INTRODUCTION TO DATA SCIENCE

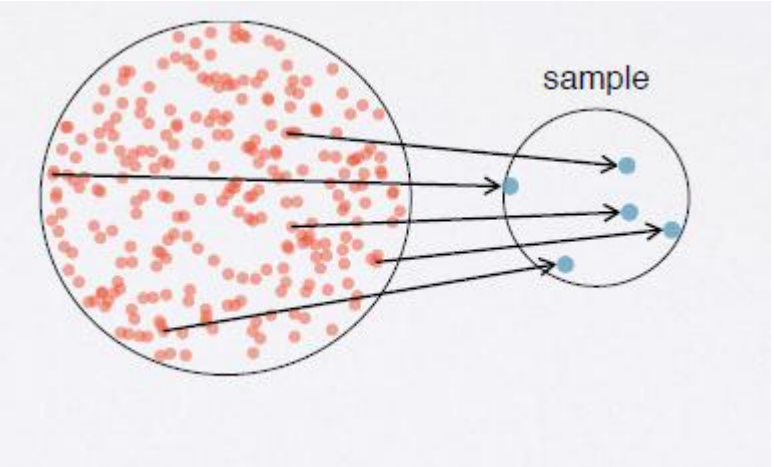
Lecture based on:
M. Cetinkays-Rundel, „Data Analysis and Statistical Inference", Univ. of Duke

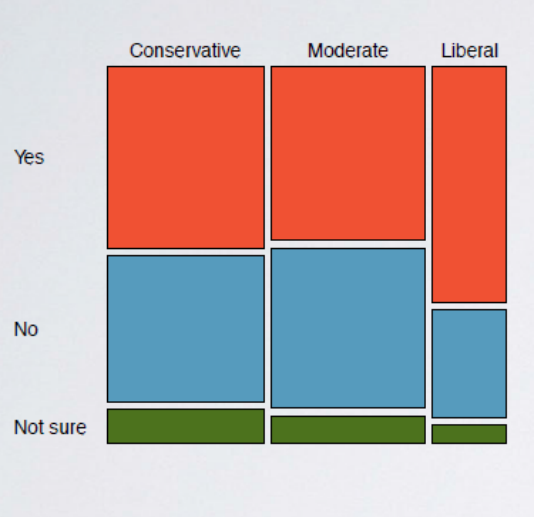
8/10/2019

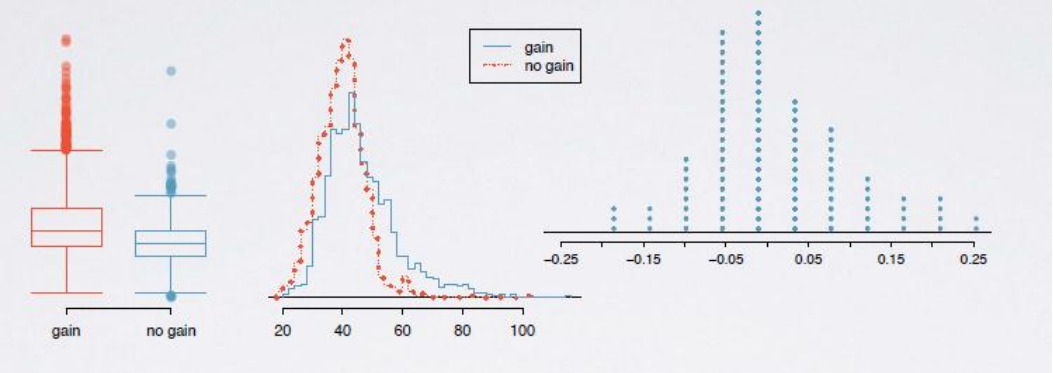
WFAiS UJ, Informatyka Stosowana
I stopień studiów

Exploratory data analysis

How to collect, visualise and interpret the data.







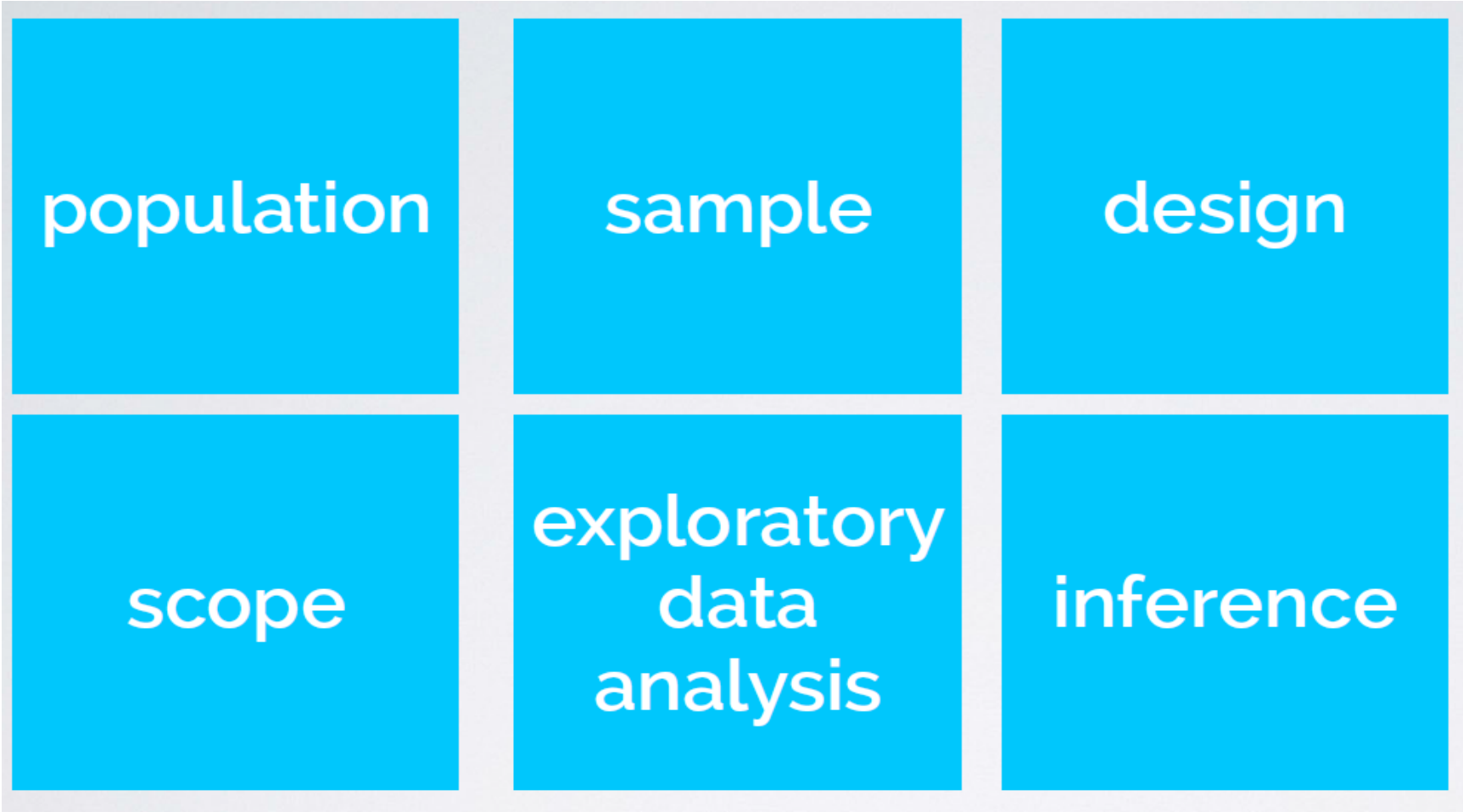
populations and samples

research question	population	sample	generalize to
Are consumers of certain alcohol brands more likely to end up in the emergency room with injuries?	Everyone	ER patients at the Johns Hopkins Hospital in Baltimore in the US	Residents of Baltimore

Source: Jernigan, David H., et al. "Alcohol brand use and injury in the emergency department: A pilot study." Substance use & misuse (2013).

Image credit: Jon Sullivan
http://www.public-domain-image.com/food-and-drink-public-domain-images-pictures/wine-public-domain-images-pictures/champagne-flutes-glasses-bubbles.jpg.html

Exploratory data analysis



Data: basics

- Observations, variables, data matrices
- Type of variables
- Relationship between variables

Example: data matrix

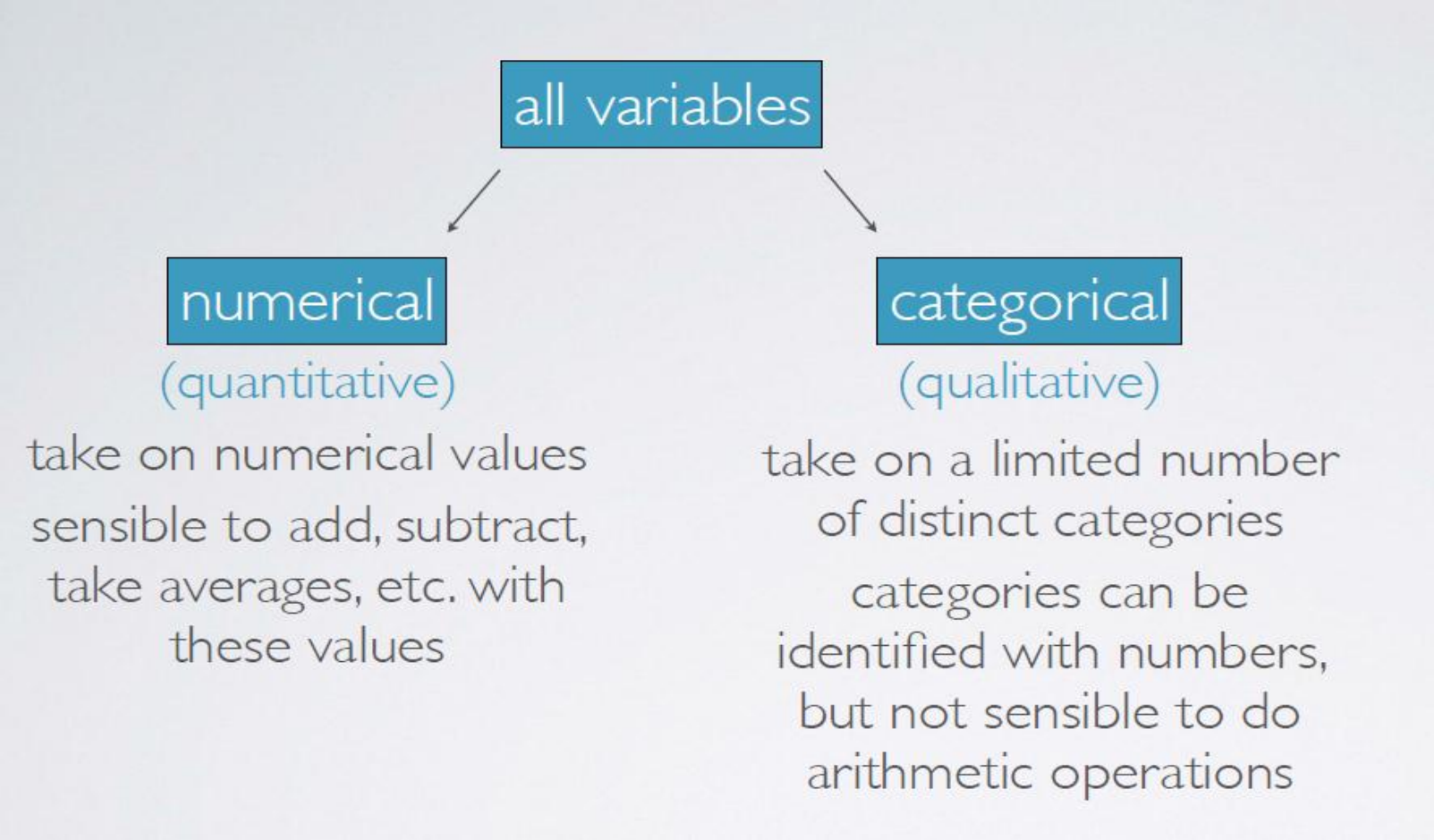
Requests send to Google to remove links from the search engine database.

country	cr_req	cr_comply	ud_req	ud_comply	…	hemisphere	hdi
Argentina	21	100	134	32	…	southern	very high
Australia	10	40	361	73	…	southern	very high
Belgium	<10	100	90	67	…	northern	very high
Brazil	224	67	703	82	…	southern	high
…	…	…	…	…	…	…	…
United States	92	63	5950	93	…	northern	very high

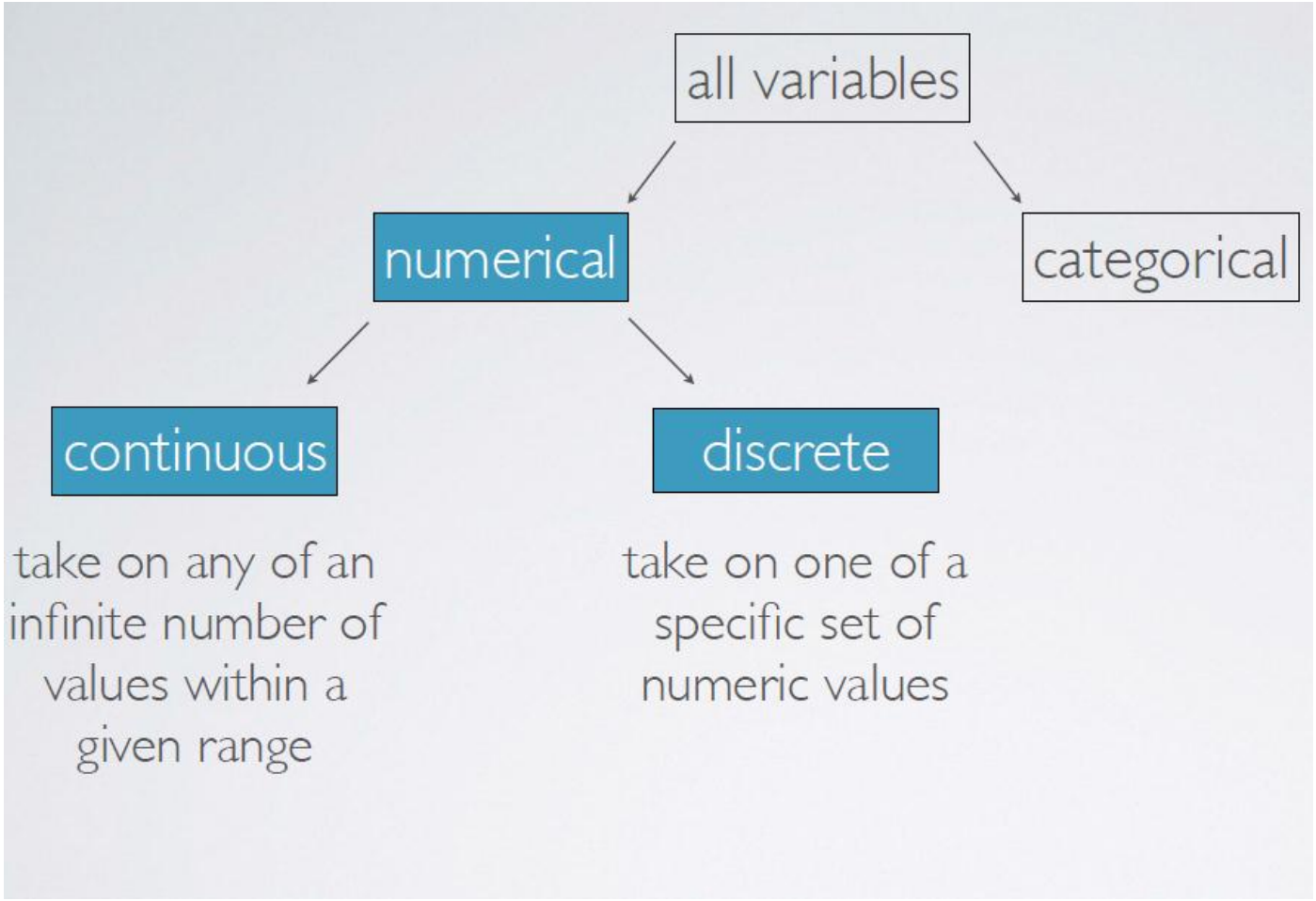
observation (case)

variable

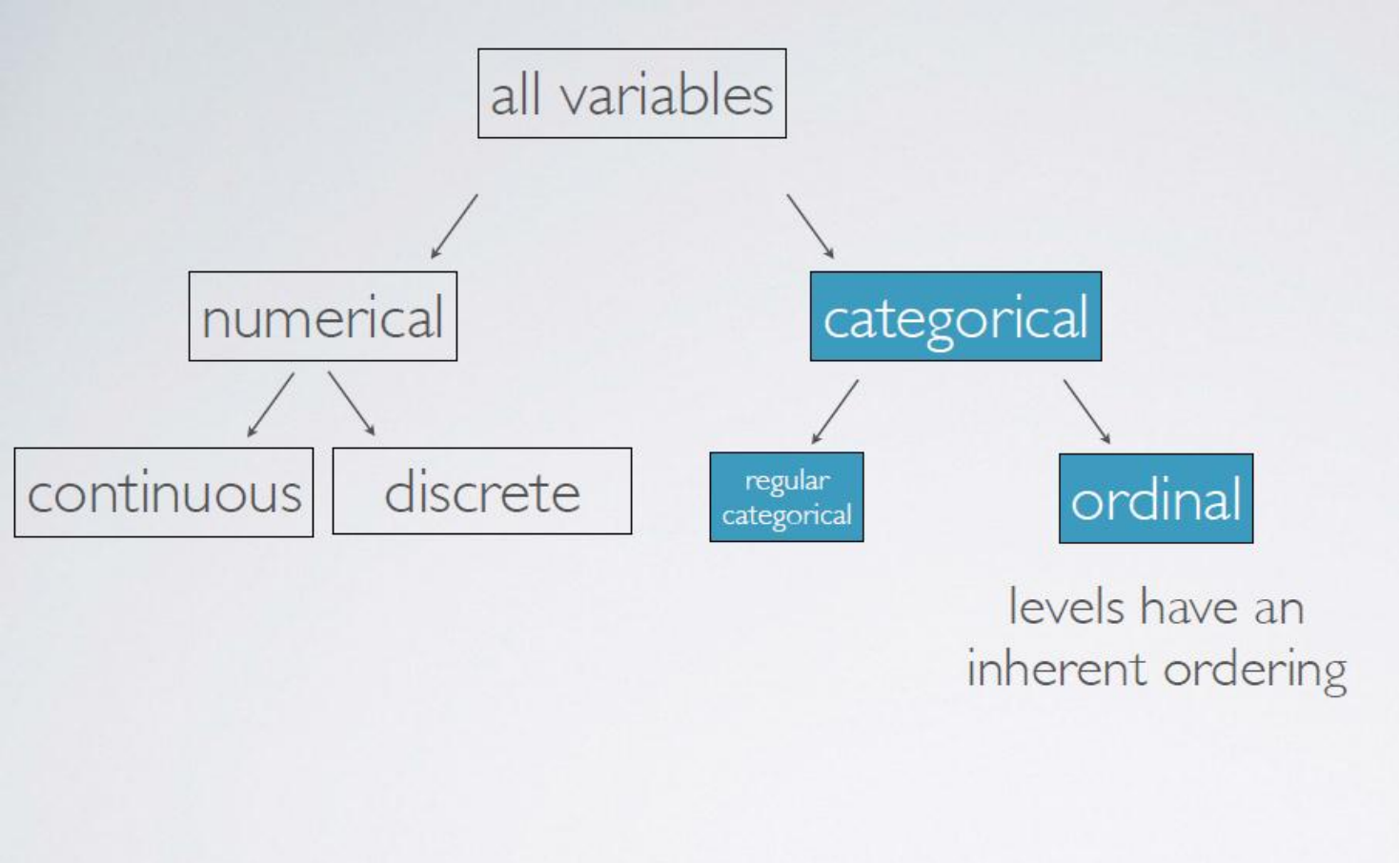
Type of variables



Numerical variables



Categorical variables



Data matrix

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Brazil	224	67	703	82	…	southern	high
…	…	…	…	…	…	…	…
United States	92	63	5950	93	…	northern	very high

`country`: Name of the country

Data matrix

country	cr_req	cr_comply	ud_req	ud_comply	…	hemisphere	hdi
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Brazil	224	67	703	82	…	southern	high
…	…	…	…	…	…	…	…
United States	92	63	5950	93	…	northern	very high

`cr_req`: Number of content removal requests made to Google

discrete numerical

Data matrix

country	cr_req	cr_comply	ud_req	ud_comply	…	hemisphere	hdi
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Brazil	224	67	703	82	…	southern	high
…	…	…	…	…	…	…	…
United States	92	63	5950	93	…	northern	very high

`cr_comply`: Percentage of content removal requests Google complied with

continuous numerical

Data matrix

country	cr_req	cr_comply	ud_req	ud_comply	…	hemisphere	hdi
Argentina	21	100	134	32	…	southern	very high
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Brazil	224	67	703	82	…	southern	high
…	…	…	…	…	…	…	…
United States	92	63	5950	93	…	northern	very high

`ud_req`: Number of user data requests as part of a criminal investigation

Data matrix

country	cr_req	cr_comply	ud_req	ud_comply	…	hemisphere	hdi
Argentina	21	100	134	32	…	southern	very high
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…	…	…	…	…	…	…	…
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`ud_comply`: Percentage of user data requests Google complied with **continuous numerical**

Data matrix

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…	…	…	…	…	…	…	…
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categorical

`hemisphere`: Hemisphere that the country is located in (southern, northern)

Data matrix

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…	…	…	…	…	…	…	…
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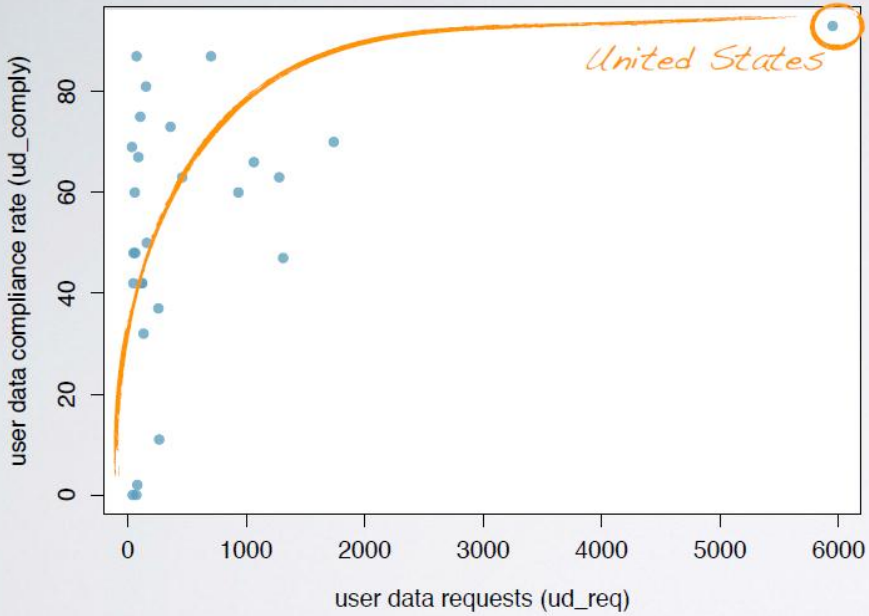
`hdi`: Human Development Index
(very high, high, medium, low)

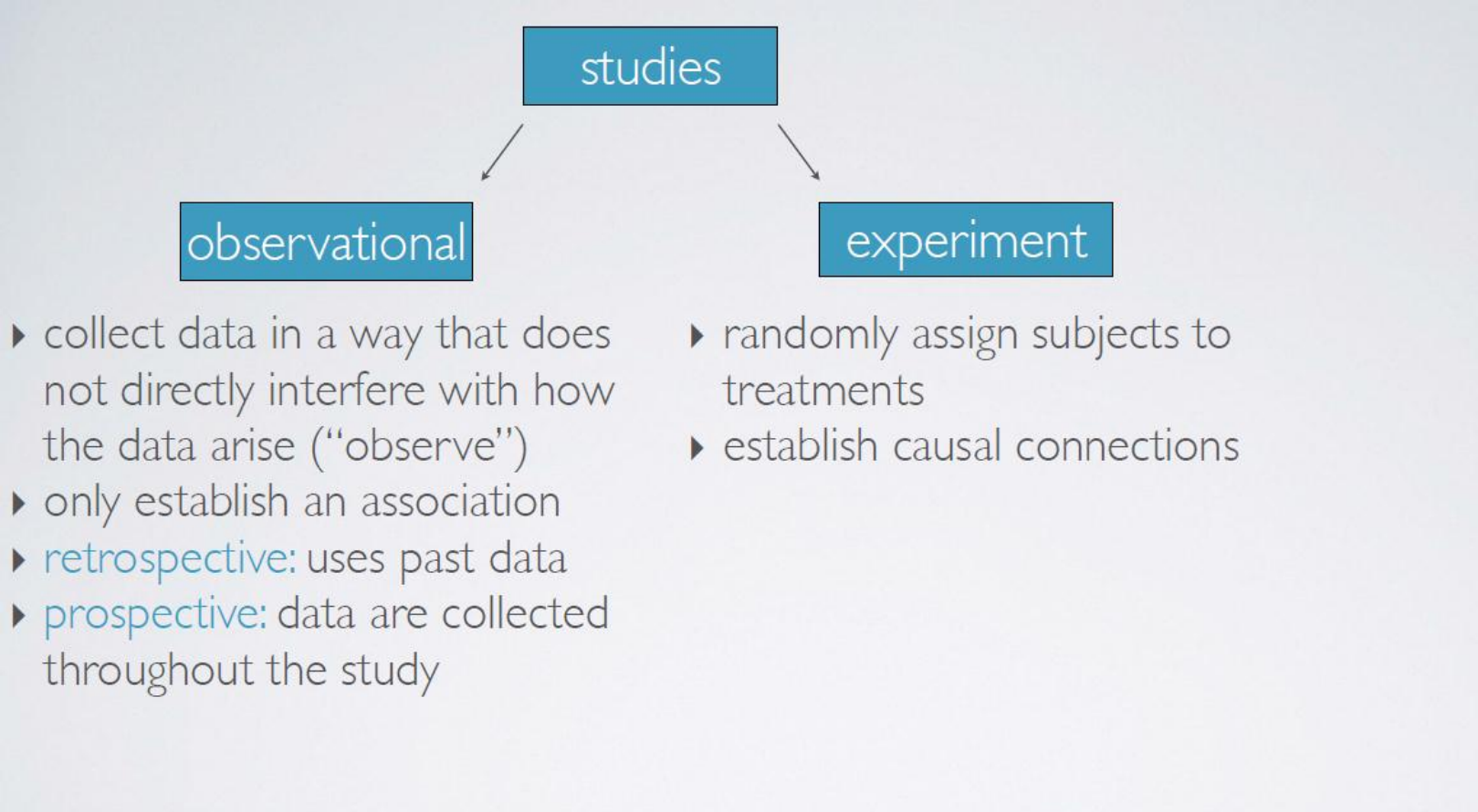
Relationships between variables

relationships between variables

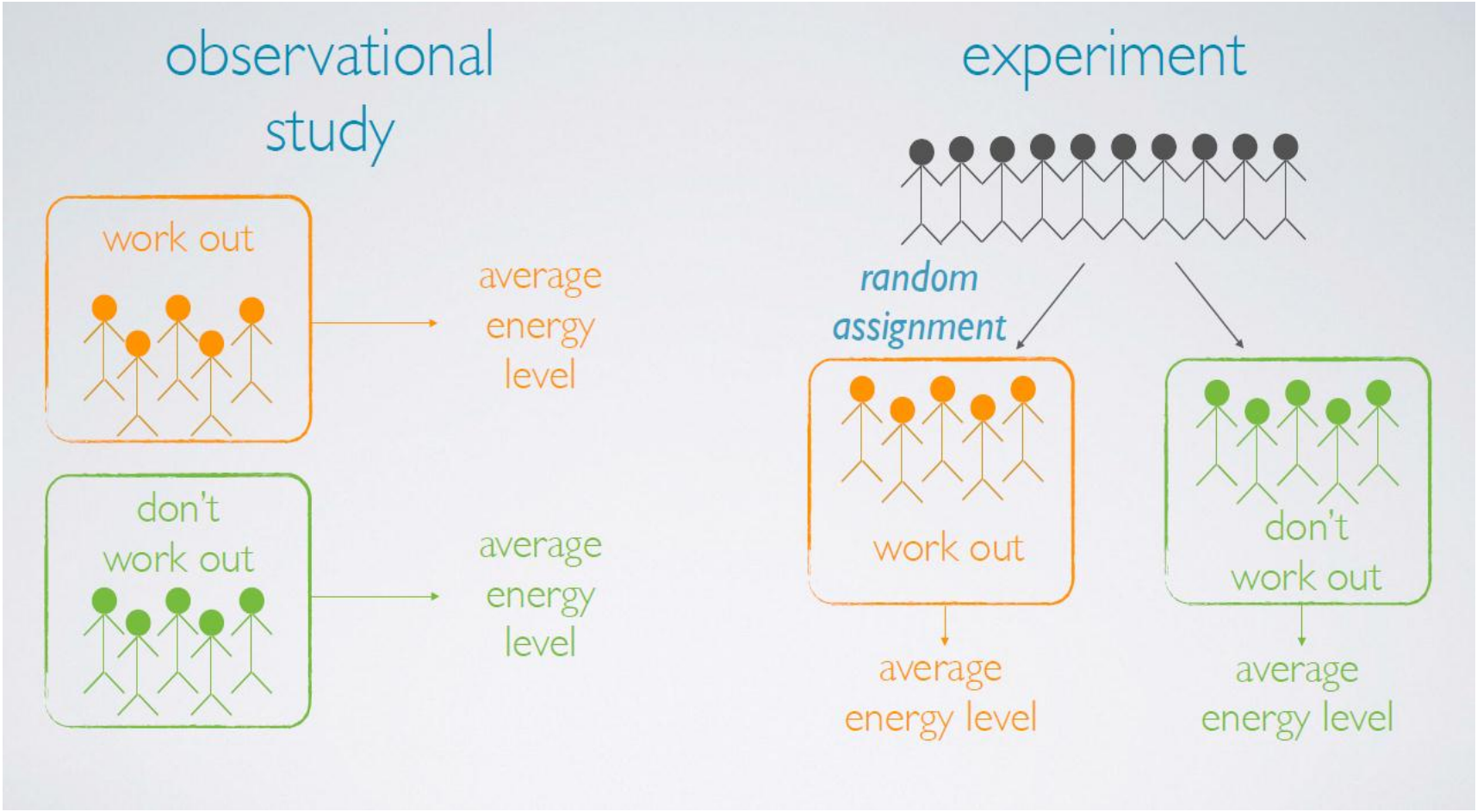


- Two variables that show some connection with one another are called associated (dependent)
- Association can be further described as positive or negative
- If two variables are not associated, they are said to be independent

Observational studies & experiments



Observational studies & experiments



Correlation & Causation

- Case study

Study: Breakfast cereal keeps girls slim

USA TODAY
Sept 8, 2005

[…]

Girls who ate breakfast of any type had a lower average body mass index, a common obesity gauge, than those who said they didn't. The index was even lower for girls who said they ate cereal for breakfast, according to findings of the study conducted by the Maryland Medical Research Institute with funding from the National Institutes of Health (NIH) and cereal-maker General Mills.

[…]

The results were gleaned from a larger NIH survey of 2,379 girls in California, Ohio, and Maryland who were tracked between the ages of 9 and 19.

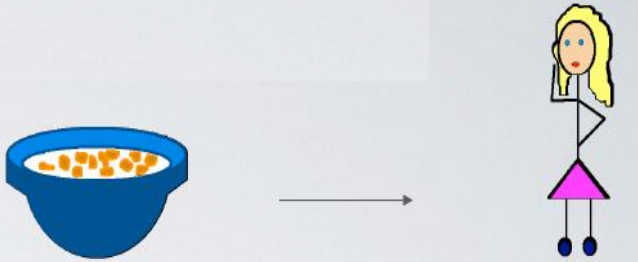
[…]

As part of the survey, the girls were asked once a year what they had eaten during the previous three days.

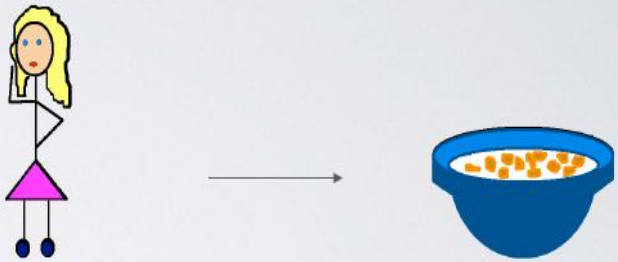
[…]

Possible explanations

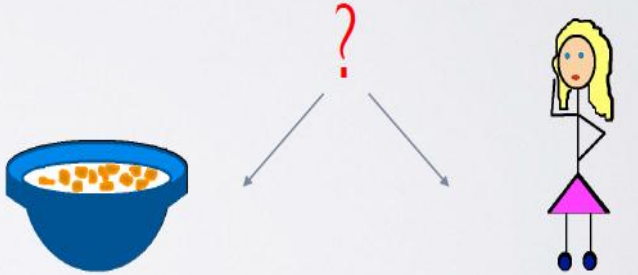
1. eating breakfast causes girls to be slimmer



2. being slim causes girls to eat breakfast

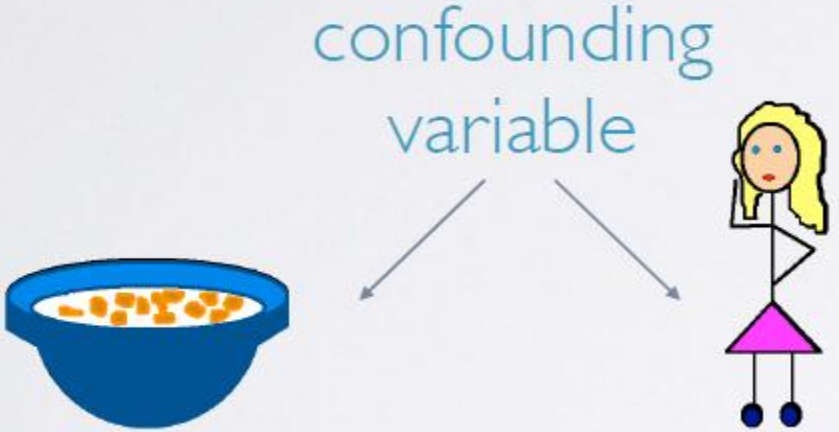


3. a third variable is responsible for both



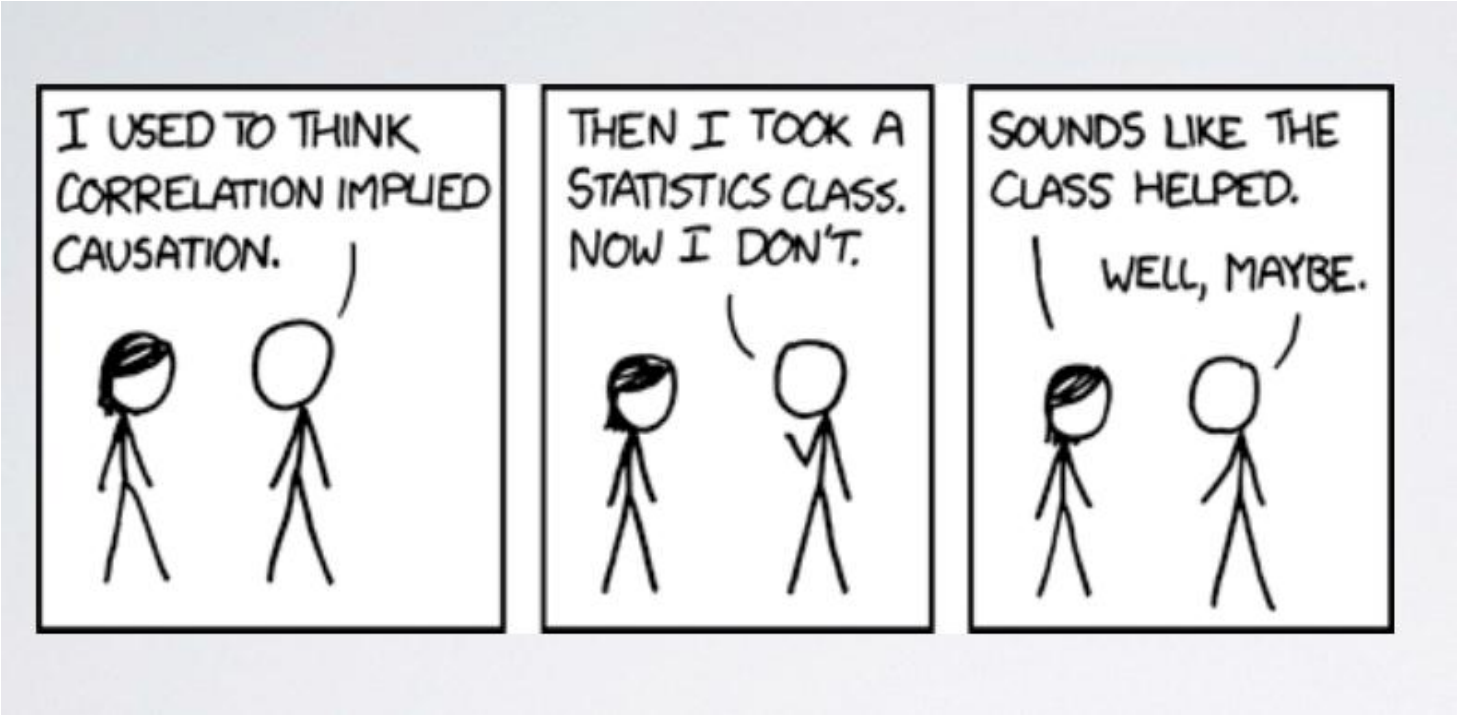
Confounding variables

extraneous variables that affect both the explanatory and the response variable, and that make it seem like there is a relationship between them



Correlation & Causation

- Correlation does not imply causation



Sampling & sources bias

- Census vs sample
- Source o bias
- Sampling methods

Census

Wouldn't it be better to just include everyone and "sample" the entire population, i.e. conduct a census?

- Some individuals are hard to locate or measure, and these people be different from the rest of the population.
- Populations rarely stand still.

Illegal Immigrants Reluctant To Fill Out Census Form

by PETER O'DOWD

March 31, 2010 4:00 AM

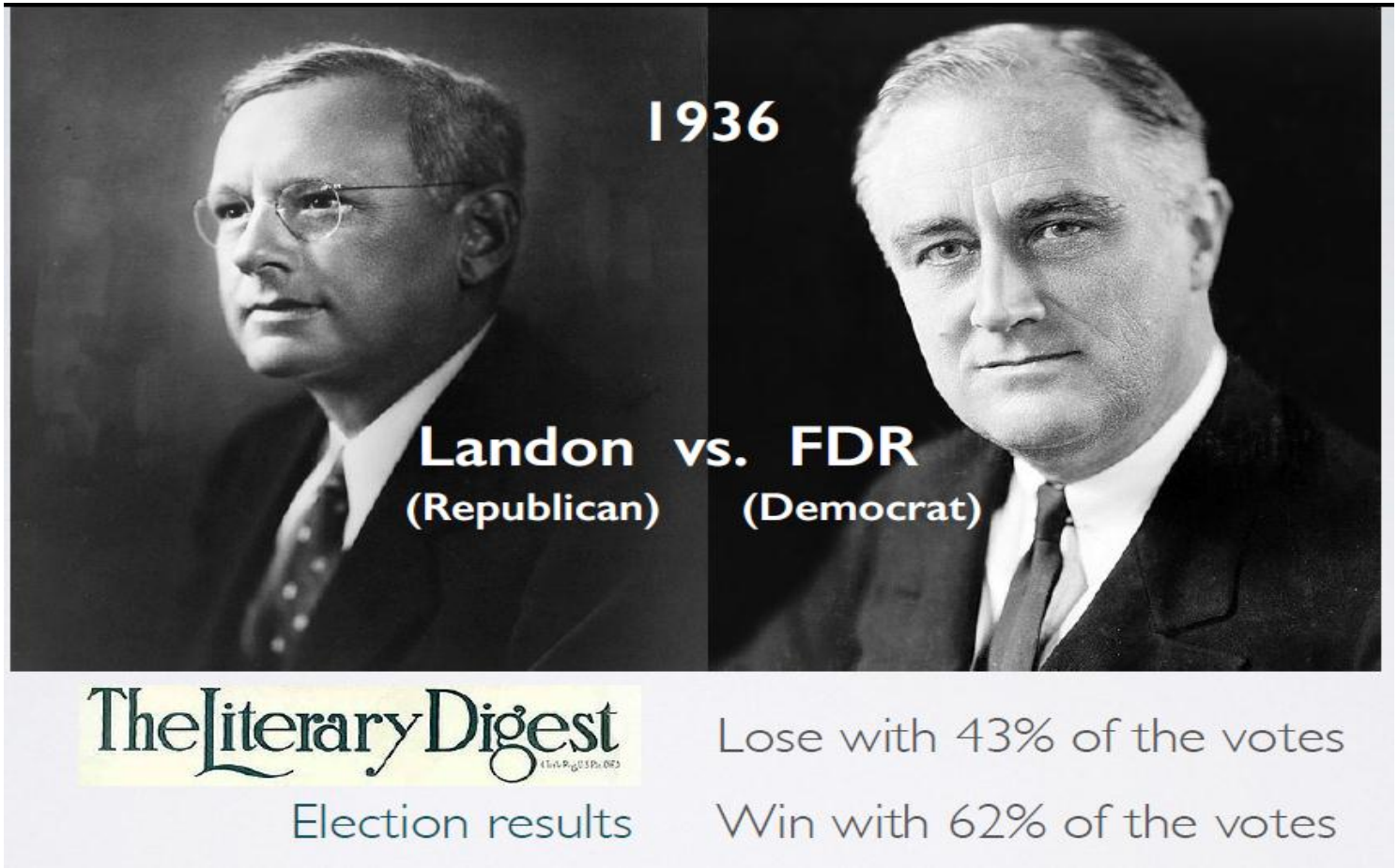
npr from KJZZ

There is an effort underway to make sure Hispanics are accurately counted in the 2010 Census. Phoenix has some of the country's "hardest-to-count" districts. Some Latinos, especially illegal residents, fear that participating in the count will expose them to immigration raids or government harassment.

A few sources of sampling bias

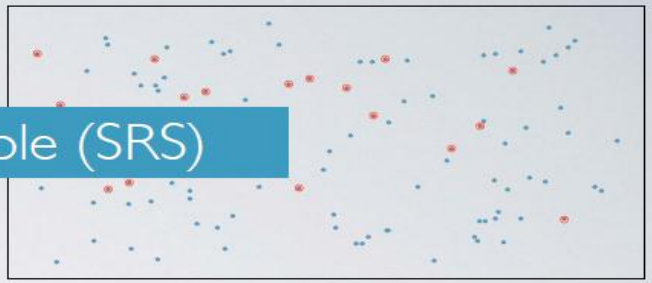
- Convenience sample: Individuals who are easily accessible are more likely to be included in the sample
- Non-response: If only a (non-random) fraction of the randomly sampled people respond to a survey such that the sample is no longer representative of the population
- Voluntary response: Occurs when the sample consists of people who volunteer to respond because they have strong opinions on the issue

A few sources of sampling bias

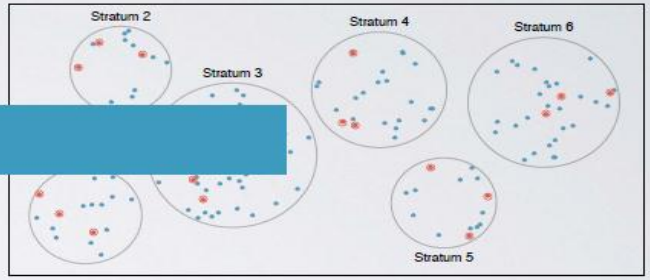


Sampling methods

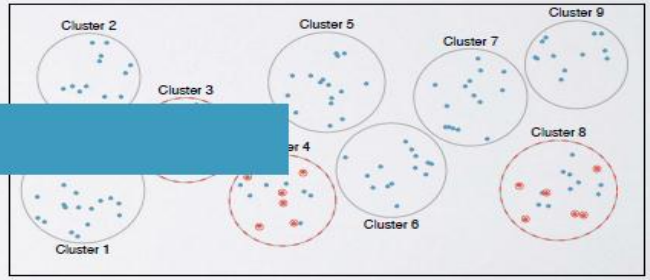
simple random sample (SRS)



stratified sample

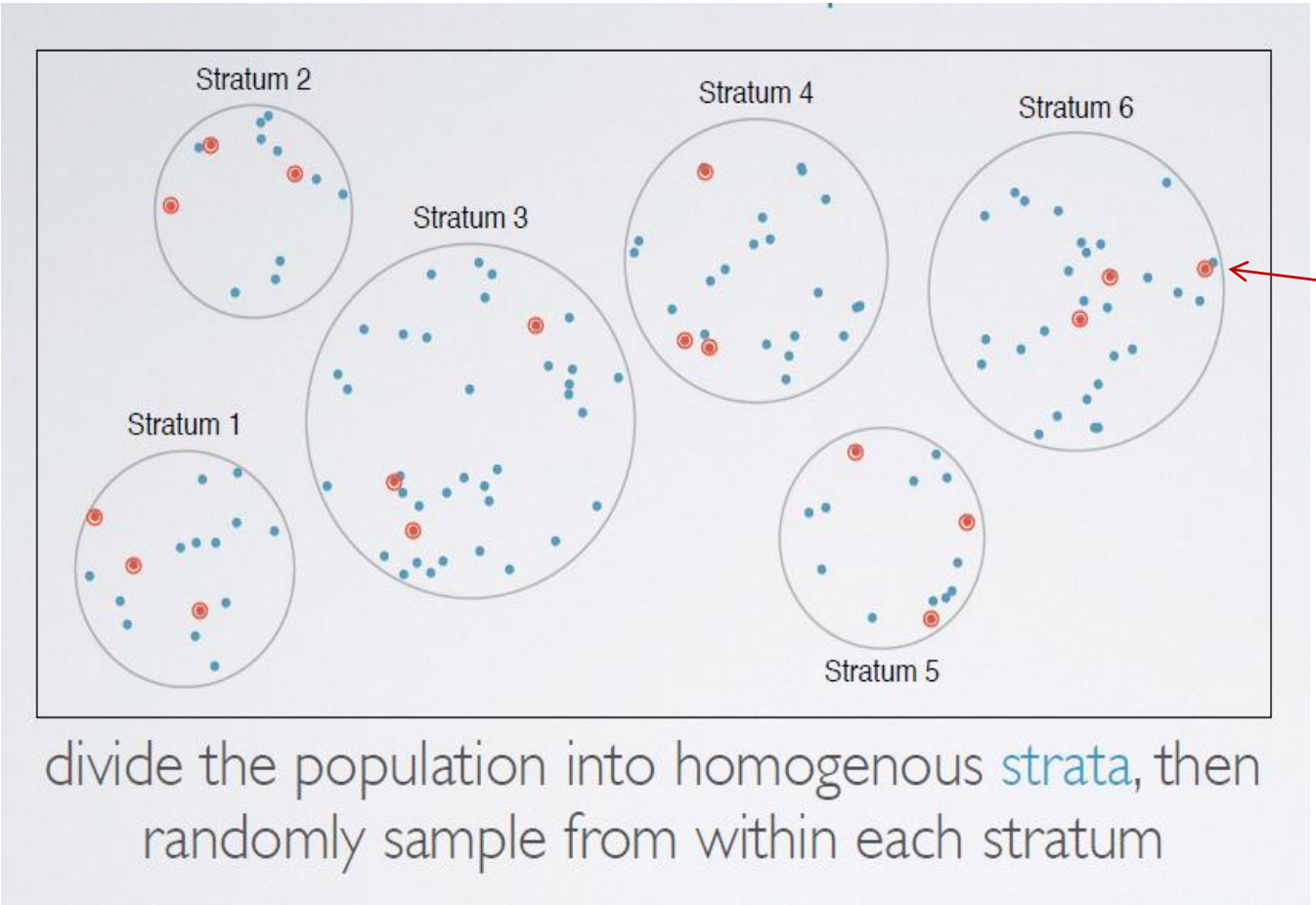


cluster sample

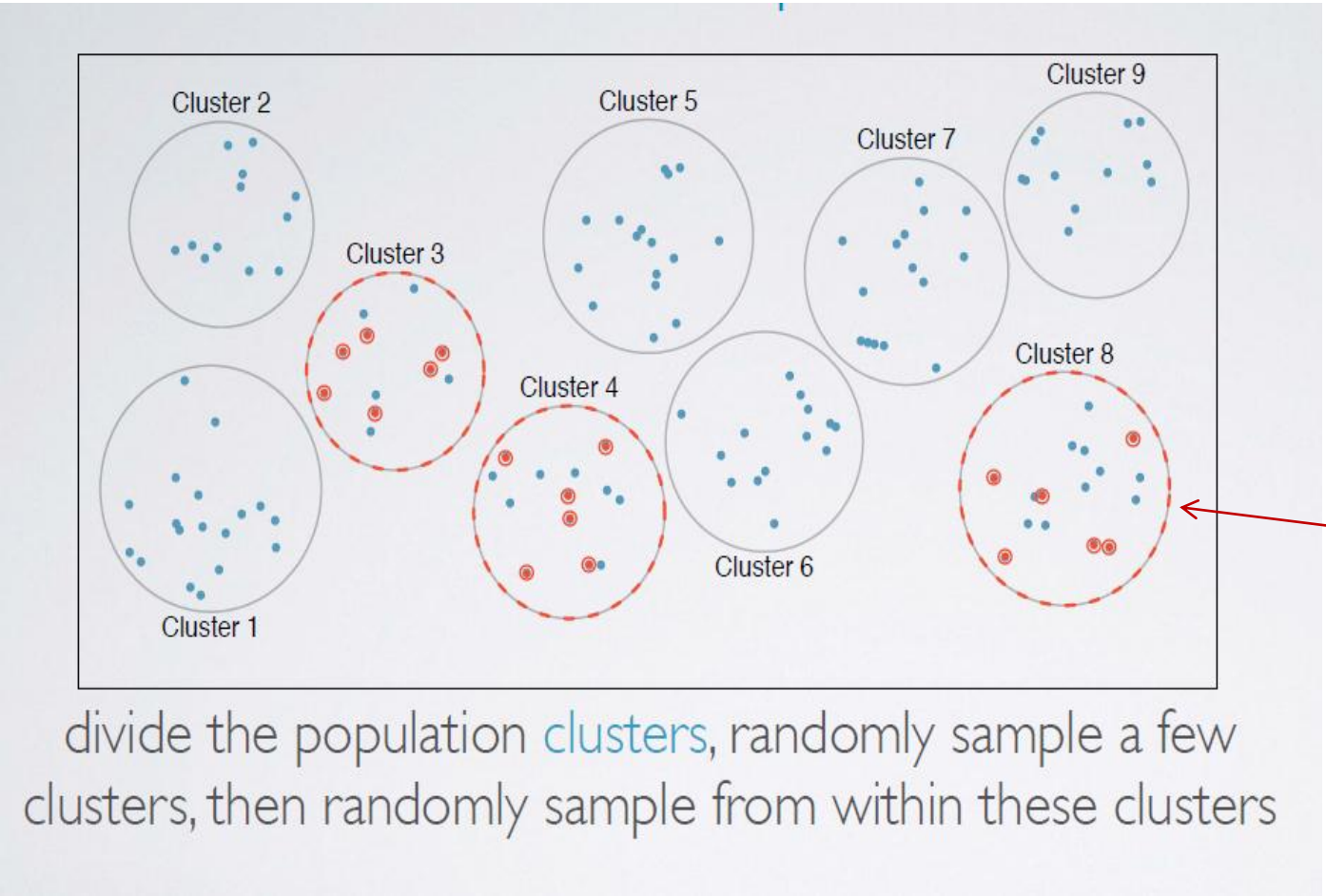


Sampling methods: random sampling

Sampling methods: stratified sample



Sampling methods: cluster



Vizualizing numerical data

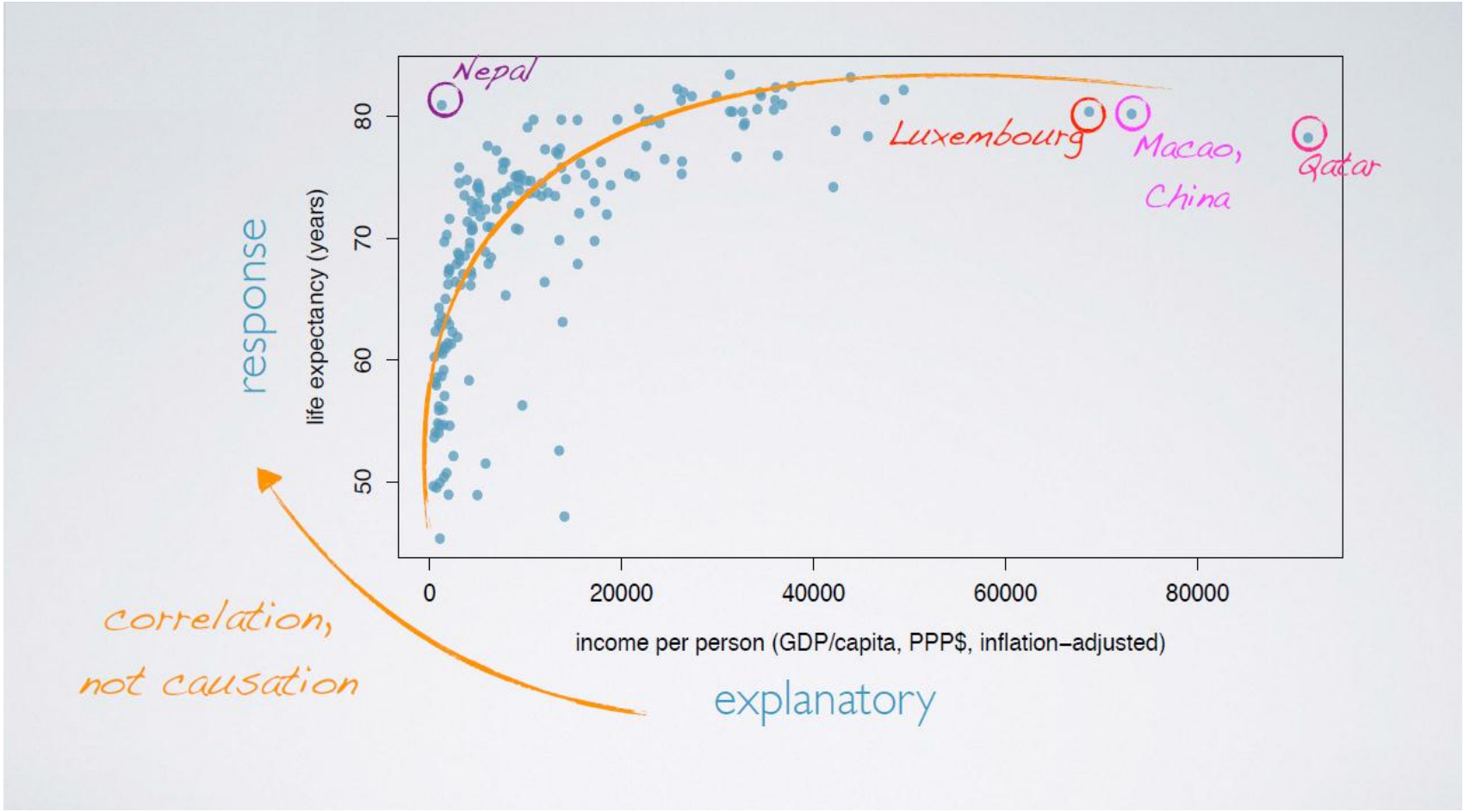
- Scatter plots for paired data
- Other visualizations for describing distributions of numerical variables

Data matrix

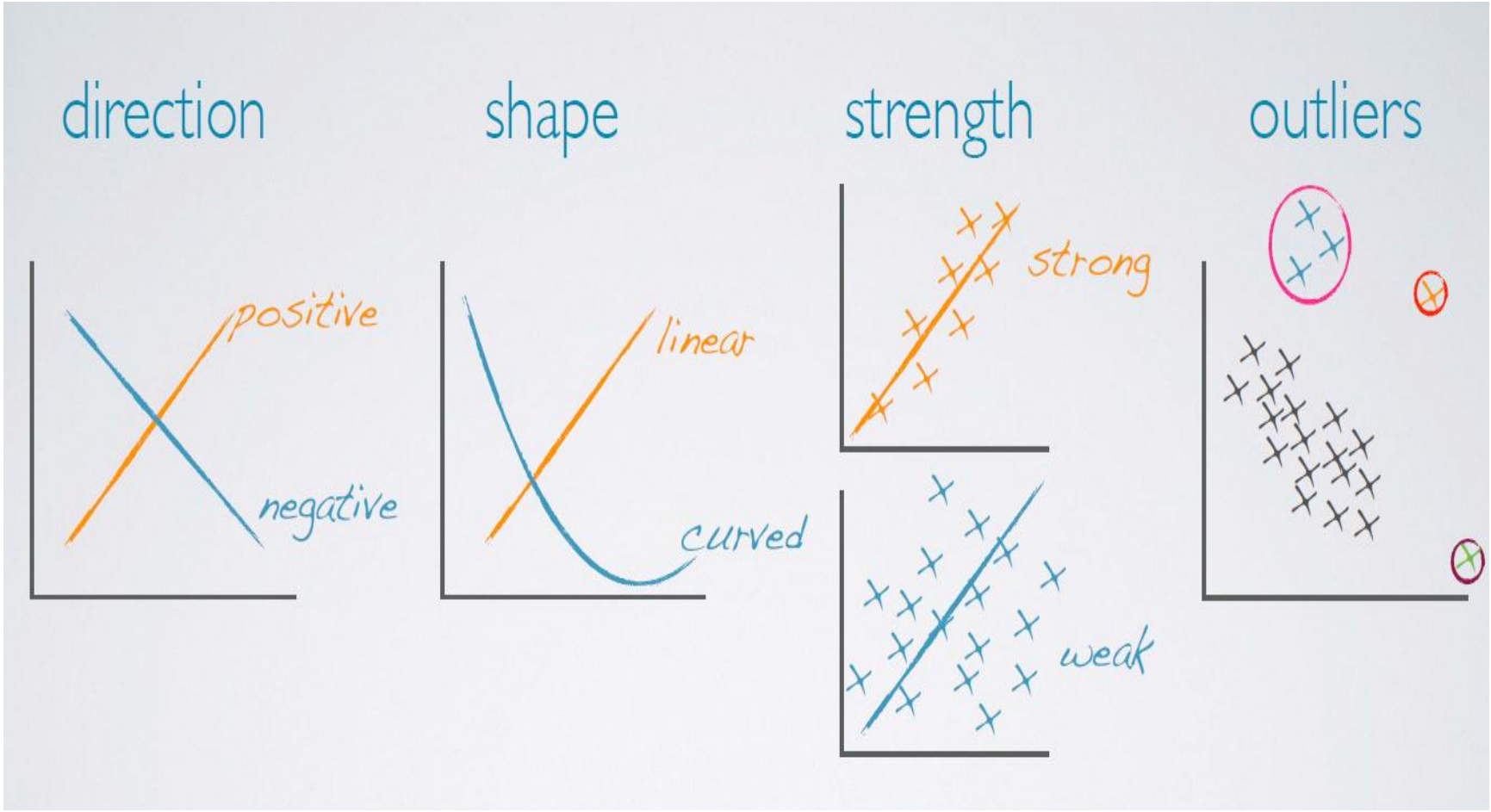
data	income per person ($, 2012)	life expectancy (years, 2012)
Afghanistan	1359.7	60.254
Albania	6969.3	77.185
Algeria	6419.1	70.874
…	…	…
Zimbabwe	545.3	58.142

Source: gapminder.com

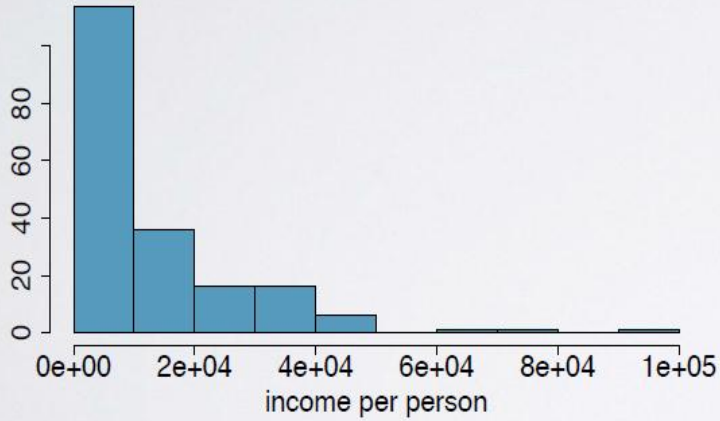
Scatterplots



Evaluating their relationship



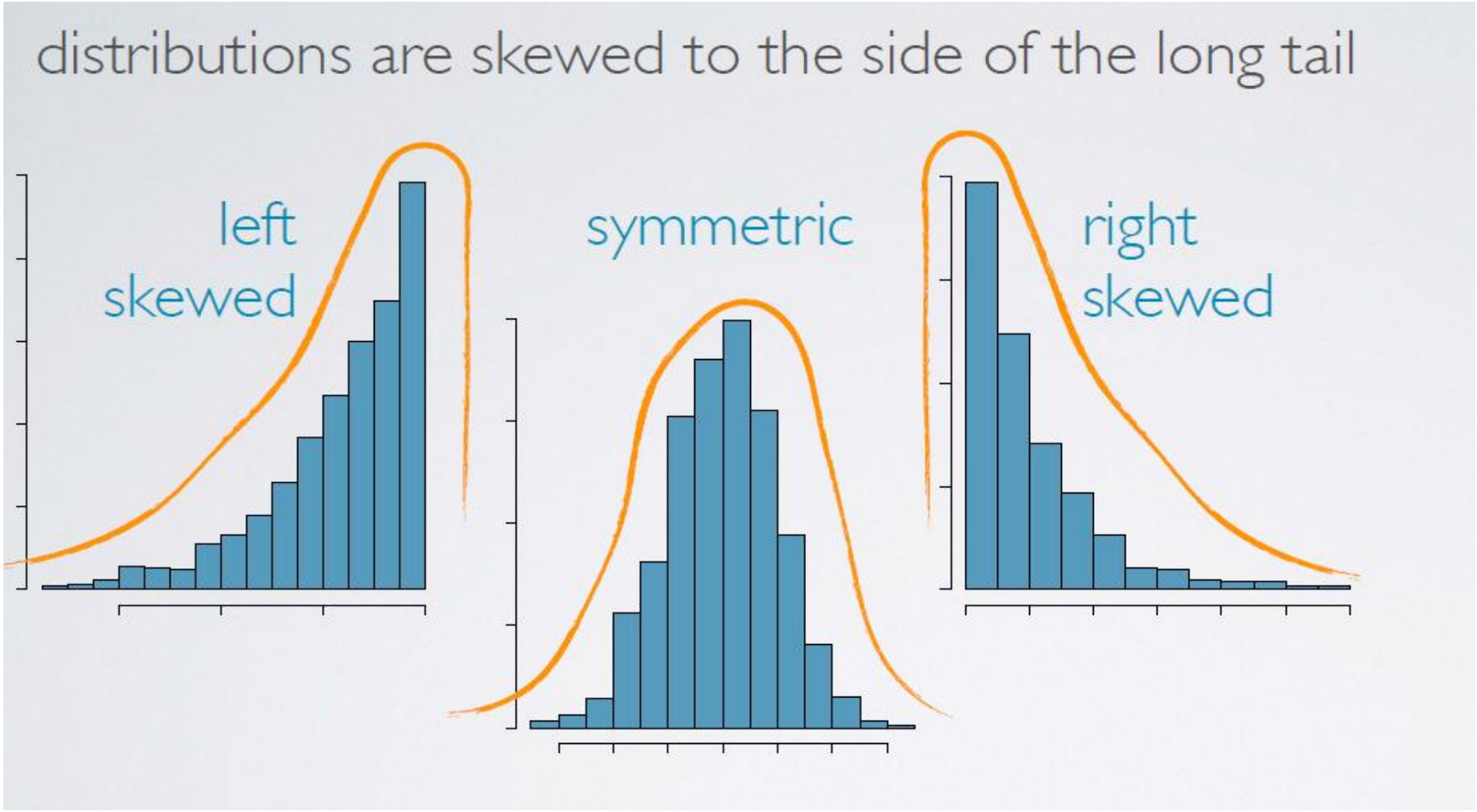
Histogram



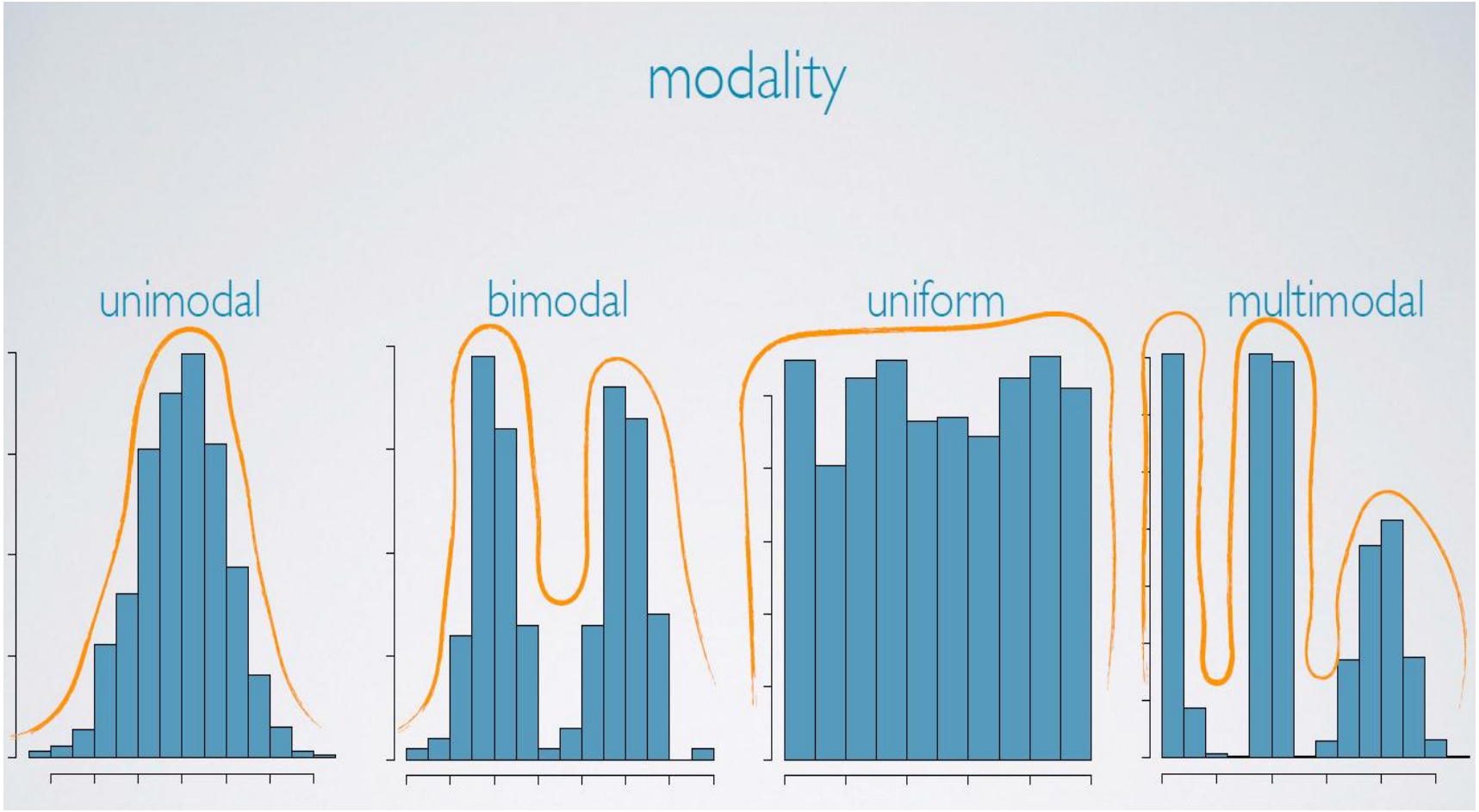
histogram

- provides a view of the data density
- especially useful for describing the shape of the distribution

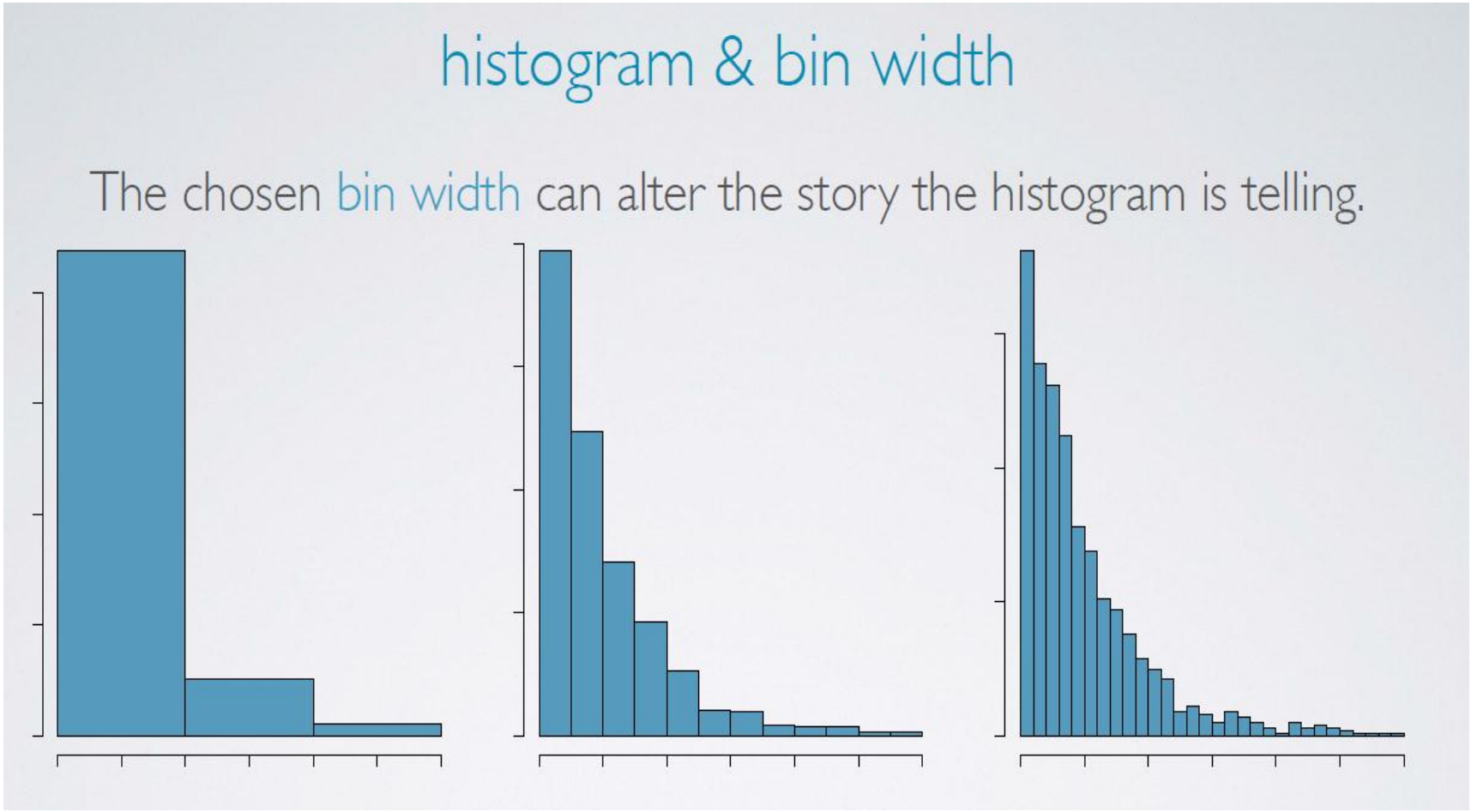
Histogram


distributions are skewed to the side of the long tail
left skewed
symmetric
right skewed

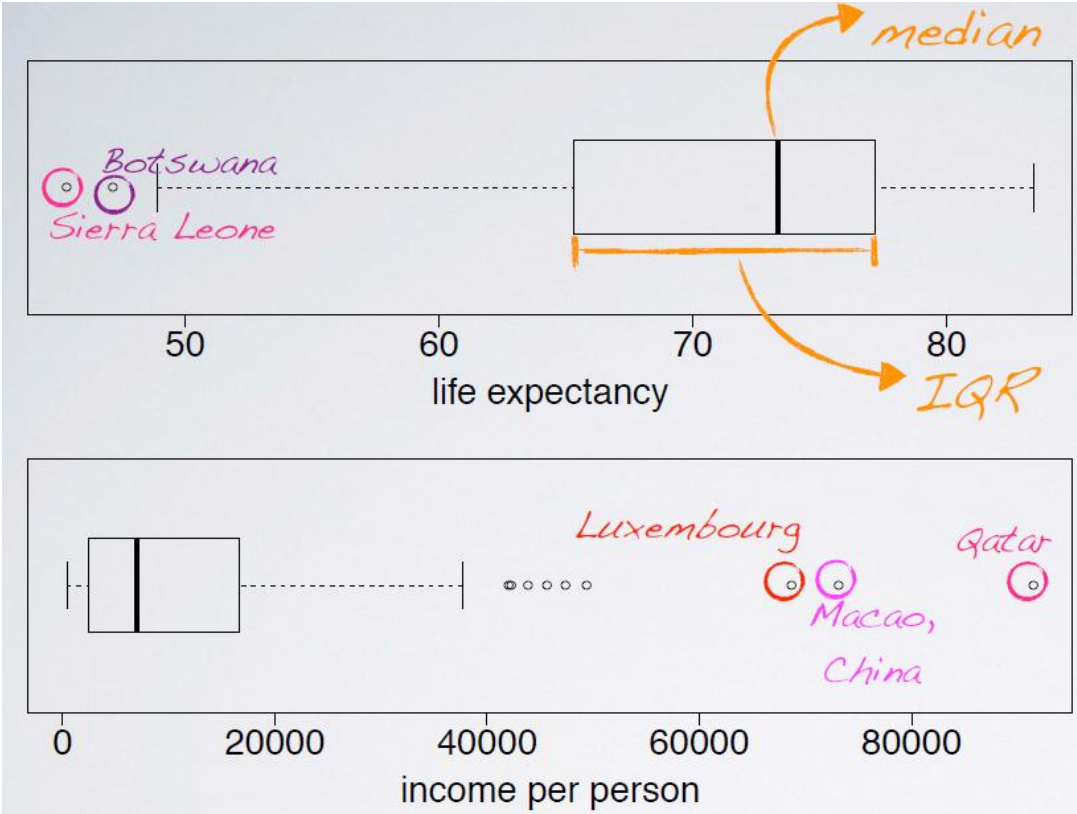
Histogram



Histogram


histogram & bin width
The chosen bin width can alter the story the histogram is telling.

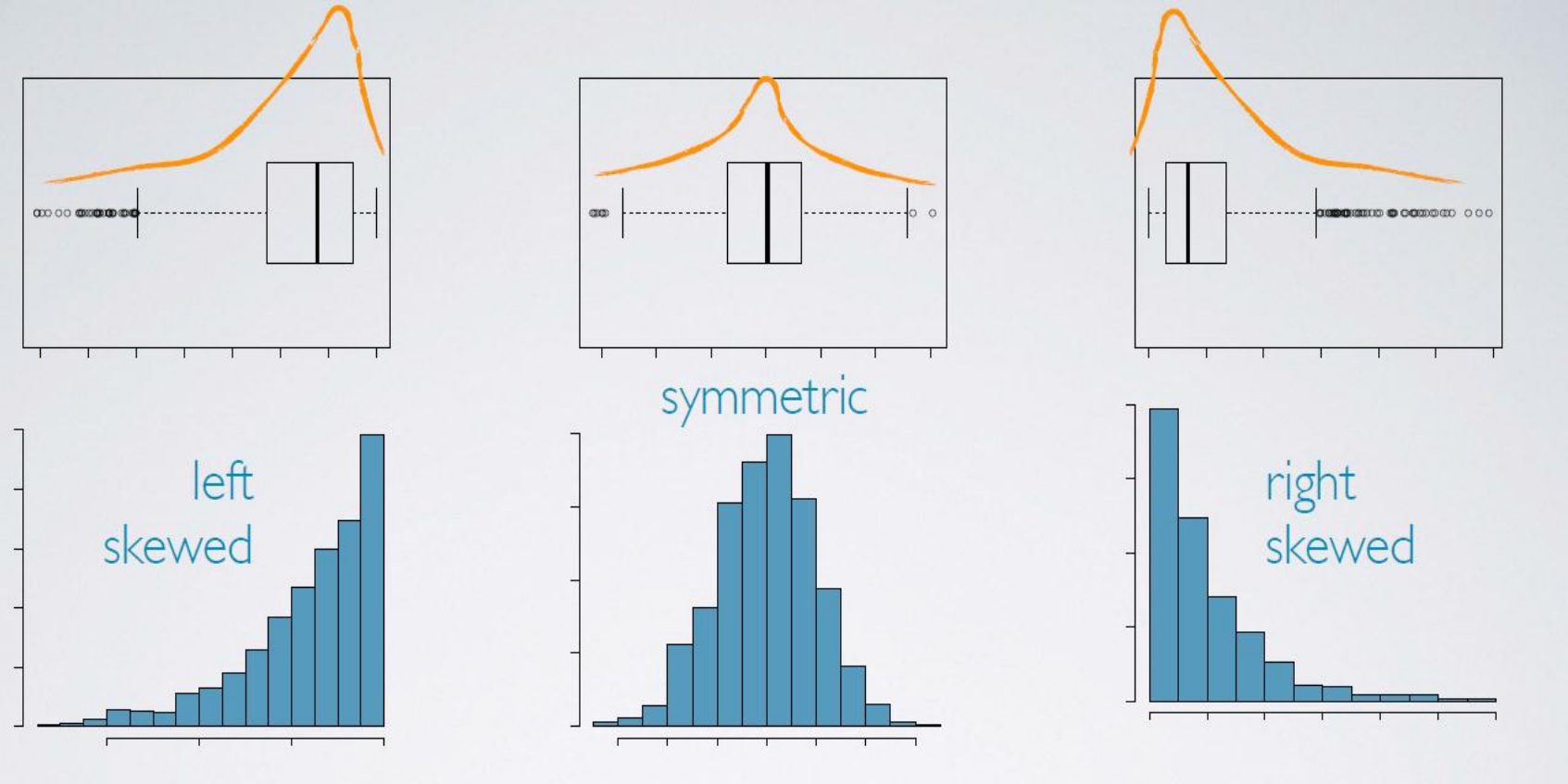
Box plot



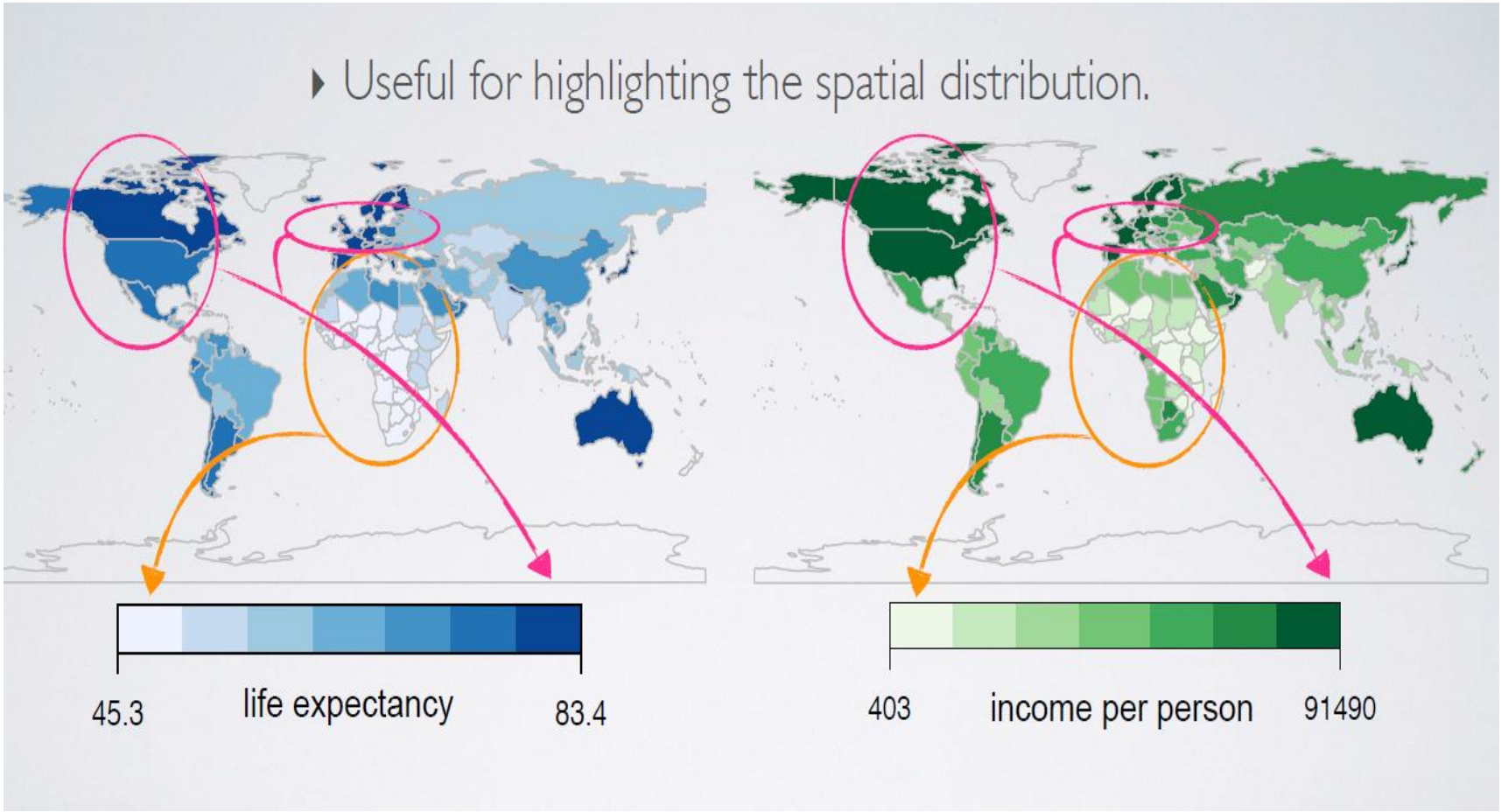
box plot

useful for highlighting outliers, median, IQR

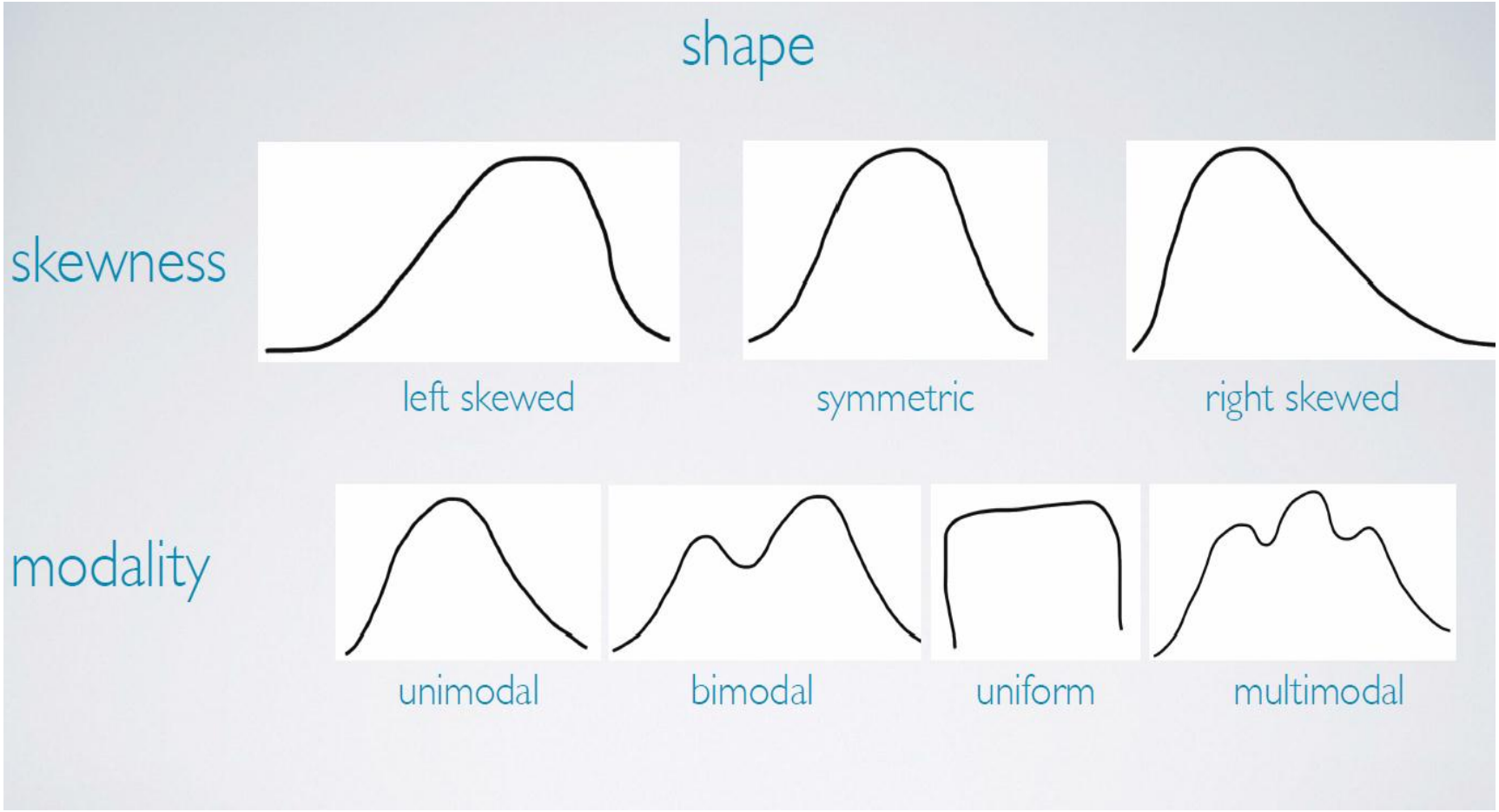
Box plot



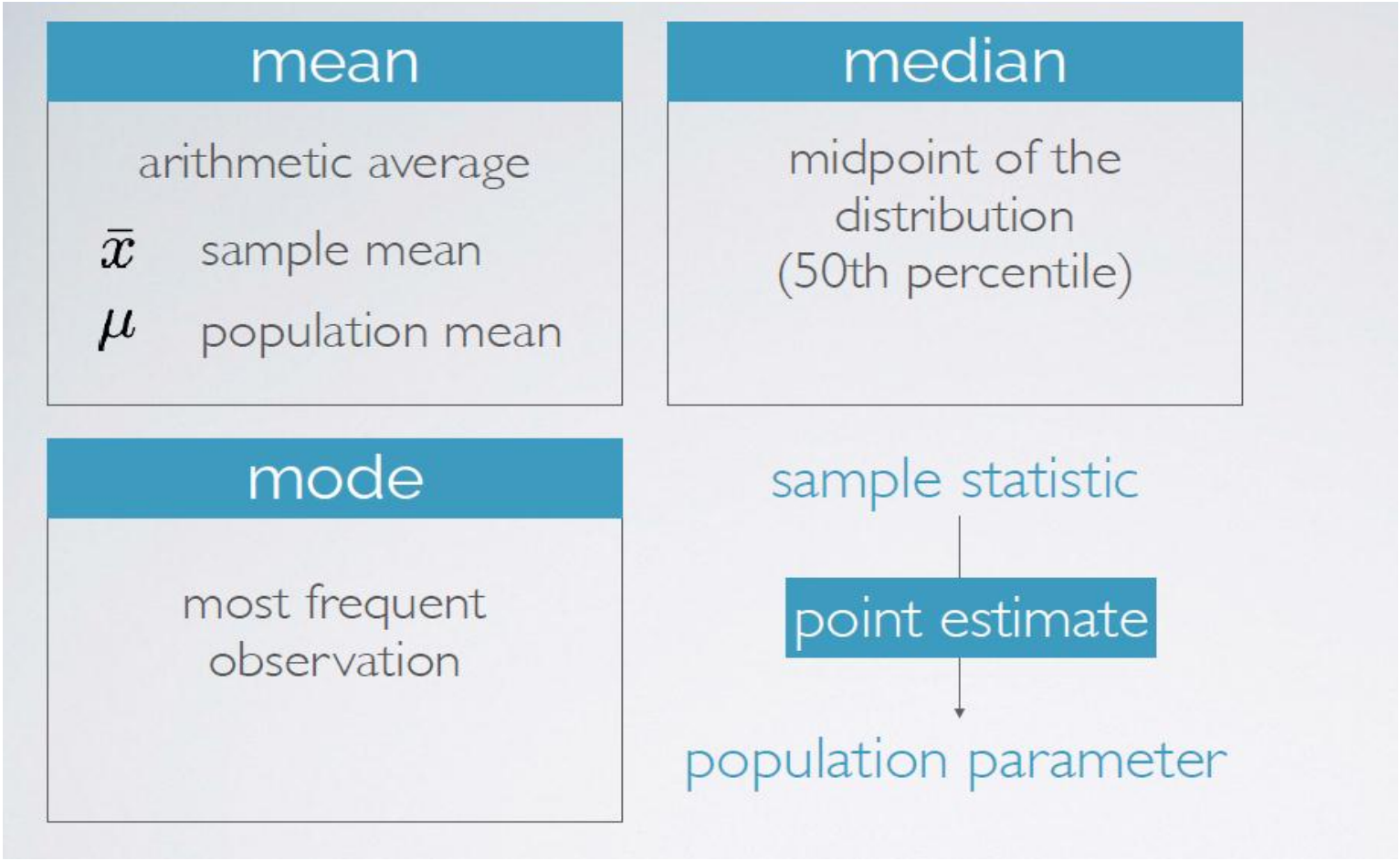
Intensity map



Measures of center



Measures of center



Measures of center

example 9 students' exam scores:

75, 69, 88, 93, 95, 54, 87, 88, 27

mean: $\frac{75+69+88+93+95+54+87+88+27}{9} = 75.11$

mode: 88

median: 27, 54, 69, 75, 87, 88, 88, 93, 95

Data matrix

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Afghanistan	1359.7	60.254
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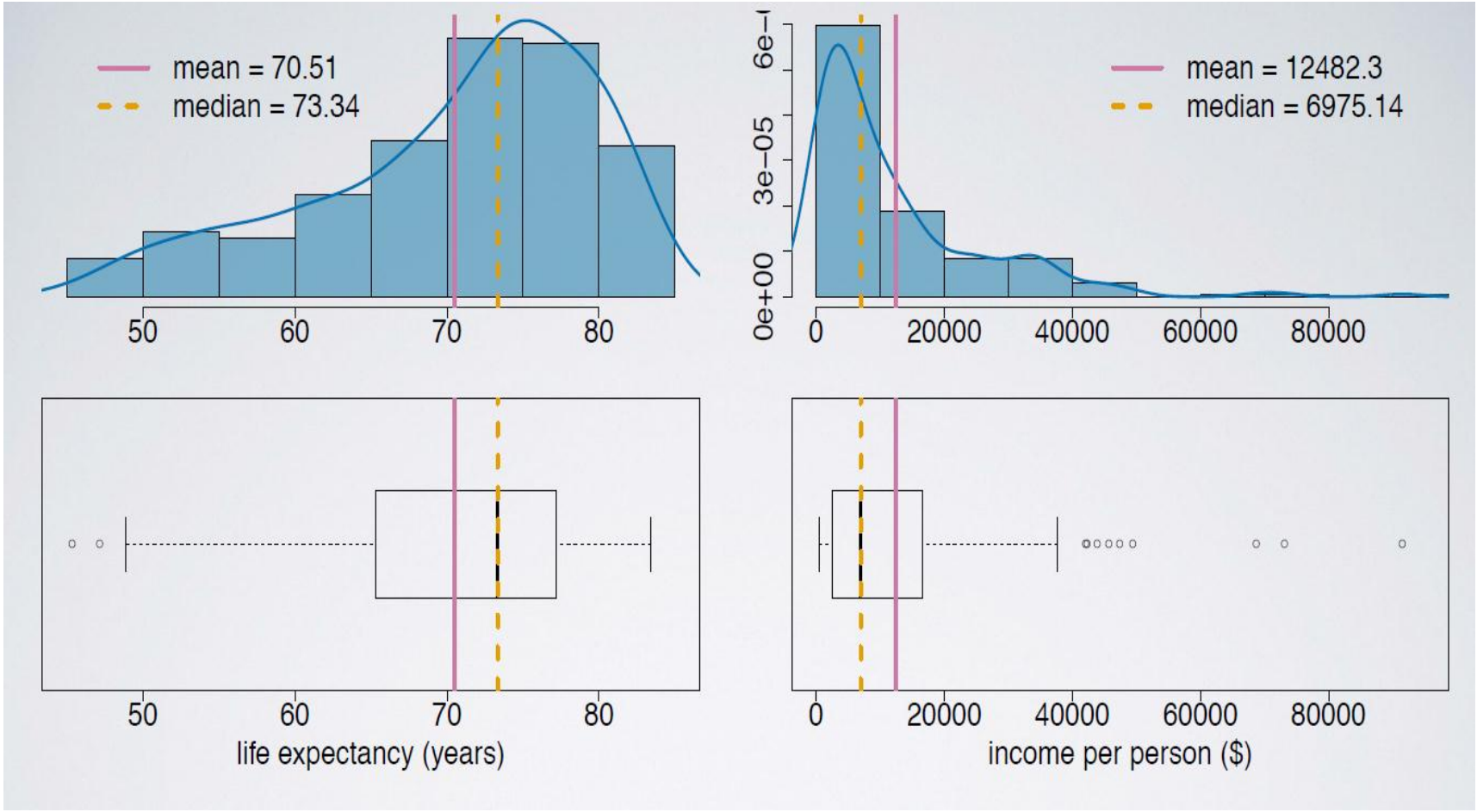
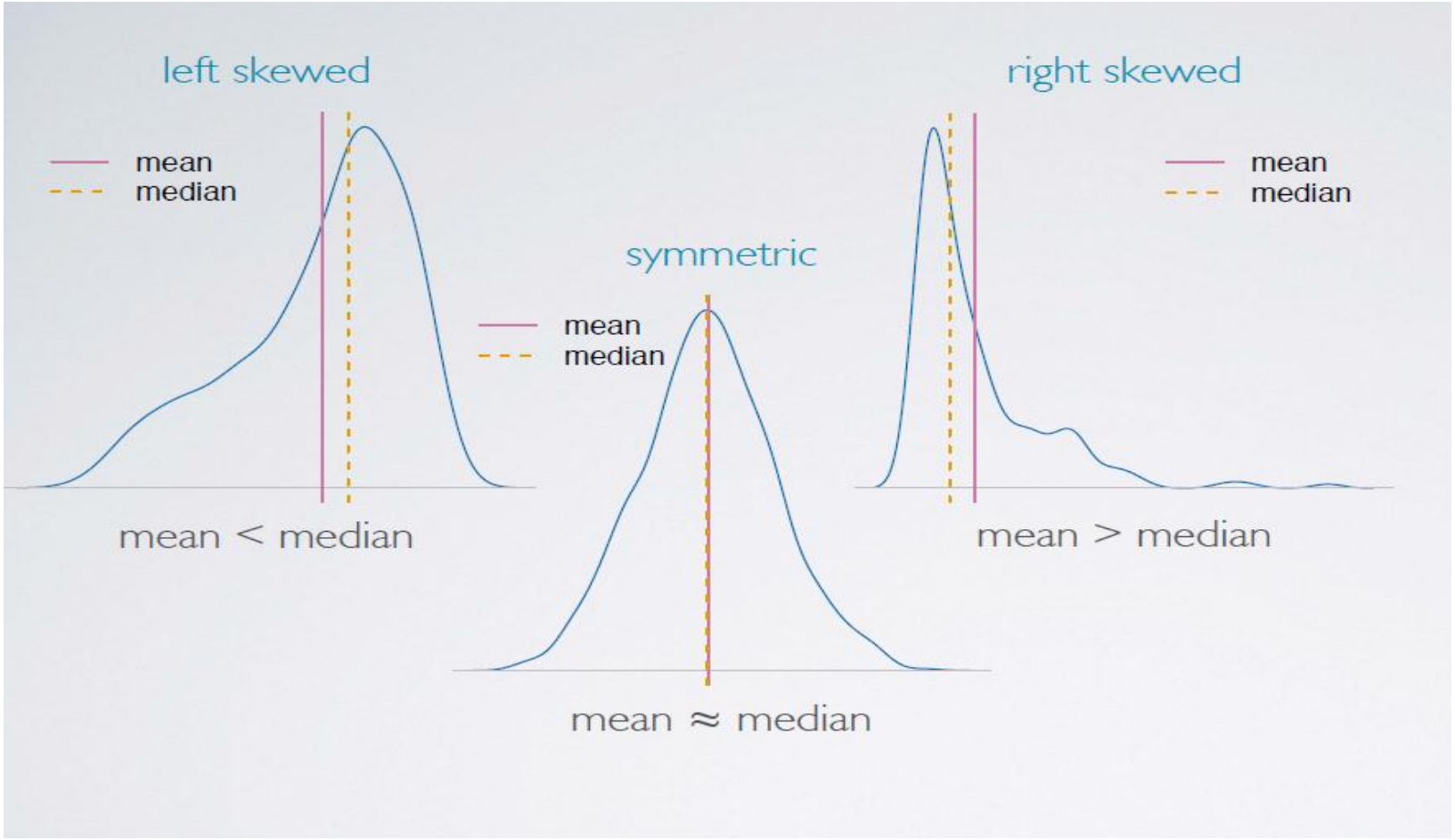
Measures of center

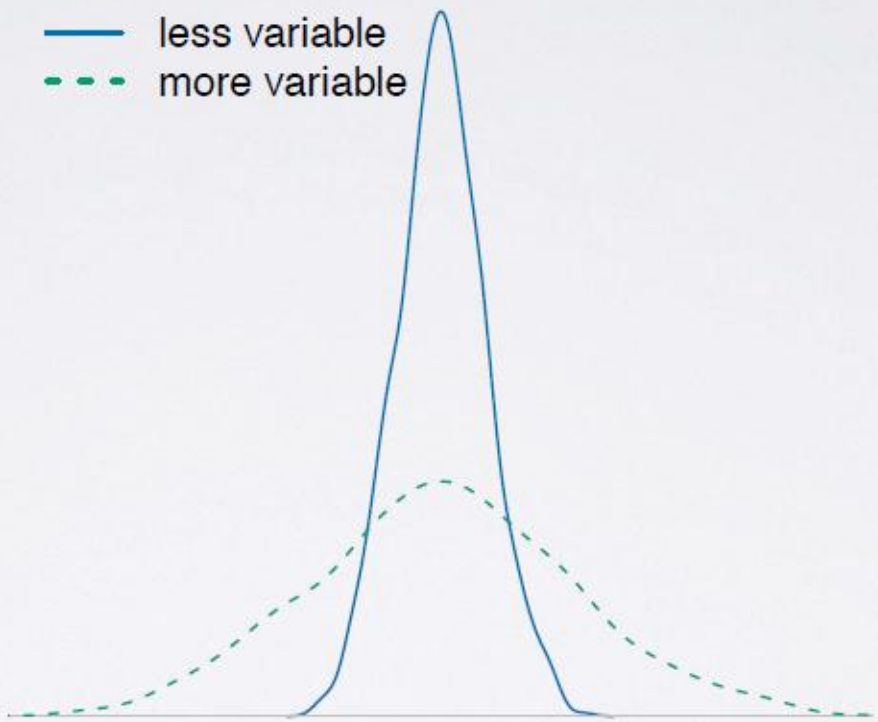


Skewness vs. measures of center



Measures of spread

- range: *(max - min)*
- variance
- standard deviation
- inter-quartile range



Measures of spread

variance

sample variance s^2

population variance σ^2

roughly the average squared deviation from the mean

$$s^2 = \frac{\sum_1^{n=1}(x_i - \bar{x})^2}{n-1}$$

example Given that the average life expectancy is 70.5, and there are 201 countries in the dataset:

$$s^2 = \frac{(60.3 - 70.5)^2 + (77.2 - 70.5)^2 + \ldots + (58.1 - 70.5)^2}{201 - 1}$$

$= 83.06 \text{ years}^2$

	country	life exp
1	Afghanistan	60.3
2	Albania	77.2
3	Algeria	70.9
	…	…
201	Zimbabwe	58.1

Measures of spread

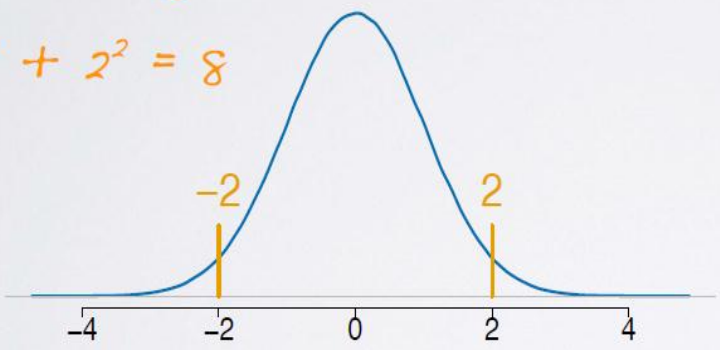
Why do we square the differences?

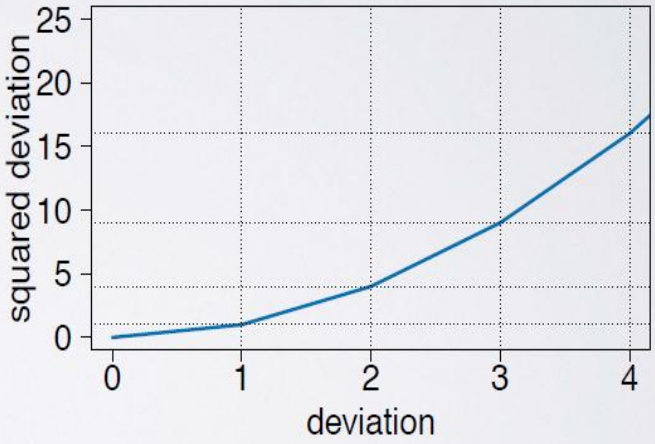
$$s^2 = \frac{\sum_1^{n=1}(x_i - \bar{x})^2}{n-1}$$

- get rid of negatives so that negatives and positives don't cancel each other when added together
- increase larger deviations more than smaller ones so that they are weighed more heavily

$(-2) + 2 = 0$

$(-2)^2 + 2^2 = 8$





Measures of spread

standard deviation

sample sd
s

population sd
σ

roughly the average deviation around the mean, and has the same units as the data.

$$s = \sqrt{s^2} = \sqrt{\frac{\sum_1^{n=1}(x_i - \bar{x})^2}{n-1}}$$

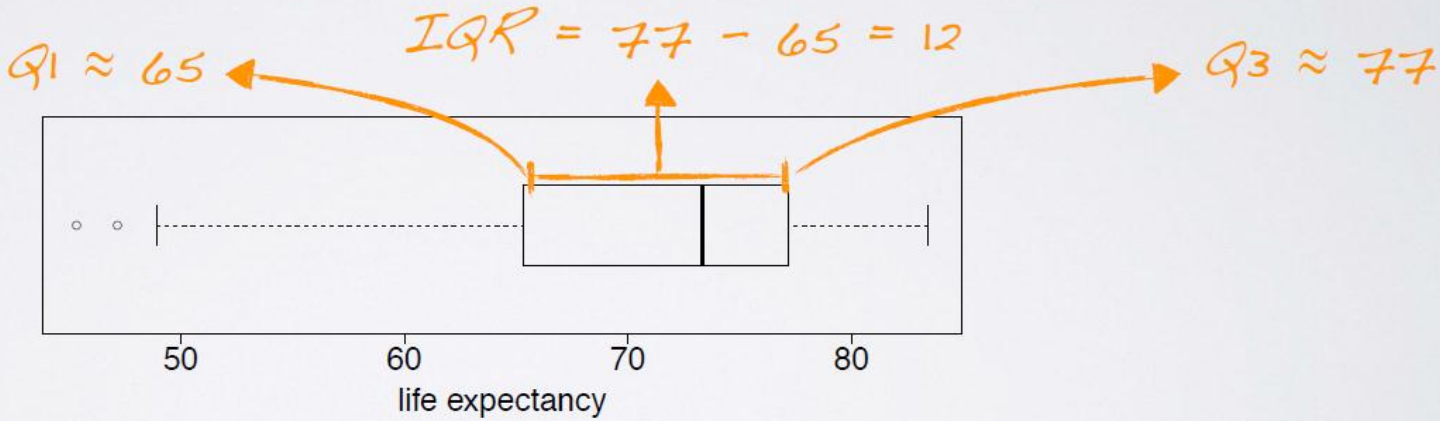
square root of the variance

Measures of spread

interquartile range

range of the middle 50% of the data, distance between the first quartile (25th percentile) and third quartile (75th percentile)

$$IQR = Q3 - Q1$$



Robust statistics

we define robust statistics as measures on which extreme observations have little effect

example

data	mean	median
1, 2, 3, 4, 5, 6	3.5	3.5
1, 2, 3, 4, 5, 1000	169	3.5

Robust statistics

	robust	non-robust
center	median	mean
spread	IQR	SD, range

skewed, with extreme observations

symmetric

Transforming data

- a transformation is a rescaling of the data using a function
- when data are very strongly skewed, we sometimes transform them so they are easier to model

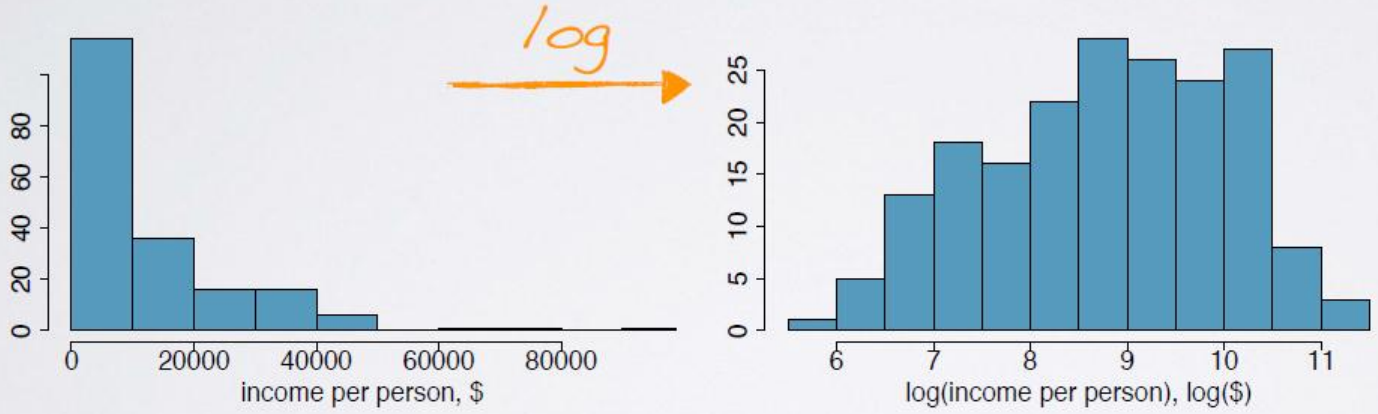
goals of transformations

- to see the data structure differently
- to reduce skew assist in modeling
- to straighten a nonlinear relationship in a scatterplot

Transforming data

(natural) log transformation

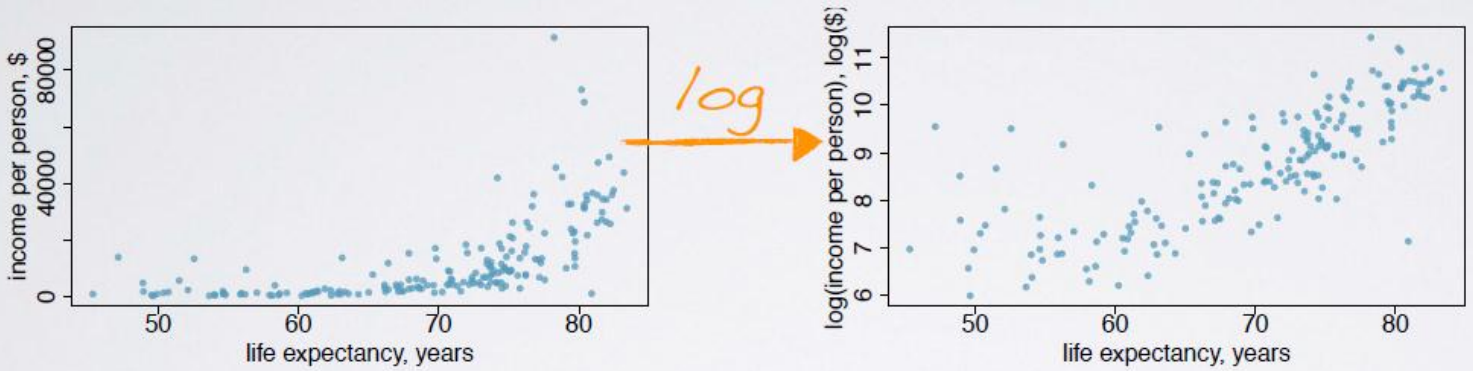
often applied when much of the data cluster near zero (relative to the larger values in the data set) and all observations are positive



Transforming data

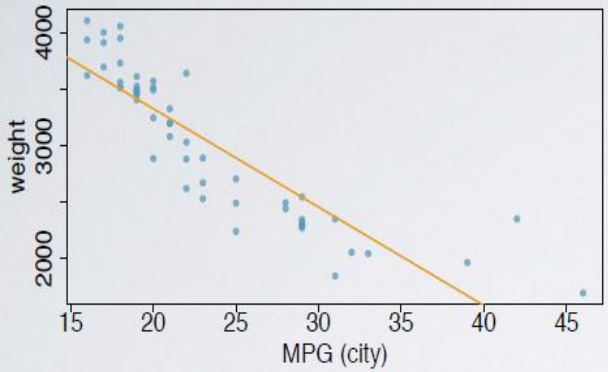
log transformation

to make the relationship between the variables more linear, and hence easier to model with simple methods

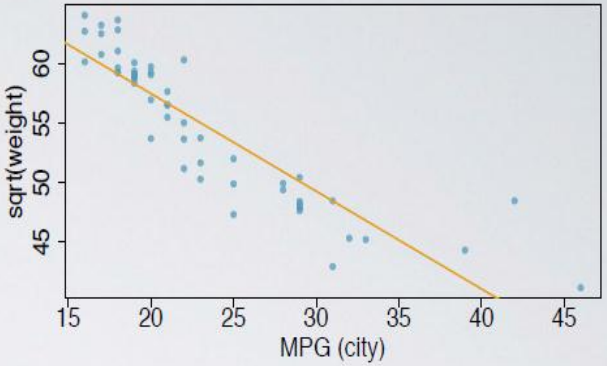


Transforming data

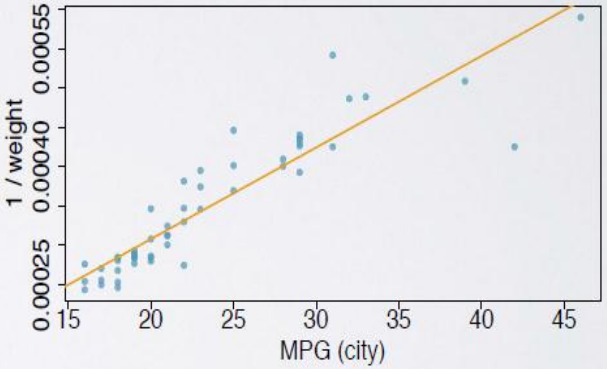
other transformations



square root



inverse

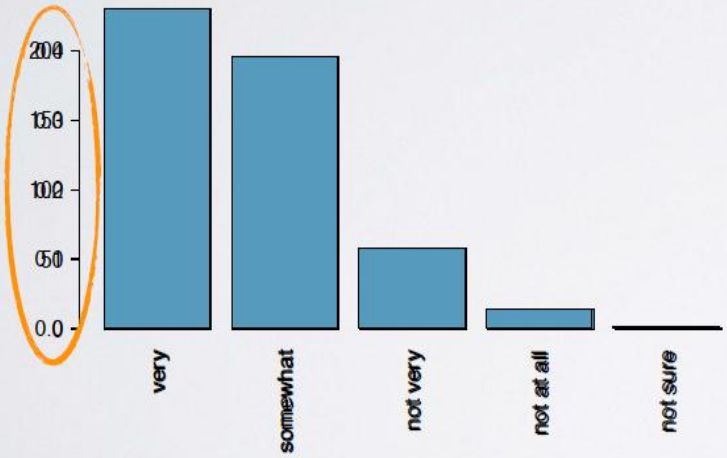


Exploring categorical variables

- describe distribution of a single categorical variable
- evaluate relationship between two categorical variables
- evaluate relationship between a categorical and a numerical variable

Exploring categorical variables

Difficulty saving money	Counts	Frequencies
Very	231	46%
Somewhat	196	39%
Not very	58	12%
Not at all	14	3%
Not sure	1	~0%
Total	500	100%

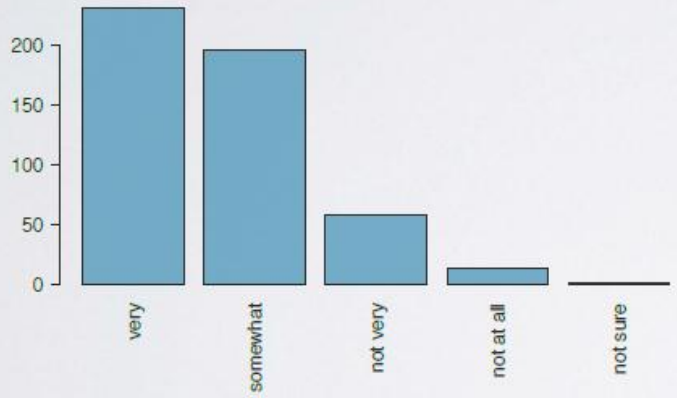


frequency table & bar plot

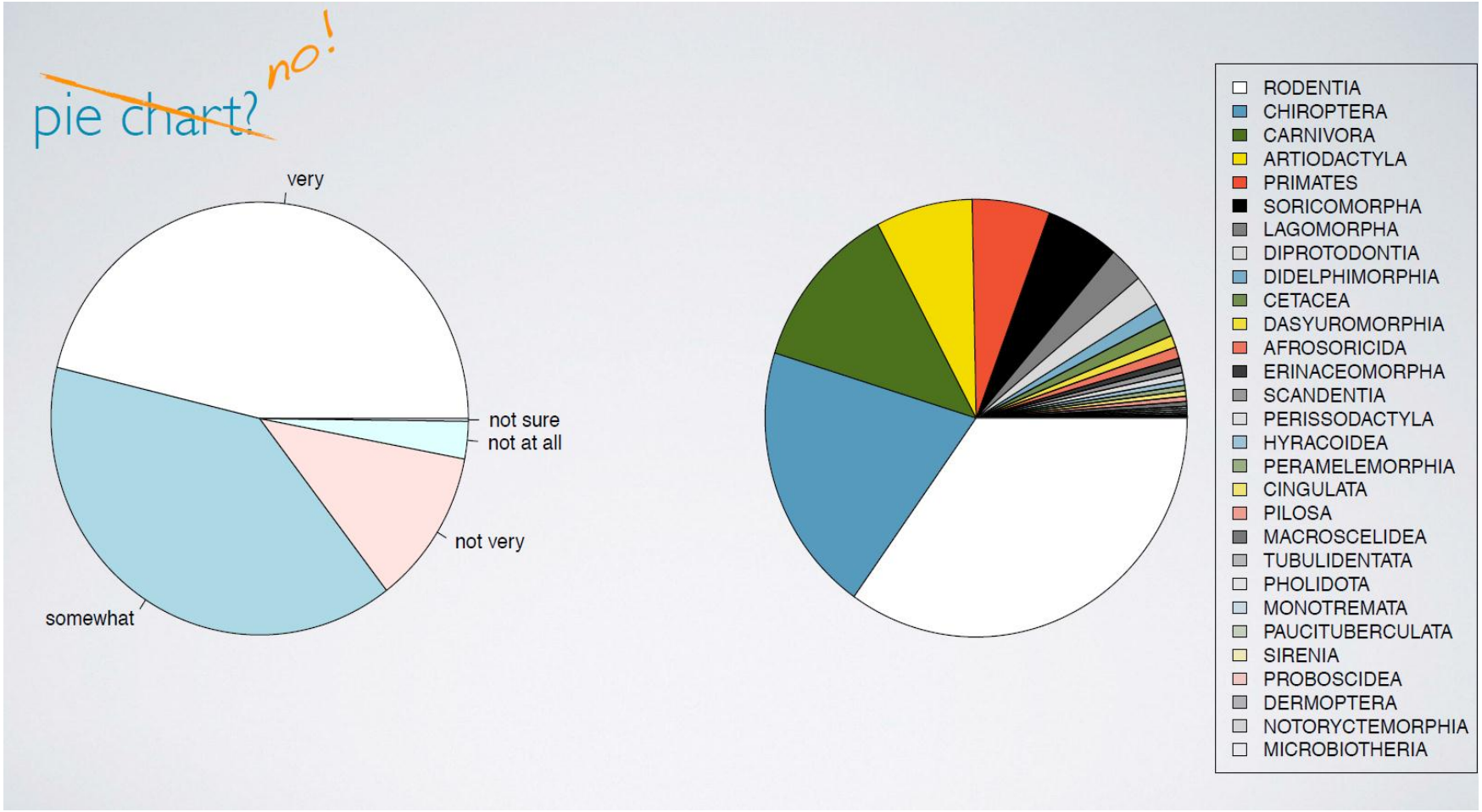
Exploring categorical variables

How are bar plots different than histograms?

- barplots for categorical variables, histograms for numerical variables
- x-axis on a histogram is a number line, and the ordering of the bars are not interchangeable



Exploring categorical variables



Exploring categorical variables

contingency table

		Income				
		< $40K	$40-80K	> $80K	Refused	Total
Difficulty saving	Very	128	63	31	9	231
	Somewhat	54	71	61	10	196
	Not very	17	7	27	7	58
	Not at all	3	6	5	0	14
	Not sure	0	1	0	0	1
	Total	202	148	124	26	500

Exploring categorical variables

- Relative frequencies

		Income				
		< $40K	$40K - $80K	> $80K	Refused	Total
Difficulty saving	Very	128	63	31	9	231
	Somewhat	54	71	61	10	196
	Not very	17	7	27	7	58
	Not at all	3	6	5	0	14
	Not sure	0	1	0	0	1
	Total	202	148	124	26	500

<$40K: 128 / 202 = 63% find it very difficult to save

$40K–$80K: 63 / 148 = 43%

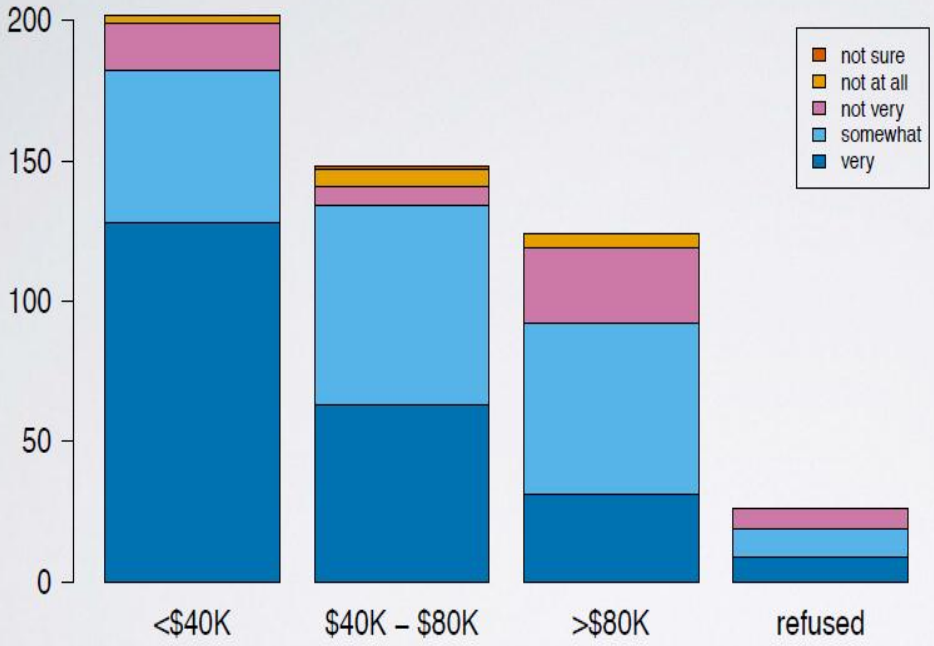
>$80K: 31 / 124 = 25%

Refused: 9 / 26 = 35%

feelings about difficulty of saving money and income are associated (dependent)

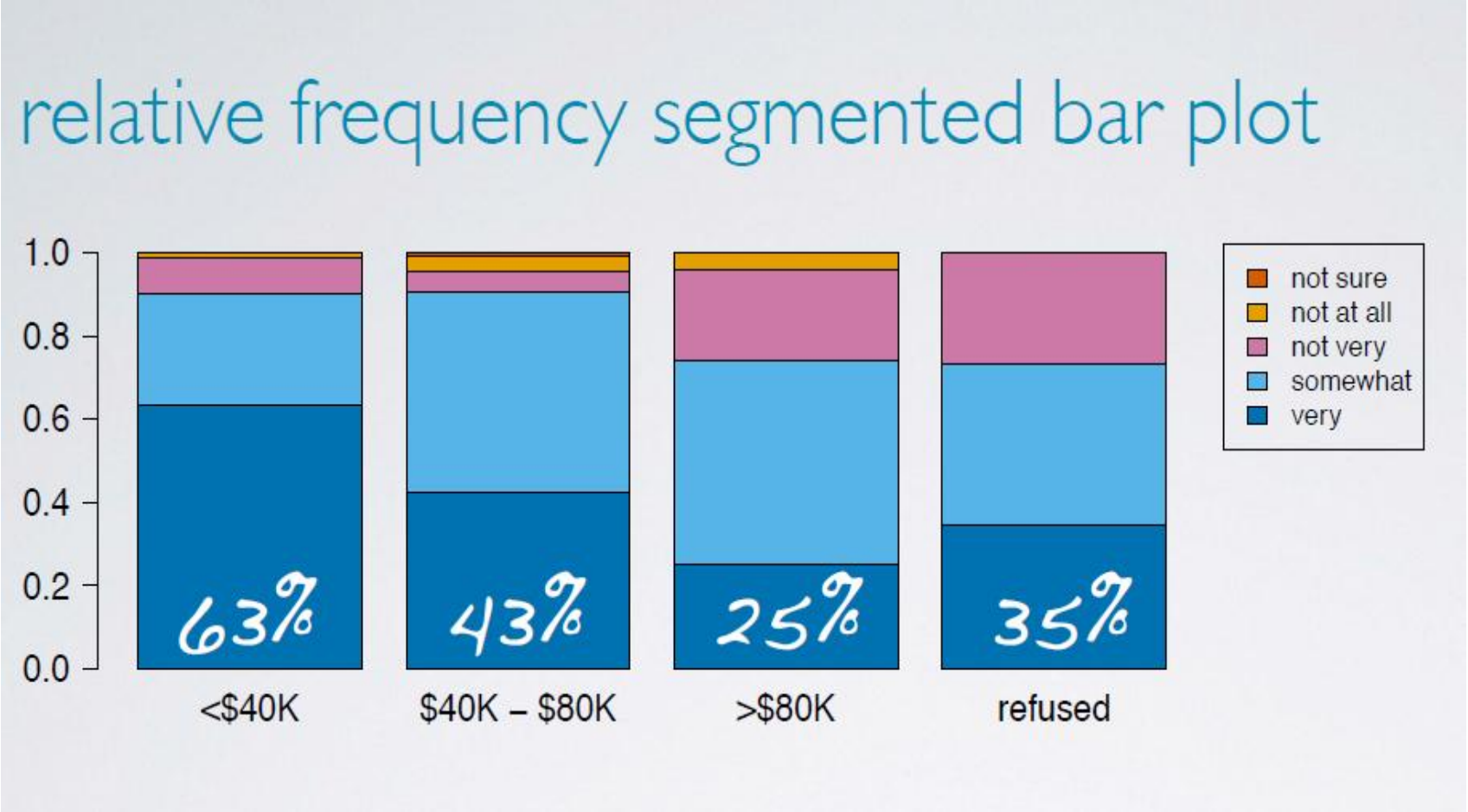
Exploring categorical variables

segmented bar plot

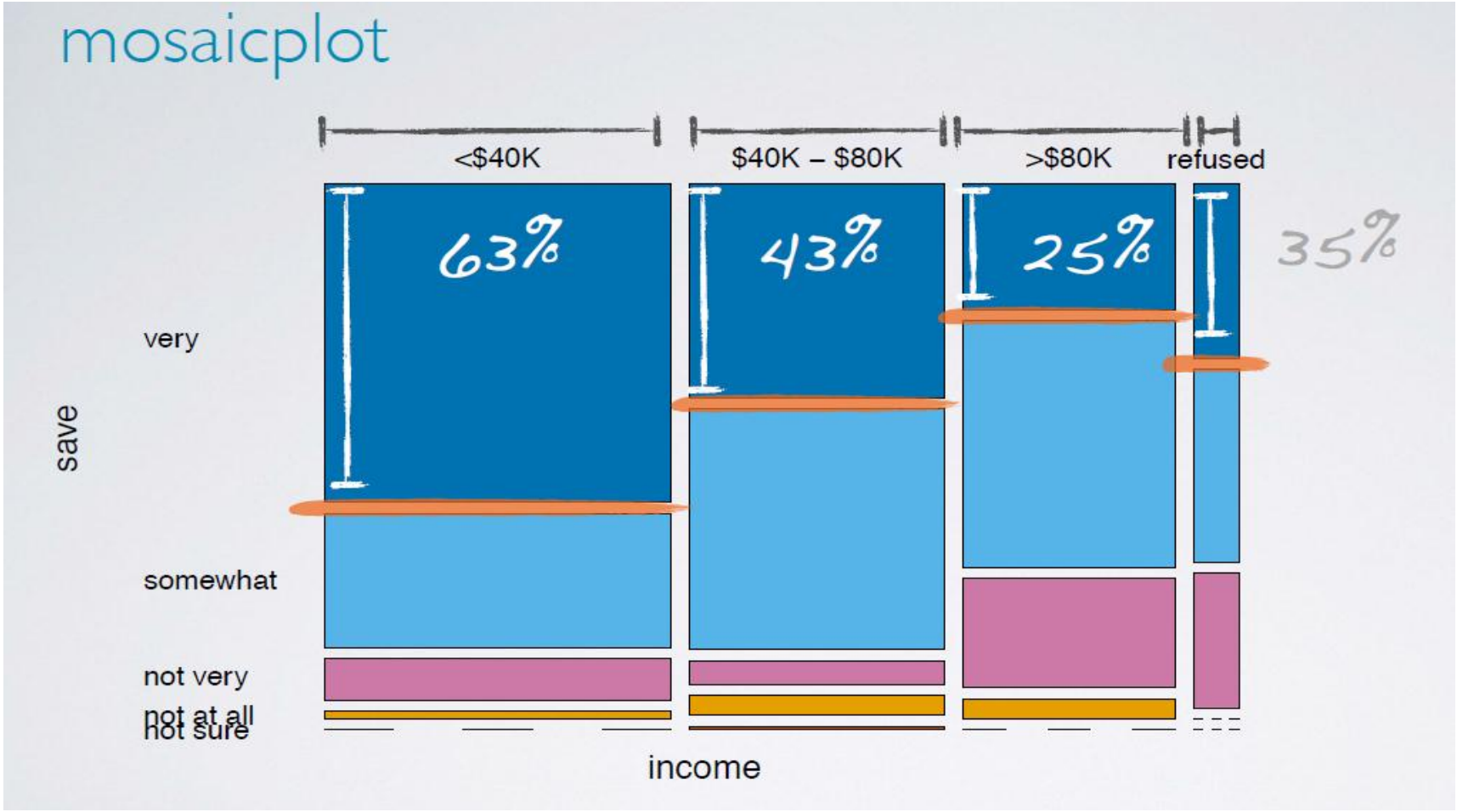


- useful for visualizing conditional frequency distributions
- compare relative frequencies to explore the relationship between the variables

Exploring categorical variables



Exploring categorical variables



Exploring categorical variables

side-by-side box plots