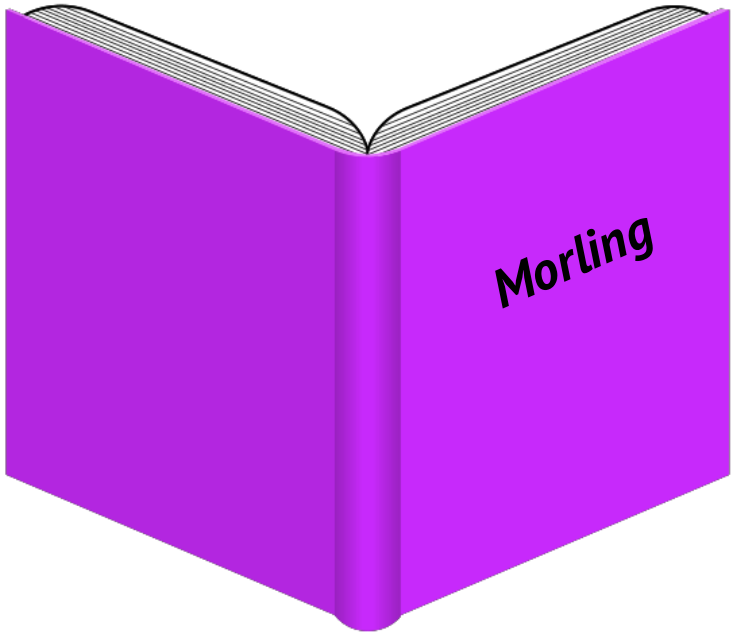

Research Methods and Statistics

Lecture 3: Why are statistics needed? + Exploring data

Johnny van Doorn

Pictures source: pixabay.org


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DELL

Induction

Observation

Theory

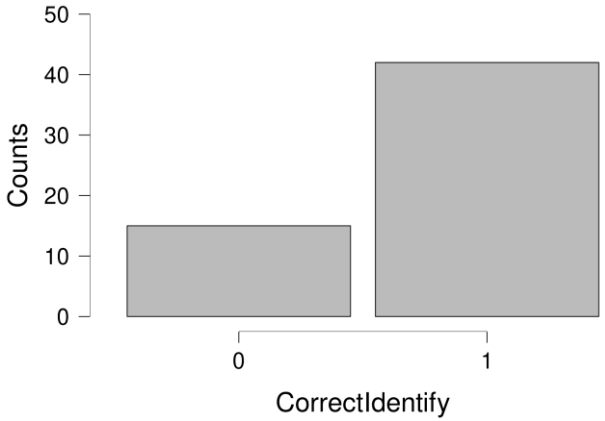
Evaluation

Deduction

42 correct (73.7%)
15 incorrect (26.3%)

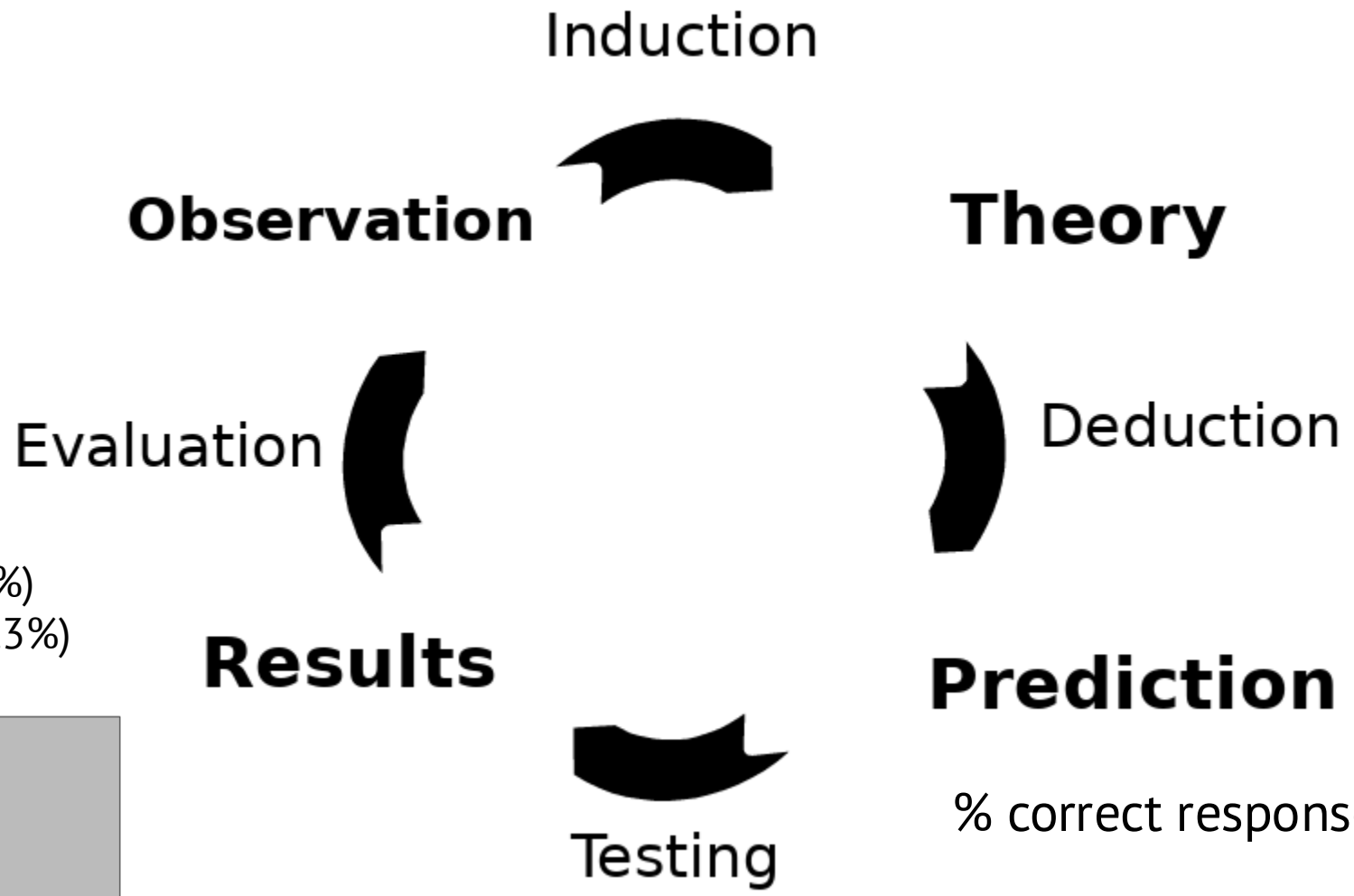
Results

Prediction

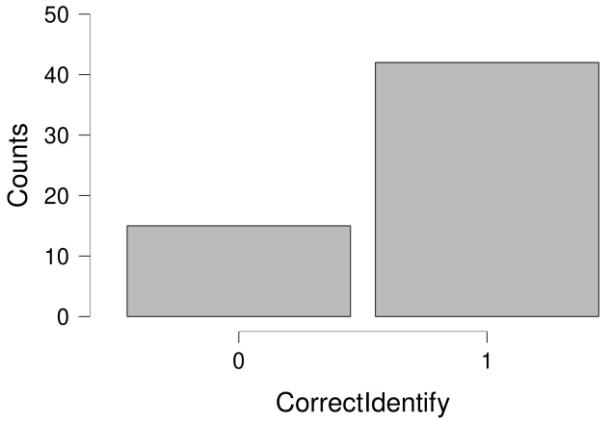


Testing

% correct responses = 50%



42 correct (73.7%)
15 incorrect (26.3%)



% correct responses > 50%

Questions that come up

- How do we know that this conclusion is correct?
- How do we know that this study is performed accurately?
- How do we know that this is not a coincidence?

Today

1. **Why are statistics needed?**
2. A little bit about the course
   - The book: Agresti & Franklin
   - Comparison to high school math
   - How to prepare
3. How can you explore data?
   - Types of data
   - Displaying data
   - Characteristics of a distribution
4. Recap
   - Next time
   - Example exam question

Why are statistics needed?

What is science?

Last week Riet said: “The search for how the world works”

- Formal vs empirical sciences
- Empirical sciences are based on experience / observation
- Inductive reasoning: specific → general

Why are statistics needed?

What is statistics?

Agresti & Franklin: "*Statistics is the art and science of learning from data*" (p. 4)

- Systematically note experiences/observations → data
- Data become overwhelming quickly

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Why are statistics needed?

What is statistics?

Agresti & Franklin: "Statistics is the art and science of learning from data" (p. 4)

- Systematically note experiences/observations → data
- Data become overwhelming quickly
  - CITO data: 159,994 children, 200 questions (picture displays 30 children x 22 questions)
  - IQ scores: +- 1,000 observations
- And we want to *learn* from the data!

Why are statistics needed?

What is statistics?

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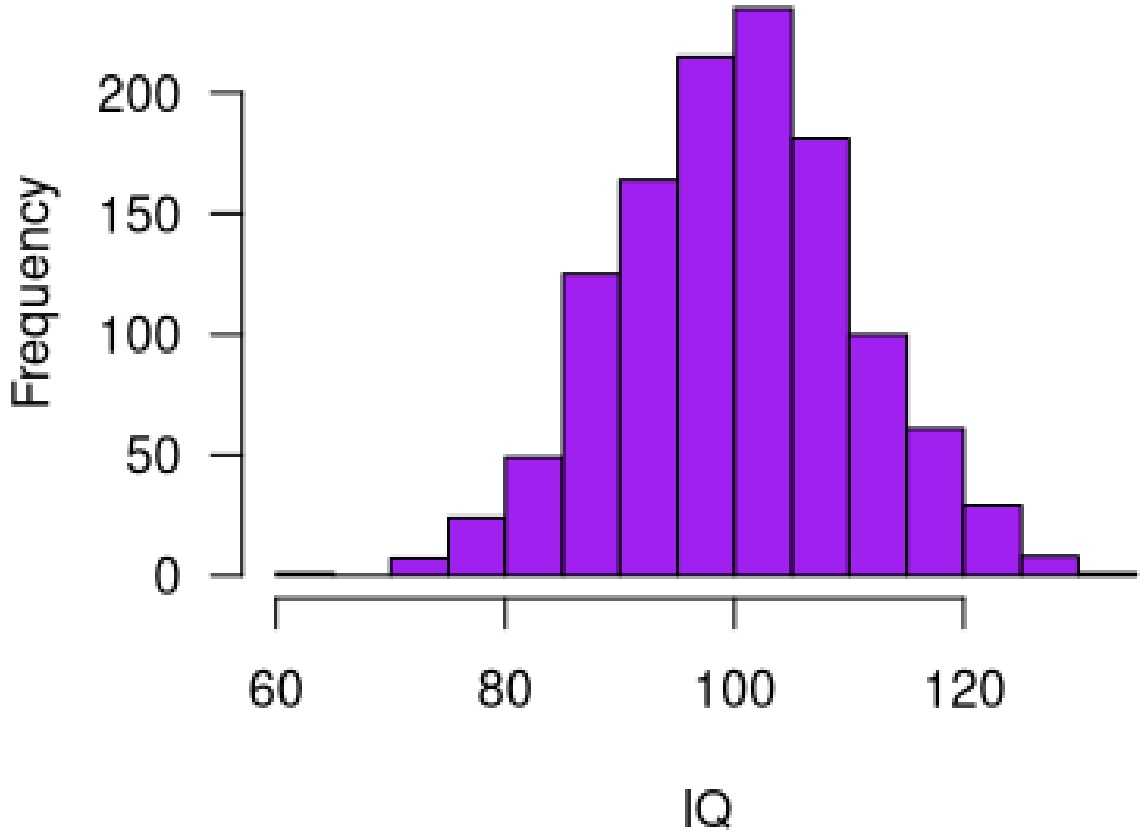
Three components:

- *Experimental Design* (i.e., Research Methods)
- *Descriptive statistics* (summarize/compress all the data)
- *Inferential statistics* (learn from the data, generalize)

Why are statistics needed?

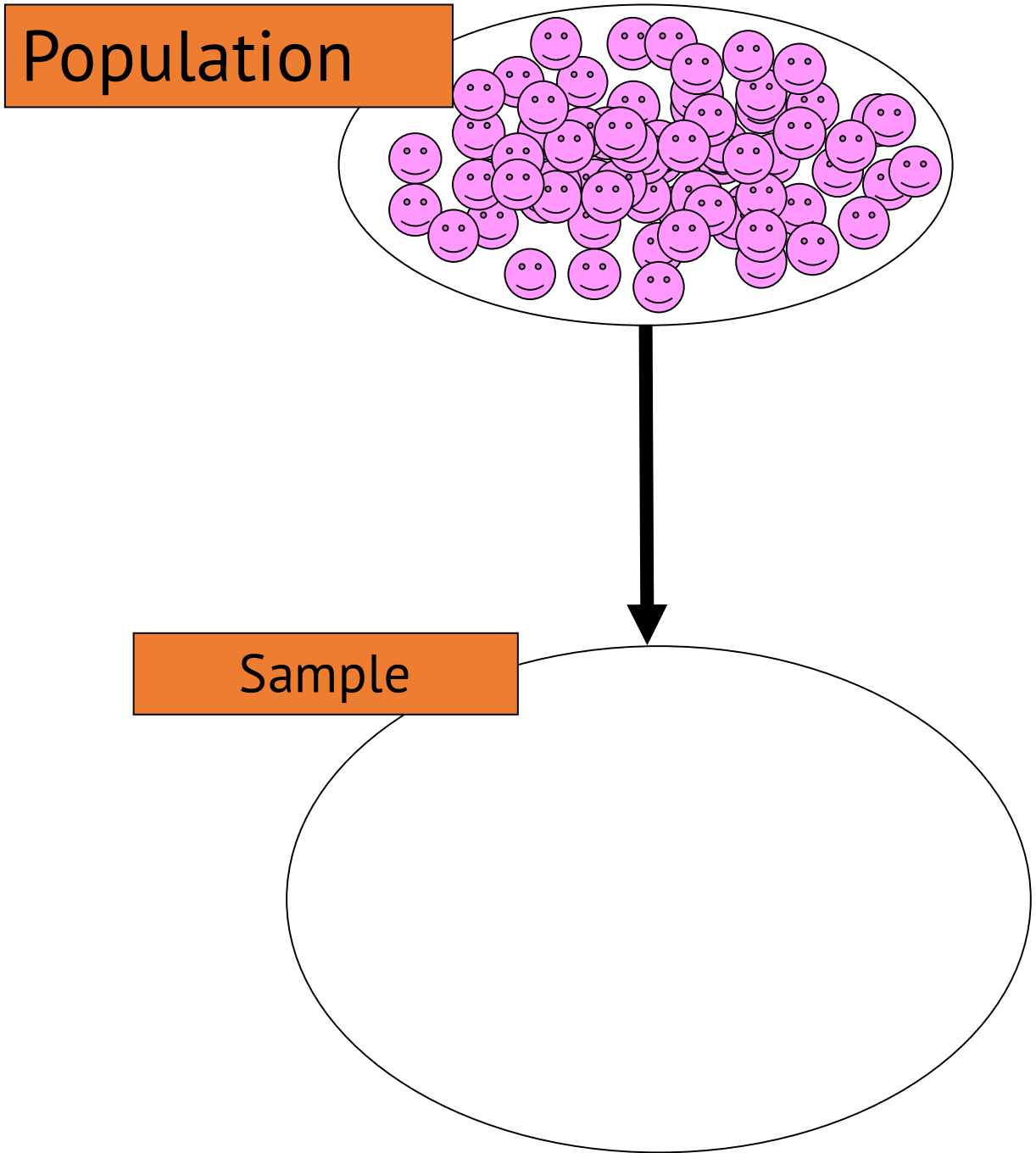
- Descriptive statistics
  - Numerically (ie, average values)
    - → Mean IQ = 101.3
  - Graphically (ie, a histogram)



A Statistic: A numerical summary of the data is called a statistic

Why are statistics needed?

- Inferential statistics
  - Making predictions and decisions about the **population**
  - Assessing the uncertainty about statements


Population
Sample

Why are statistics needed?

- Inferential statistics
  - Making predictions and decisions about the population

Population: **All** scores/data we are interested in
Sample: The part of the population that we have actually observed
Inference: Drawing a conclusion about the population, based on the sample

- Many things can go wrong when drawing inferences → Statistics

Why are statistics needed?

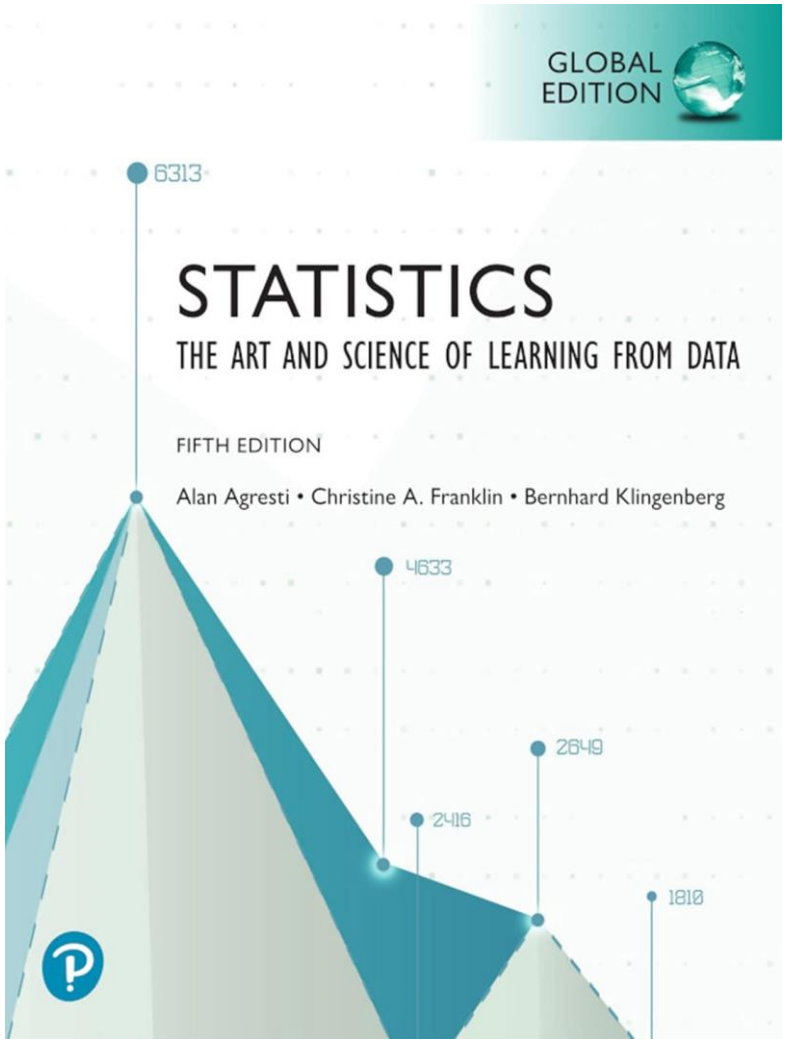
- Reproducibility crisis:
  - Center for Open Science tried to replicate 100 published psychological studies
  - Only 35 studies replicated

- https://science.sciencemag.org/content/349/6251/aac4716.full?ijkey=1xgFoCnpLswpk&keytype=ref&siteid=sci
- https://en.wikipedia.org/wiki/Reproducibility_Project

Overview of Today

1. Why are statistics needed?
2. **A little bit about the course**
   - The book: Agresti & Franklin
   - Comparison to high school math
   - How to prepare
3. How can you explore data?
   - Types of data
   - Displaying data
   - Characteristics of a distribution
4. Recap
   - Next time
   - Example exam question

Agresti & Franklin book



Do we all have the book?

+ Excellent explanations
+ Many examples
+ Many practice questions
+ Summary of each chapter
- Boring at times
- Difficult to find specific topics

Basis of the course: Read -> Practice

Lectures vs practice

- Learning Statistics is mainly ***doing***
  - "Like riding a bike"
- Practice, Practice, Practice

- Lectures:
  - Provide structure
  - Point to important topics
  - Extra explanation of difficult topics

- *Caveat: The lectures are not a complete summary of all topics!*
  - *Always check the Canvas modules for the interim exam information*
  - *→ Formula sheet*

Comparison to high school math

- Some topics are a repetition of high school math (Dutch system: “Wiskunde A/C”)
- Examples:
  - Some descriptive statistics (mean, median, quartiles, standard deviation) and graphs
  - Probability, probability distributions etc.
  - Population vs sample
  - Hypothesis testing

- In our course:
  - Short recap + extension
  - Deeper knowledge + relevant applications to psychological science

- *More focus on **understanding***

How to prepare for the course (stats)?!

- The different stages of confusion when learning statistics
  - Book: can keep rereading
  - Exercises: can keep (re)doing
  - Lectures: happen once

- Use the practicals
- Use the Canvas discussion board
  - Preferred to sending us a direct message
    - If you do send a direct message, please indicate who you send it to! (Riet and/or Johnny)
- Work together on the exercises

How to prepare for the exam?!

- Practice the exercises, WA, trial exam, formula sheet (see Canvas)
- Practice the software (Ans calculator, later Excel)
  → Speed is important!
- Read the book while keeping lecture slides in mind

- On the exam:
  - You don’t have to stick to the question order!
  - Focus on **fast** questions (e.g., without calculations)
  - Focus on **open** question (partial points possible)
  - Then go back to time intensive questions

You'll get there!

https://www.youtube.com/watch?v=JC82Il2cjqA

Overview of Today

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3. **How can you explore data?**
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Types of data

Variable (general): A thing that can take multiple "values"
Variable (book): Any characteristic observed in a study (p. 25)

- "Length": I am 184 cm, you are (most likely) something else
- "Eye Color": Some have green eyes, others have brown eyes

Categorical: Each observation belongs to one category
Quantitative: Each observation has a numerical value representing a magnitude

Discrete: Every observation is one of a specific set of values (e.g., 0, 1, 2)
Continuous: Every observation comes from a range (e.g., 0-3)

Let’s practice this

- “Race track”
  - → Categorical
- “Weight”
  - → Quantitative, continuous
- “Number of students”?
  - → Quantitative, discrete
- “Percentage of students that will pass this course”?
  - → Quantitative, continuous
- “Study year”?
  - → Quantitative, Discrete or Continuous?

Displaying Data

- Data is often overwhelming
- Data is often complex

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24	1	1	1	1	0	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	0	1	0	1	1	1	1	1
25	0	1	1	1	1	1	0	1	1	1	1	1	1	0	0	0	1	1	1	0	1	1	1	1	1	1	1	1	0	1	1	0	1	1	1
26	1	1	1	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1
27	1	1	1	1	1	1	0	0	0	0	1	1	1	1	0	1	0	1	1	0	1	1	1	1	1	1	1	1	0	1	0	1	0	1	0
28	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1
29	1	1	1	1	1	0	1	1	1	1	1	0	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	1
30	1	1	0	1	1	1	0	0	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	0	1	1

- Good display methods help you focus on the relevant aspects of the data

Example 1: Movie genres of the IMDB Top 250

Frequencies for Genres

Genres	Frequency
Drama	73
Comedy	21
Action	35
Crime	34
Adventure	23
Biography	22
Animation	24
Horror	5
Mystery	6
Western	5
Sci-Fi	1
Film-Noir	1
Missing	0
Total	250

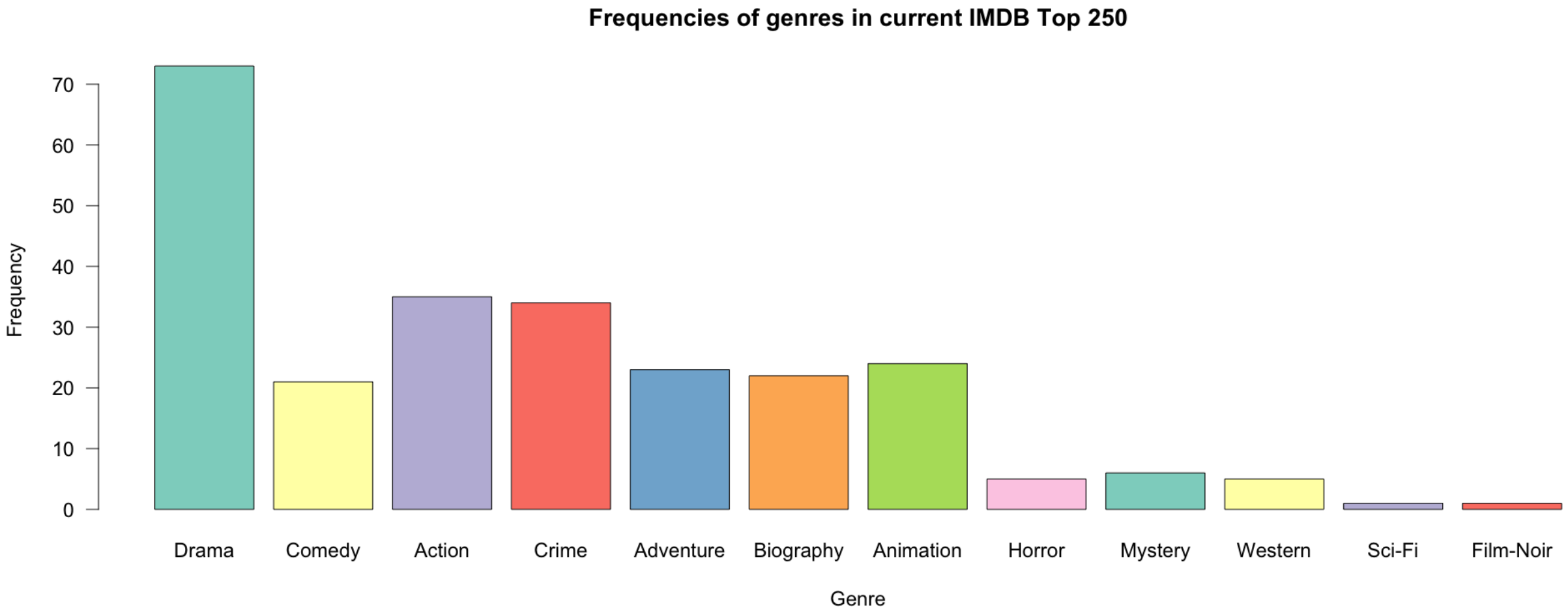
Example 1: Movie genres of the IMDB Top 250

Frequencies for Genres

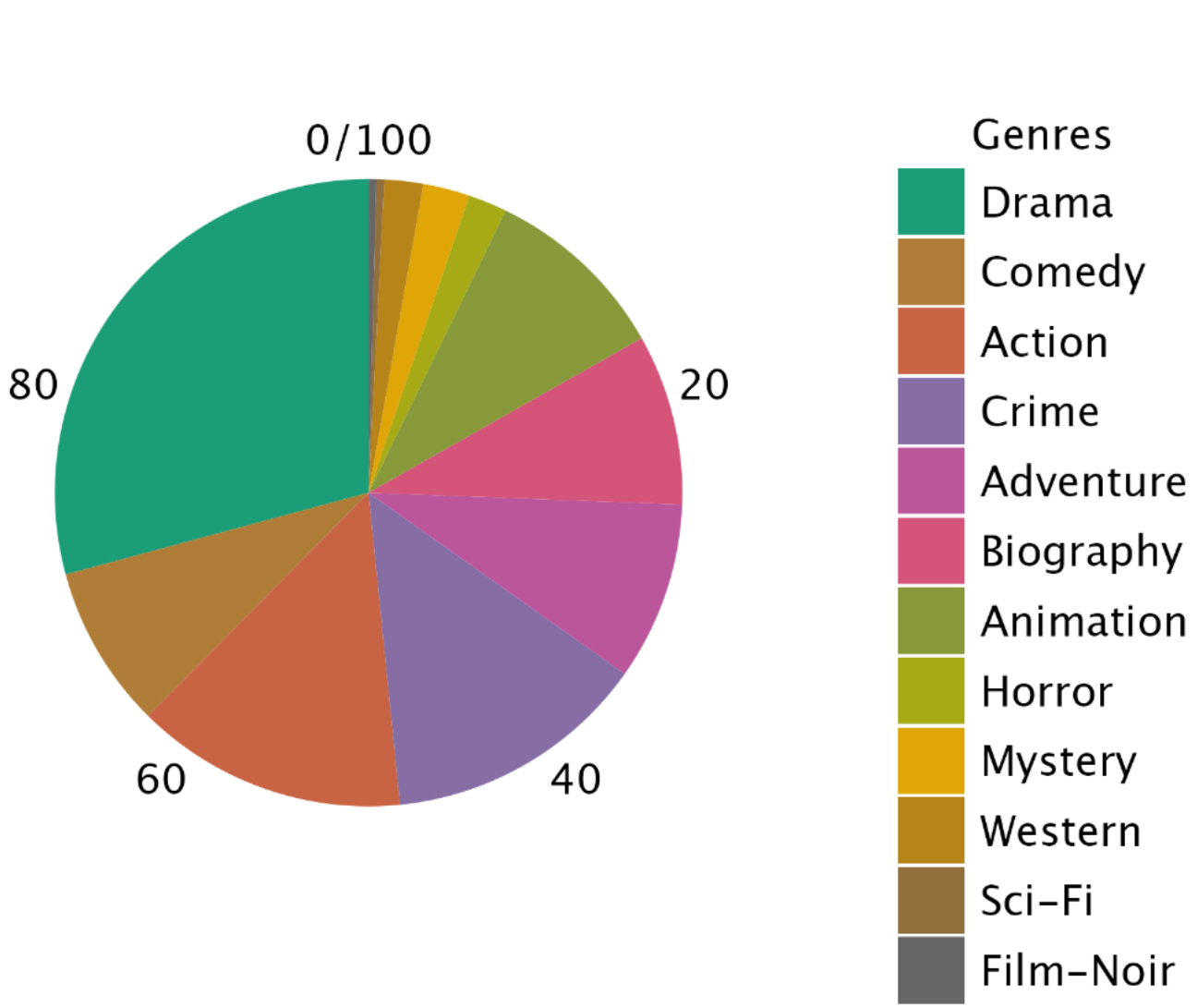
Genres	Frequency	Percent
Drama	73	29.200
Comedy	21	8.400
Action	35	14.000
Crime	34	13.600
Adventure	23	9.200
Biography	22	8.800
Animation	24	9.600
Horror	5	2.000
Mystery	6	2.400
Western	5	2.000
Sci-Fi	1	0.400
Film-Noir	1	0.400
Missing	0	0.000
Total	250	100.000

e.g., 73 / 250 = 0.292 → 29.2%

We can also visualize the frequency table using a bar chart:



We can also visualize the frequency table using a pie chart:



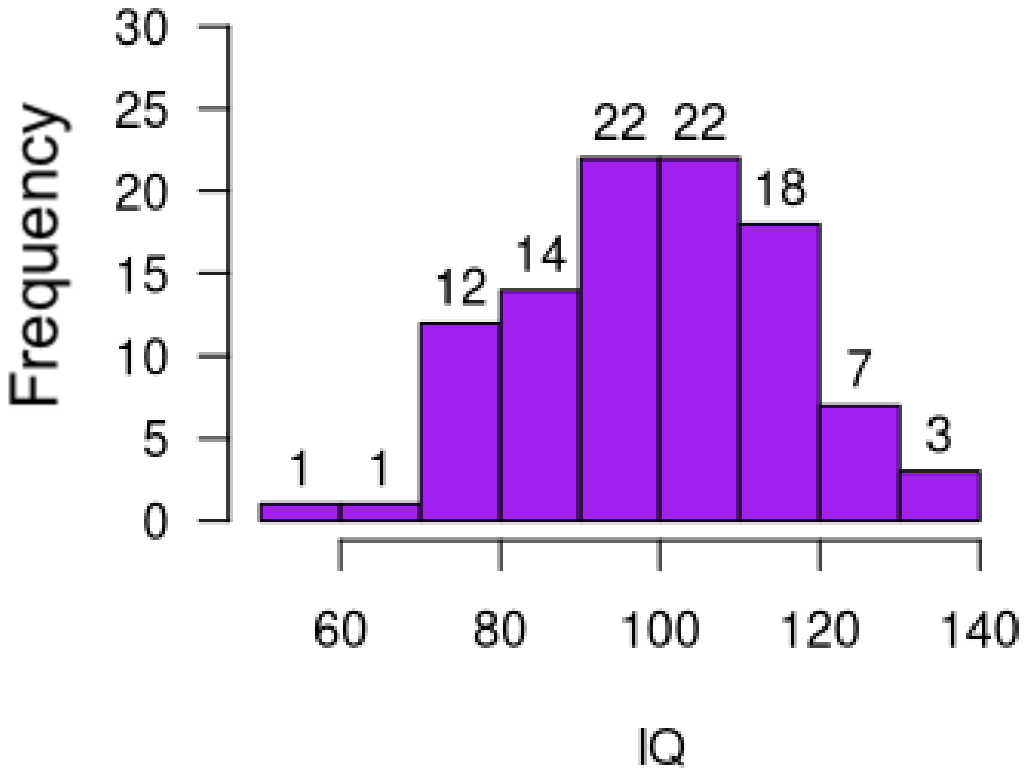
Example 2: IQ

- Standard measure of intelligence
- Set of questions/items leads to a score, such that 100 is average

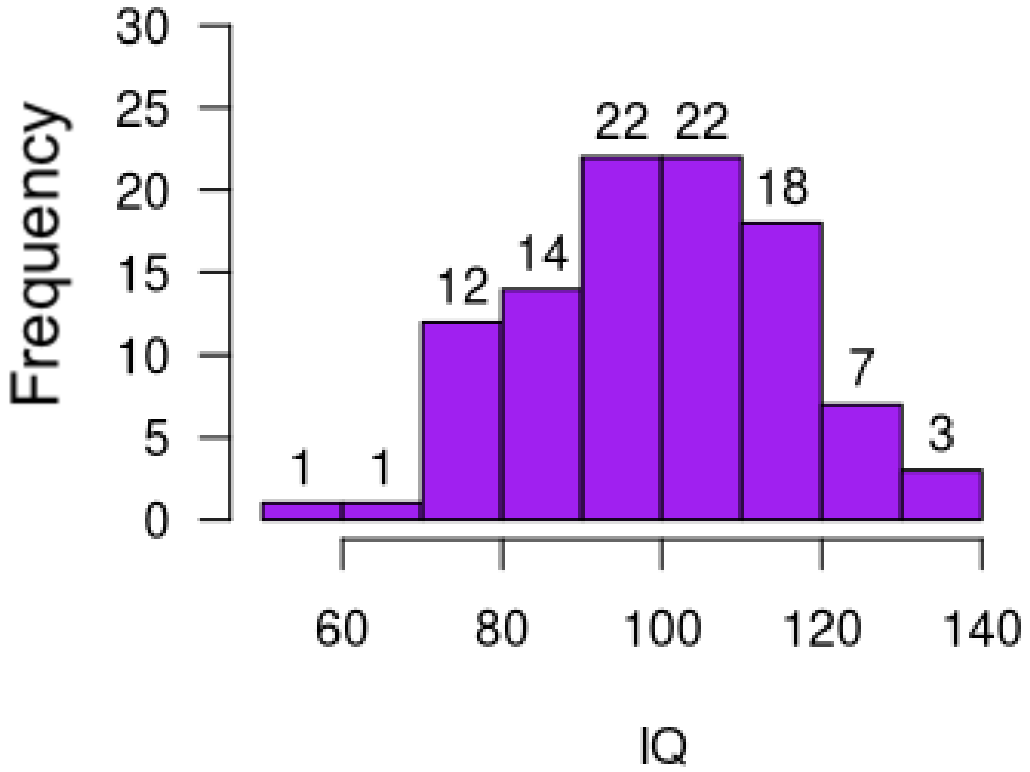
https://en.wikipedia.org/wiki/Alfred_Binet

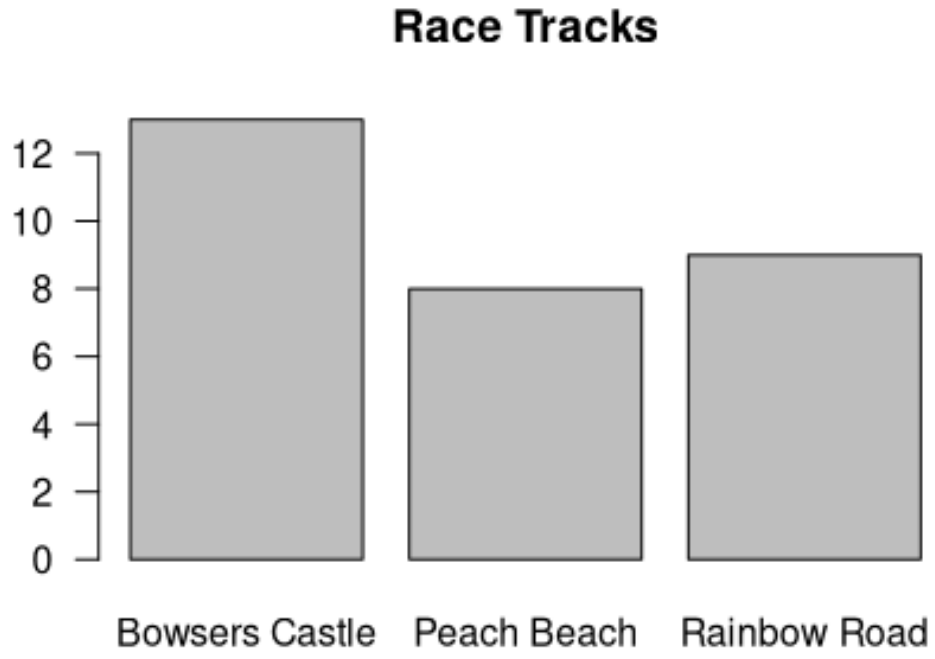
Example 2: IQ Frequencies

IQ range	Frequency
50-60	1
60-70	1
70-80	12
80-90	14
90-100	22
100-110	22
110-120	18
120-130	7
130-140	3
	***n* = 100**



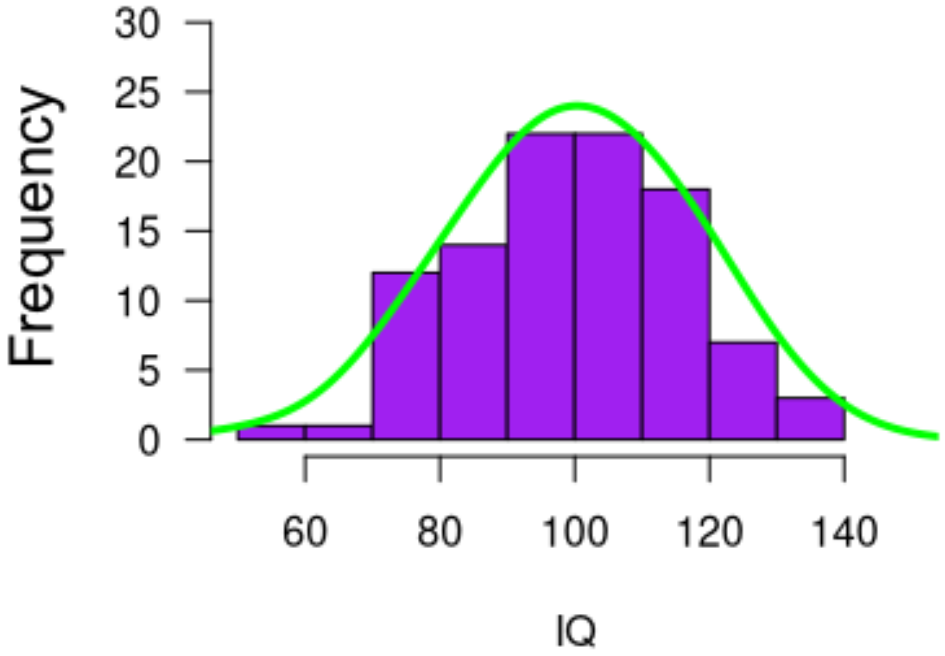
Histogram vs Bar chart



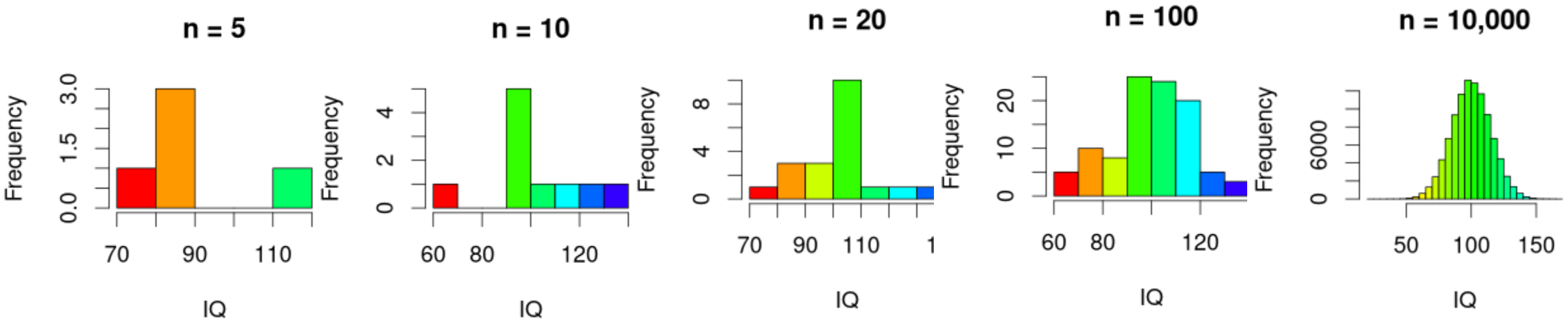


Example 2: IQ

- Really a quantitative variable
- Histogram describes the **sample**
- But the **population** is described by a continuous distribution



From histogram to continuous distribution



Statistic vs parameter

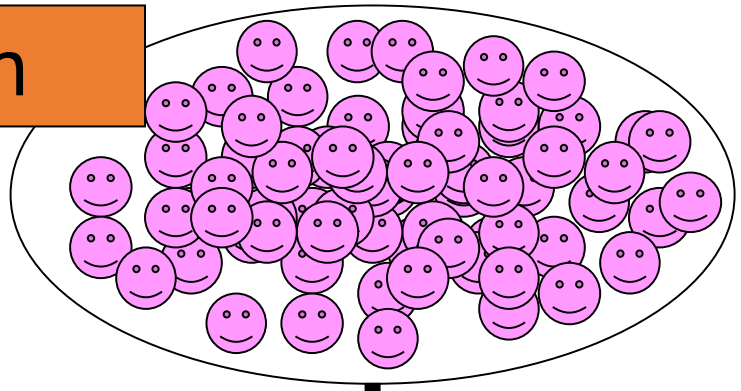
A statistic: A numerical summary of the data is called a statistic

- You can compute this! (mean, median, standard deviation, etc)

A *parameter*: A numerical summary of the population is called a parameter

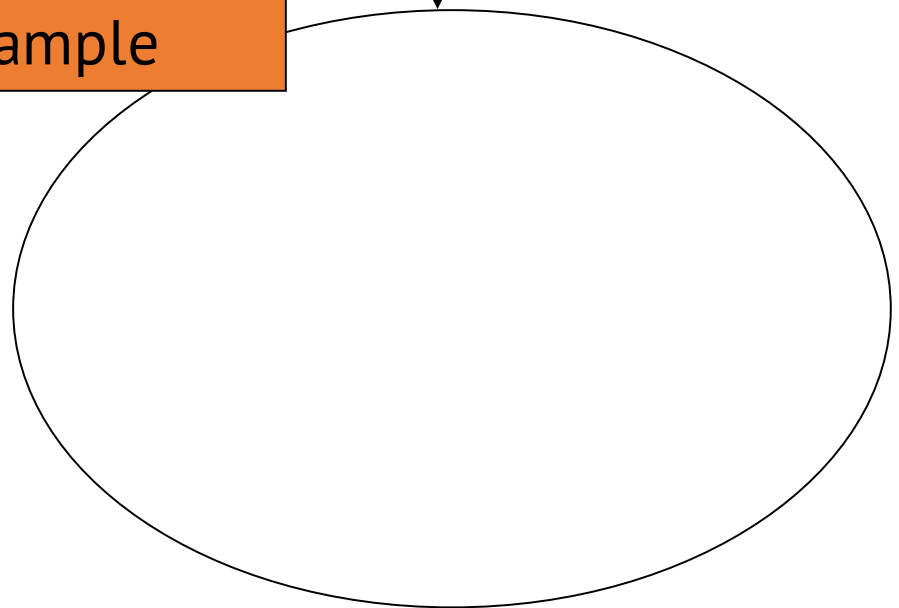
- This cannot be computed (usually)

Population



A *parameter*: A numerical summary of the population is called a parameter

Sample



A statistic: A numerical summary of the data is called a statistic

Statistic vs parameter

A statistic: A numerical summary of the data is called a statistic

- You can compute this! (mean, median, standard deviation, etc)

A *parameter*: A numerical summary of the population is called a parameter

- This cannot be computed (usually)

- ❼ We use statistics to **estimate** parameters

Example: Mean IQ

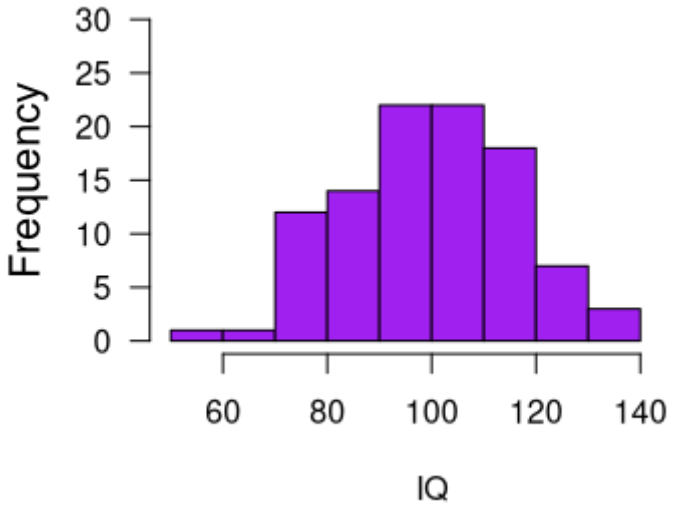
- We want to know the average IQ in particular populations
  - E.g., soccer players vs chess players

- *Location* of the distribution

Source: pixabay.com

Location of the distribution: mean

#	IQ
1	86
2	108
3	64
…	…
99	91
100	**109**

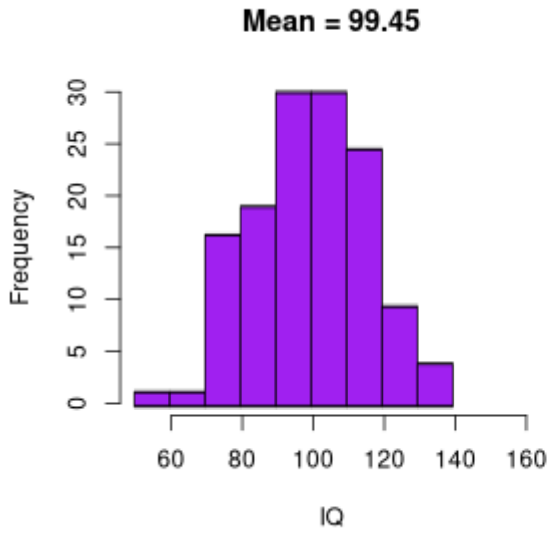


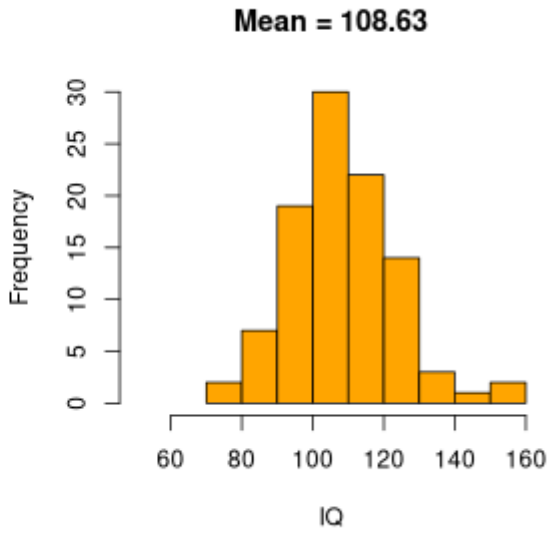
- $\bar{x} = \frac{86+108+64+\cdots+91+109}{100} = 99.45$
- $\bar{x} = \frac{\sum x}{n}$

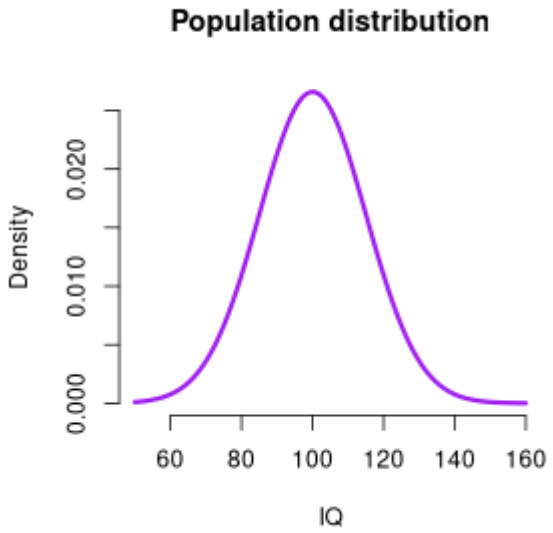
Statistic

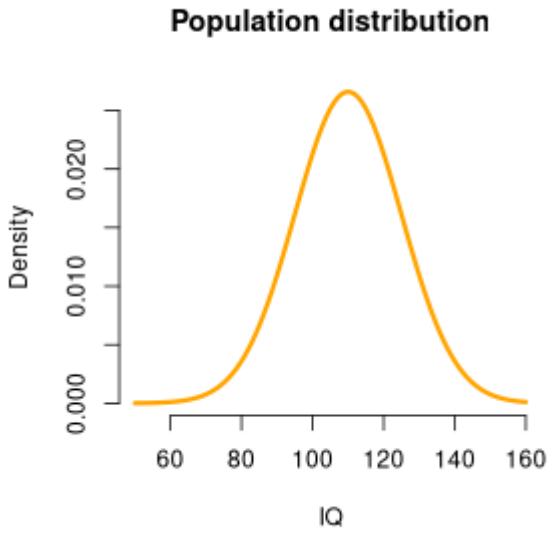
($\sum$ is the symbol for summing up all values of x)

Statistic vs parameter









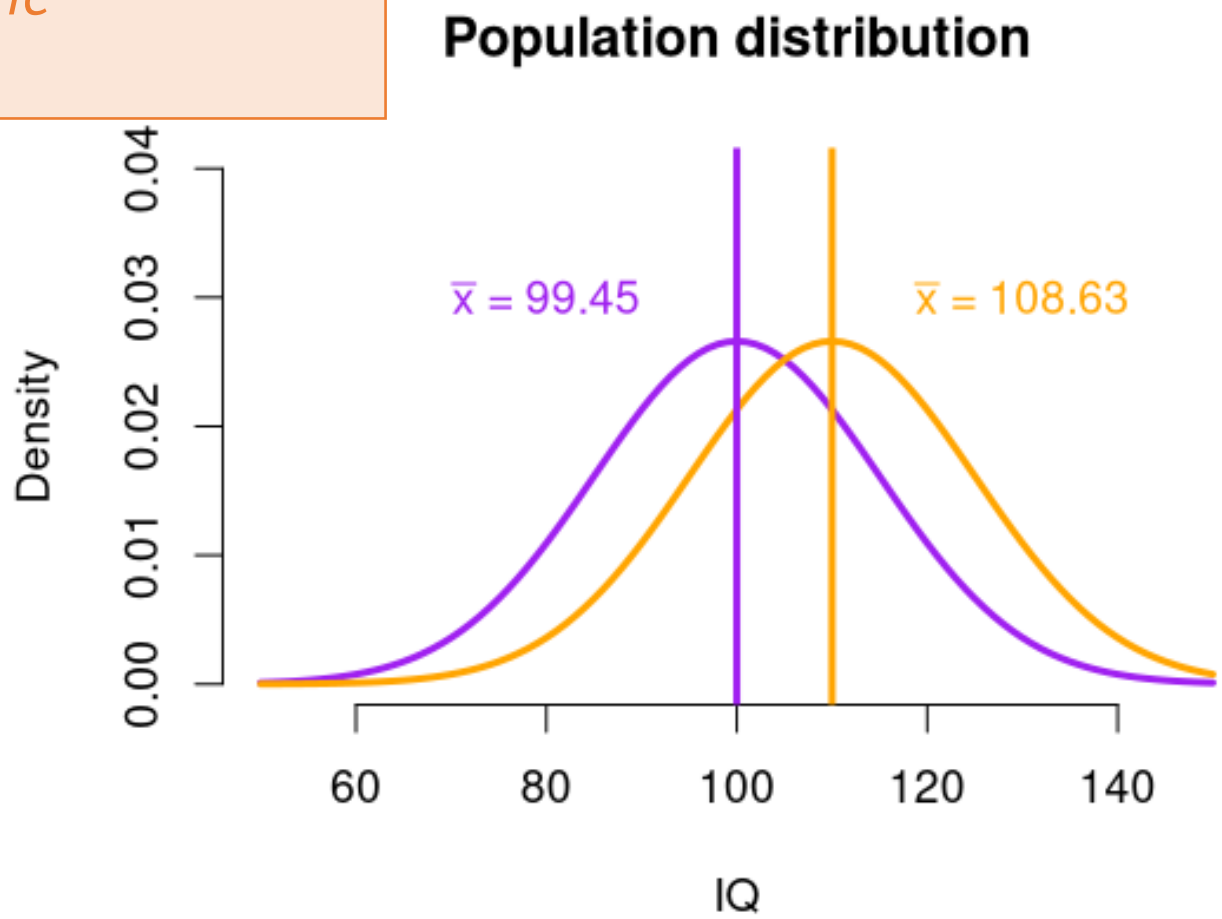
We use the sample to obtain an approximation/estimate of population distribution and parameters

In this case, our best estimate of the population mean, is the sample mean

A difference in means reflects a difference in distributions

Statistic vs parameter

Estimates of the parameters:



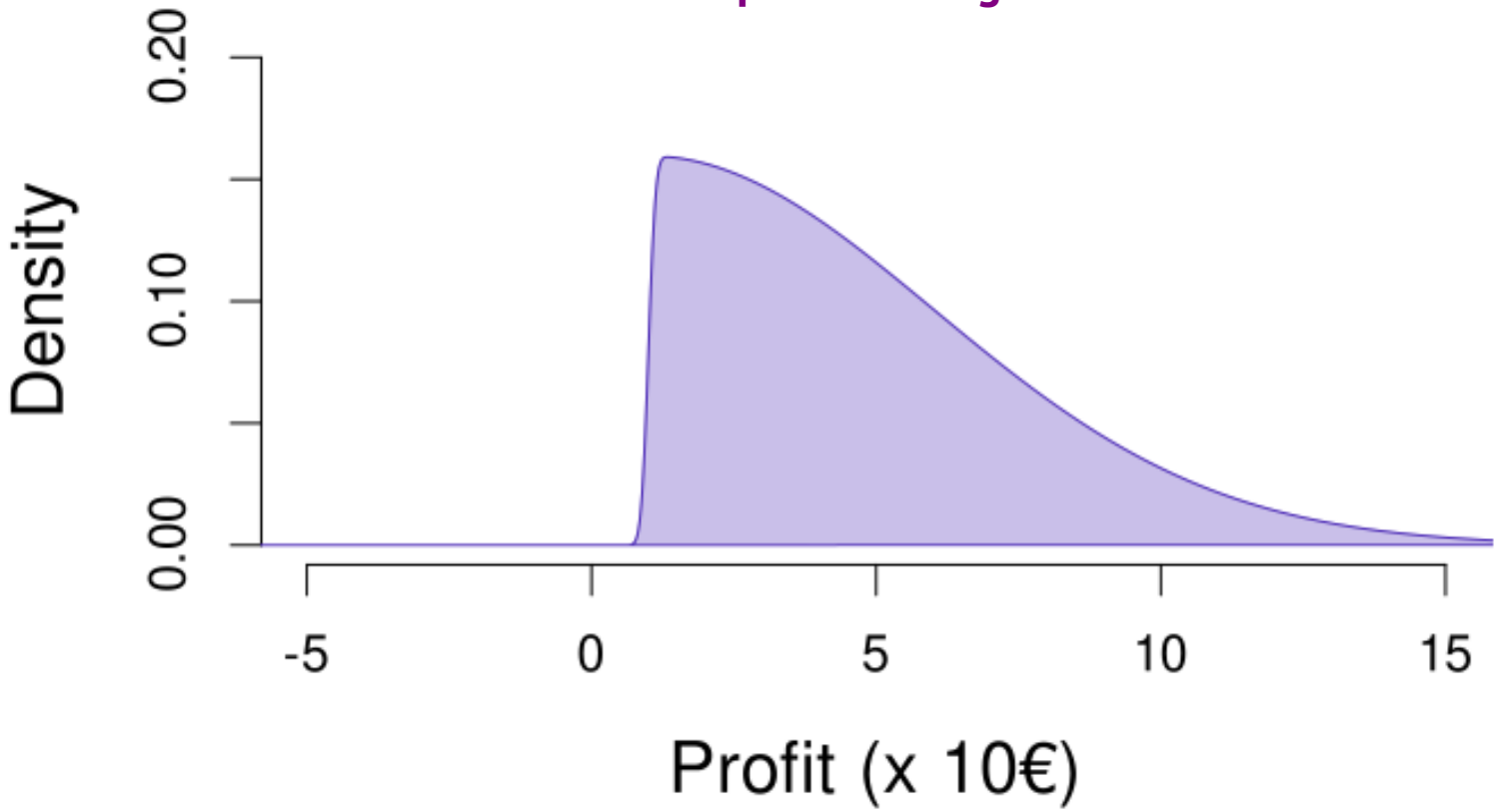
In this case, our best estimate of the population mean, is the sample mean

A difference in means reflects a difference in distributions

Allows us to conclude that there is a difference between the two populations?
→ inferential statistics (later in this course)

Location vs shape of Continuous distributions

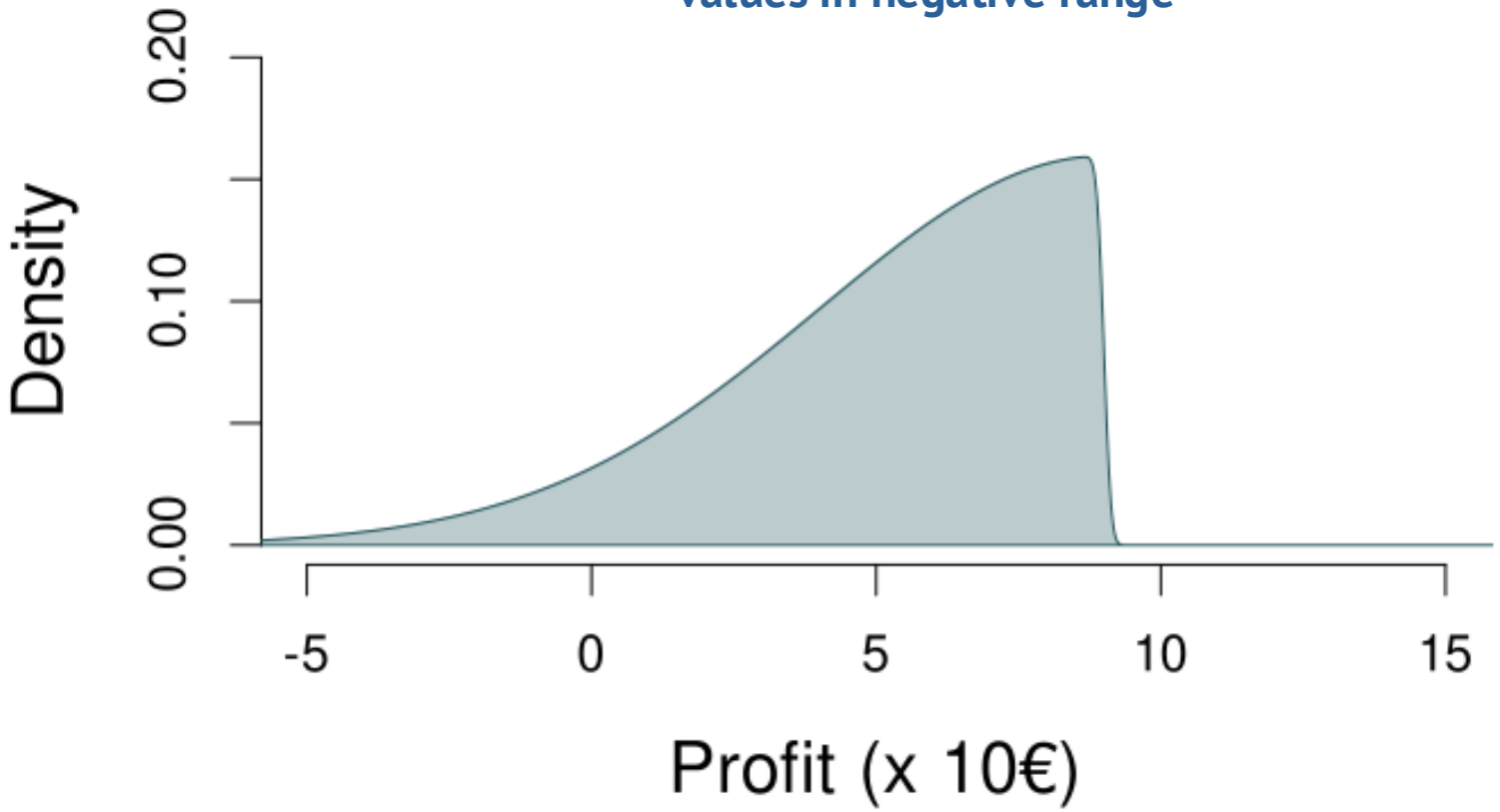
Always a profit, extreme results in the positive range



Source: pixabay.com

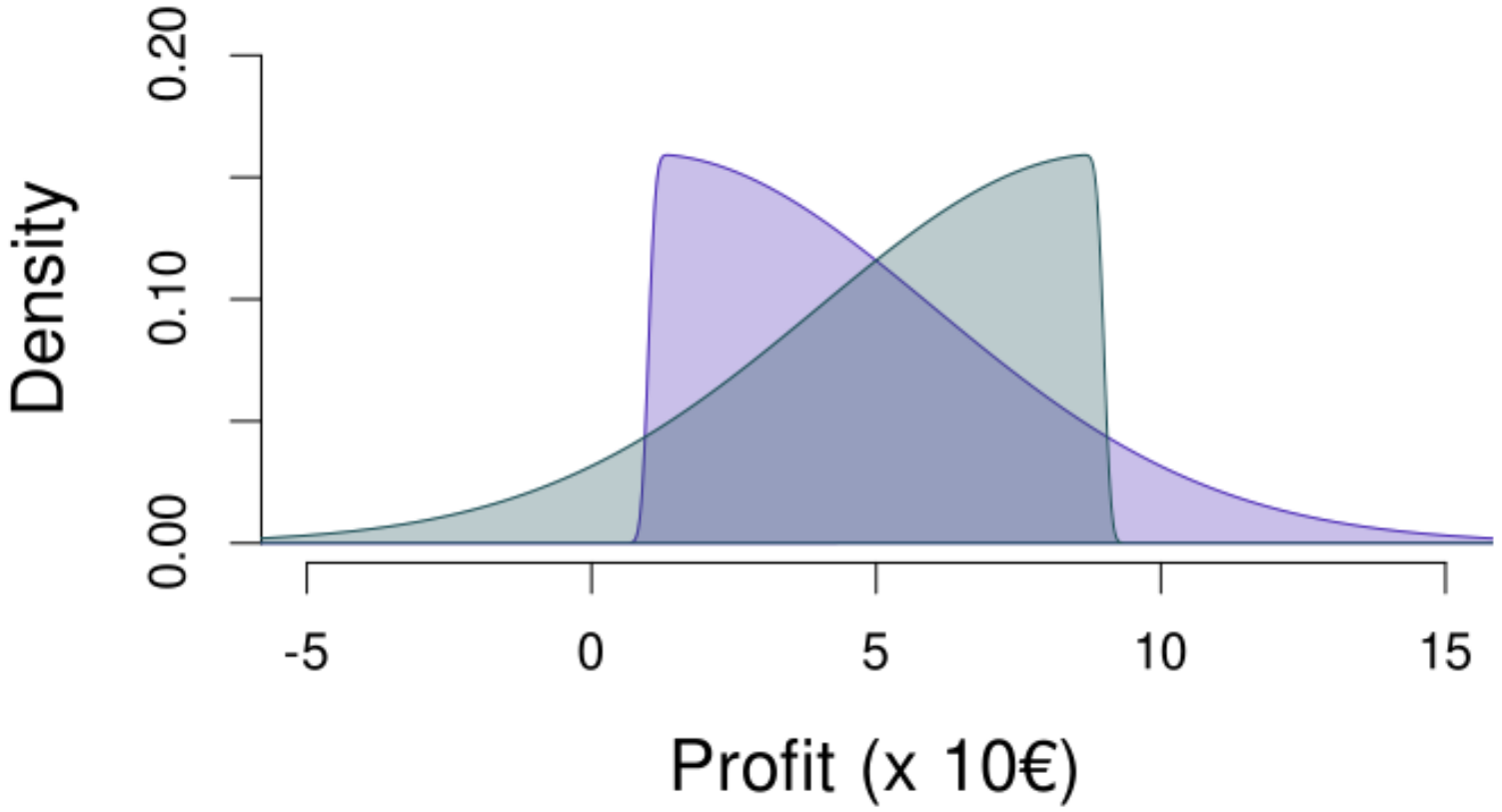
Location vs shape of Continuous distributions

Can suffer loss, extreme values in negative range



Source: pixabay.com

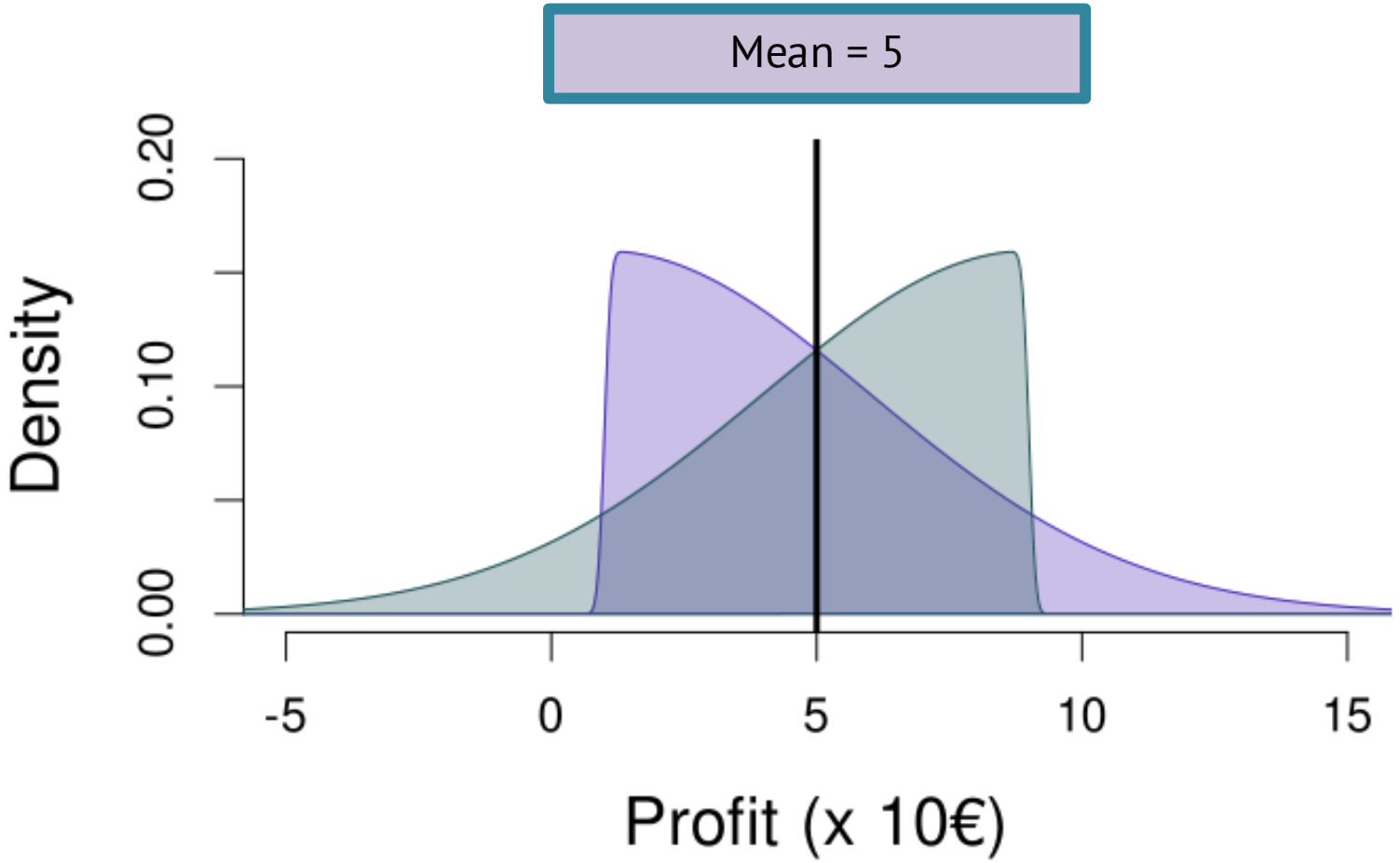
Location vs shape of Continuous distributions



Always a profit, extreme results in the positive range

Can suffer loss, extreme values in negative range

Location vs shape of Continuous distributions



Always a profit, extreme results in the positive range

Can suffer loss, extreme values in negative range

Another location measure: median

- The value that divides the lower 50% of the observations

1. Order all observations
   - If odd *n*: Middle observation

Median = **4**

n = 9

x: 1,9,2,4,5,3,3,7,12

x: 1,2,3,3,**4**,5,7,9,12 (ordered)

   - If even *n*: Mean of middle two observations

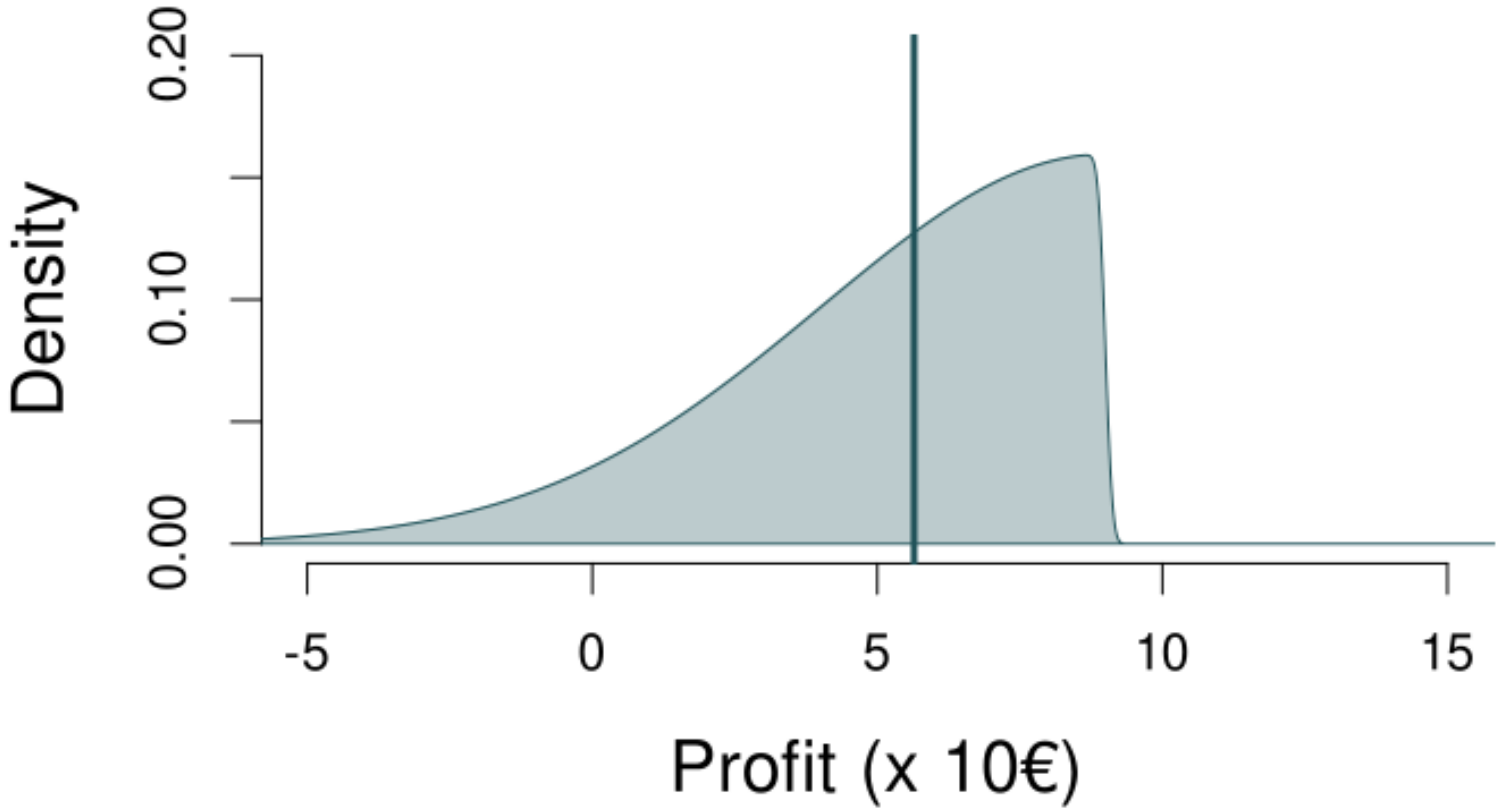
Median = (5+7)/2 = **6**

n = 8

x: 7,9,4,5,-1,8,9,2

x: -1,2,4,**5,7**,8,9,9 (ordered)

The Median of a Continuous Distribution



Median ≈ 5.63

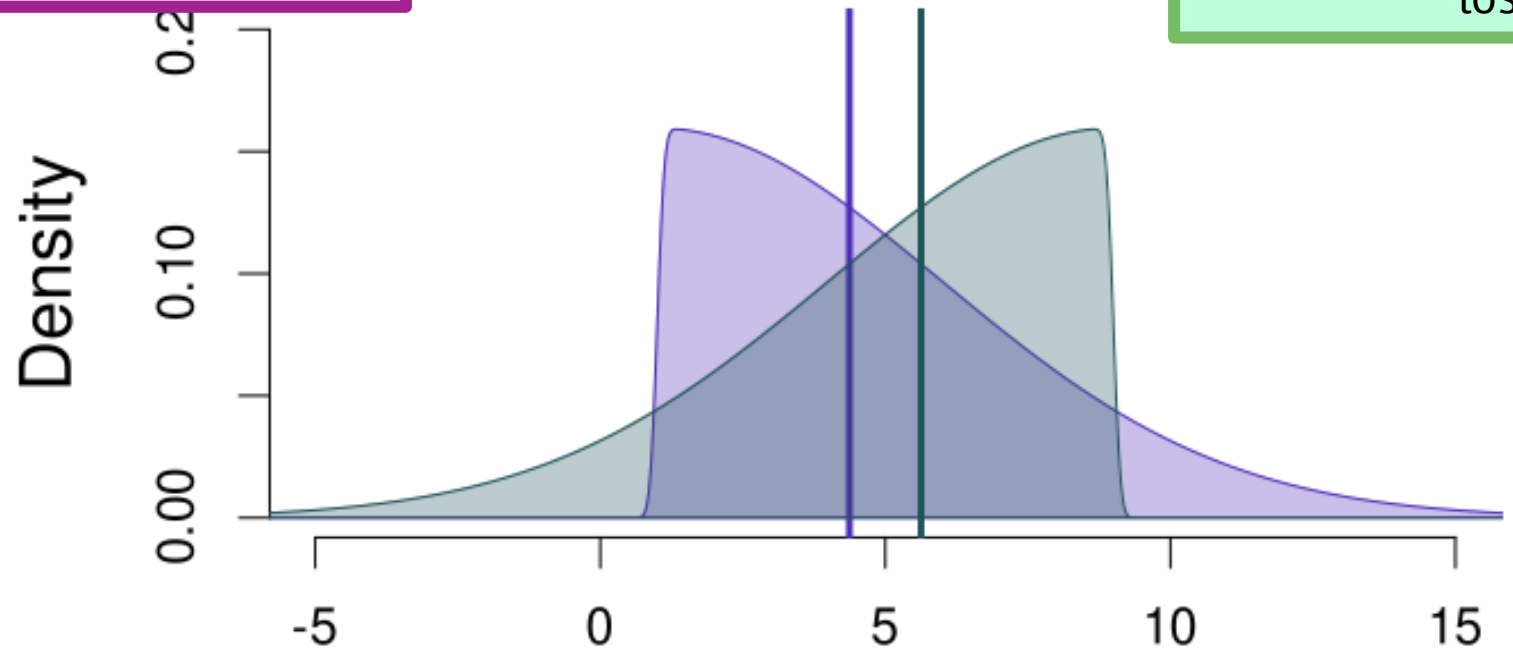
If you play this game, there is a 50% probability that your profit is 5.63 or **lower**

If you play this game, there is a 50% probability that your profit is 5.63 or **higher**

The Median of a Continuous Distribution

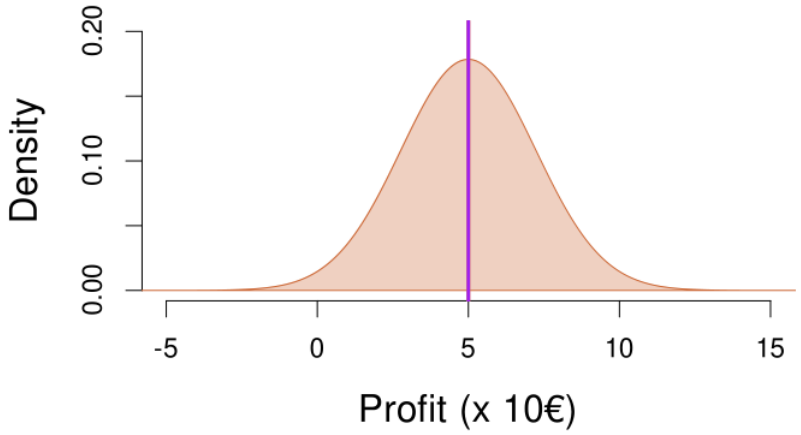
Median ≈ 4.37
Most sessions pay less than average, with a rare big win

Median ≈ 5.63
Most sessions pay more than average, with a rare heavy loss



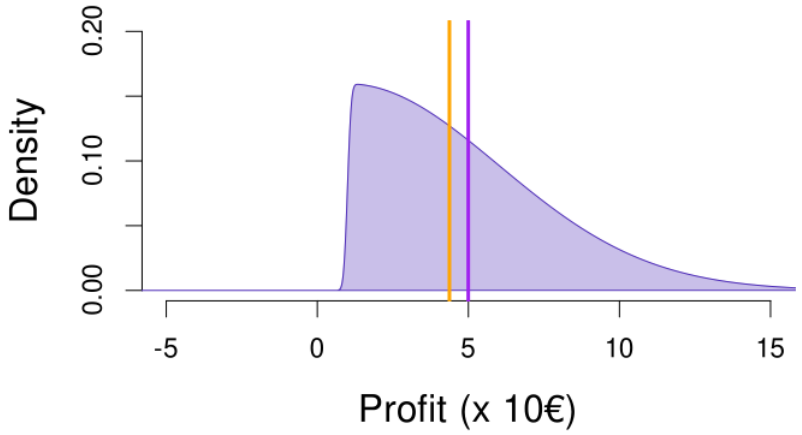
On average (over the course of many sessions), it will not matter for your wallet, but each machine provides a different experience:
Purple: chasing a jackpot, while never losing
Green: getting many bigger wins but suffering the occasional loss

Mean vs Median tells something about shape of a distribution



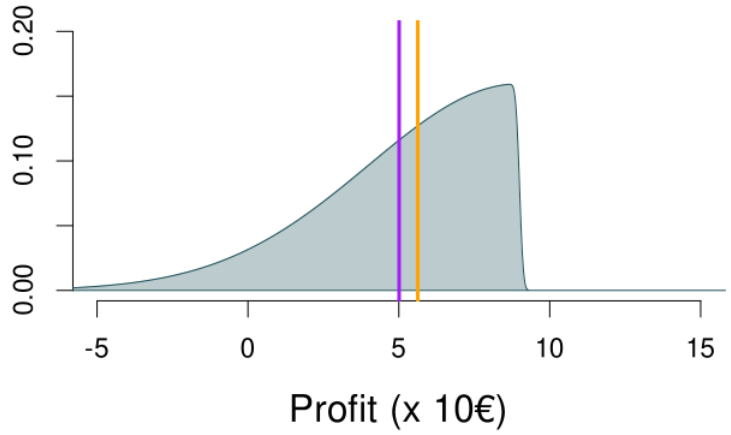
Symmetric distribution

Mean = *Median*



Skewed to the right

Mean > *Median*



Skewed to the left

Mean < *Median*

Why is that?

- x = 3, 5, 4, 8, 10
  - ➔ Mean: (3 + 5 + 4 + 8 + 10) / 5 = 6
  - ➔ Median: n is odd, so middle number of sorted x ⟶ 5
- x = 3, 5, 4, 8, 9000
  - ➔ Mean: (3 + 5 + 4 + 8 + 9000) / 5 = 1804
  - ➔ Median: n is odd, so middle number of sorted x ⟶ 5

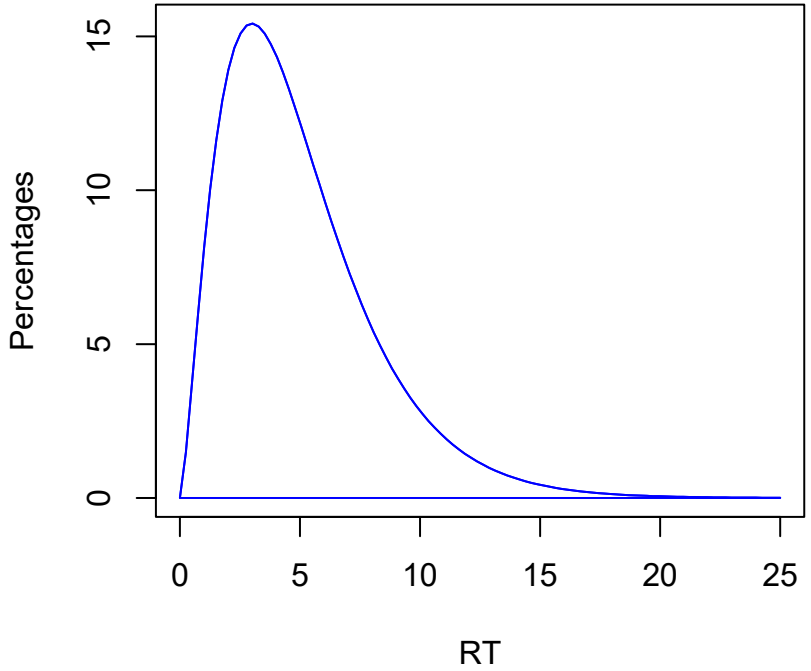
The median ignores extreme values, so is less affected by those (compared to the mean)

Overview of Today

1. Why are statistics needed?
2. A little bit about the course
   - The book: Agresti & Franklin
   - Comparison to high school math
   - How to prepare
3. How can you explore data?
   - Types of data
   - Displaying data
   - Characteristics of a distribution
4. **Recap**
   - Next time
   - Example exam question

Example question

- The figure displays a skewed distribution



- Which statement about the mean and median of this distribution is true?

a. median < mean

b. median = mean

c. median > mean

Recap of Today

- Why statistics?
  - Get an overview of data, numerically or graphically → descriptive statistics
  - Make statements about the whole population, based on a sample from the population → inferential statistics
- Different types of variables exist (e.g., discrete vs. continuous)

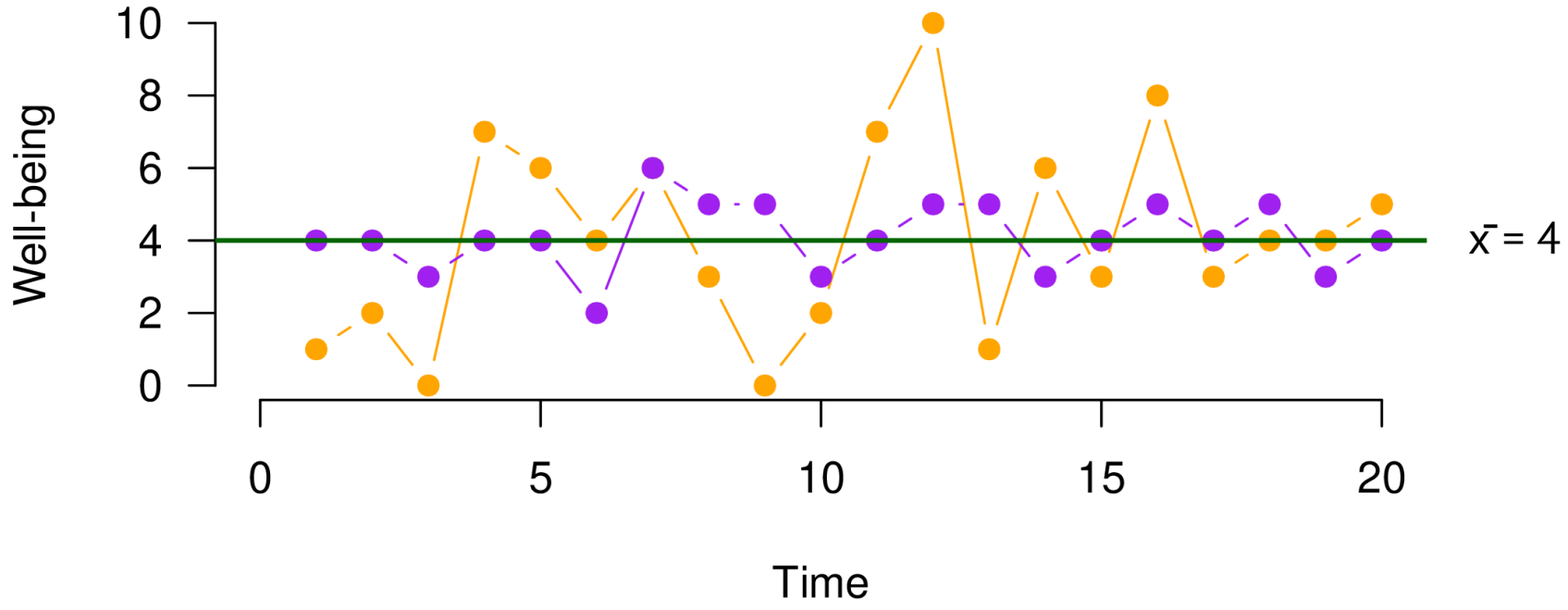
- Science quality = methods + statistics

Design experiments & gather data

Analyze the data and draw conclusions

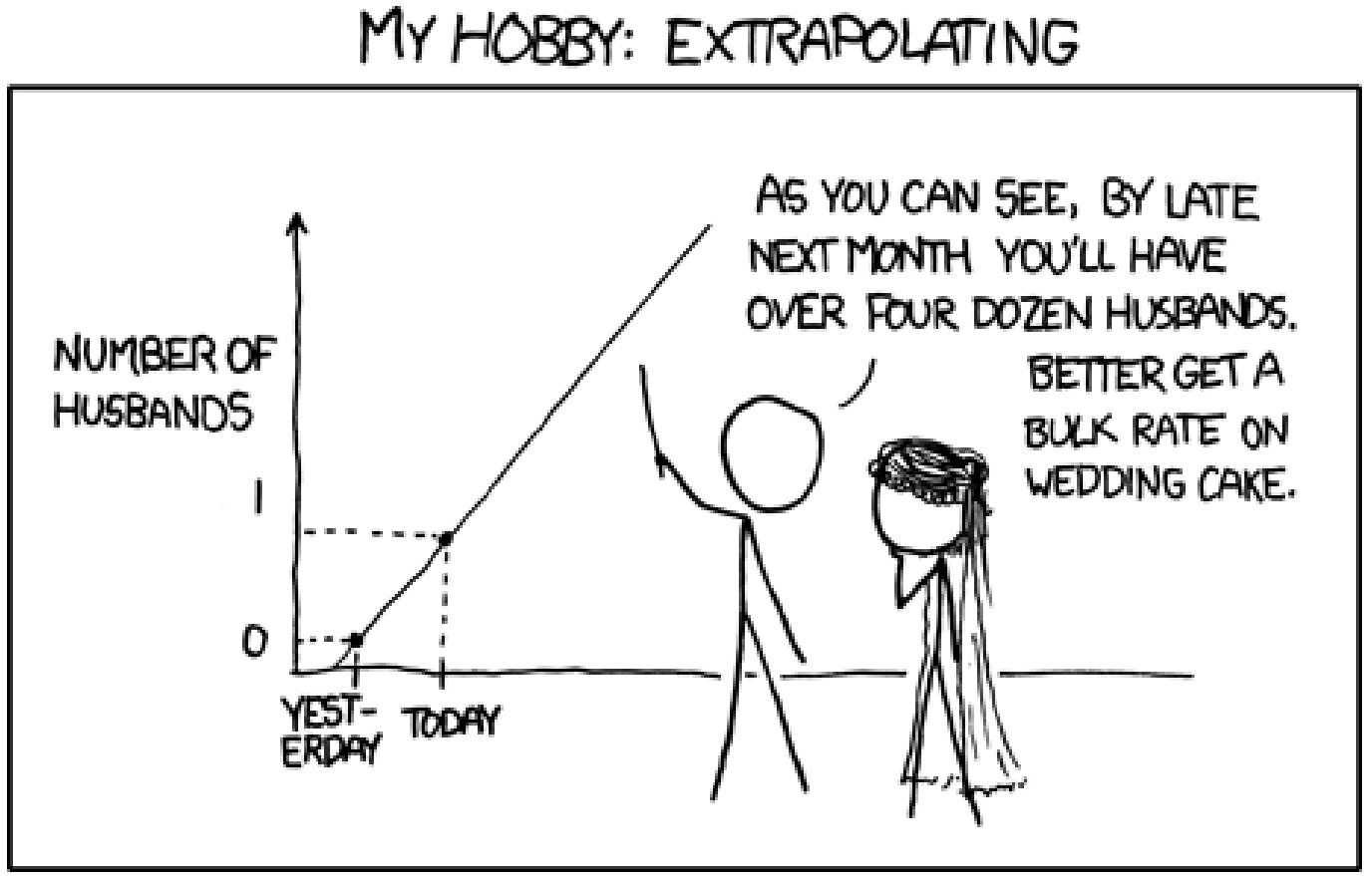
Next time

- Variability in behavior



Questions?

Thank you for your attention



Source: https://www.xkcd.com/605/

Bonus Video

Hans Rosling on Data Visualization

https://www.youtube.com/watch?v=jbkSRLYSojo

"Having the data is not enough – I have to show it in ways people enjoy and understand"