Lack of correlation between X and Y does not mean that X doesn't cause Y
- Ice cream sales are positively related to increases in drowning deaths

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## Hypothesis Testing

- Parameters estimated from sample data have error
- How do we know if a given estimate is correct?
- How big is the error likely to be (confidence intervals)?
- Inferential Statistics - covered later
  - Formulas to calculate probability, confidence intervals.
  - Higher N is better
  - “statistical significance” not the same as “clinical significance”

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## Statistical vs Clinical Significance<sup>520</sup>

- Regarding the change in the Dependent Variable (DV)
- Statistical Significance:
  - Could the change be due to chance?
  - P value ( $p < .05$  : less than 5% probability)
- Clinical Significance
  - Was the change big enough to matter?
  - Effect Size ( $R^2$ )
  - Depends on context

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## Significance vs. Effect Size

- Two coin flips : both heads (100%)
  - big effect size (50%)
  - not statistically significant ( $p=0.25$ )
- 1000 coin flips, 490 heads (49.0%)
  - small effect (1%)
  - statistically significant ( $p=0.02$ )
- 1000 coin flips, 350 heads (35%)
  - big effect (15%)
  - statistically significant ( $p<.00000001$ )

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## Lies, damned lies, and statistics

- Statistical significance (P) is a function of...
  - Errors of measurement (E)
  - Effect Size (R)
  - Sample Size (N)
- $P \sim E / (R \times N)$

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## Reporting Results

- Headline: “Men had higher IQ than women. Results were significant  $p < .001$ ”
- ?—> “that’s very significant”
- ?—> “men are much smarter than women”
- P-value : statistically significant: Yes
- Effect Size : clinically significant: ? Unknown

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## Review : Is race “real”?

- Pre-DNA theory
- Post-DNA theory

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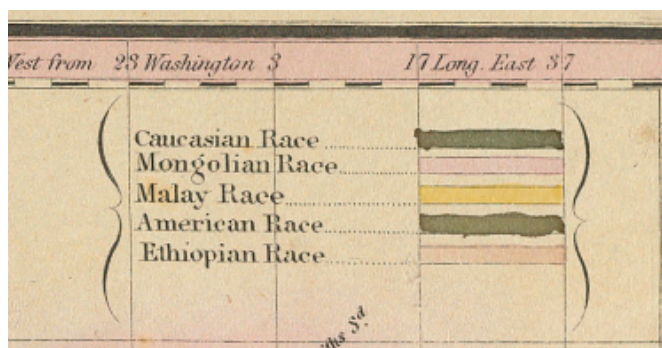
## Pre-DNA

- Gold, Silver, Brass, Iron -- Plato
- “There is a physical difference between the white and black races which I believe will for ever forbid the two races living together on terms of social and political equality.” -- Abraham Lincoln

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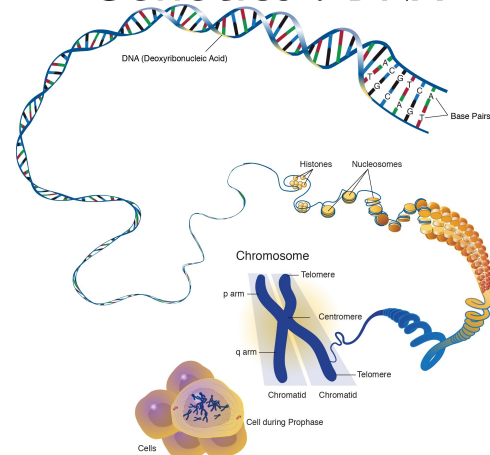
## Five Races?



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## Genetics : DNA



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# Genetics

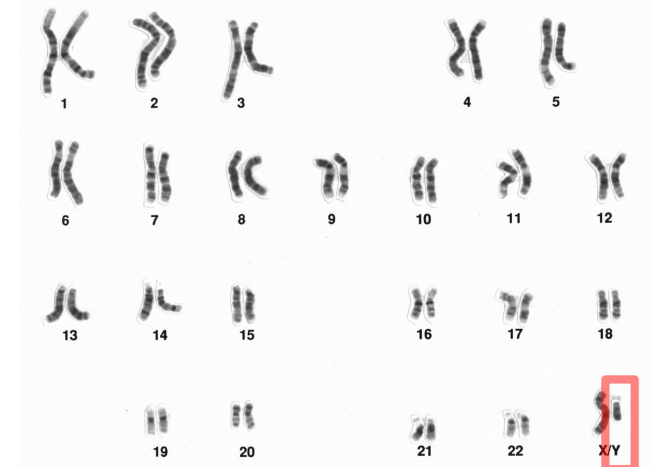
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- Human genome contains about 3 billion pairs of deoxyribonucleic acid (DNA)
- DNA is Transcribed into RNA
- RNA is Translated into Proteins
- Proteins
  - serve as structural components
  - function as enzymes to catalyze biochemical reactions
- Human DNA is grouped into 46 chromosomes
  - 23 pairs, one of each pair comes from each parent
  - 22 pairs in both males and females (autosomes)
  - 1 pair determines sex: either "XX" (females) or "XY" (males)

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# Humans: 46 Chromosomes - 23 pairs

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# Gene

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- DNA is subdivided into Chromosomes
- Chromosomes are subdivided into Genes
- Gene is a functional unit of DNA
- makes one thing (single protein or RNA)

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# Genetics : Species Differences

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organism	estimated size (base pairs)	# genes	gene size	# chromosomes
Homo sapiens (human)	3.2 billion	~25,000	1 gene per 100,000 bases	46
Mus musculus (mouse)	2.6 billion	~25,000	1 gene per 100,000 bases	40
Drosophila melanogaster (fruit fly)	137 million	13,000	1 gene per 9,000 bases	8
Arabidopsis thaliana (plant)	100 million	25,000	1 gene per 4000 bases	10
Caenorhabditis elegans (roundworm)	97 million	19,000	1 gene per 5000 bases	12
Saccharomyces cerevisiae (yeast)	12.1 million	6000	1 gene per 2000 bases	32
Escherichia coli (bacteria)	4.6 million	3200	1 gene per 1400 bases	1
H. influenzae (bacteria)	1.8 million	1700	1 gene per 1000 bases	1

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# Visible differences?

Indigenous  
Australian  
Melanesia  
African  
European



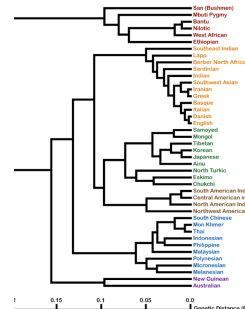
Australian and  
Africans are  
most genetically  
different

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# Genetic Differences

- Sub-Saharan African
- Indo-European
- East Asian
- Native American
- South Asian
- Aboriginal



Fst = % of  
subpopulation  
variance

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## DNA Variation

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## DNA Variation

- variation between individuals : 3mbp / person
- variation within groups : 85%
- variation between groups: 15%
  - 5% - within *population groups*
  - 10% - between *population groups*
- *Note: skin color is one of the few traits where the pattern is reversed*

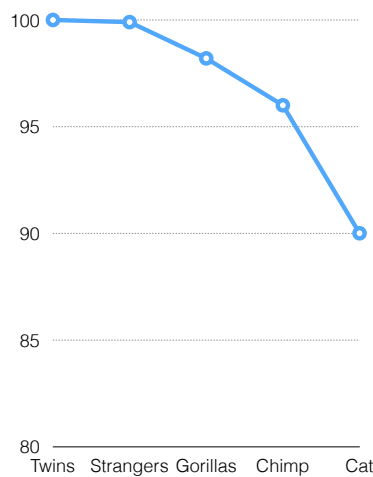
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## DNA Differences

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- Identical Twins
  - 0.0%
- Human vs. Human
  - 0.1%
- Humans vs Gorillas
  - 1.6%
- Humans vs Chimps:
  - 4.0%
- Humans vs. Cats
  - 10.0%



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## Post-DNA theory

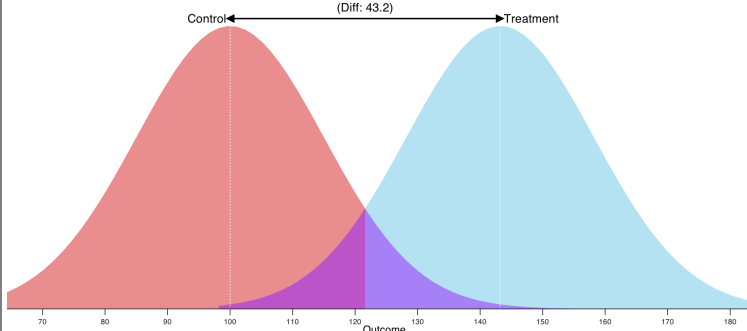
- Variance
  - variation between individuals
    - aka variation *within races population groups*
  - variation *between population groups*

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## Skin Color

Cohen's d: 2.9  
(Diff: 43.2)



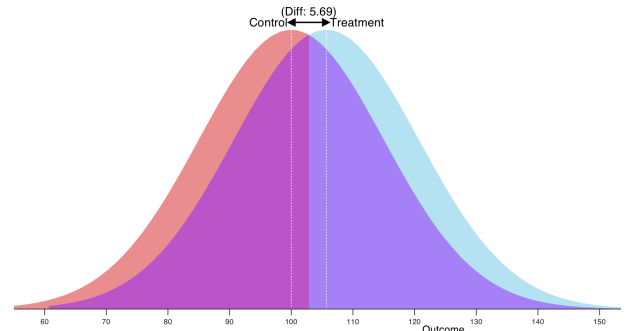
- 85% between group, 15% within group
- 98% probability blue person higher than red

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## Many other traits

Cohen's d: 0.38  
(Diff: 5.69)



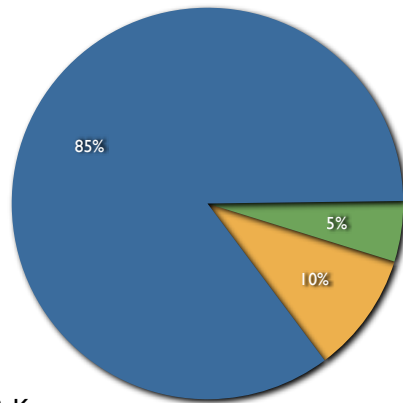
- 15% between group, 85% within group
- 61% chance blue person higher than red

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## Variance: Genetic Variation

- Within local populations
- Within "race"
- Between "race"



For example:

- 85% within Japanese
- 5% between Japanese & Korean
- 10% between Asian and Caucasian

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## Prehistorical Migration

