

# INTRODUCTION TO DATA SCIENCE

Lecture based on:

M. Cetinkays-Rundel, „Data Analysis and Statistical Inference”, Univ. of Duke

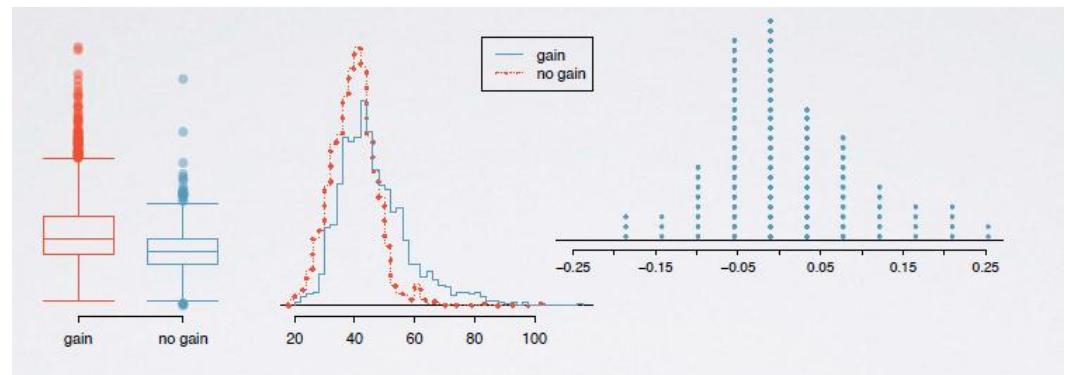
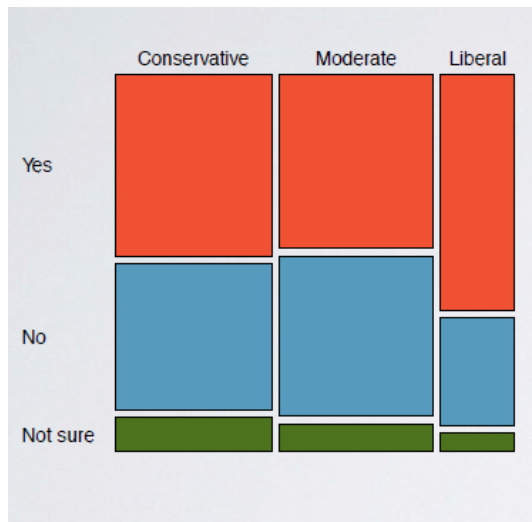
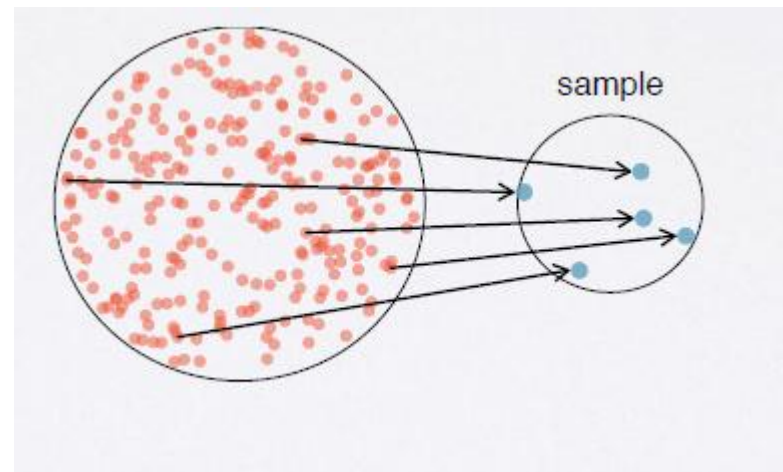
12/10/2022

WFAiS UJ, Informatyka Stosowana  
I stopień studiów

# Exploratory data analysis

2

How to collect, visualise and interpret the data.



12/10/2022

# Exploratory data analysis

3

population

sample

design

scope

exploratory  
data  
analysis

inference

# Data: basics

4

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

# Example: data matrix

5

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

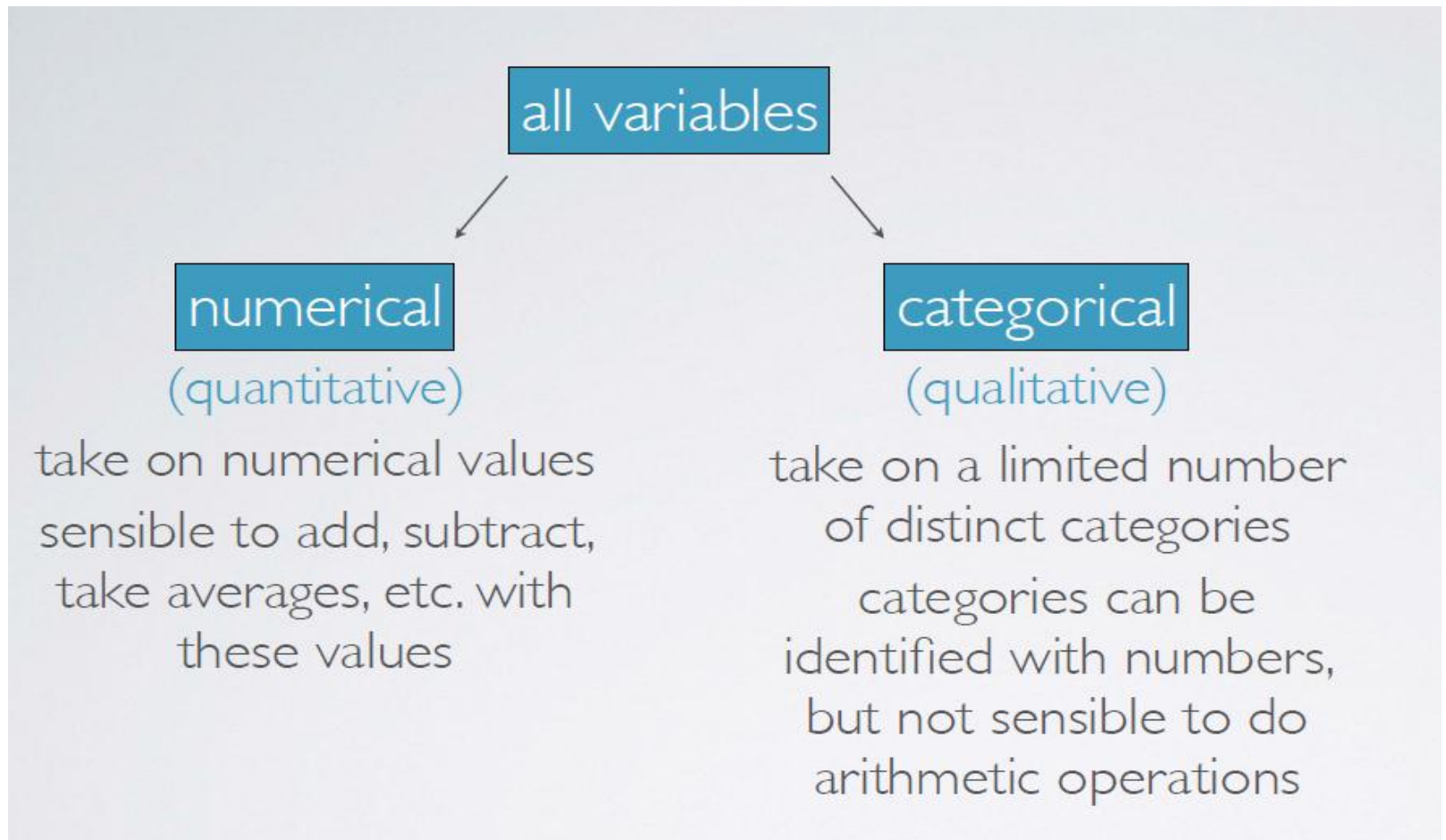
country	cr_req	cr_comply	ud_req	ud_comply	...	hemisphere	hdi
Argentina	21	100	134	32	...	southern	very high
Australia	10	40	361	73	...	southern	very high
Belgium	<10	100	90	67	...	northern	very high
Brazil	224	67	703	82	...	southern	high
...	...	...	...	...	...	...	...
United States	92	63	5950	93	...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

observation  
(case)

variable

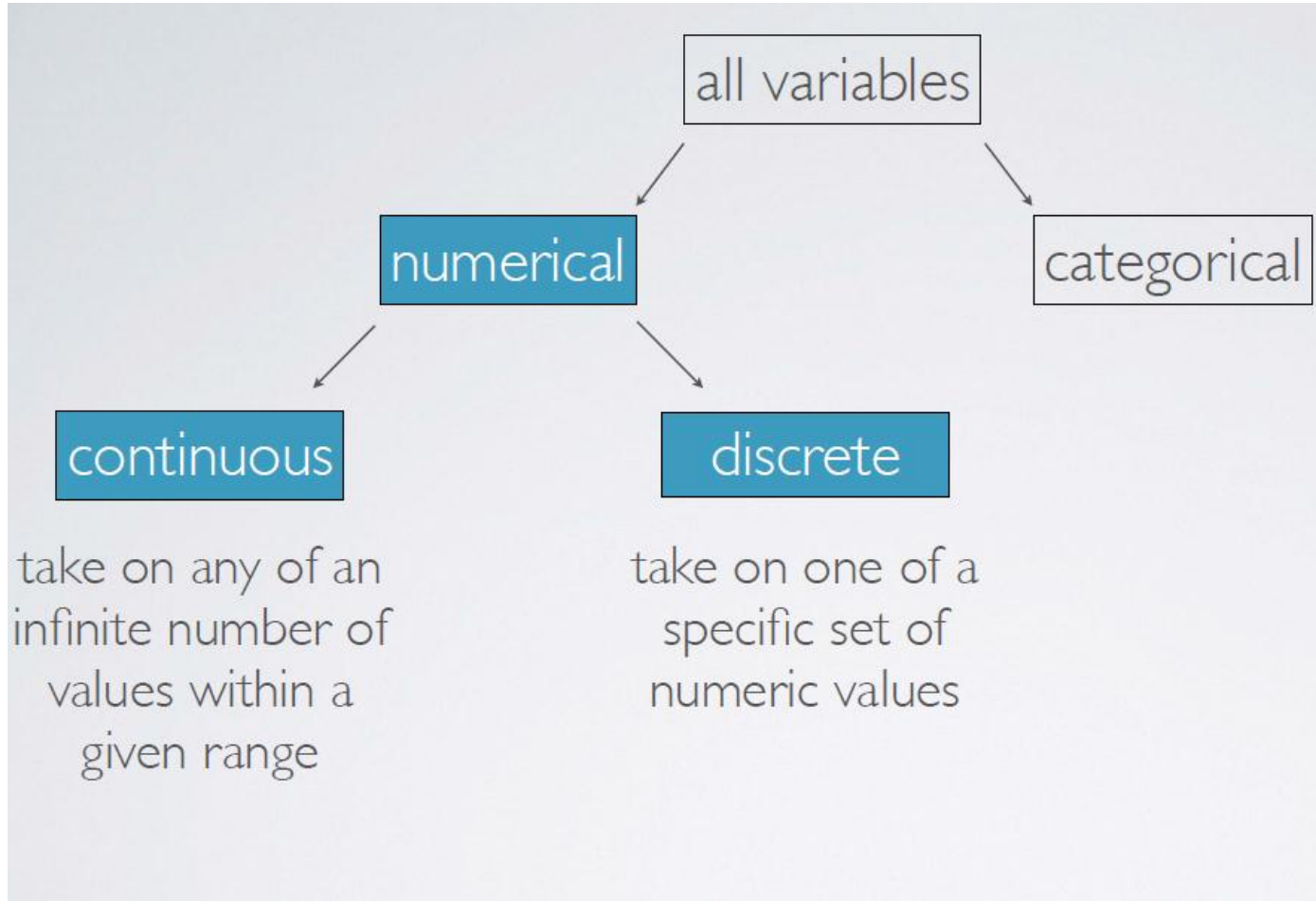
# Type of variables

6



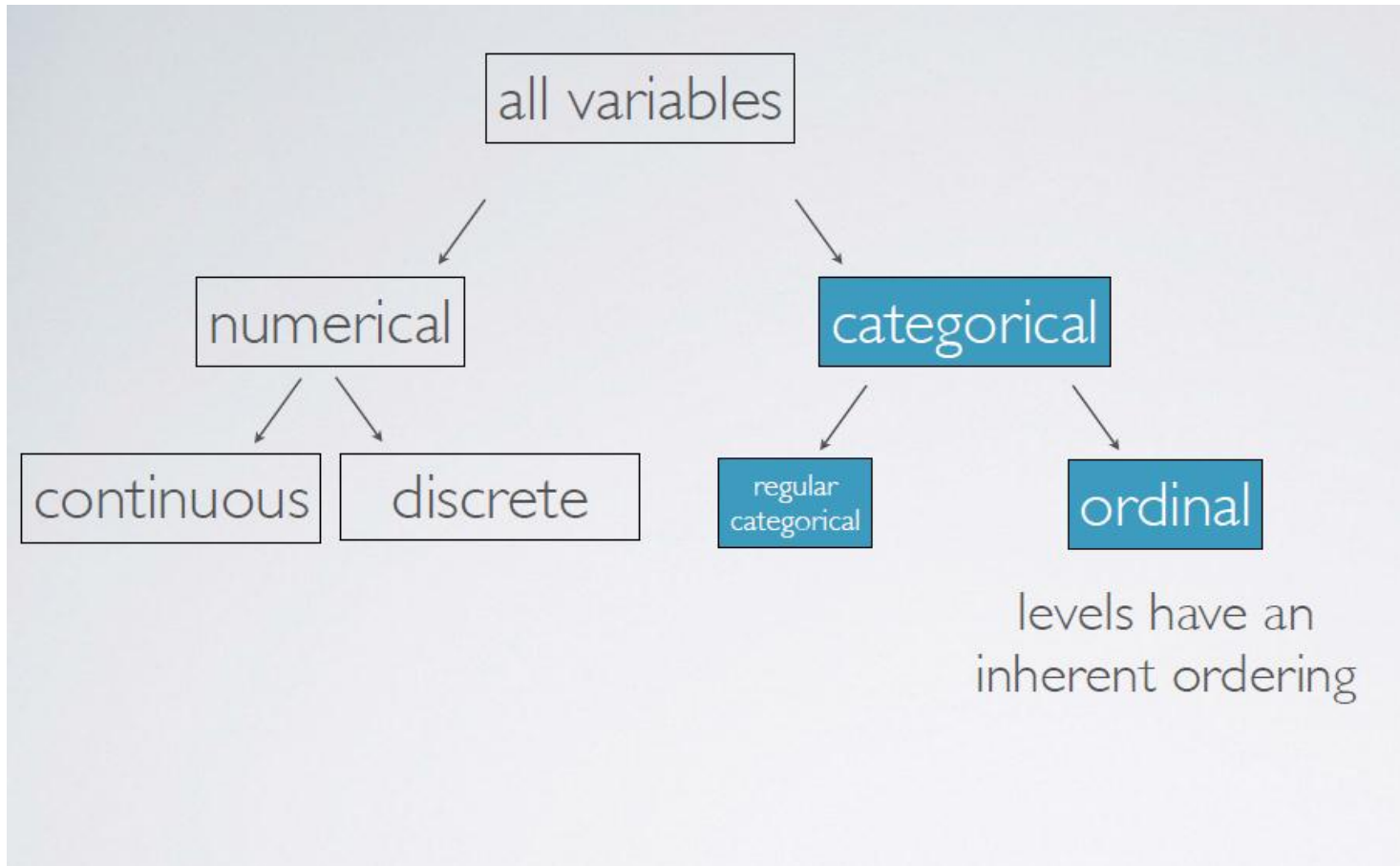
# Numerical variables

7



# Categorical variables

8





# Data matrix

9

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



country: Name of the country

# Data matrix

10

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



cr\_req: Number of content removal requests made to Google

**discrete  
numerical**

# Data matrix

11

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



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

continuous  
numerical

# Data matrix

12

country	cr_req	cr_comply	ud_req	ud_comply	...	hemisphere	hdi
Argentina	21	100	134	32	...	southern	very high
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Belgium	<10	100	90	67	...	northern	very high
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

13

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
...	...	...	...	...	...	...	...
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ud\_comply: Percentage of user data requests Google complied with

continuous  
numerical

# Data matrix

14

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

**categorical**

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

# Data matrix

15

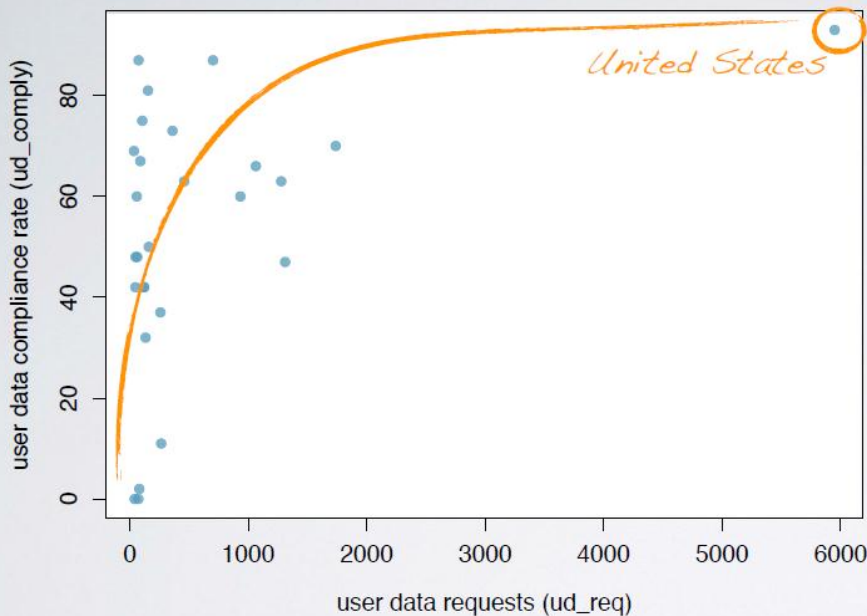
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Brazil	224	67	703	82	...	southern	high
...	...	...	...	...	...	...	...
United States	92	63	5950	93	...	northern	very high

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

# Relationships between variables

16

## relationships between variables

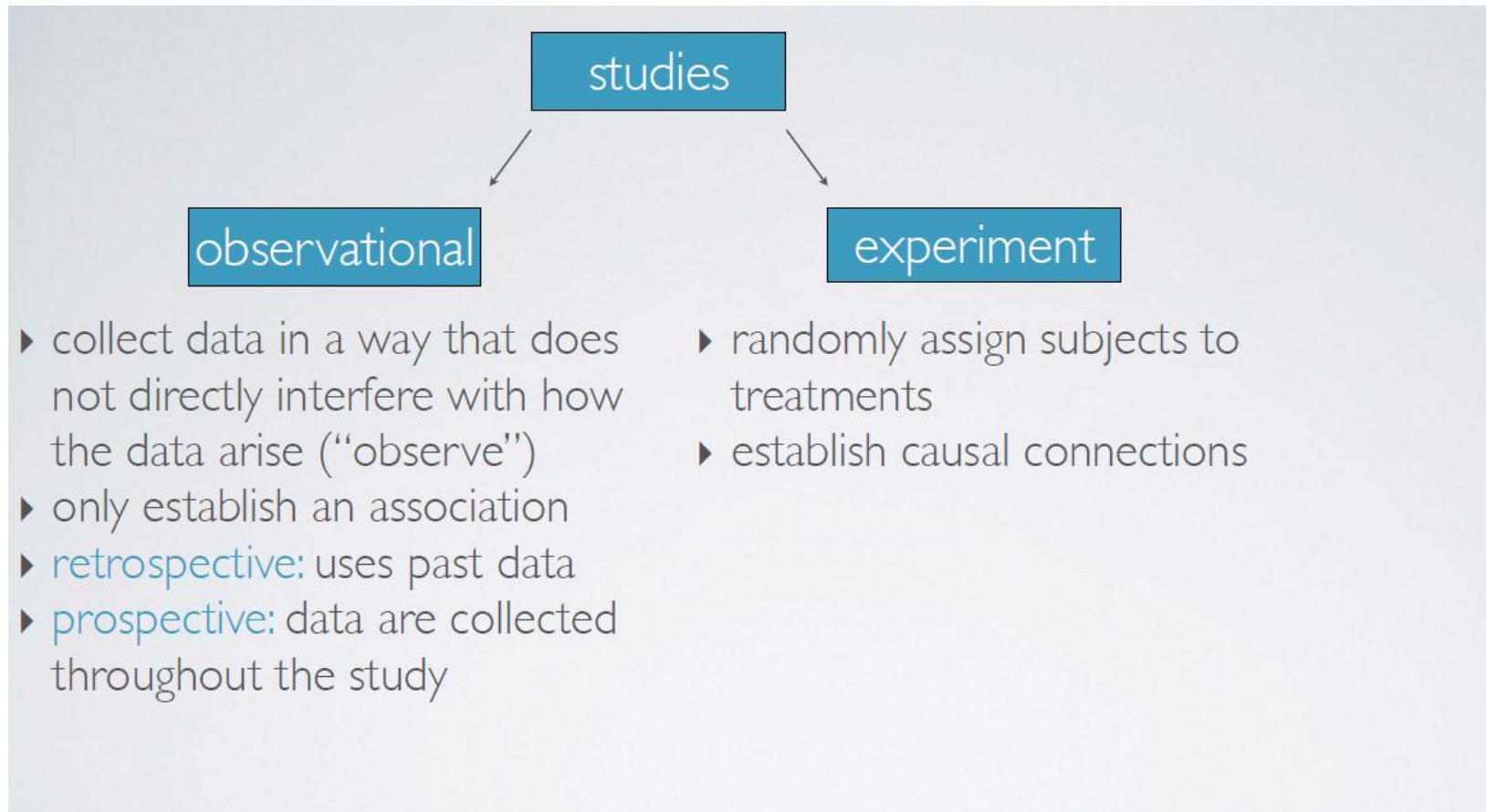


- ▶ Two variables that show some connection with one another are called **associated (dependent)**
- ▶ Association can be further described as **positive** or **negative**
- ▶ If two variables are not associated, they are said to be **independent**



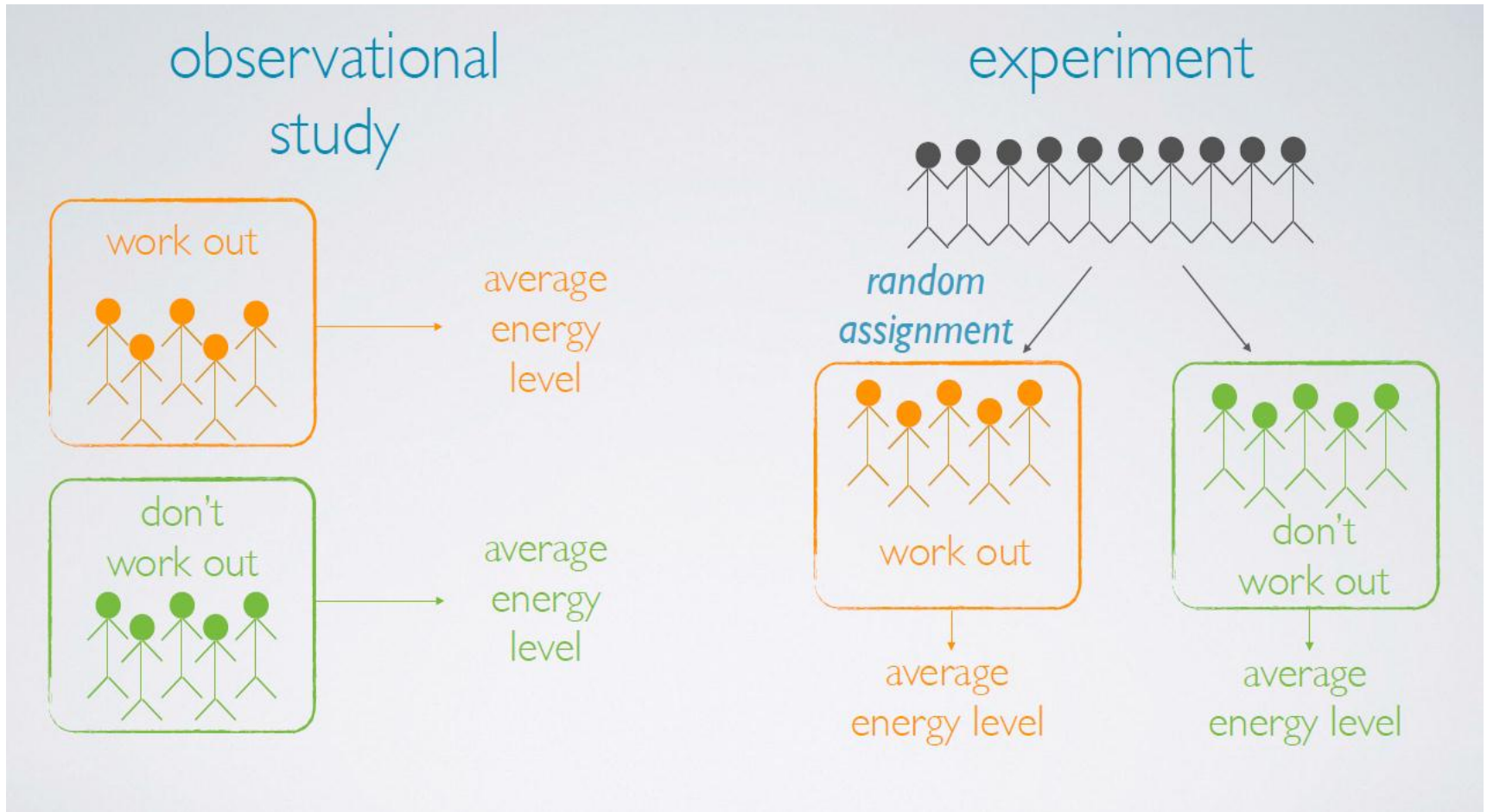
# Observational studies & experiments

17



# Observational studies & experiments

18



# Correlation & Causation

19

## □ 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

20

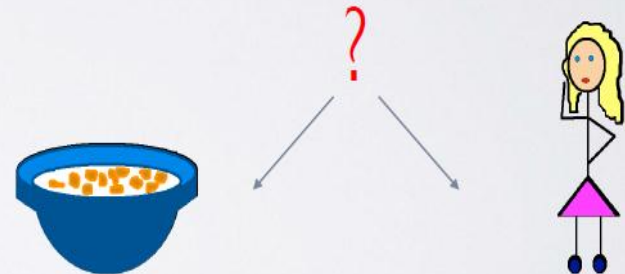
1. eating breakfast causes girls to be slimmer



2. being slim causes girls to eat breakfast



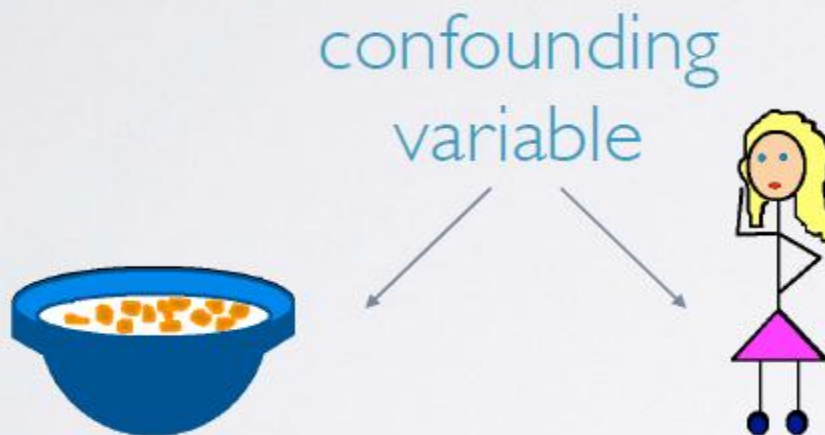
3. a third variable is responsible for both



# Confounding variables

21

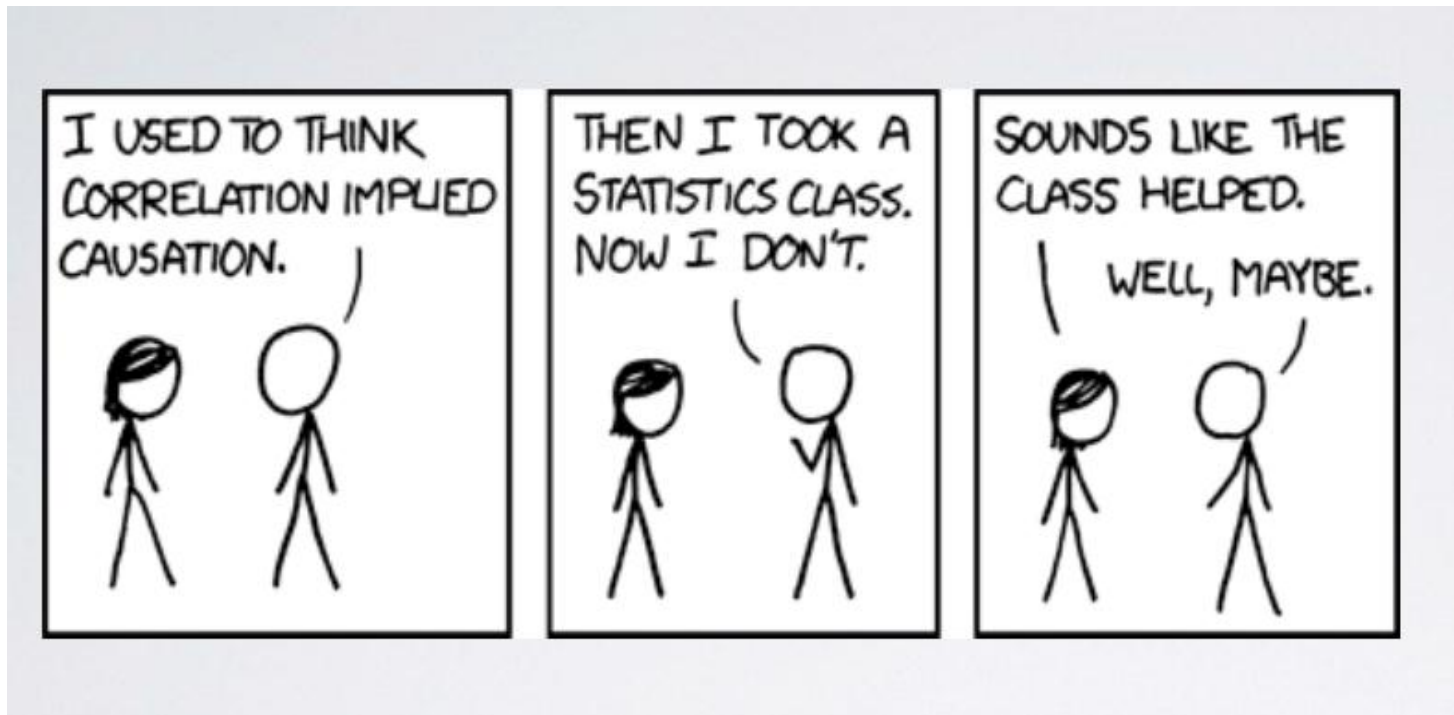
extraneous variables that affect both the explanatory and the response variable, and that make it seem like there is a relationship between them



# Correlation & Causation

22

- Correlation does not imply causation



# Sampling & sources bias

23

- Census vs sample
- Source o bias
- Sampling methods

# Census

24

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



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

25

- ▶ **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

**QUICK VOTE**

Should the West intervene in Syria?

Yes  No

**VOTE** or view results

---

**QUICK VOTE**

Should the West intervene in Syria?

Yes 34% 534

No 66% 1038

Total Votes: 1572

This is not a scientific poll

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# A few sources of sampling bias

26

1936

**Landon vs. FDR**  
(Republican) (Democrat)

**The Literary Digest**  
EST. 1893

Election results

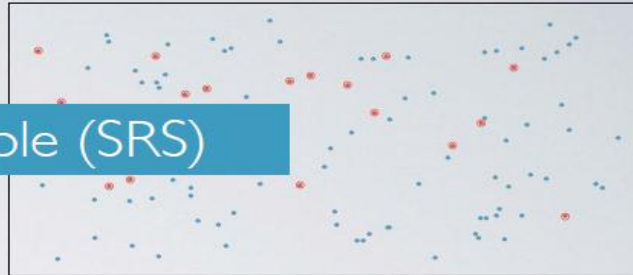
Lose with 43% of the votes  
Win with 62% of the votes

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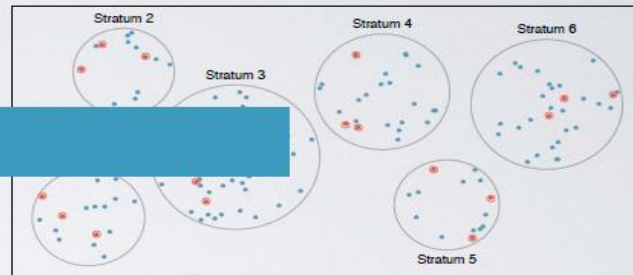
# Sampling methods

27

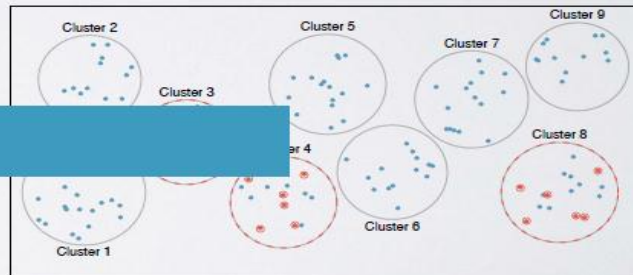
simple random sample (SRS)



stratified sample



cluster sample



# Sampling methods: random sampling

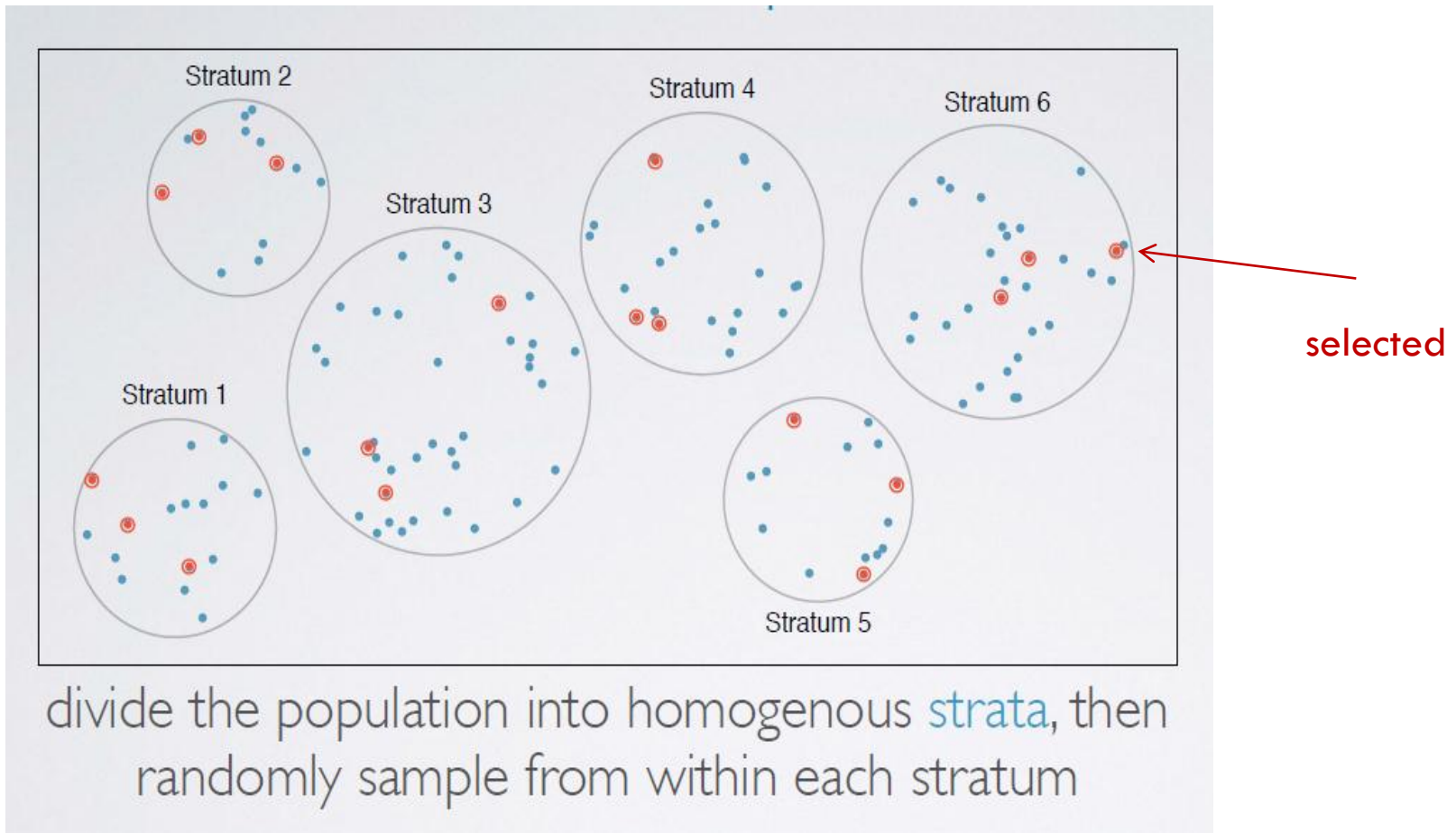
28



each case is equally likely to be selected

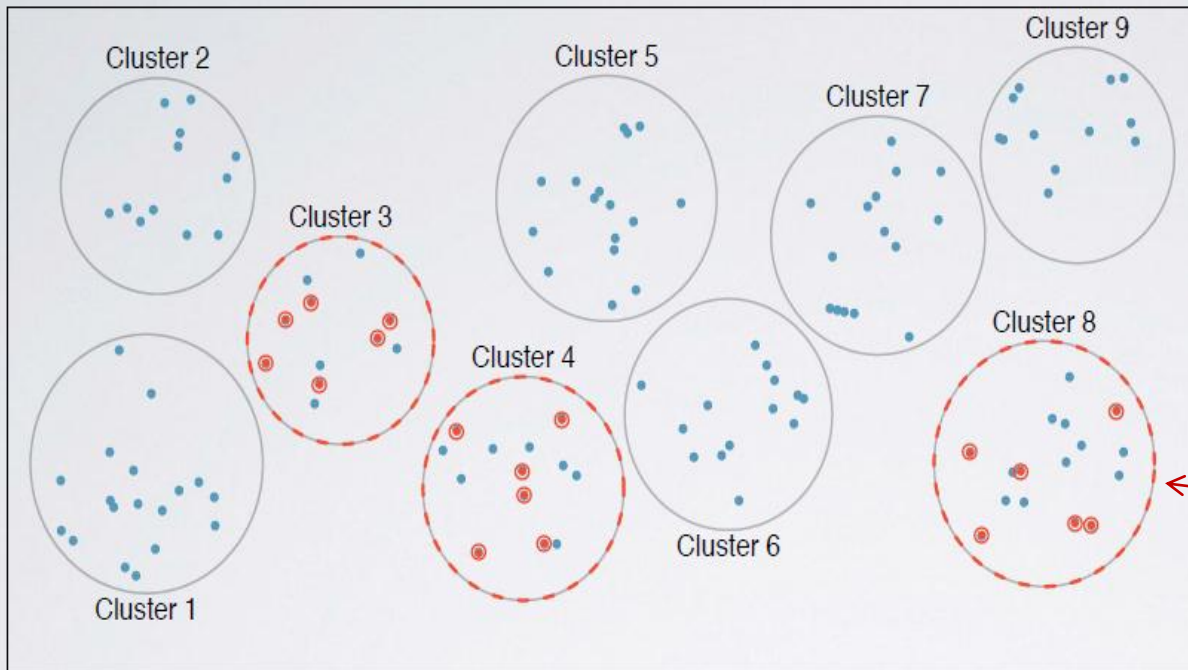
# Sampling methods: stratified sample

29



# Sampling methods: cluster

30



divide the population **clusters**, randomly sample a few clusters, then randomly sample from within these clusters

# Vizualizing numerical data

31

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

# Data matrix

32

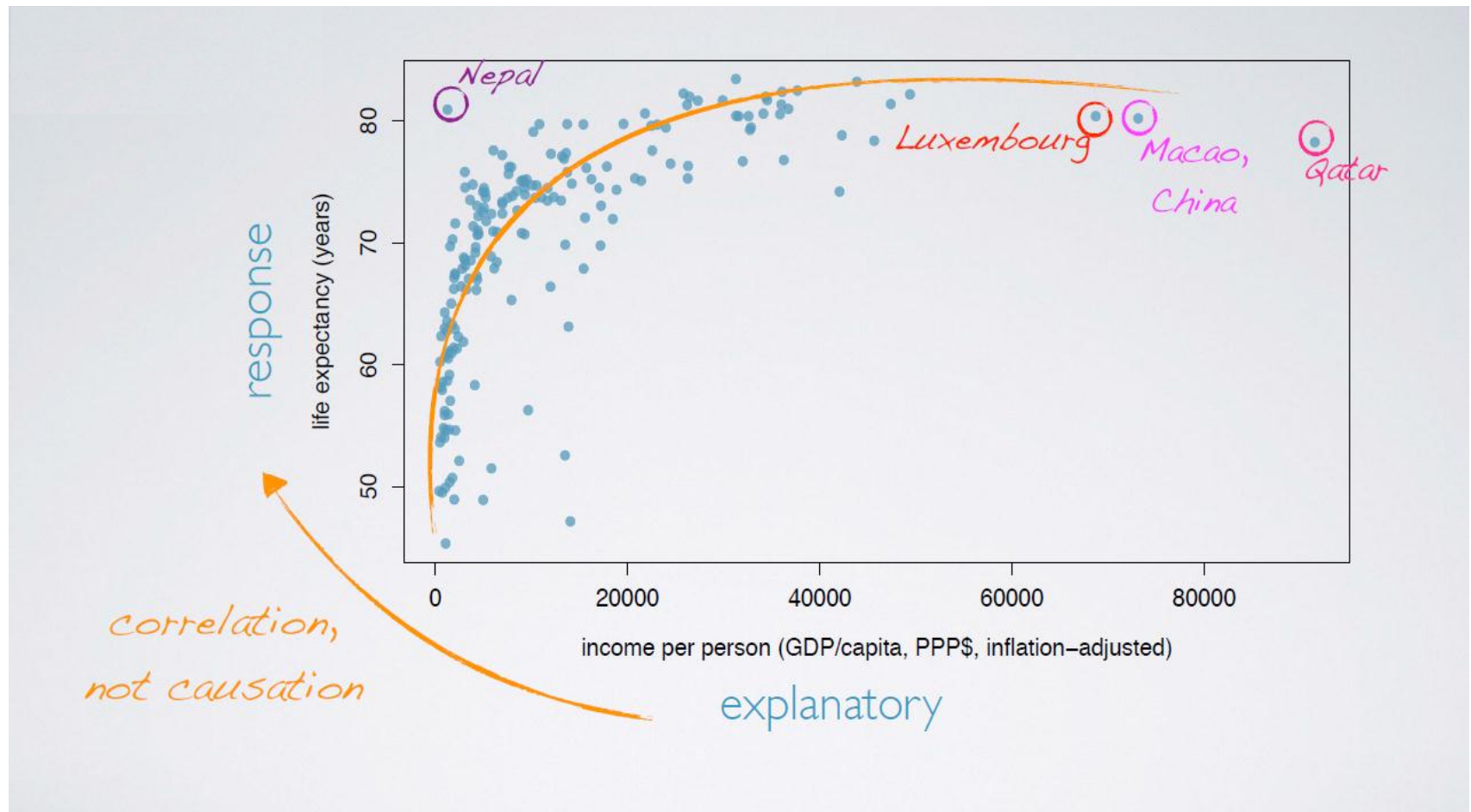
data	income per person (\$, 2012)	life expectancy (years, 2012)
Afghanistan	1359.7	60.254
Albania	6969.3	77.185
Algeria	6419.1	70.874
...	...	...
Zimbabwe	545.3	58.142

Source: [gapminder.com](http://gapminder.com)



# Scatterplots

33



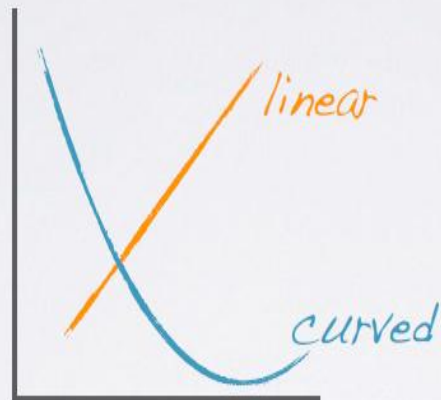
# Evaluating their relationship

34

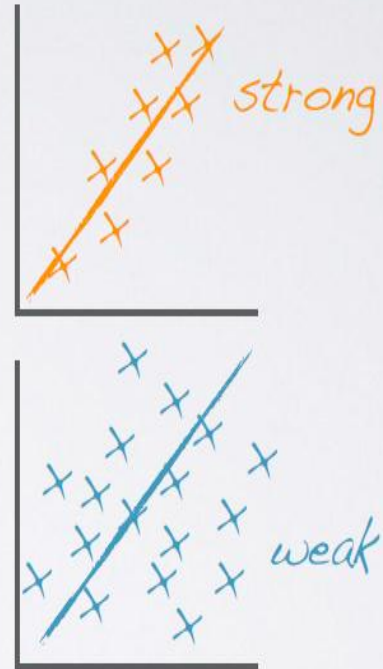
direction



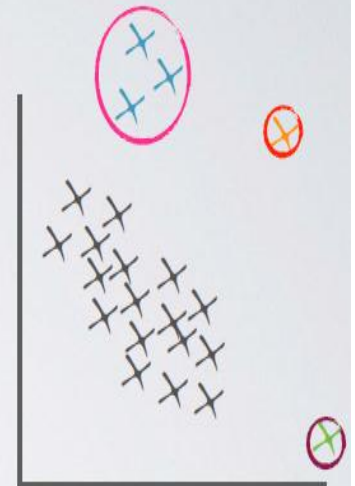
shape



strength

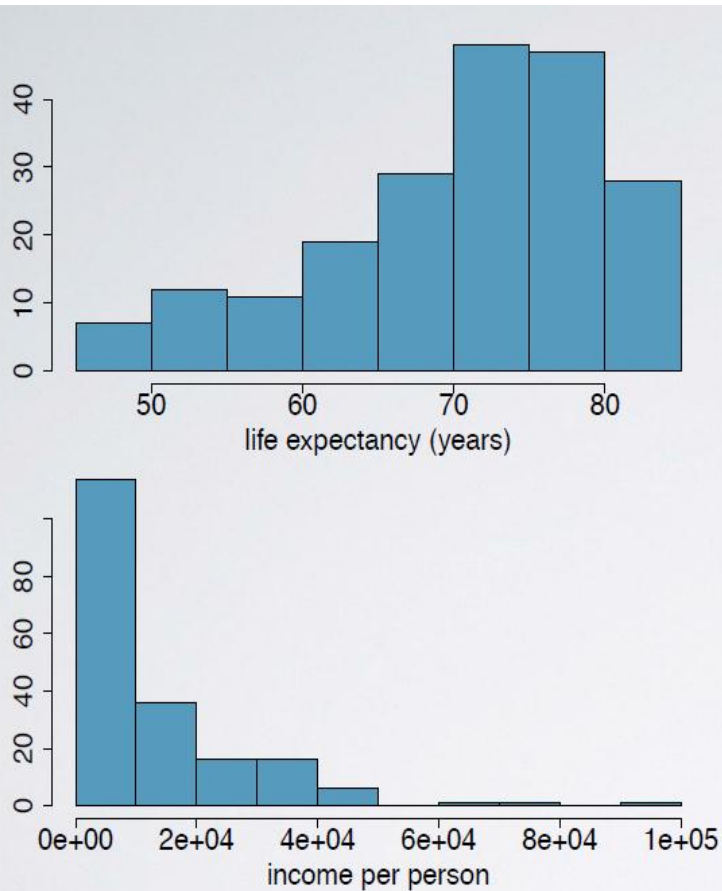


outliers



# Histogram

35



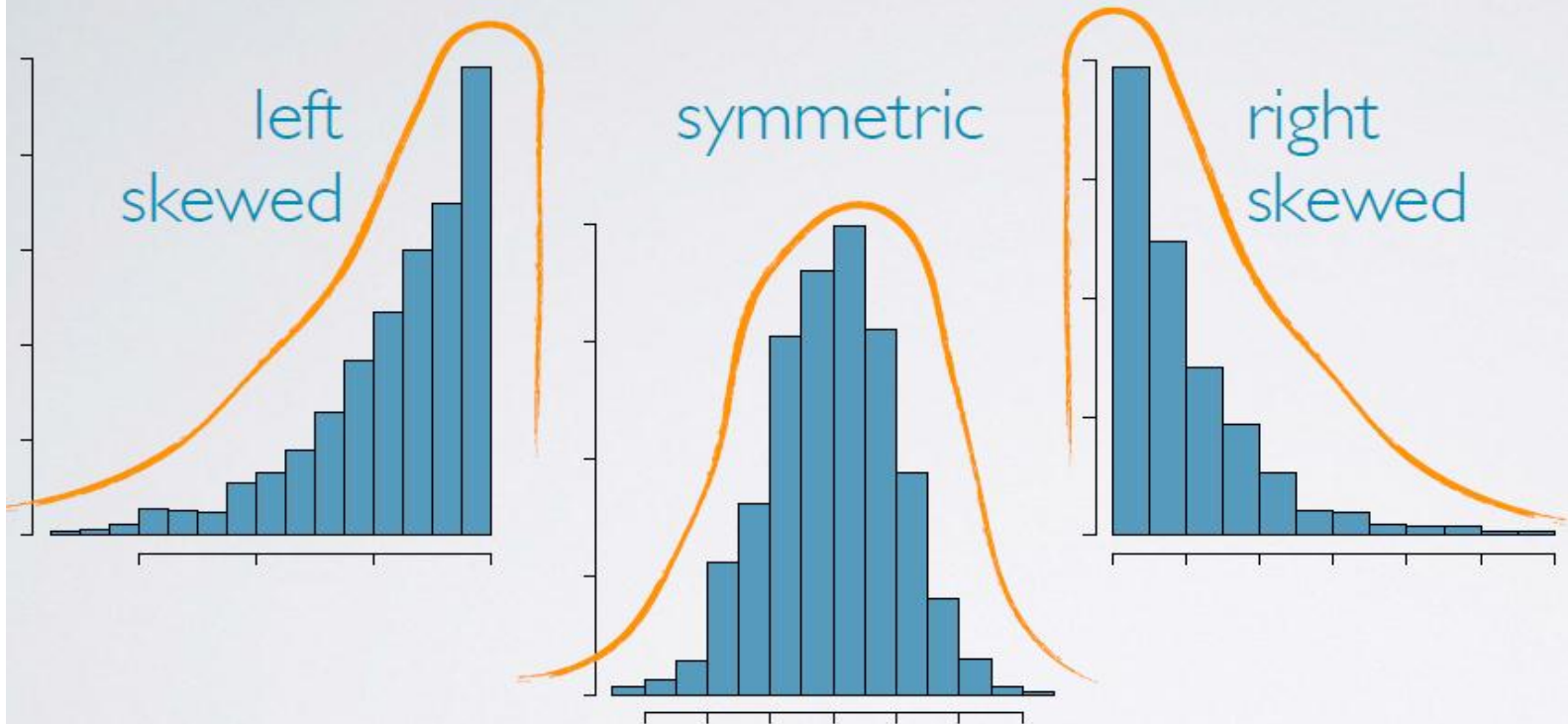
## histogram

- ▶ provides a view of the [data density](#)
- ▶ especially useful for describing the shape of the distribution

# Histogram

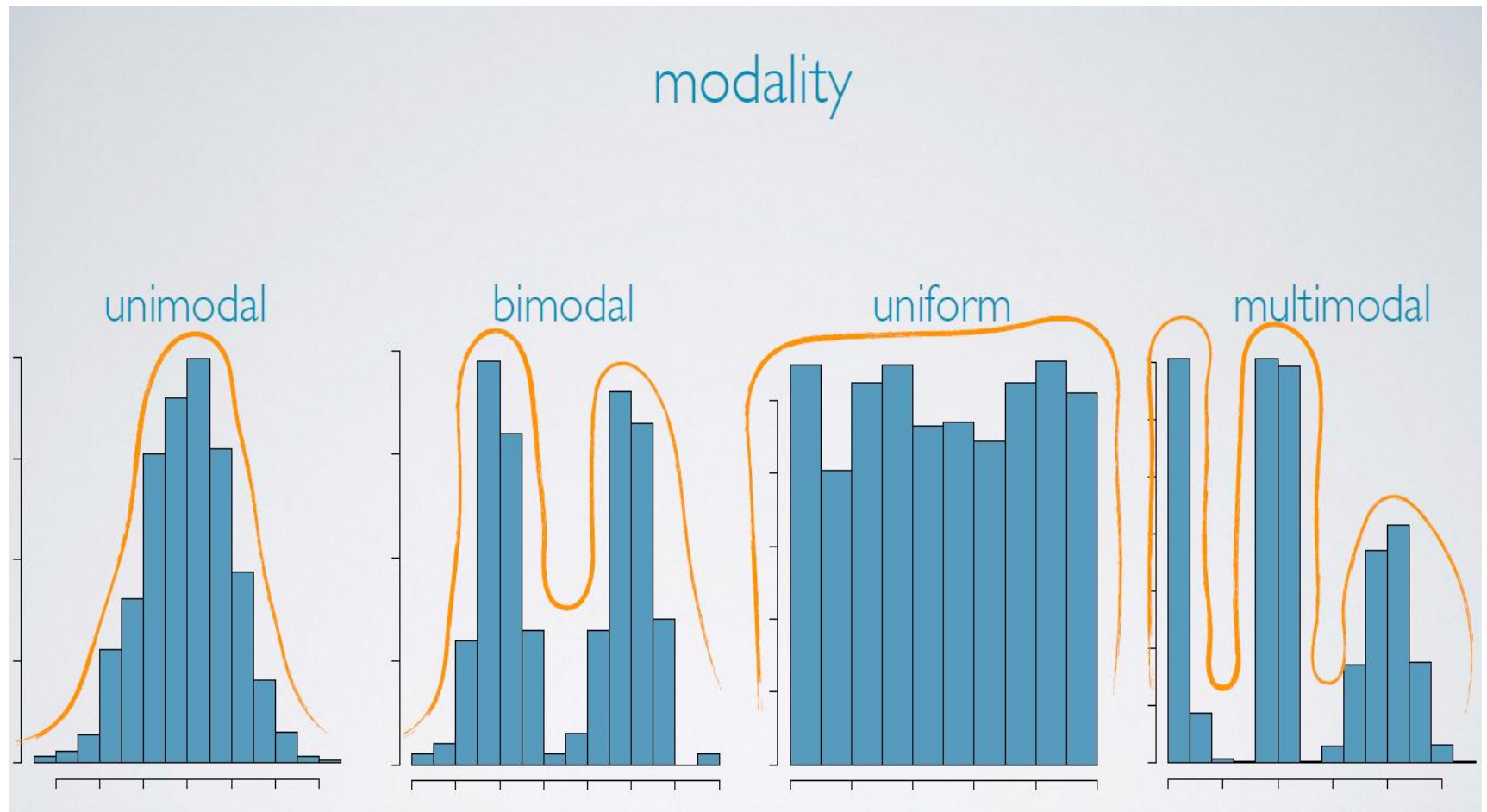
36

distributions are skewed to the side of the long tail



# Histogram

37



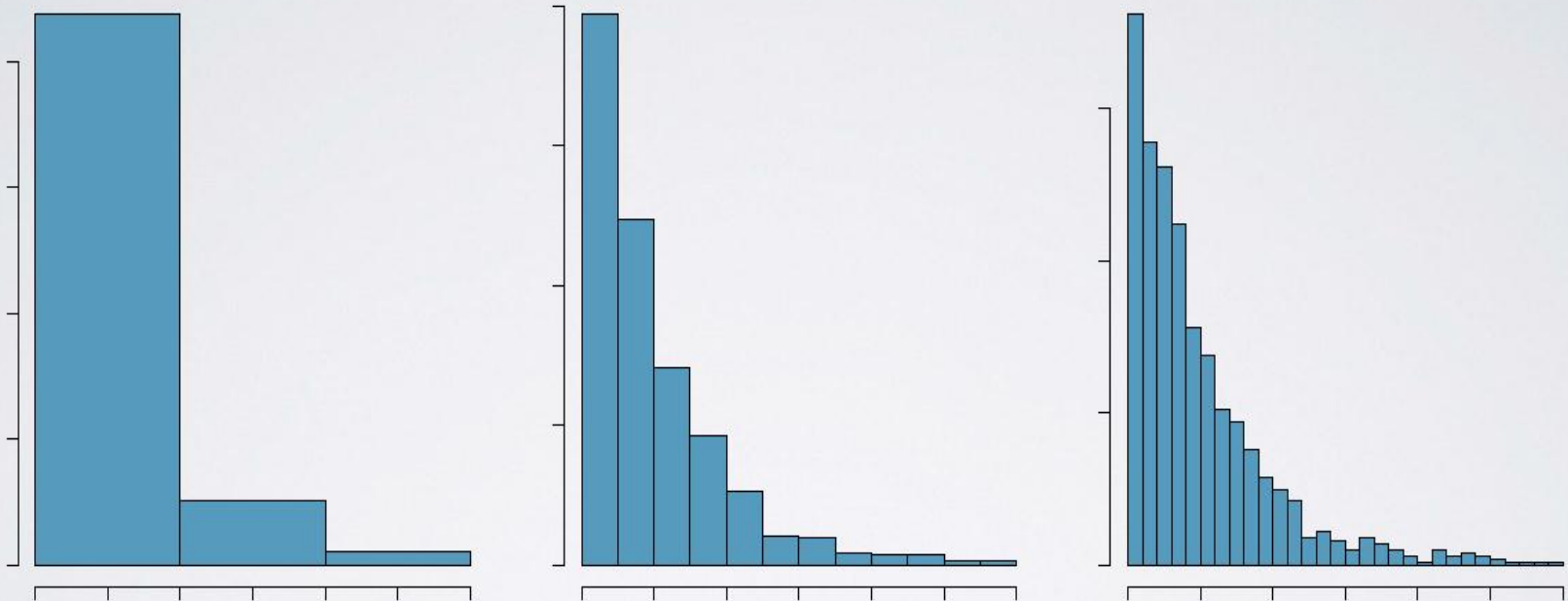
12/10/2022

# Histogram

38

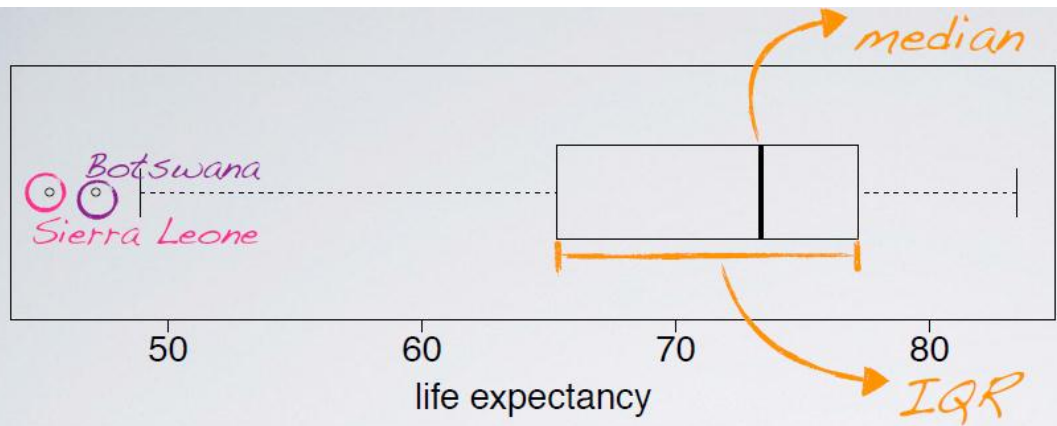
## histogram & bin width

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



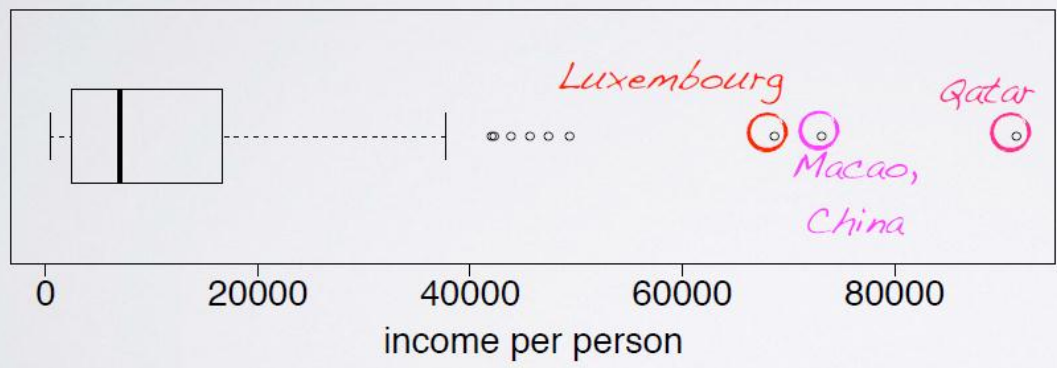
# Box plot

39



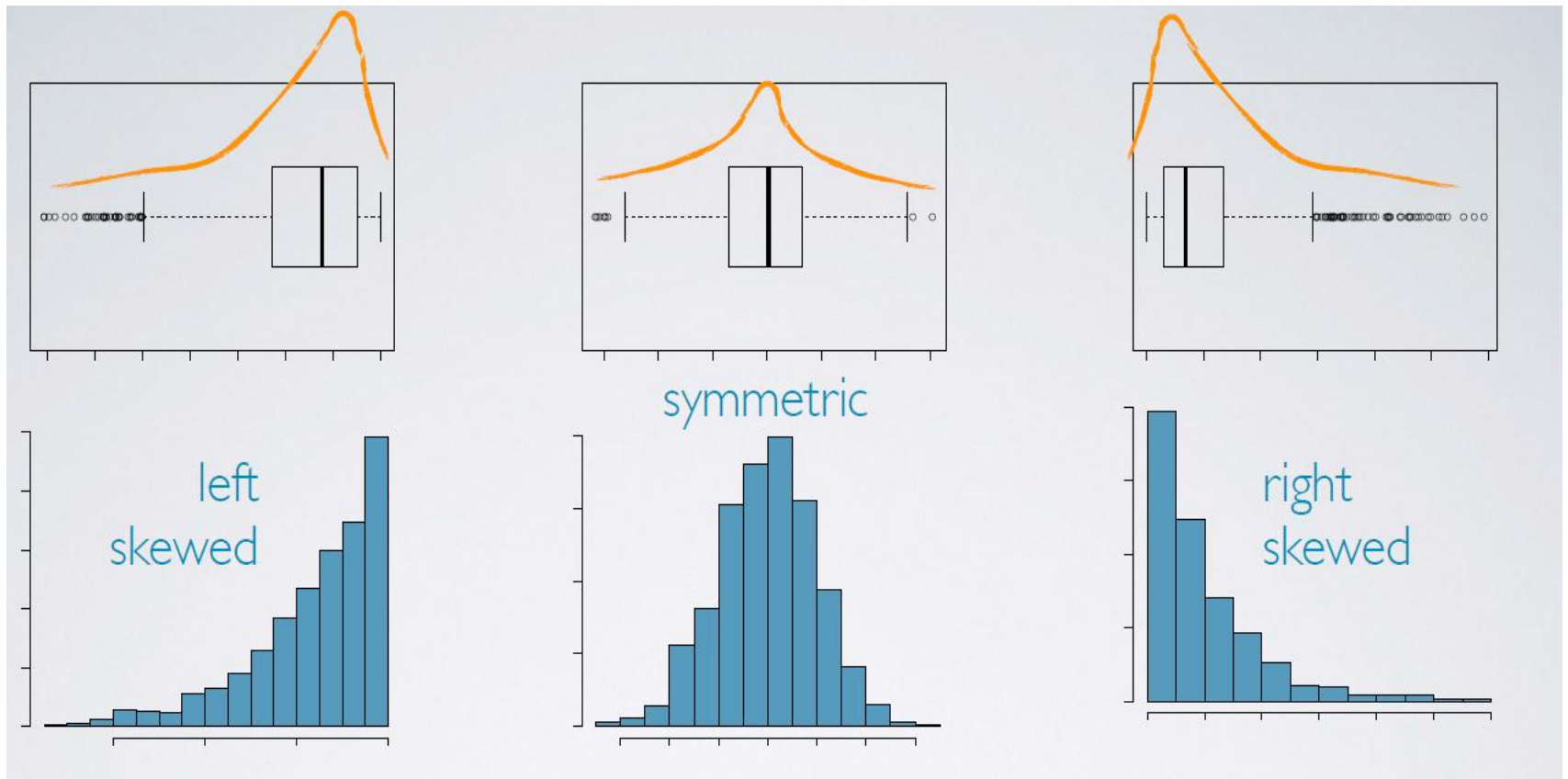
box plot

useful for highlighting outliers, median, IQR



# Box plot

40

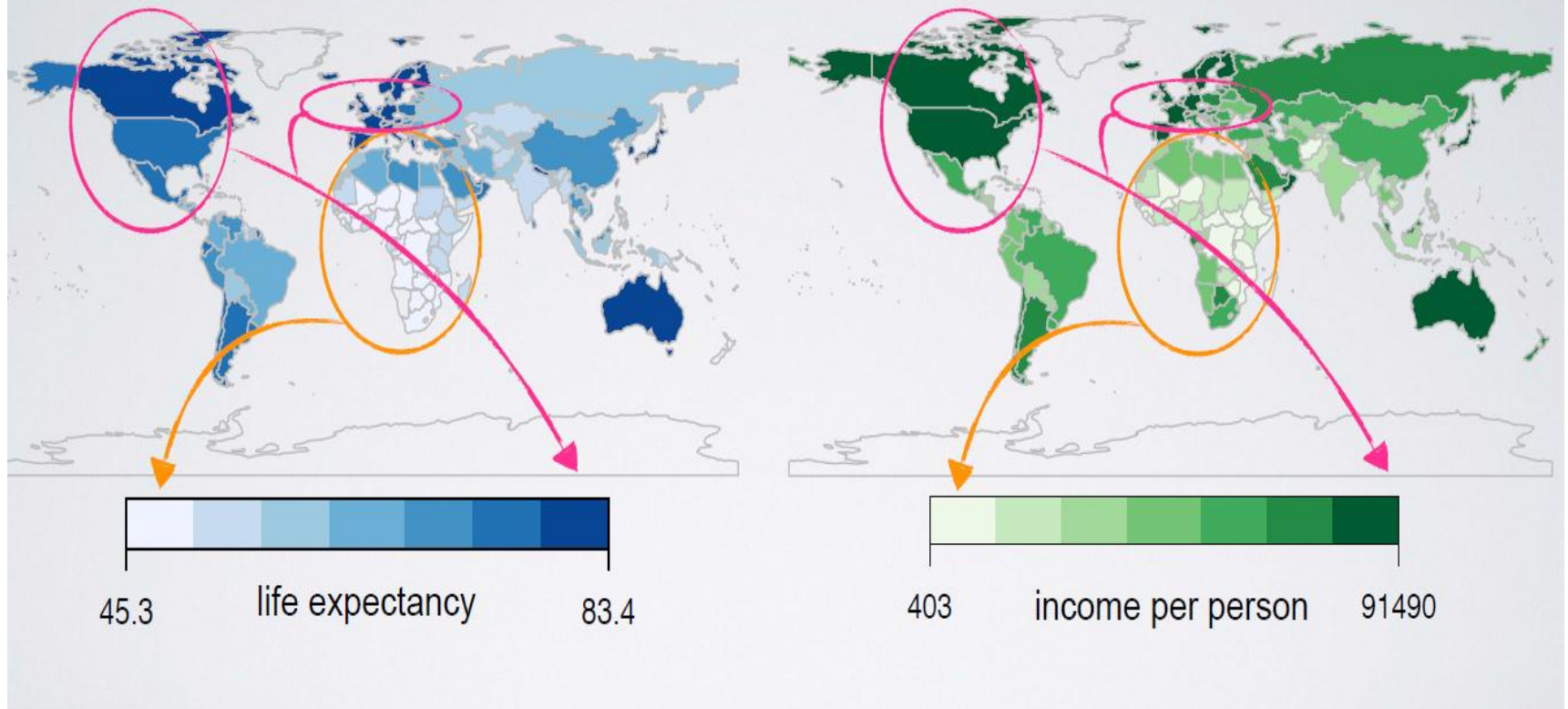




# Intensity map

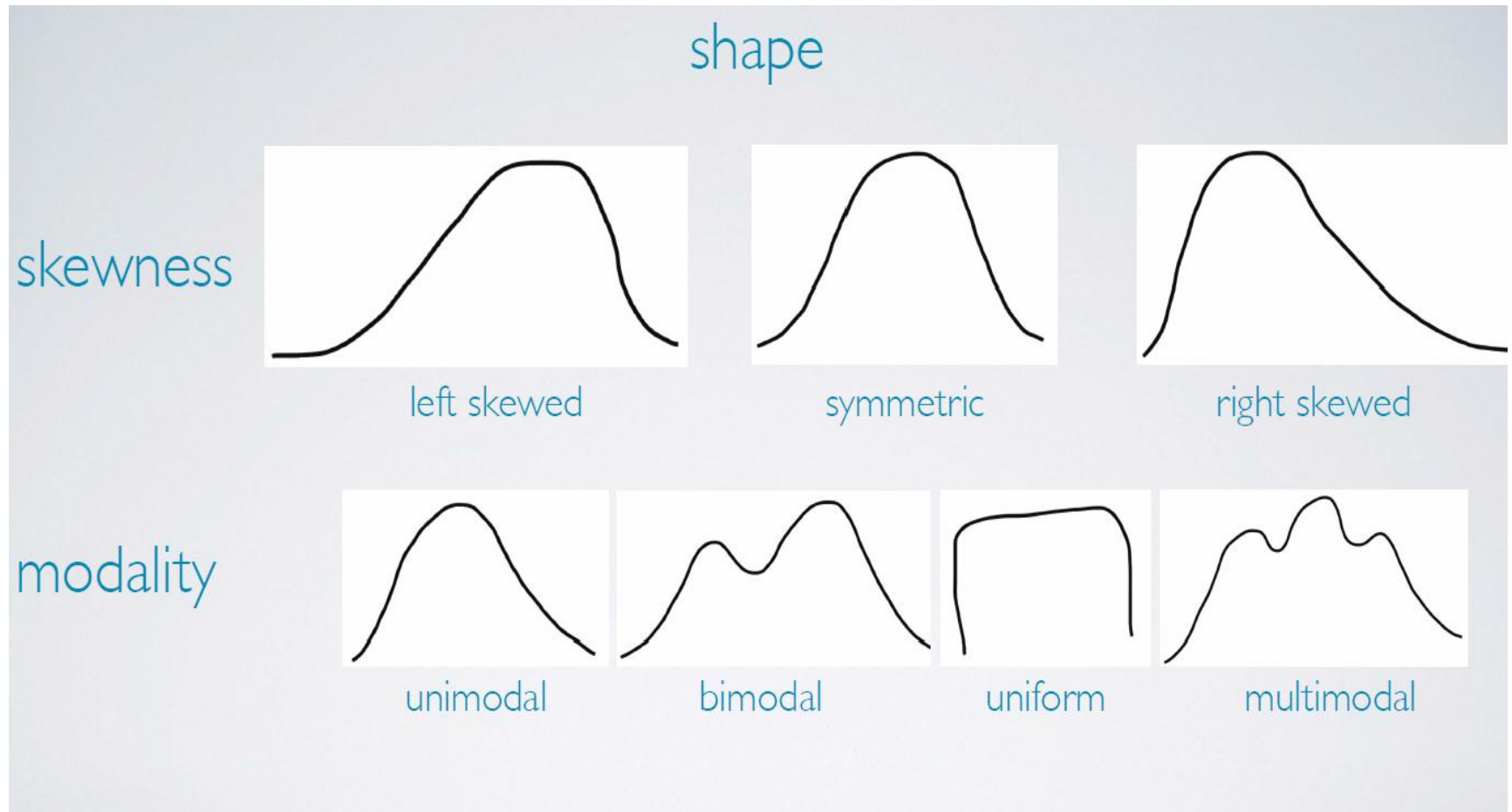
41

► Useful for highlighting the spatial distribution.



# Measures of center

42



# Measures of center

43

## mean

arithmetic average

$\bar{x}$  sample mean

$\mu$  population mean

## median

midpoint of the  
distribution  
(50th percentile)

## mode

most frequent  
observation

sample statistic

point estimate

population parameter

# Measures of center

44

*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

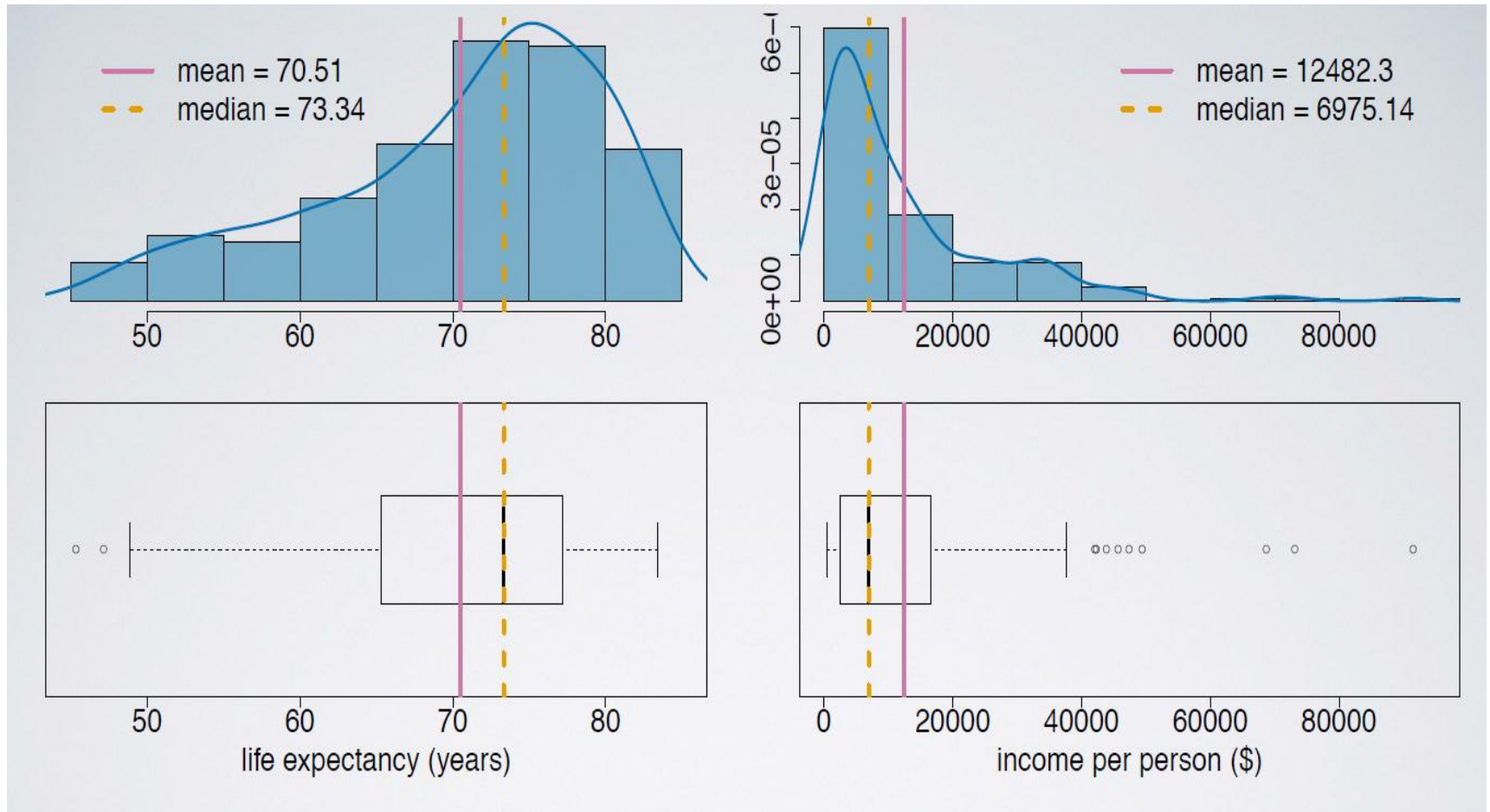
45

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](http://gapminder.com)

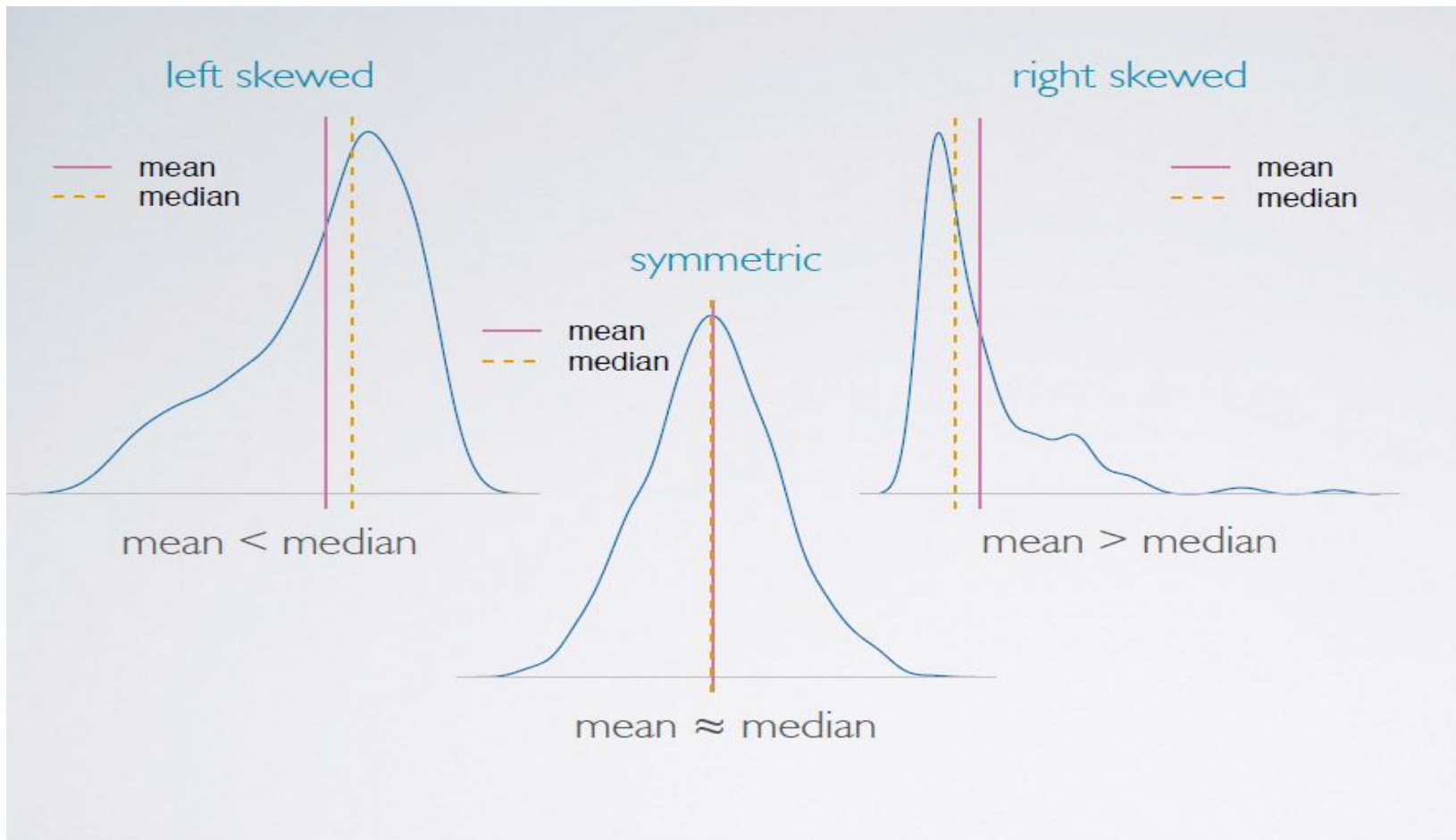
# Measures of center

46



# Skewness vs. measures of center

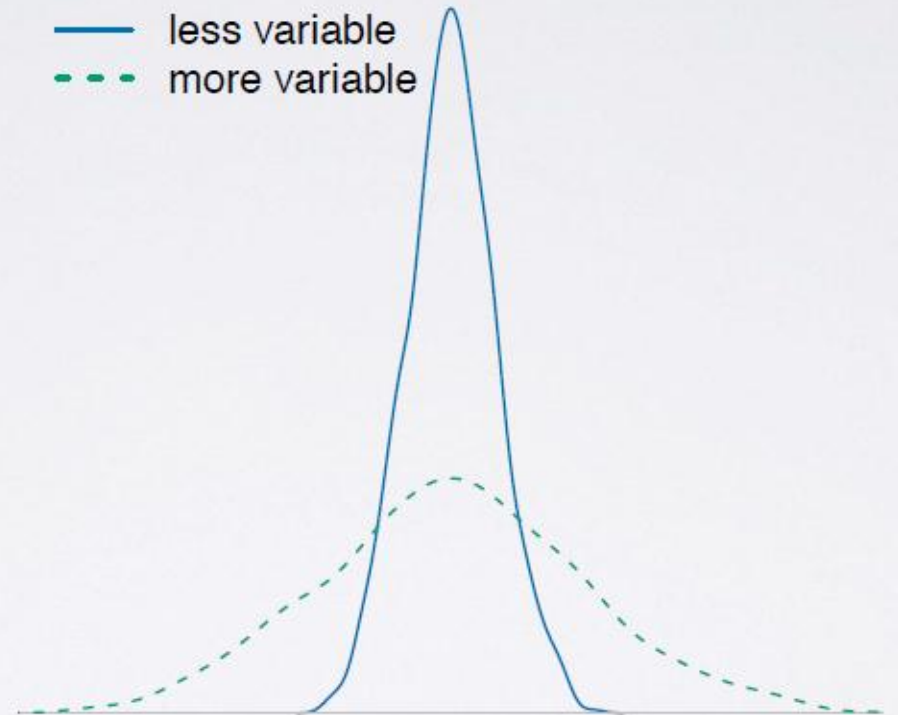
47



# Measures of spread

48

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





# Measures of spread

49

## variance

sample  
variance  
 $s^2$   
population  
variance  
 $\sigma^2$

roughly the average squared deviation from the mean

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

*example*

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

$$s^2 = \frac{(60.3 - 70.5)^2 + (77.2 - 70.5)^2 + \dots + (58.1 - 70.5)^2}{201 - 1}$$
$$= 83.06 \text{ years}^2$$

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

# Measures of spread

50

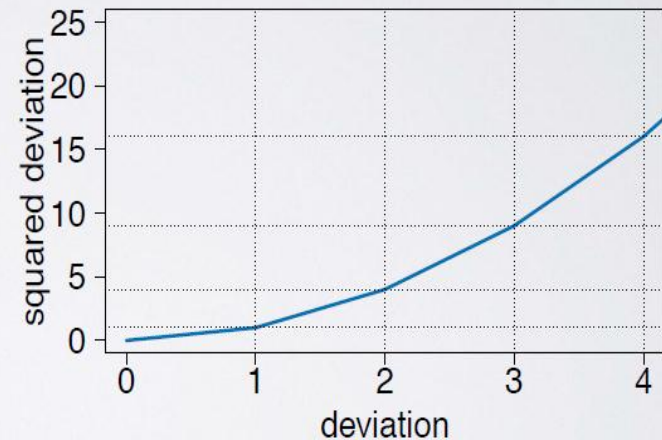
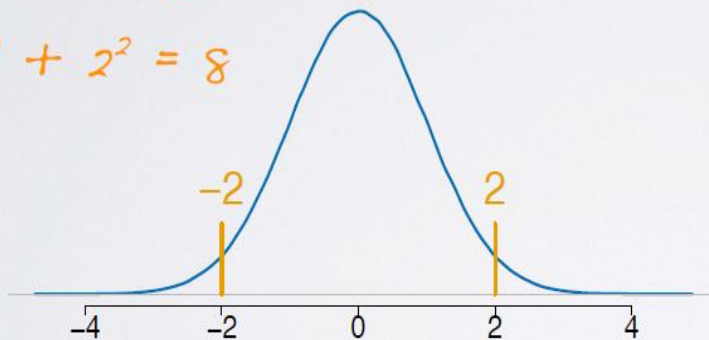
Why do we square the differences?

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

- ▶ 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

51

## standard deviation

sample sd  
 $s$   
population sd  
 $\sigma$

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

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

*square root of  
the variance*

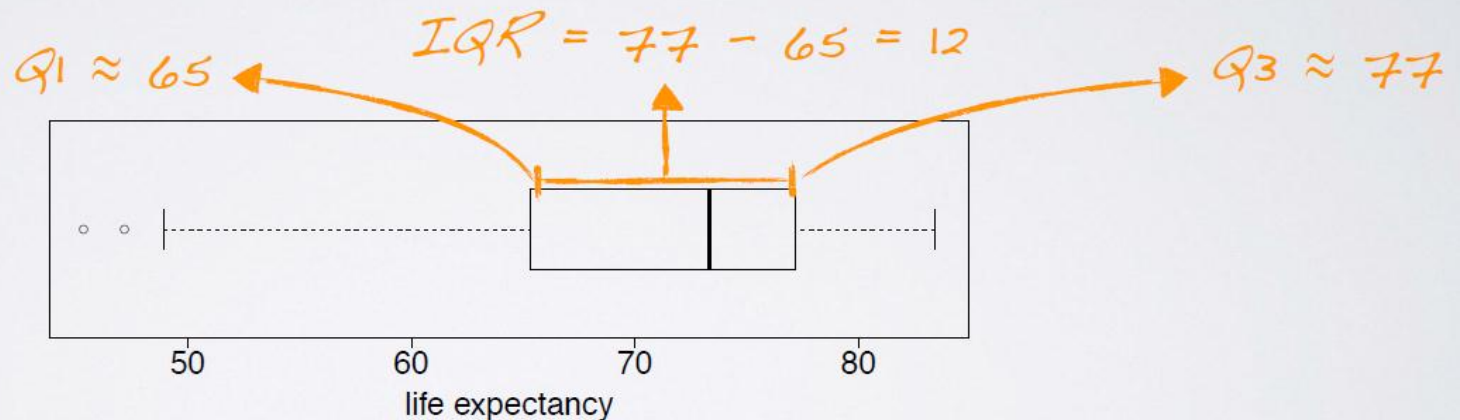
# Measures of spread

52

## 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

53

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

54

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

*skewed,  
with extreme  
observations*

*symmetric*

# Transforming data

55

- ▶ 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

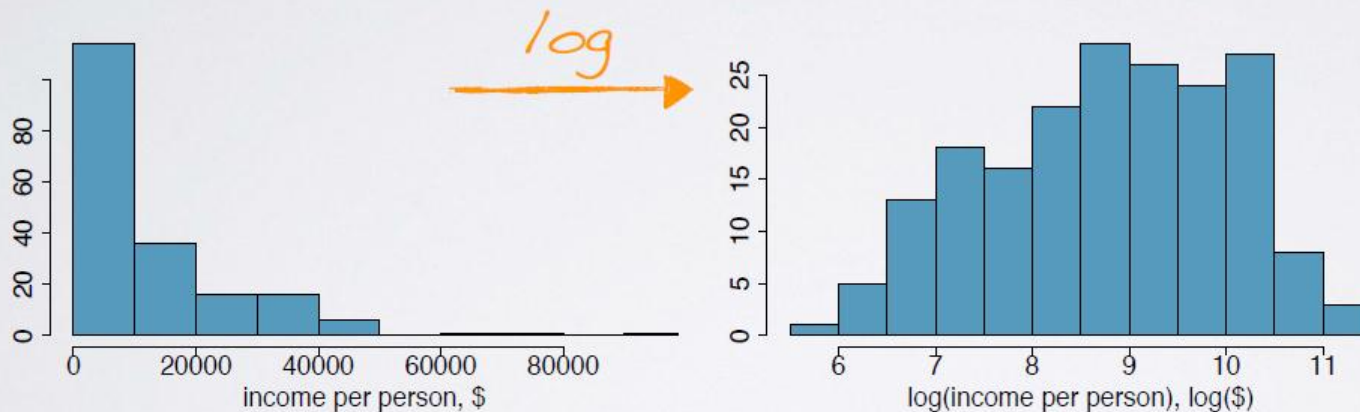
- ▶ to see the data structure differently
- ▶ to reduce skew assist in modeling
- ▶ to straighten a nonlinear relationship in a scatterplot

# Transforming data

56

## (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



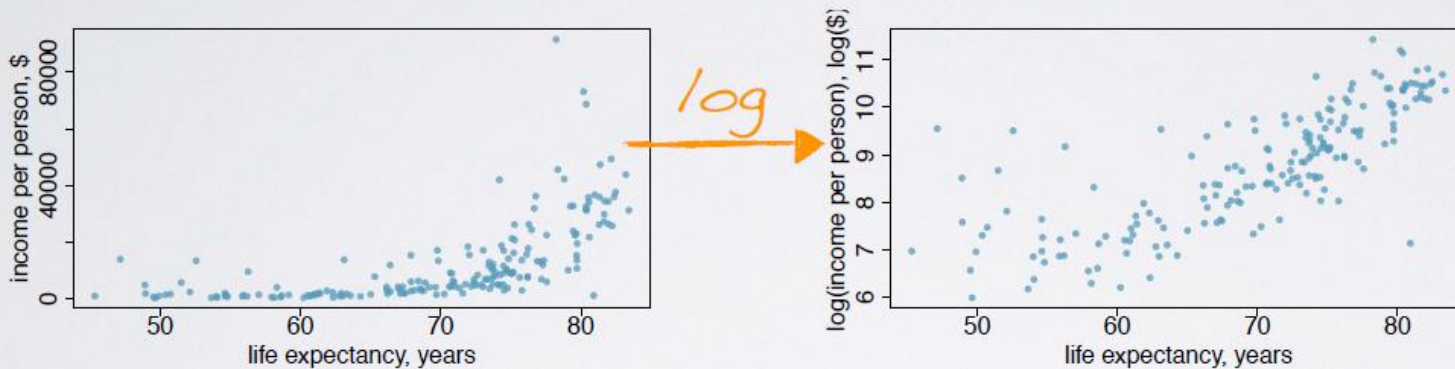


# Transforming data

57

## log transformation

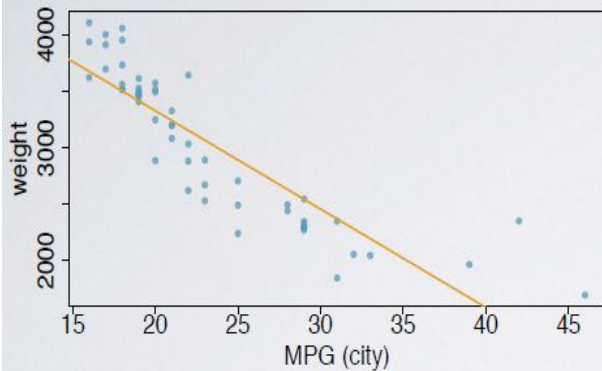
to make the relationship between the variables more linear, and hence easier to model with simple methods



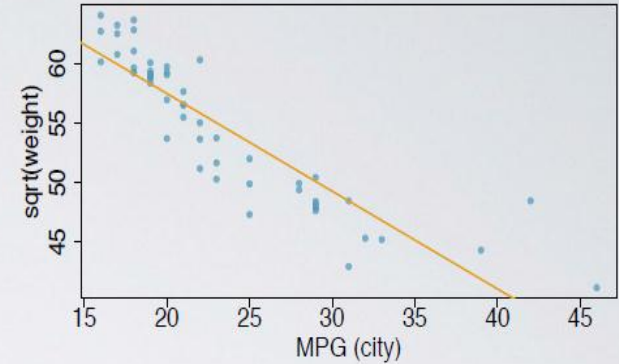
# Transforming data

58

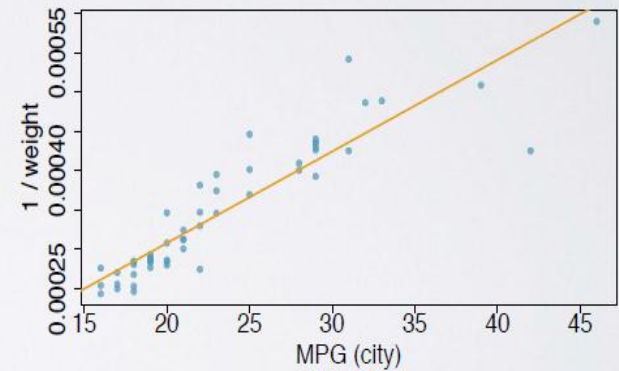
other transformations



*square root*



*inverse*



# Exploring categorical variables

59

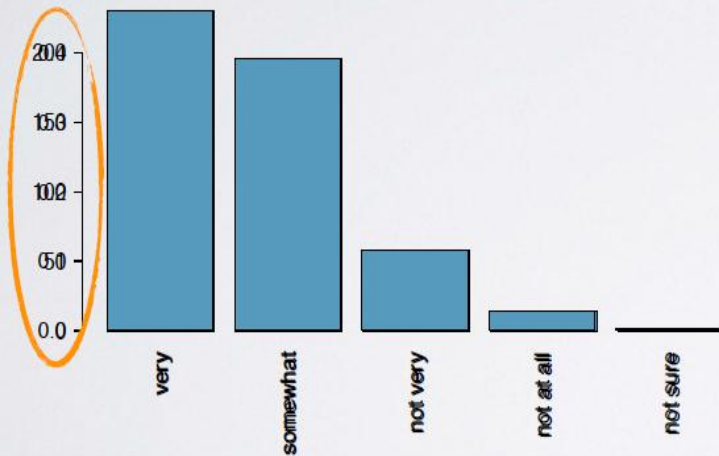
- ▶ describe distribution of a single categorical variable
- ▶ evaluate relationship between two categorical variables
- ▶ evaluate relationship between a categorical and a numerical variable

# Exploring categorical variables

60

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

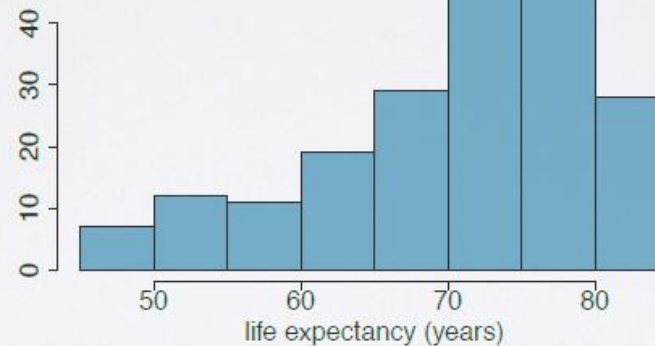
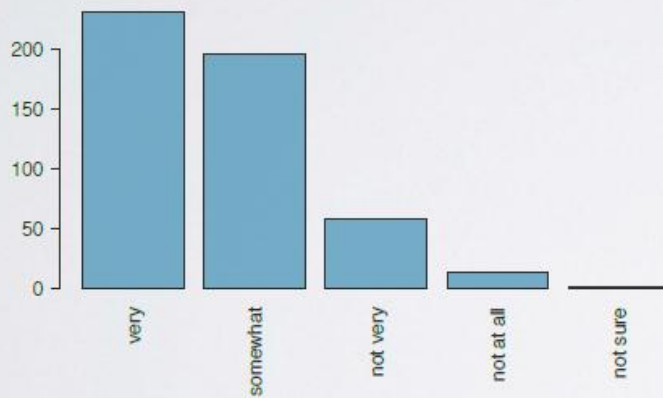


# Exploring categorical variables

61

How are bar plots different than histograms?

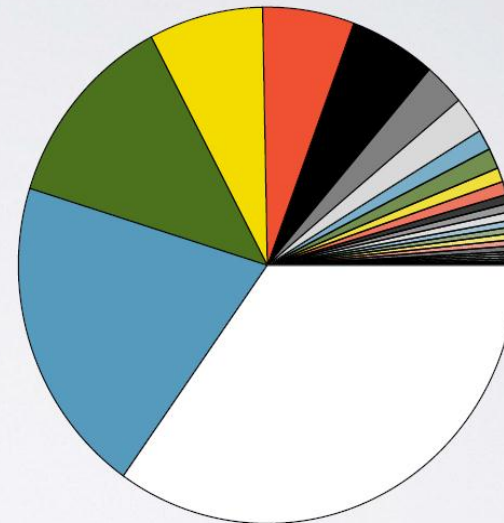
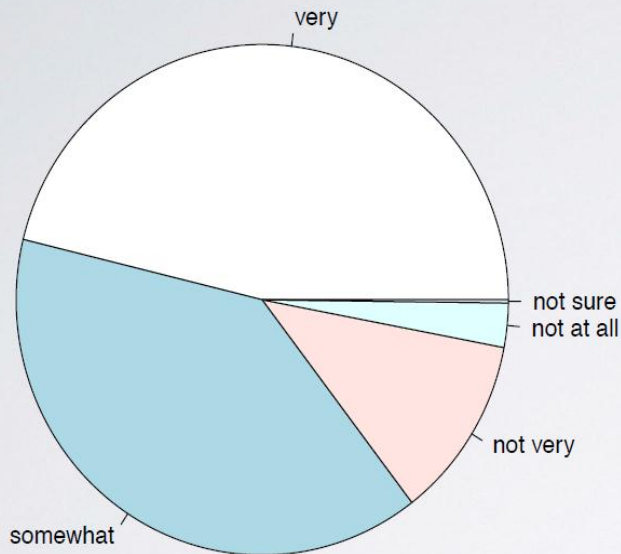
- ▶ barplots for categorical variables, histograms for numerical variables
- ▶ x-axis on a histogram is a number line, and the ordering of the bars are not interchangeable



# Exploring categorical variables

62

~~pie chart?~~ no!



- RODENTIA
- CHIROPTERA
- CARNIVORA
- ARTIODACTYLA
- PRIMATES
- SORICOMORPHA
- LAGOMORPHA
- DIPROTODONTIA
- DIDELPHIMORPHIA
- CETACEA
- DASYUROMORPHIA
- AFROSORICIDA
- ERINACEOMORPHA
- SCANDENTIA
- PERISSODACTYLA
- HYRACOIDEA
- PERAMELEMORPHIA
- CINGULATA
- PILOSA
- MACROSCELIDEA
- TUBULIDENTATA
- PHOLIDOTA
- MONOTREMATA
- PAUCITUBERCULATA
- SIRENIA
- PROBOSCIDEA
- DERMOPTERA
- NOTORYCTEMORPHIA
- MICROBIOTHERIA

# Exploring categorical variables

63

## 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

64

## □ 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

65

## segmented bar plot

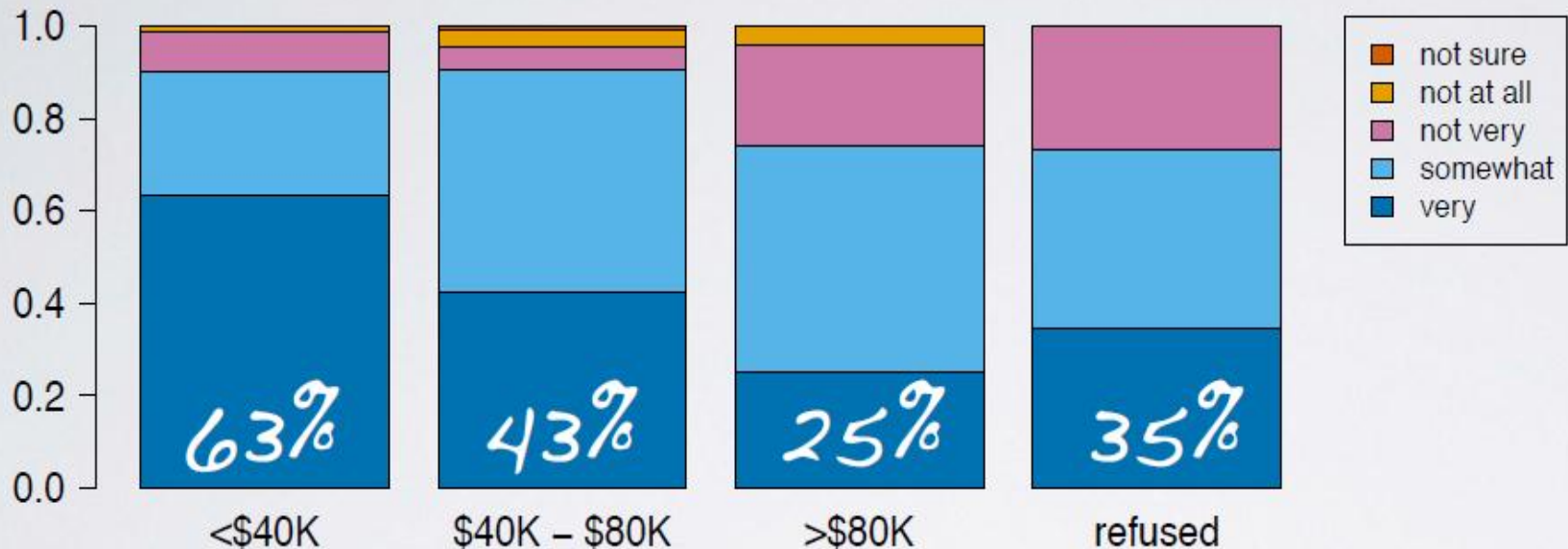


- ▶ useful for visualizing conditional frequency distributions
- ▶ compare relative frequencies to explore the relationship between the variables

# Exploring categorical variables

66

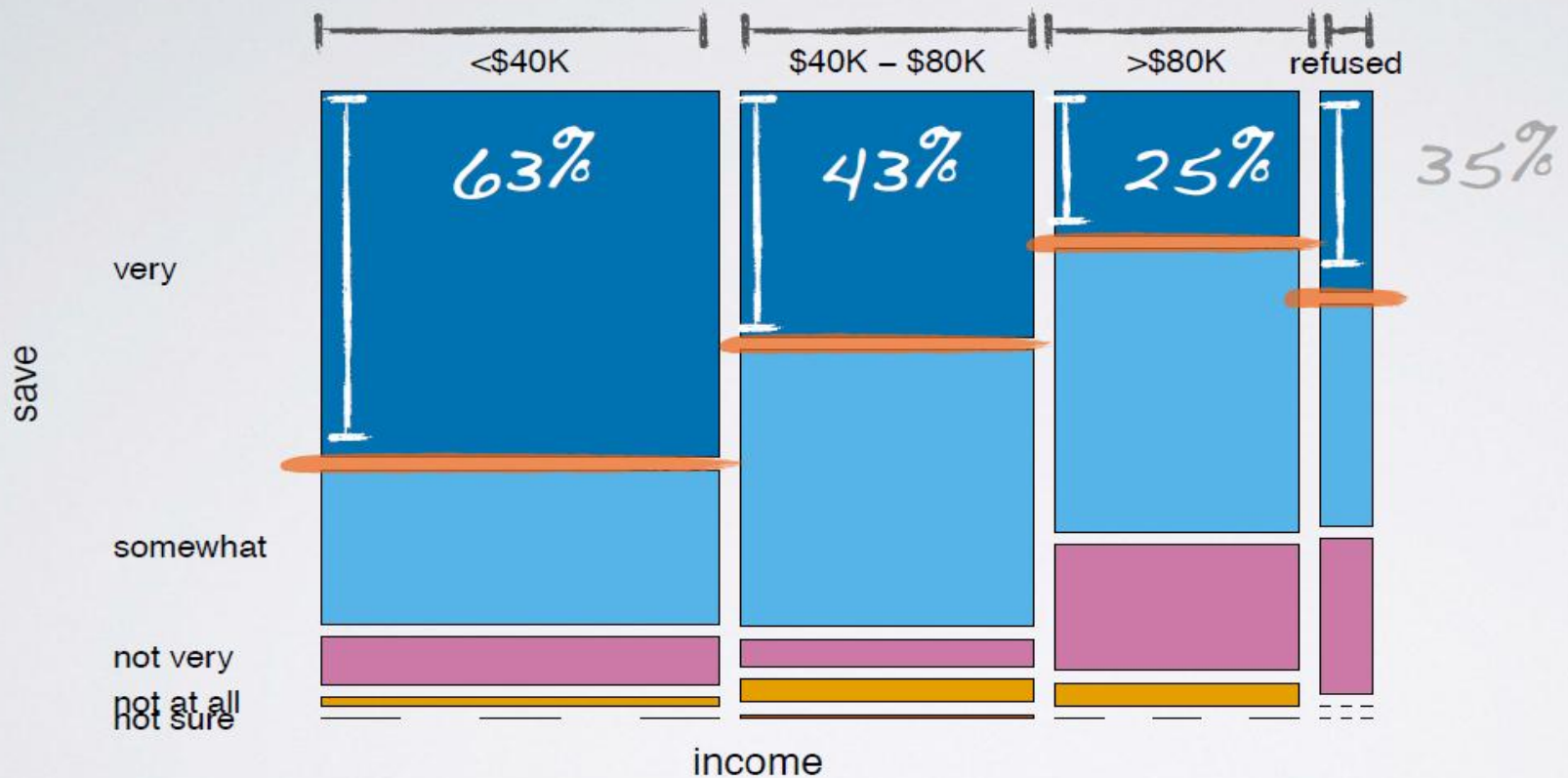
relative frequency segmented bar plot



# Exploring categorical variables

67

mosaicplot



# Exploring categorical variables

68

side-by-side box plots

