Introduction to Biostatistics & Descriptive Statistics

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Outline

1. Introduction to biostatistics
2. Descriptive statistics
3. Making effective graphs and tables

These slides were based on learning materials originally developed by Dr Marcel Wolbers, Prof Ronald Geskus and other members of the Biostatistics group at OUCRU

Introduction to biostatistics

The research process

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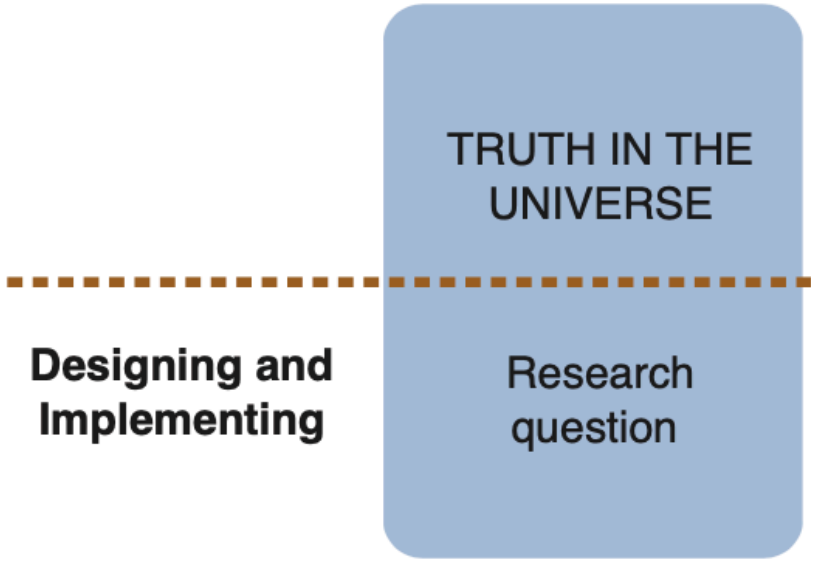

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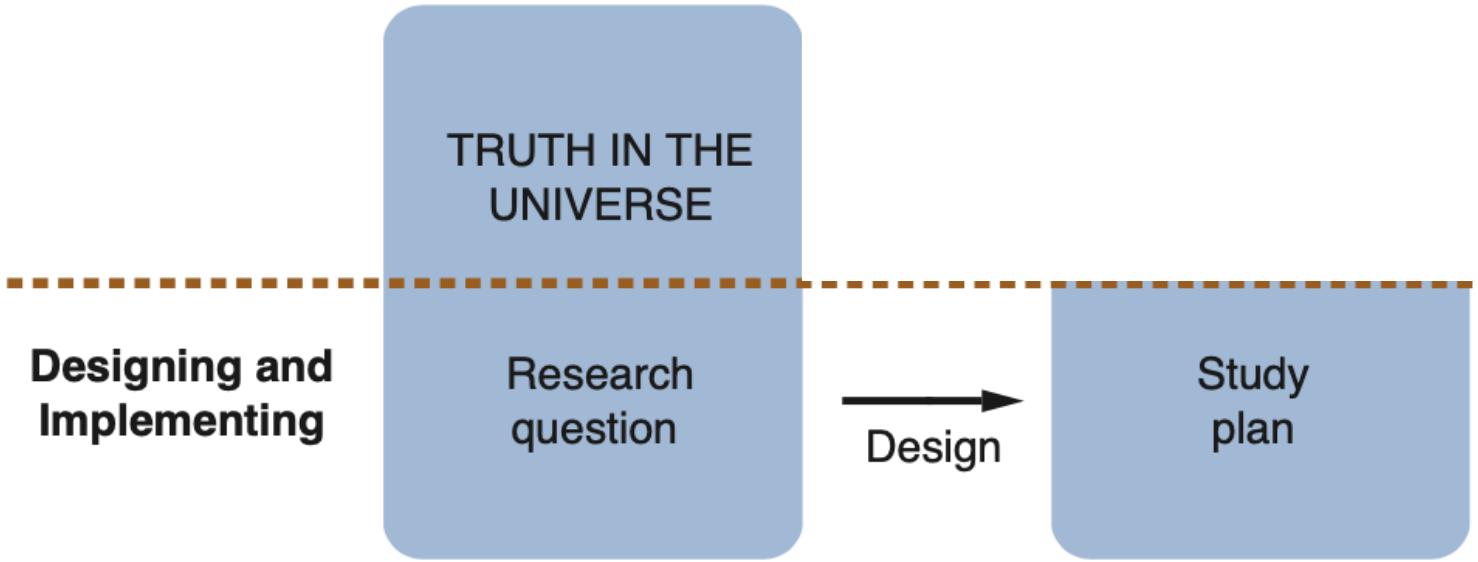

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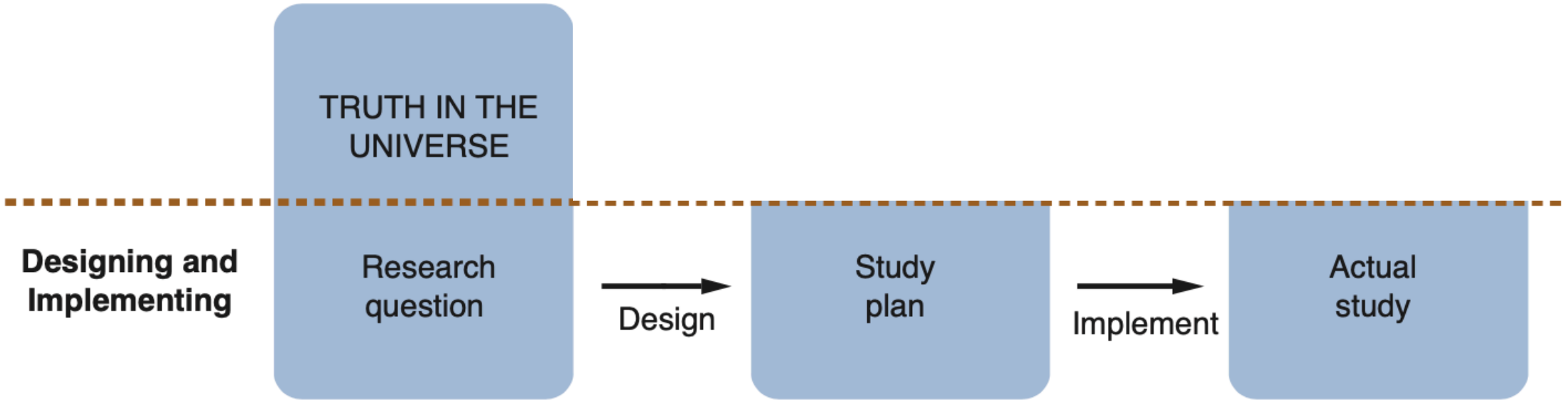

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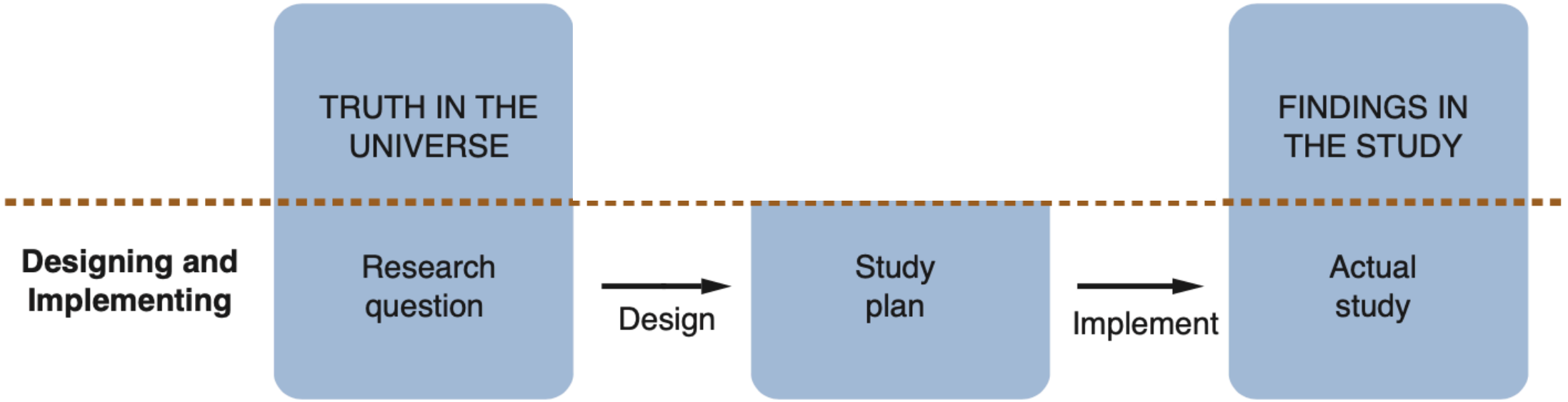

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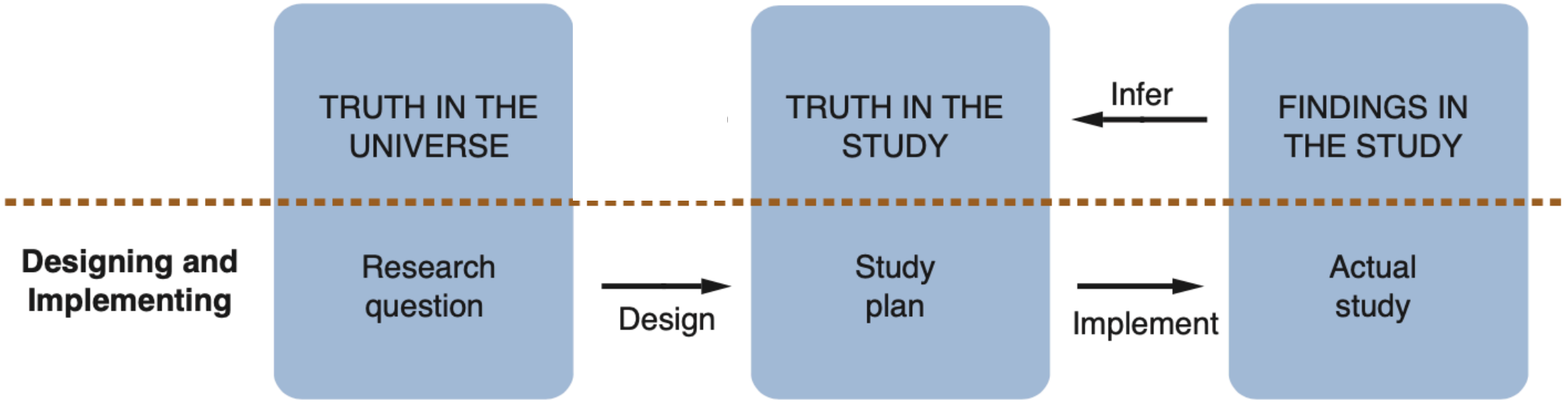

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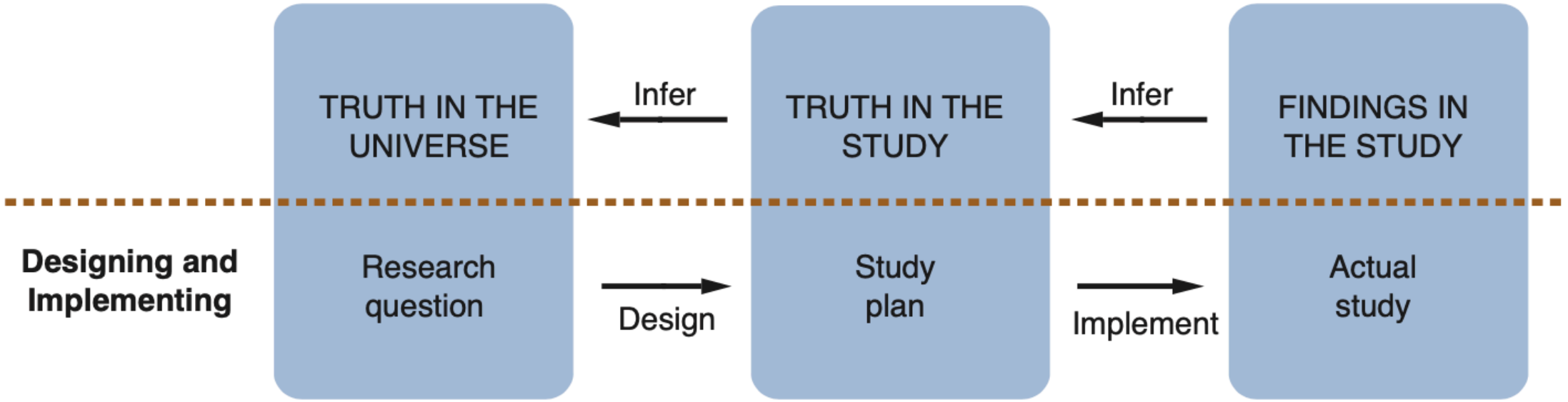

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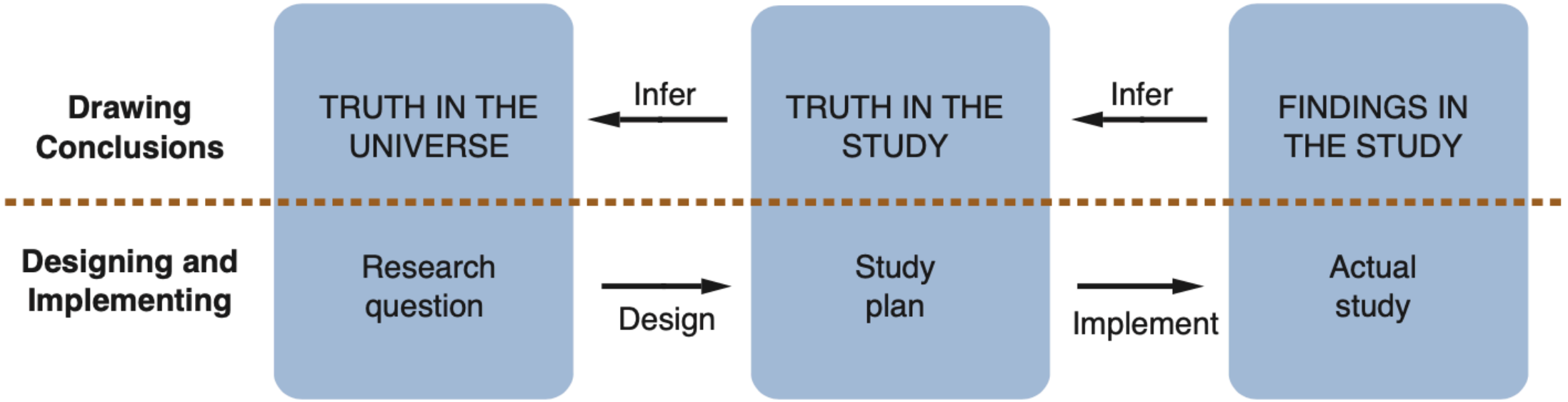

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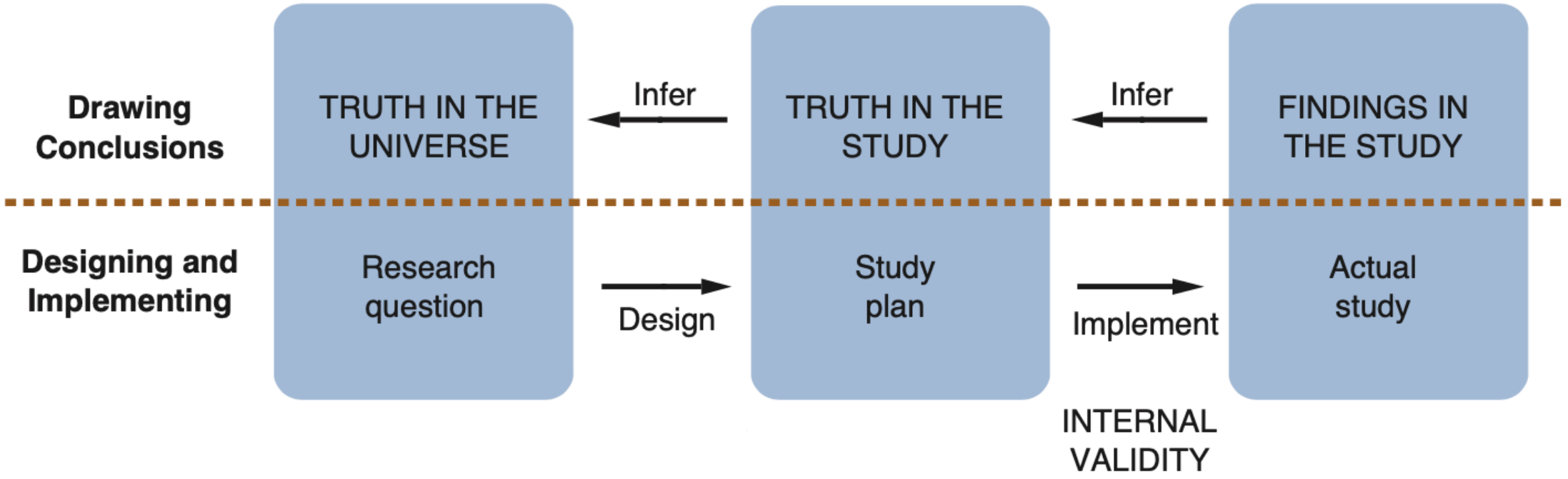

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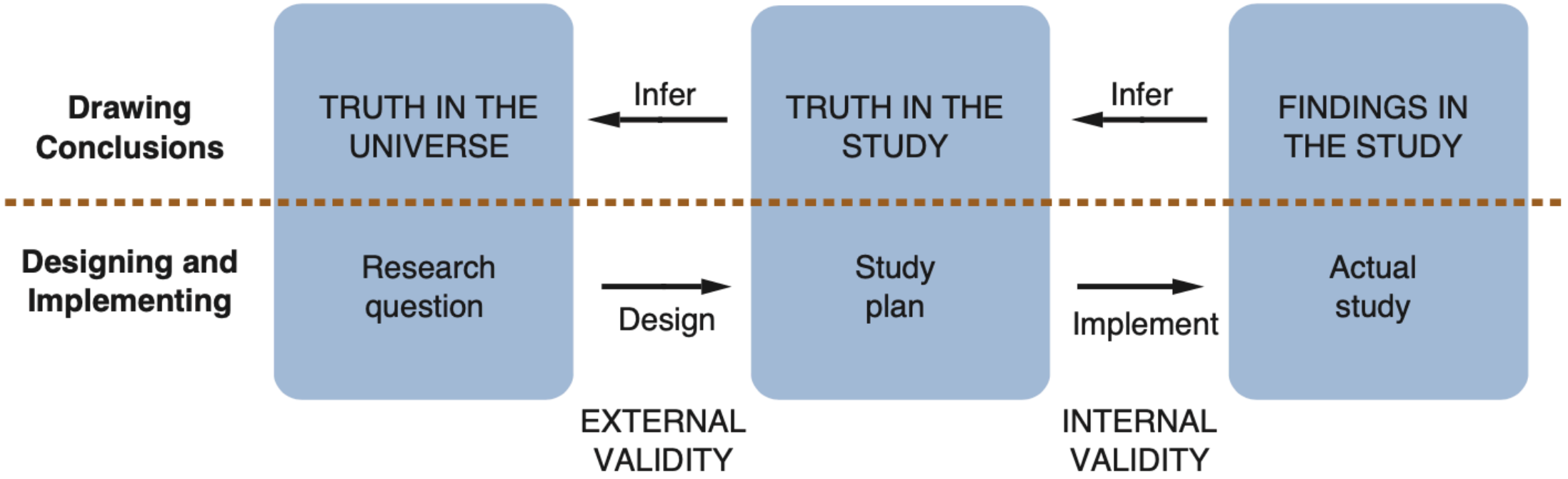

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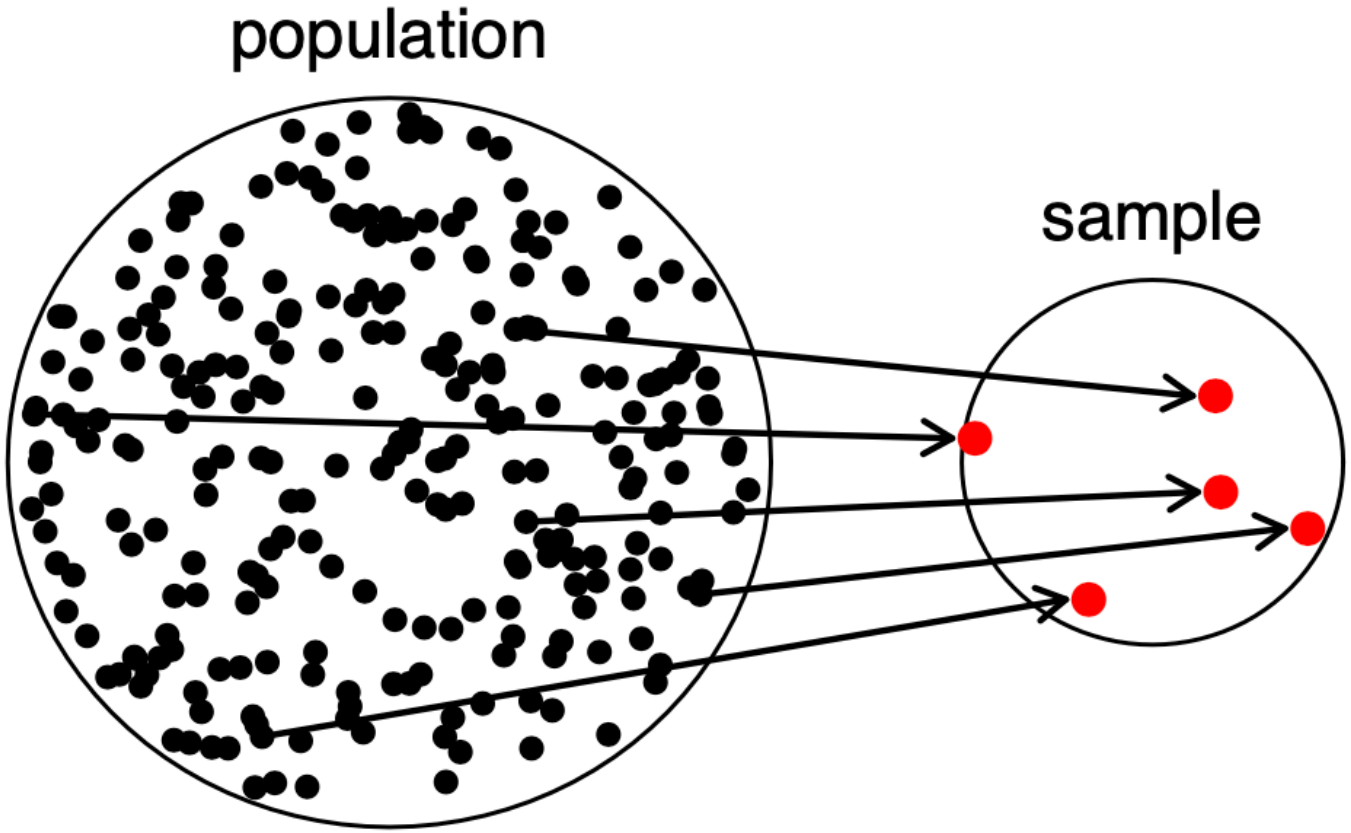
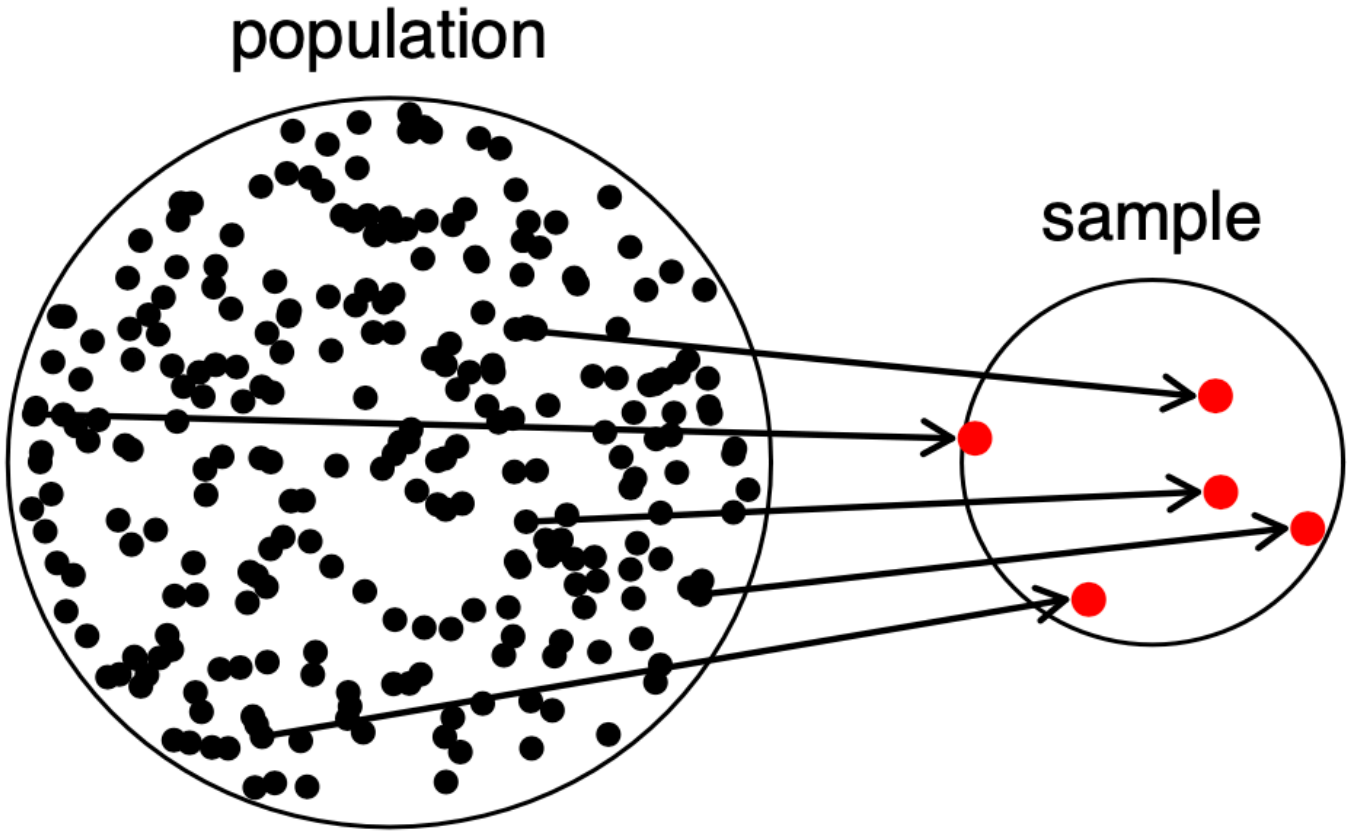


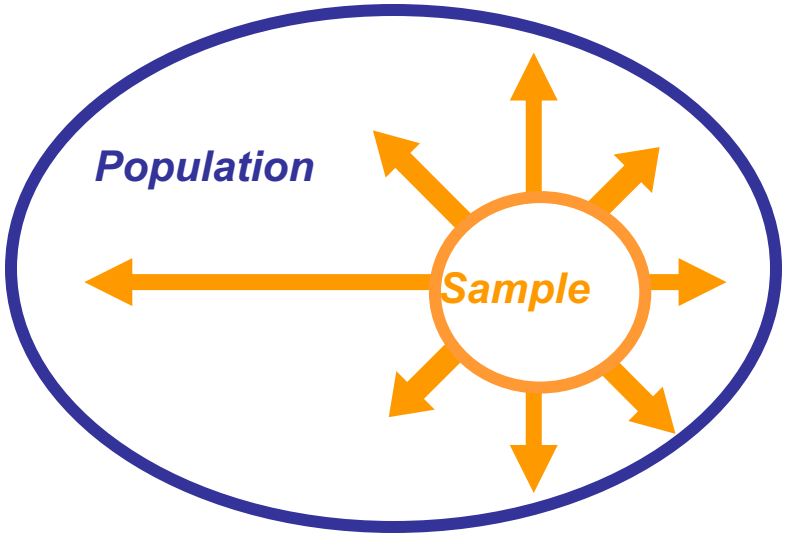
Biostatistics

INFER **DESCRIBE**



Biostatistics

- Descriptive statistics & Inferential statistics



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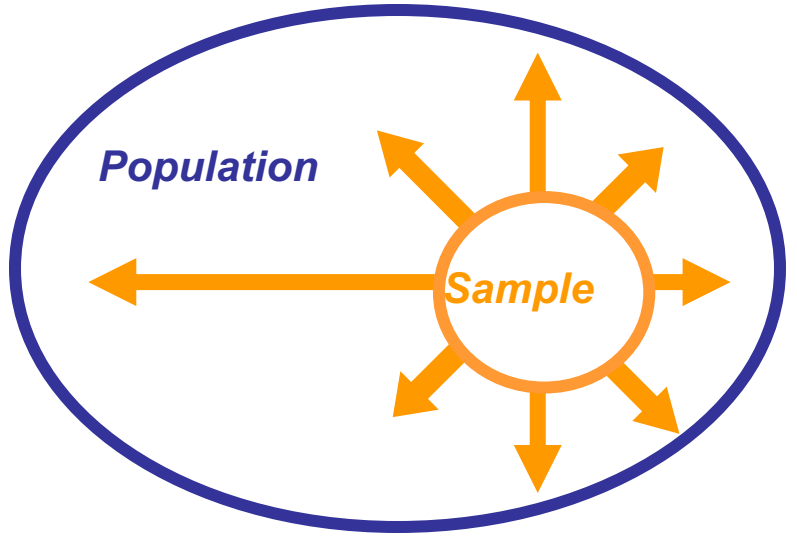

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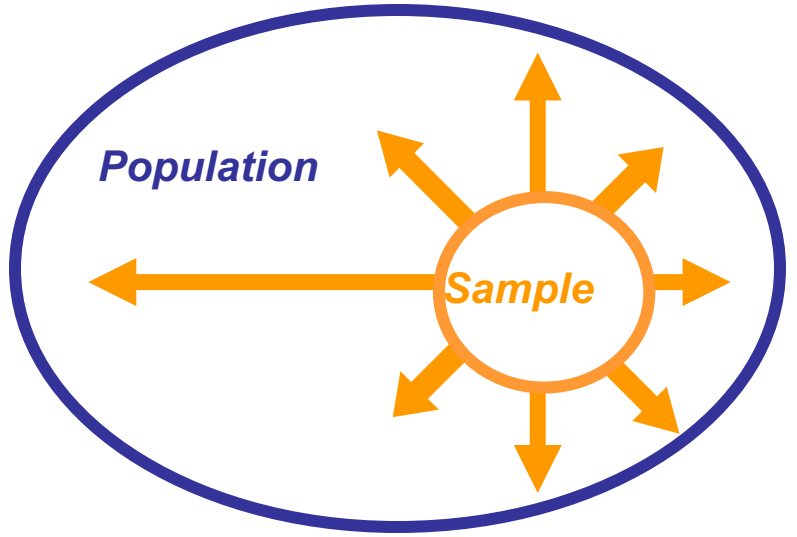
  - Description/ exploration of dataset … and beyond
  - First step in data analysis

Biostatistics



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  - Description/ exploration of dataset … and beyond
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- Inferential statistics
  - Draw conclusions about a population using a sample

Descriptive statistics

- Describe data from sample

Descriptive statistics

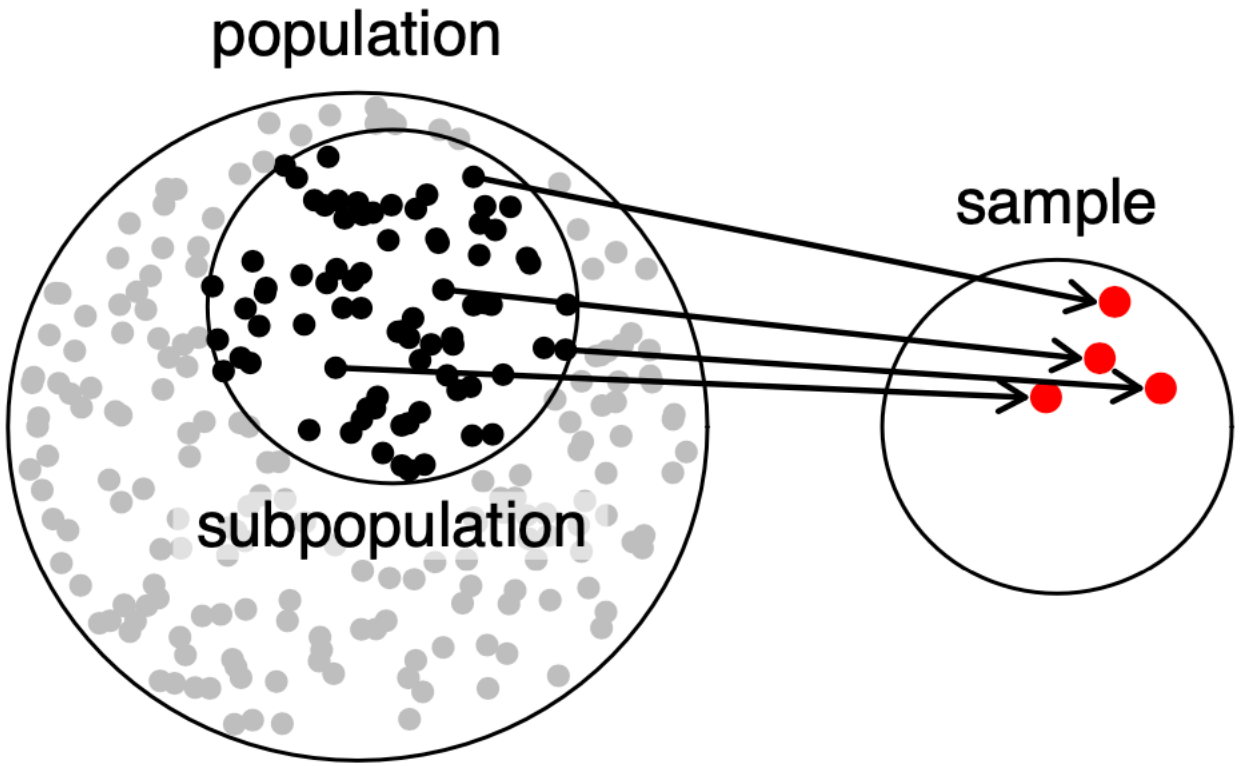
- Describe data from sample
- Use numbers and graphs

Inferential statistics

- From sample to population

Inferential statistics

- From sample to population
- But which population???



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- Representative sample: observations (summary, relations between variables) can be transferred to population
  - Data summaries ≈ population summaries
  - Some uncertainty: only (small) sample from population
  - Result slightly different if study repeated (new sample)

Quiz: target population

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- **Always ask yourself the question which population the sample represents**

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What do we want to say about the population?

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    - Does dexamethasone decrease risk of dying?
    - Role of HIV coinfection in TBM disease process?
  - **Exploration**
    - What are the risk factors for mortality in TBM patients?

Summary

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- Biostatistics
  - The development and application of statistical methods to a wide range of topics in biology and medicine

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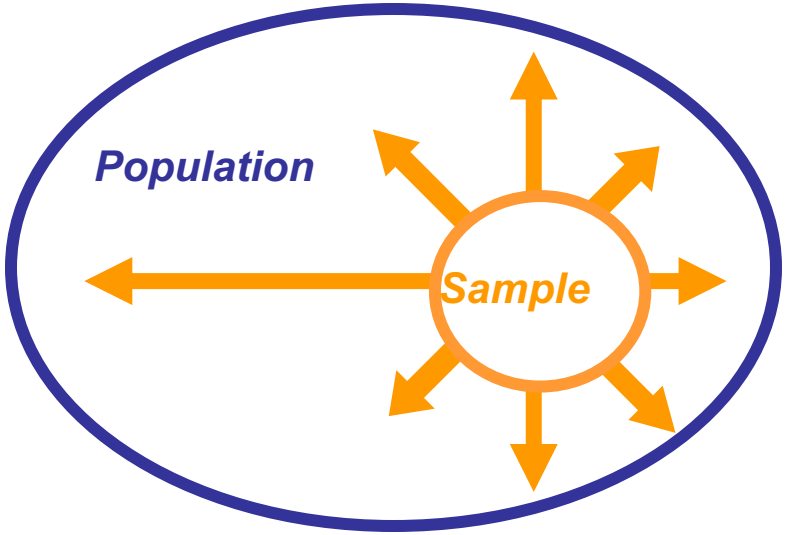
- Biostatistics
  - The development and application of statistical methods to a wide range of topics in biology and medicine
- Two main branches
  - Descriptive statistics
  - Inferential statistics



Descriptive statistics

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- **Observation:** values of variables that are measured on a unit (patients, animals, farms) at one specific time
- **Variable:** characteristic that may vary over units

Data structure

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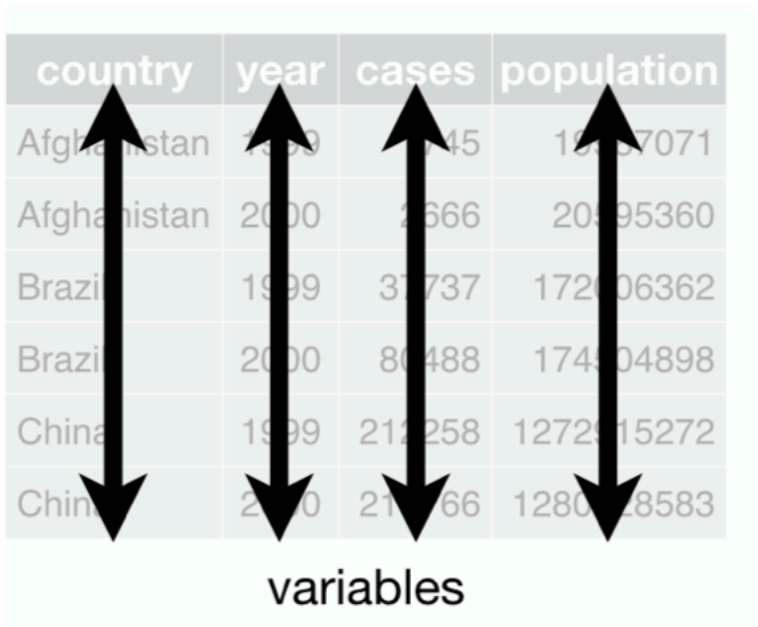
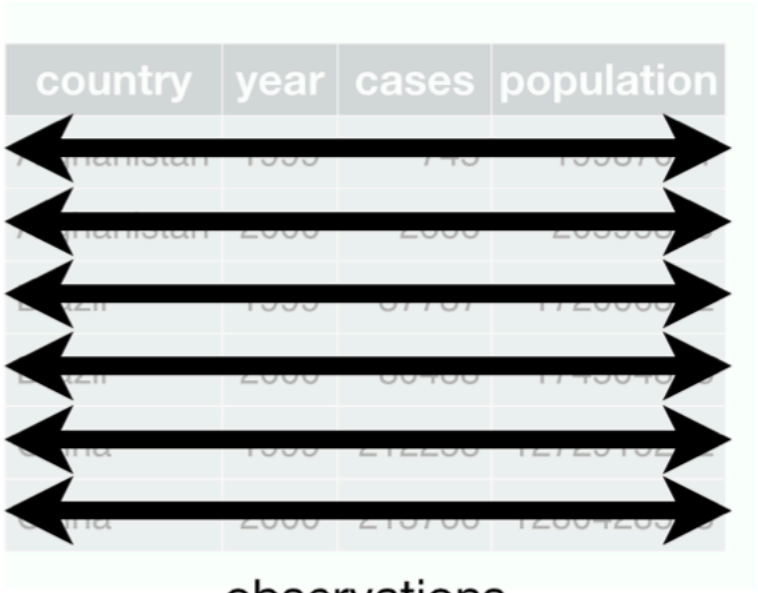
- **“Tidy”** data: link structure with semantics
  - Each observation forms a row
  - Each variable forms a column
  - One table for each type of observations
  - If you have multiple tables, they should include a column in the table that allows them to be linked

Tidy data


country
year
cases
population
variables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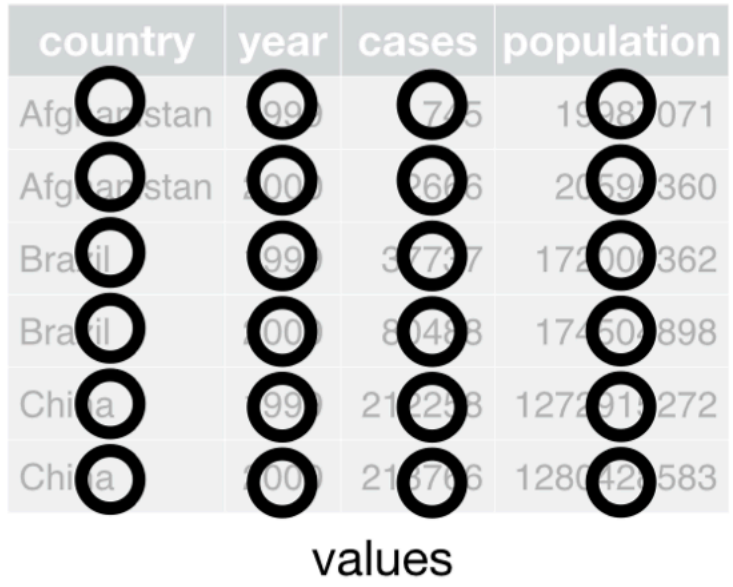
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Tidy data: example

studyno	Fluid	age	sex	hct1	plat1	hospdays	clinical_overload
400	Dextran	9	male	42	80000	4	no
401	Dextran	13	female	48	100000	4	no
402	Starch	10	female	50	47000	4	no
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- Rows: units (subjects, patients at a single time point)
- Columns: variables (outcome, response; covariates, covariables, predictors)
- Cells: values

Types of variables

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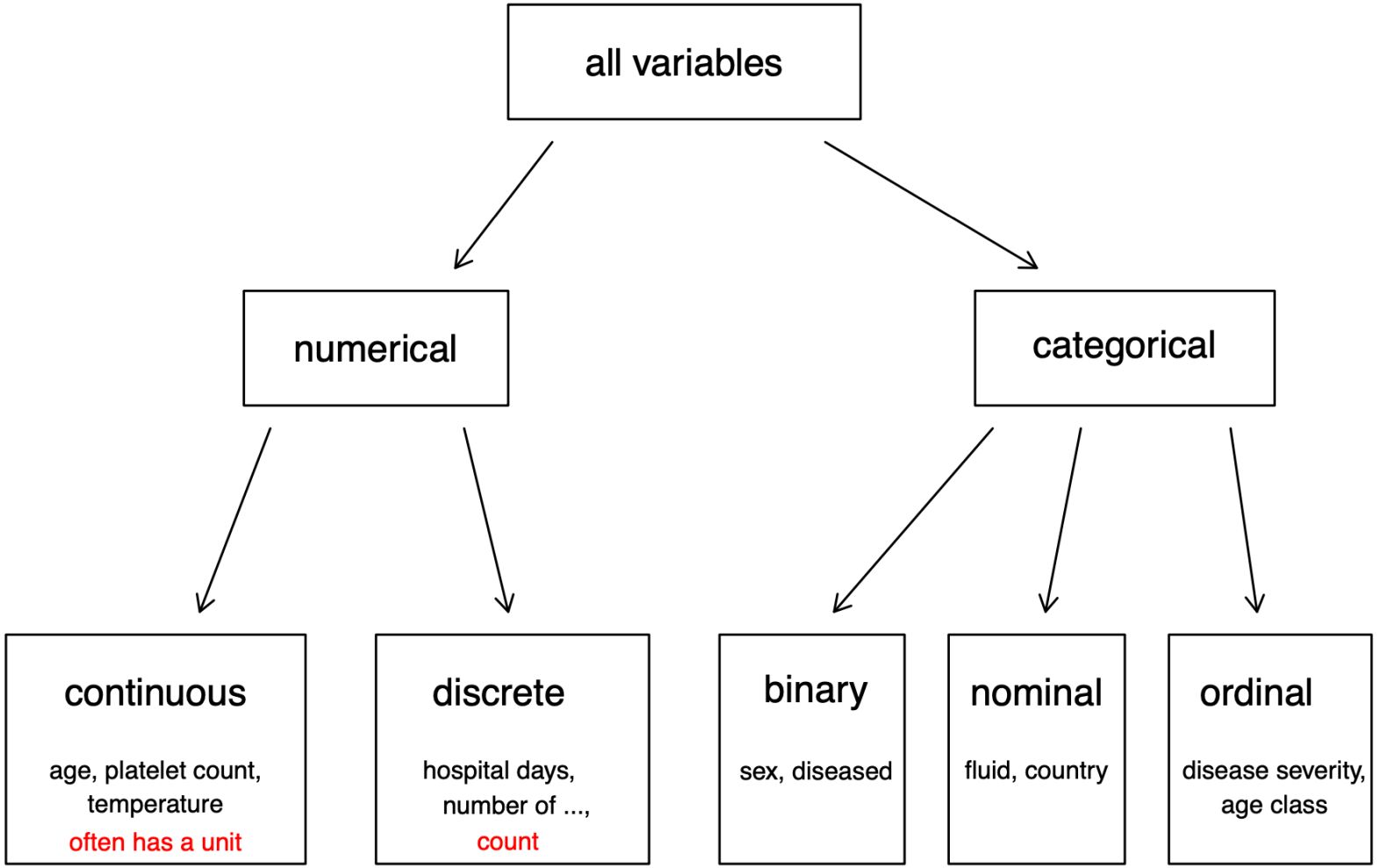

Types of variables

1) **Categorical** (binary, nominal, ordinal) and
2) **Numeric** (count, continuous):

Binary / Dichotomous - 2 levels: sex, diseased

Nominal – more than 2 levels: fluid, country

Ordinal – ordered levels: severity of disease, disability score, age class

Count – integer: number of …, calendar year, age year, hospital days

Continuous –often has a unit: temperature, platelet count, age

Quiz: Types of variables in this table?

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- Binary: sex, clinical_overload
- Nominal: Fluid, studyno
- Count: hospdays, age (if rounded, “life years” without unit)
- Continuous: age, hct1, plat1

Coding variable values

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- Categorical variables often coded numerically
  - e.g. 1=male, 2=female
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- Remember during the analyses (or better code them as character from the start)

- Missing data
  - use special code; NA (“not available”) in R
  - always report amount of missingness per variable
  - usually excluded in analysis (but may introduce bias)

Summarize data

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- Write on a sheet of paper: 20 numbers from 0 to 9

Summarize data

- Write on a sheet of paper: 20 numbers from 0 to 9
- Work in pair: verbally describe your numbers to partner

Summarize data

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Numerical

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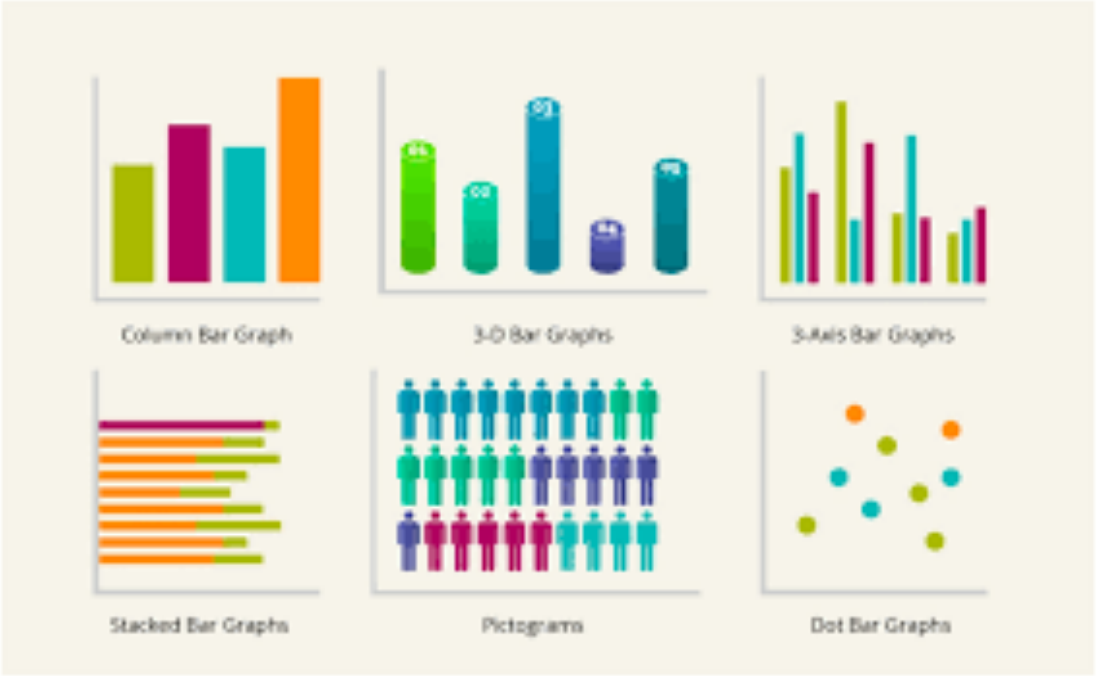
Numerical

1 2 3
4 5 6
7 8 9

Graphical



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- Numerical variables
  - **Location:** mean, median
  - **Dispersion:** standard deviation, quartiles, range

Location: mean

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  - e.g.: 5 patients age: 20, 22, 25, 63, 75
  - mean age = 205/5 =41 yrs

- General formula $$\bar{x} := \frac{1}{n} \cdot \sum_{i=1}^{n} x_i$$

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- Median splits the sample in two halves: 50% are lower, 50% are higher
  - e.g.: 5 patients age: 20, 22, 25, 63, 75
  - median age = 25 yrs

Location: mean vs. median

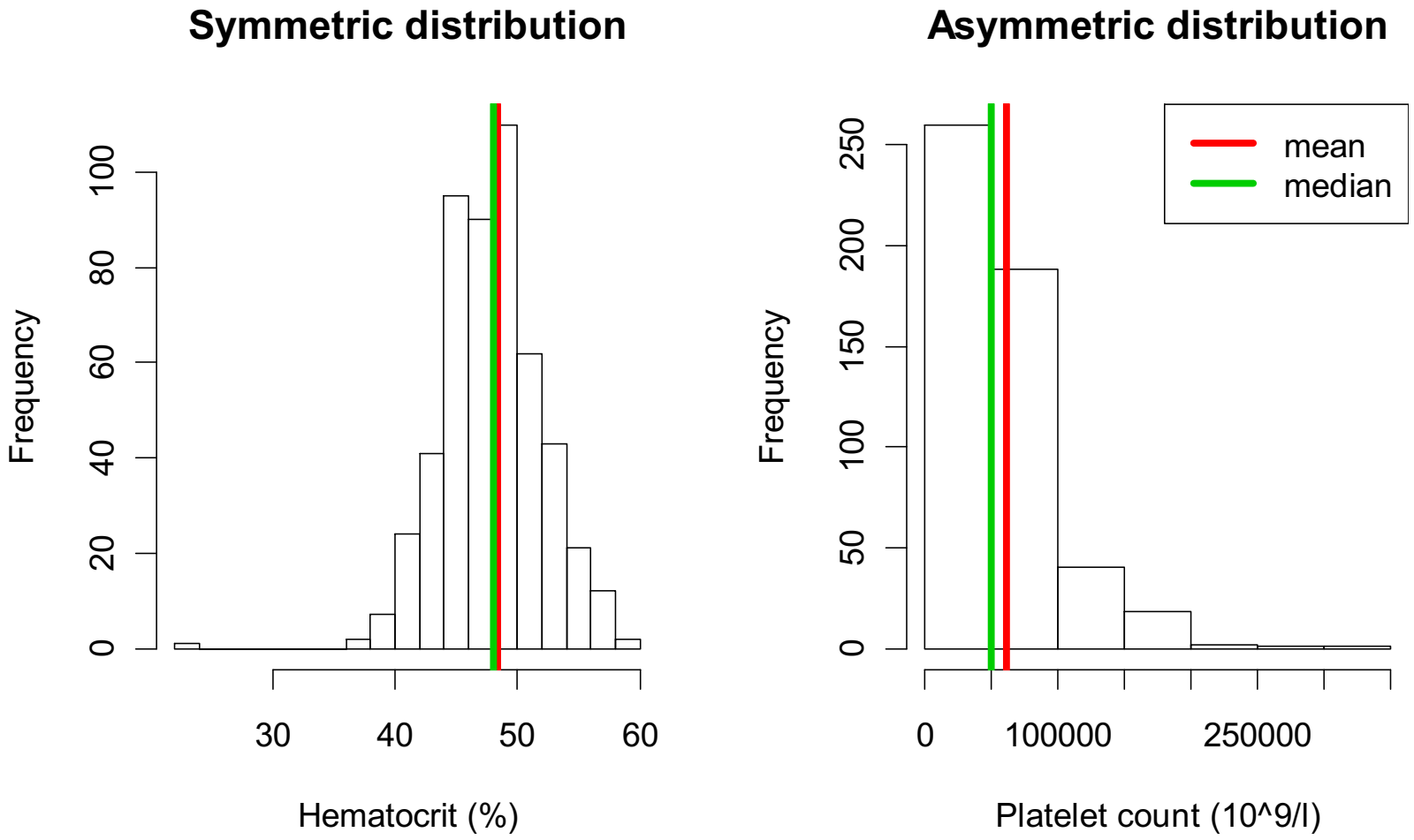
Mean

- Optimal if data distribution
  - ~ symmetric
  - No too long tails or outliers
- e.g. data from normal distribution
- Basis of most statistical models and tests

Median

- Close to sample mean if data has symmetric distribution
- Smaller than mean if distribution skewed to the right
- Still meaningful if data has extreme values

Location: mean vs. median - example



Quiz: Sample mean vs. median

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- Distribution is skewed to the right: median ~ 8 days, mean ~ 10 days

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- **Mean** or the **median** more relevant for you if
  - you are a prospective patient?
  - you are a hospital administrator interested in costs?

Dispersion

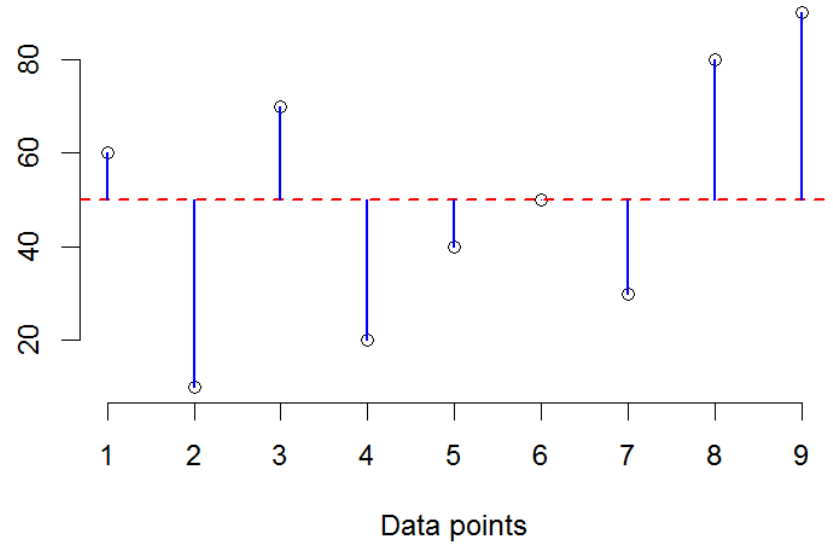
Dispersion

- Age: 60, 10, 70, 20, 40, 50, 30, 80, 90

- Age: 52, 51, 47, 49, 54, 46, 52, 46, 53

Dispersion

- Age: 60, 10, 70, 20, 40, 50, 30, 80, 90



- Age: 52, 51, 47, 49, 54, 46, 52, 46, 53

- Mean 50, but dispersion around mean is different

Dispersion I: variance and standard deviation

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- Variance: square each deviation and average

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- Rule: If data has approximately normal distribution then
  - ~68% of observations lie between $\bar{x} \pm \text{sd}$
  - ~95% of observation lie between $\bar{x} \pm 2 \cdot \text{sd}$

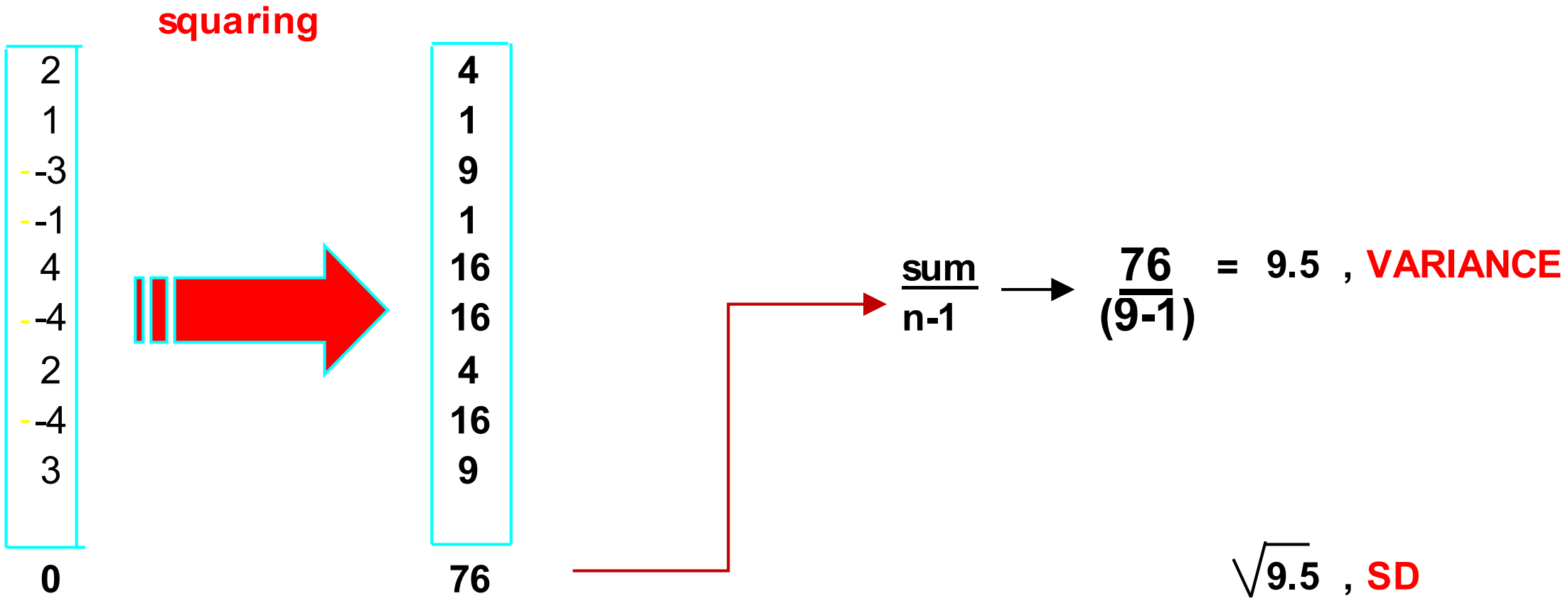
Deviation

- By definition: mean of the deviation is zero

	value	mean	deviation
	52	50	2
	51	50	1
	47	50	-3
	49	50	-1
	54	50	4
	46	50	-4
	52	50	2
	46	50	-4
	53	50	3
mean	50		0

The positive differences exactly cancel out the negative differences

Squared deviation



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  - First quartile q1: cuts off lowest 25% of data
  - Second quartile q2: cuts off lowest 50% of data (median)
  - Third quartile q3: cuts off lowest 75% of data
  - IQR: q3 – q1 (often reported as [q1, q3])

Quiz: medians and IQRs

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Compare distributions (1) and (2) based on their medians and IQRs

(1) 3, 5, 6, 7, 9	(2) 3, 5, 6, 7, 20
(1) 3, 5, 6, 7, 9	(2) 3, 5, 8, 7, 9
(1) 1, 2, 3, 4, 5	(2) 6, 7, 8, 9, 10
(1) 0, 10, 50, 60, 100	(2) 0, 100, 500, 600, 1000

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- **IQR, quartiles**
  - Always interpretable
  - Also allows to infer the skewness of the distribution (if median is also given)

Location and dispersion – Recommendations

Location and dispersion – Recommendations

- Report median (quartiles, IQR) for descriptive statistics
  - Reason: Simple and meaningful regardless whether data is symmetric or not
  - Wording: „Median (IQR) hematocrit value was 48 (46 to 51).“
- Mean and sd may be more informative for count data with many ties
  - “median (IQR) = 3 (2-3)” not very informative
- Always give location and dispersion measure

Graphical summary

Graphical summary

Categorical variables

- Pie chart (usually not recommended)
- Bar chart
- Dotplot (often preferred over bar chart)

Graphical summary

Categorical variables

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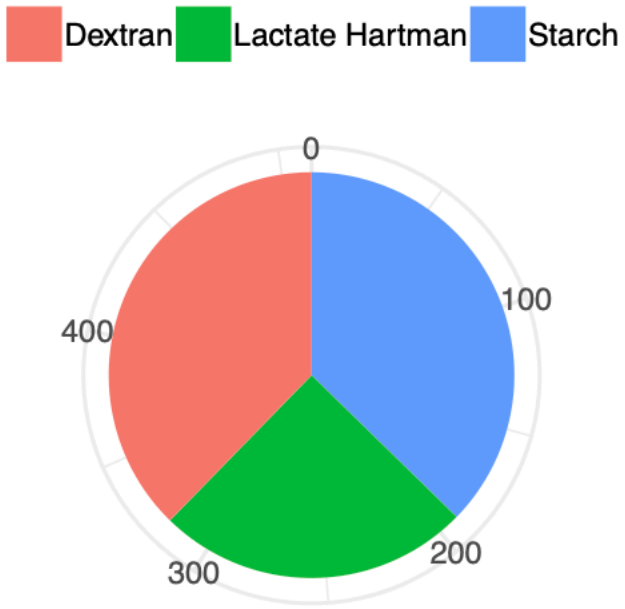
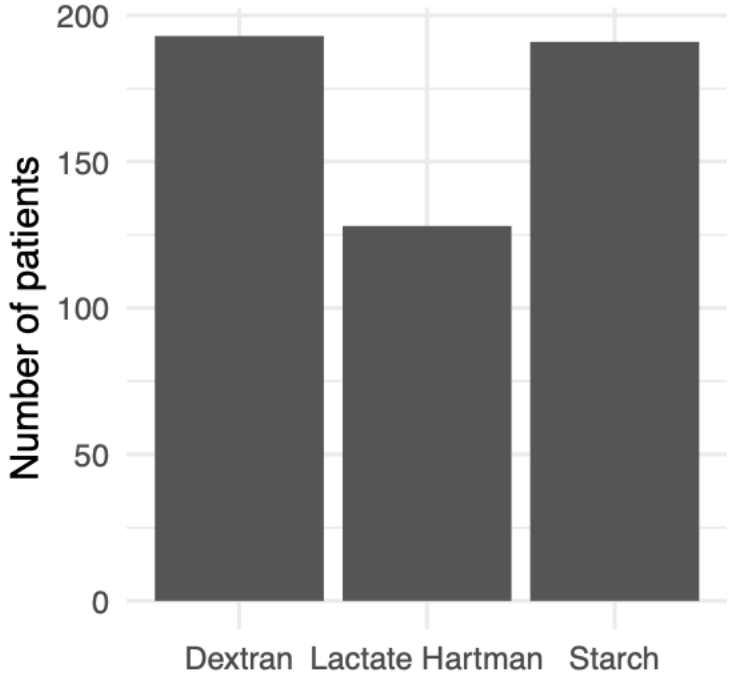
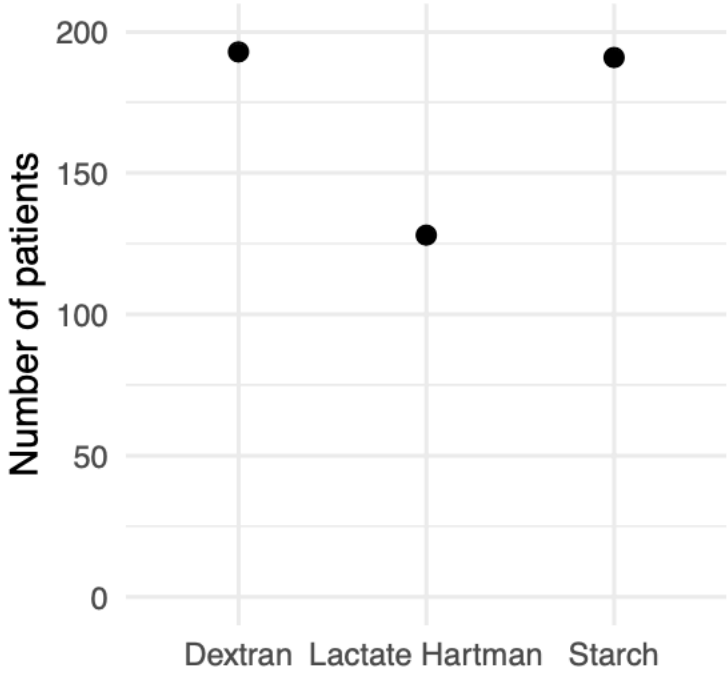
Continuous variables

- Histogram/density plot
- Boxplot

Pie, bar and dot







Histogram

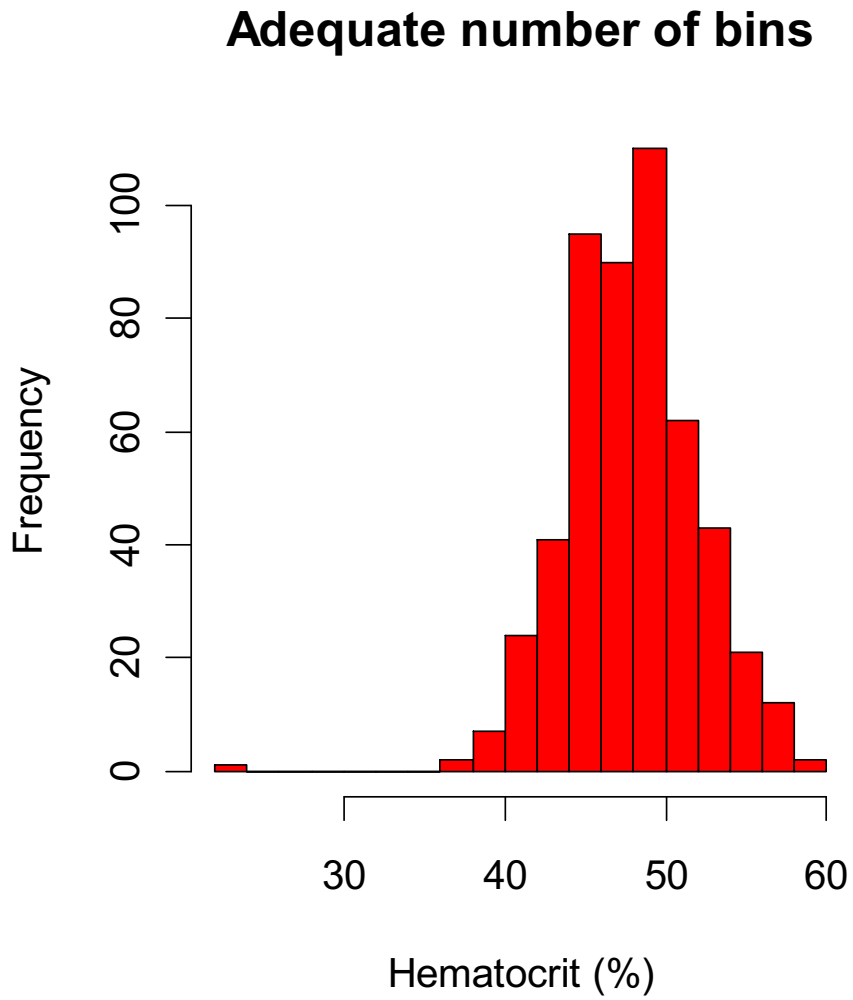
Histogram

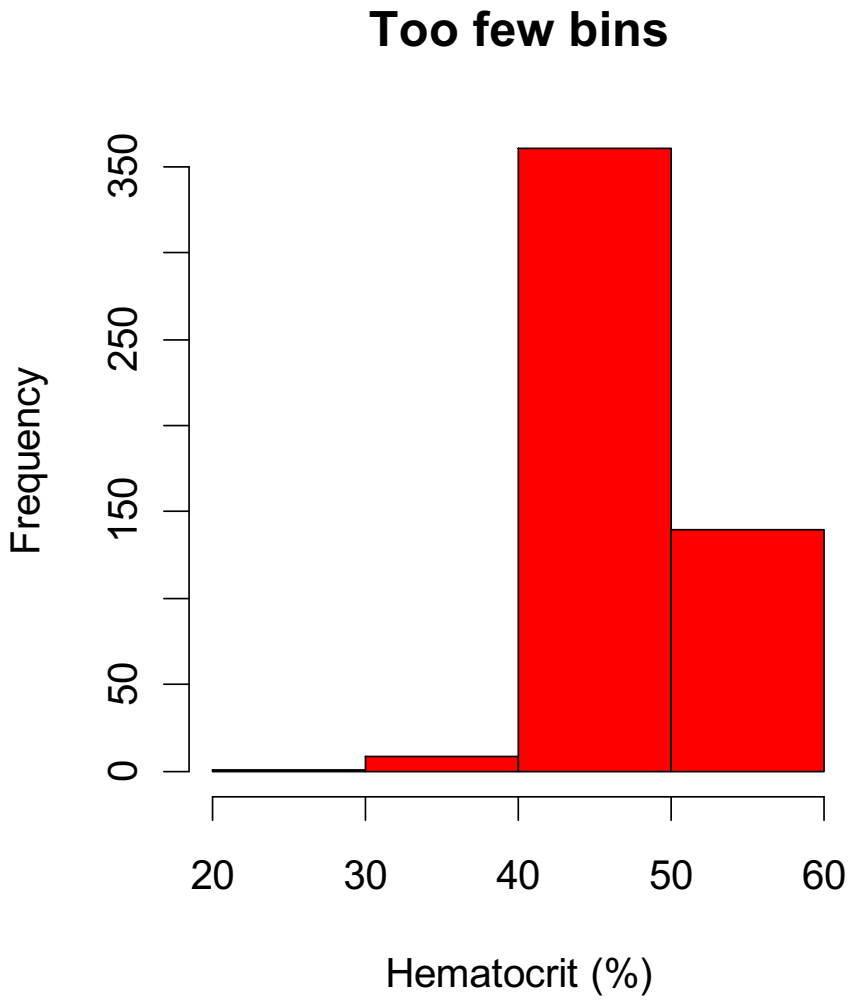
- Group values of a variable into bins of equal width; plot the number (or relative frequency) as a barchart

Histogram

- Group values of a variable into bins of equal width; plot the number (or relative frequency) as a barchart
- Caveat: visual appearance may depend on the chosen number and location of bins
- Try several groupings of the data

Histogram: examples





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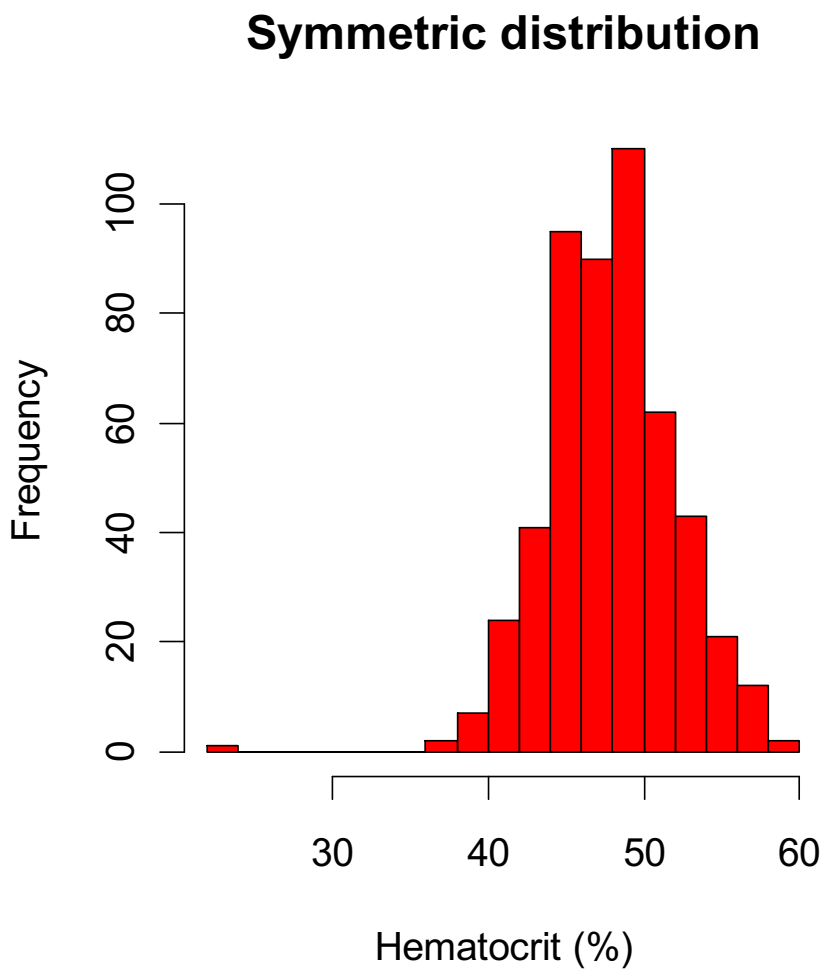
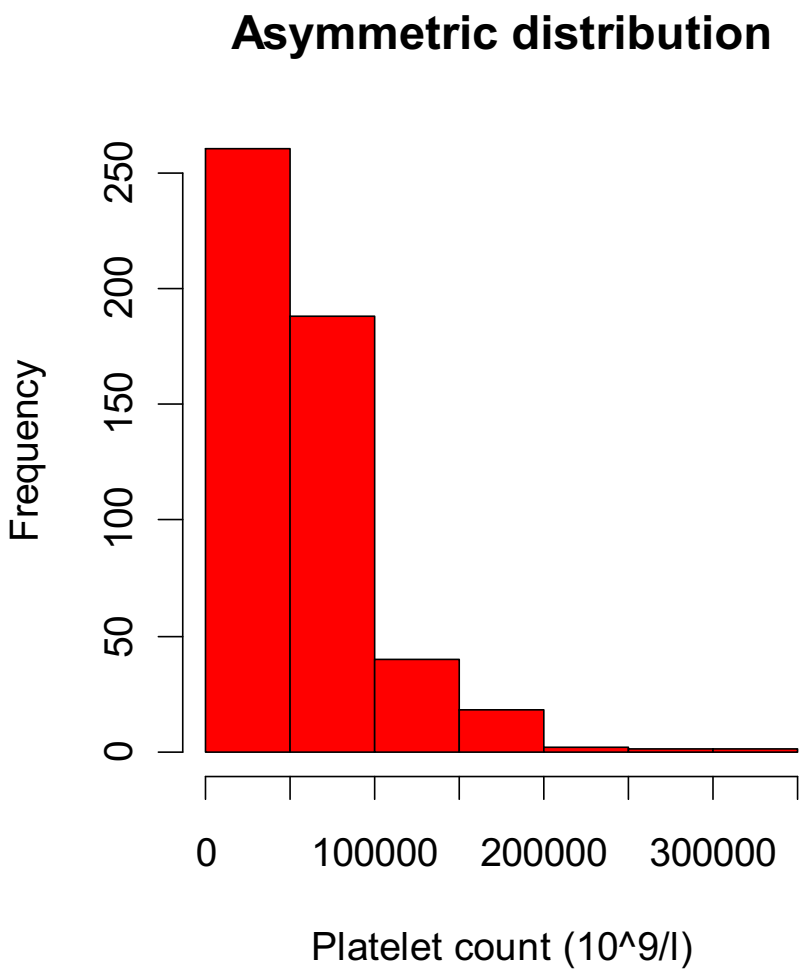
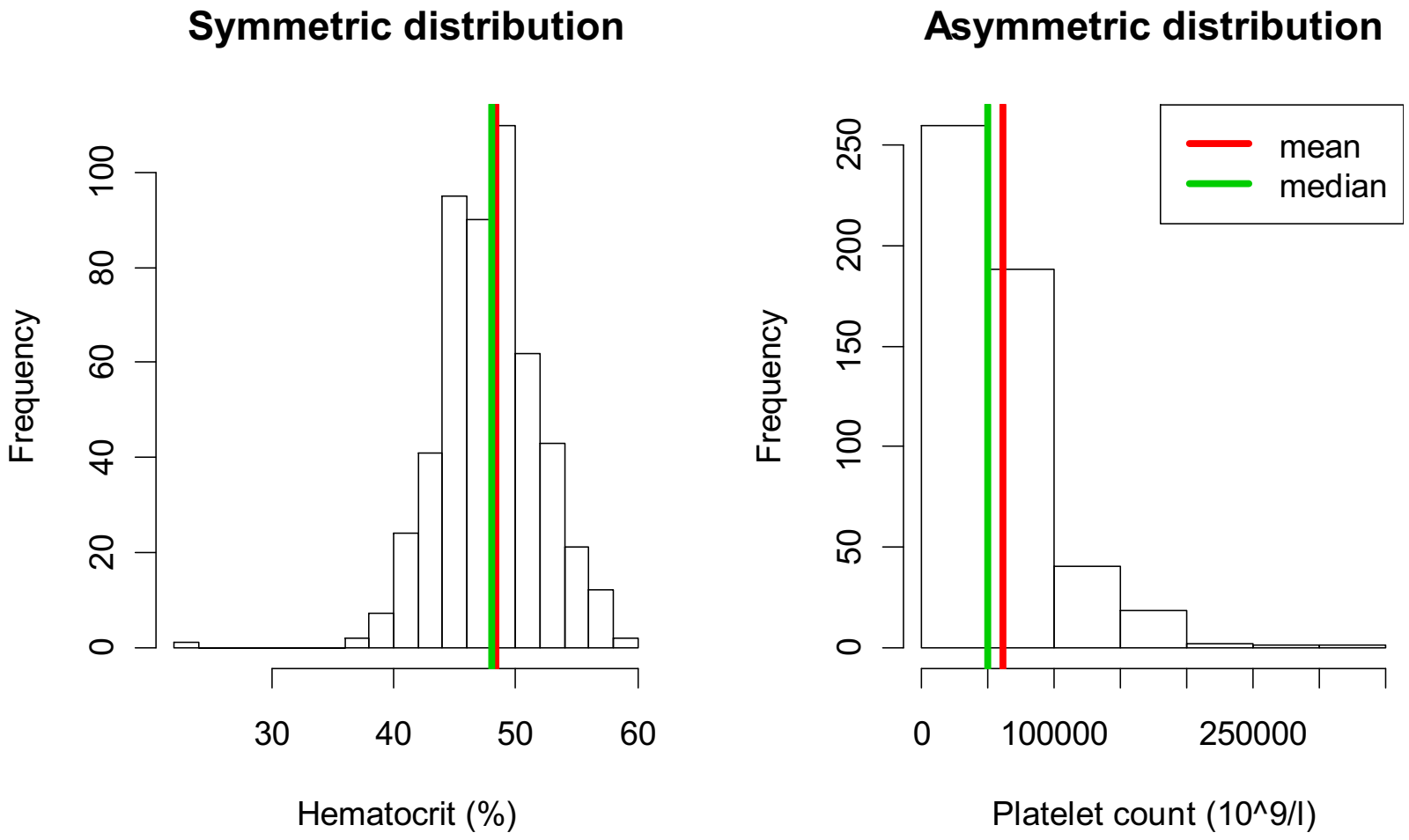




Histogram: examples

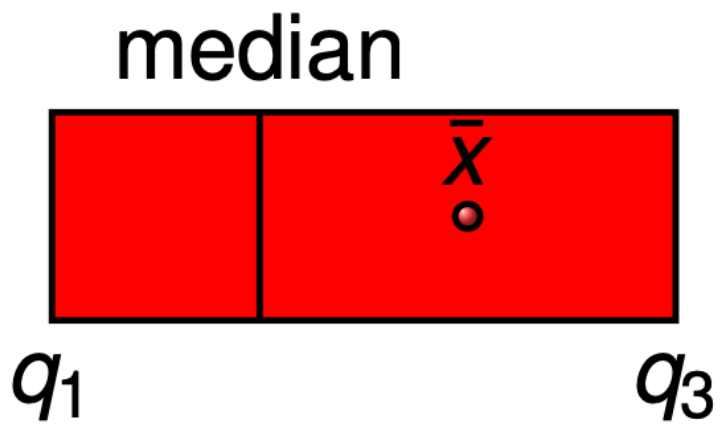


Boxplot

Boxplot

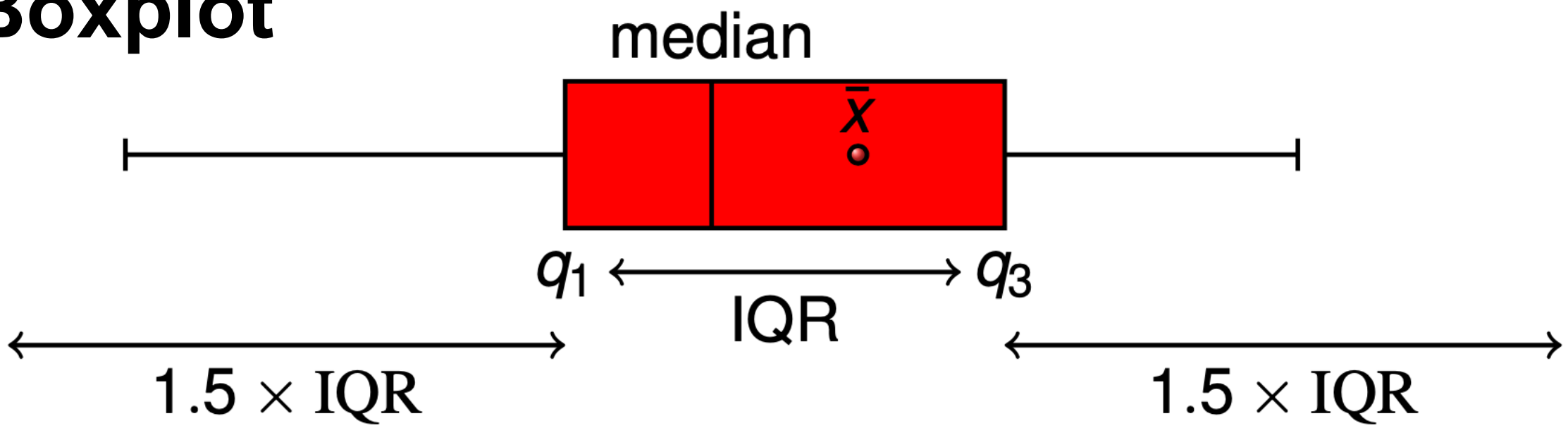
- Formal name: box-and-whisker plot

Boxplot



- Formal name: box-and-whisker plot
- Box: most common observations

Boxplot



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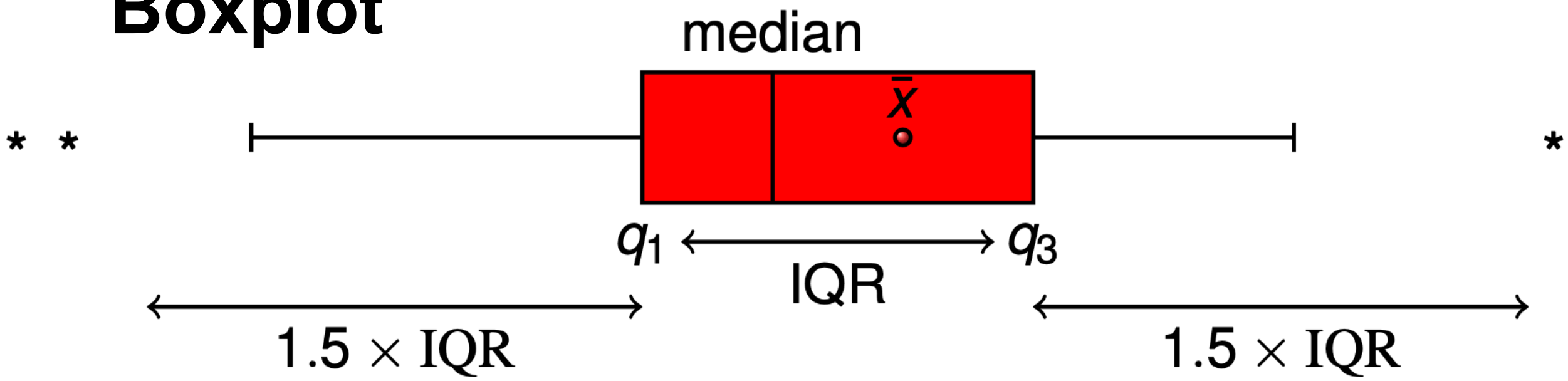
- Box: most common observations
- Whiskers: less common but still typical
  - From quartiles to the furthest away observation:
    ≥ q1 −1.5 × IQR and **≤ q3 +1.5 × IQR**

Boxplot



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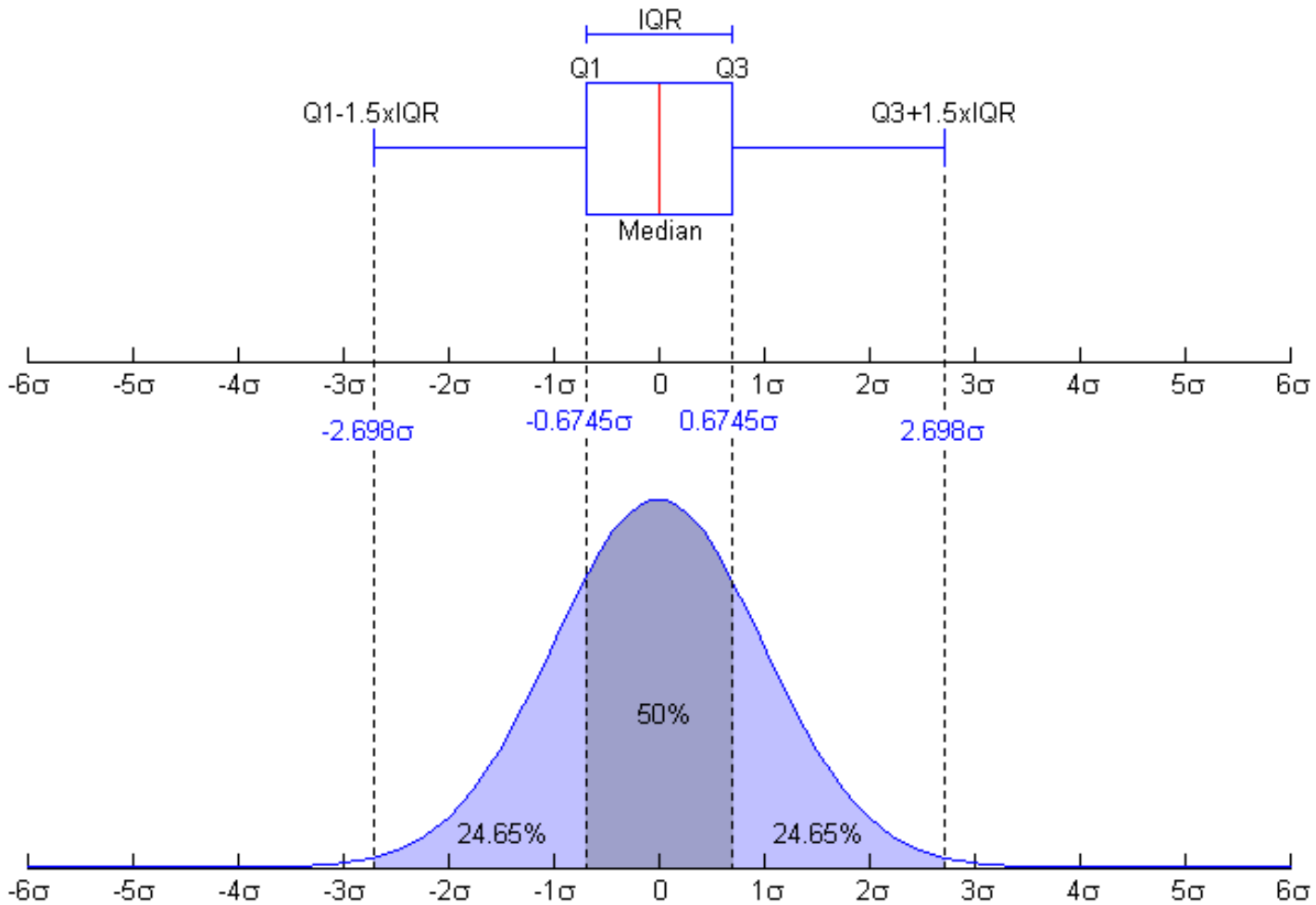
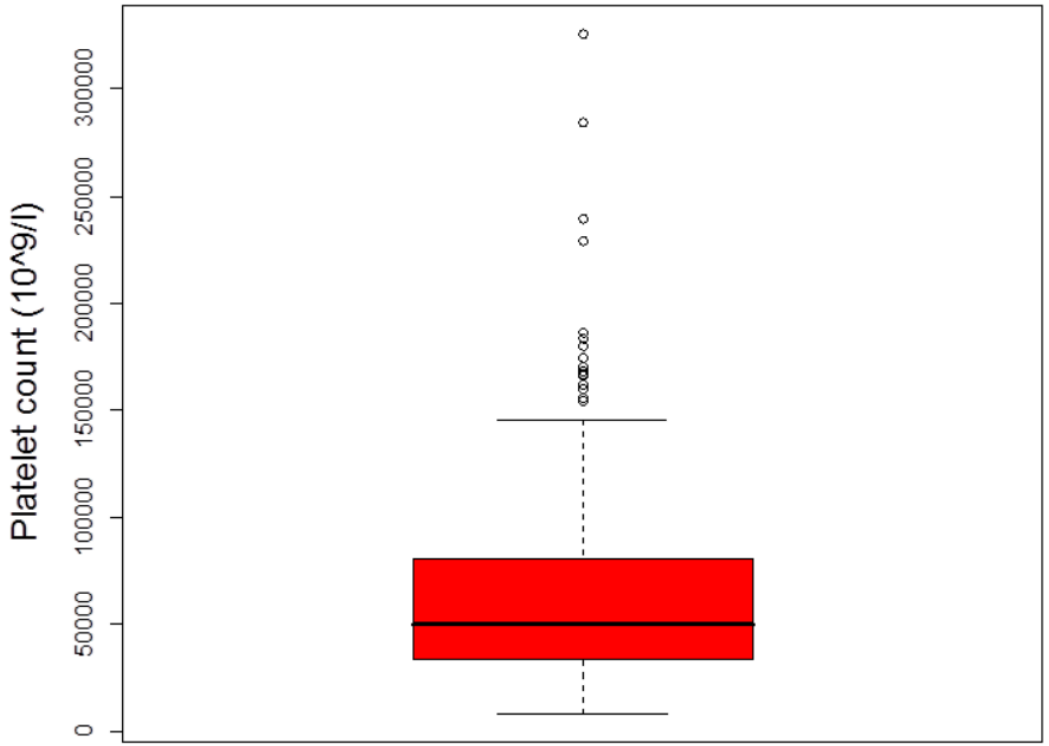
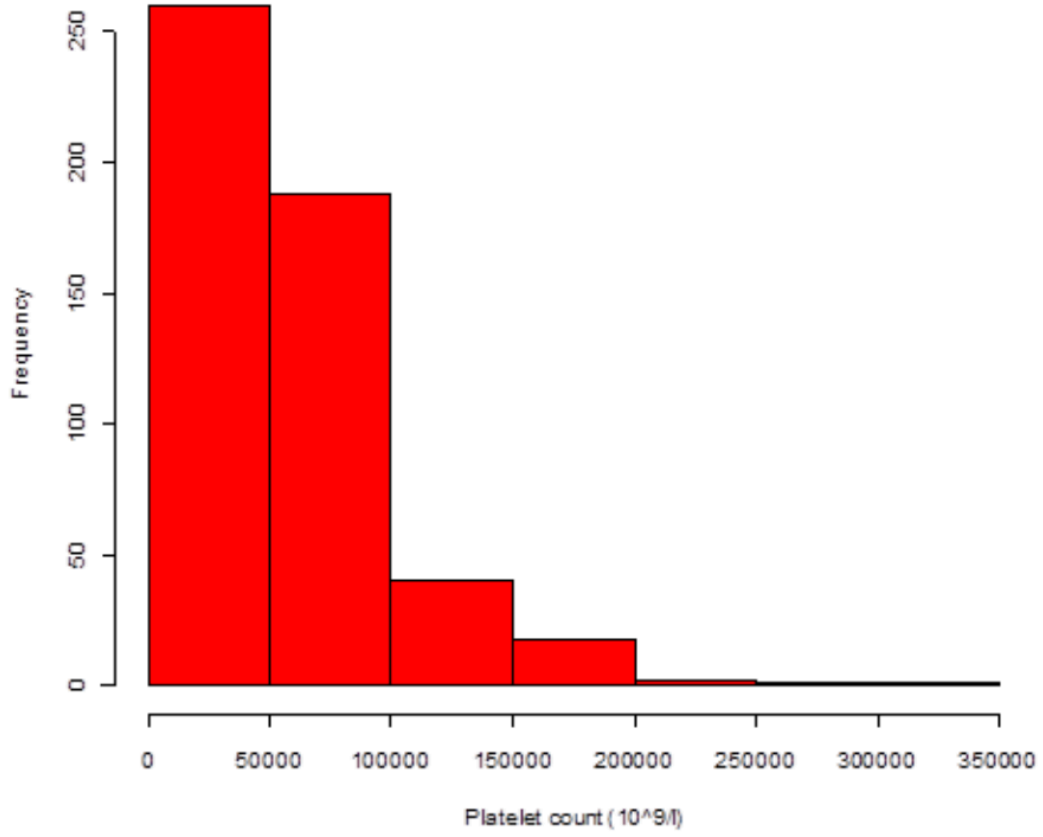
  - From quartiles to the furthest away observation:
    ≥ q1 −1.5 × IQR and **≤ q3 +1.5 × IQR**
- Outliers: All points outside of the whiskers

Boxplot for normal distribution



Boxplot vs. Histogram

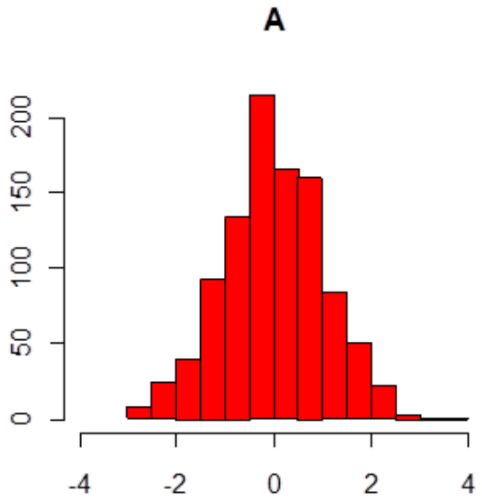


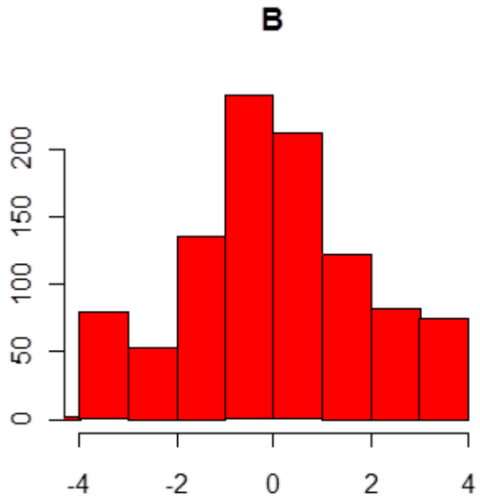


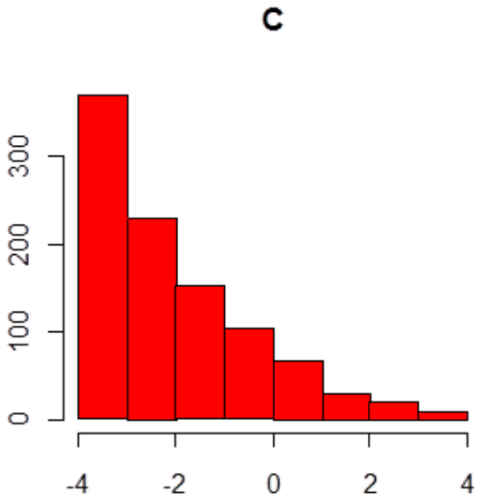
Boxplot: usage

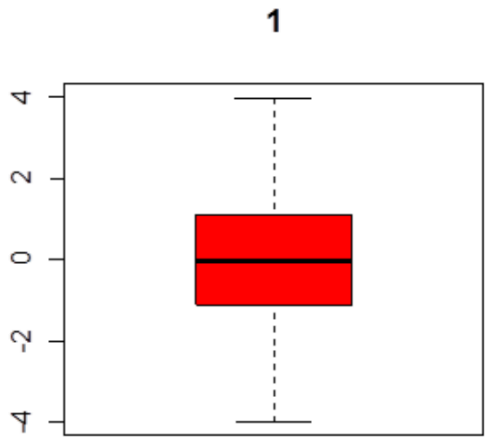
- Useful and concise summaries of the data
- Particularly useful for visual comparisons of multiple groups
- Small data sets: add individual values as dots

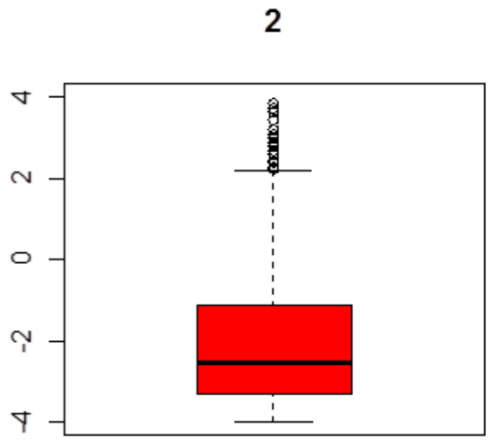
Quiz: Match histograms and boxplots

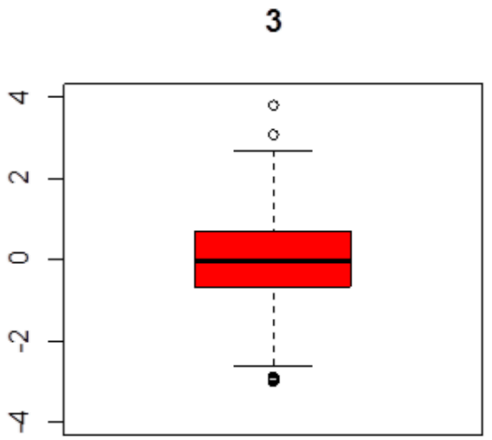












Summarizing association between continuous variables

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- Scatterplot

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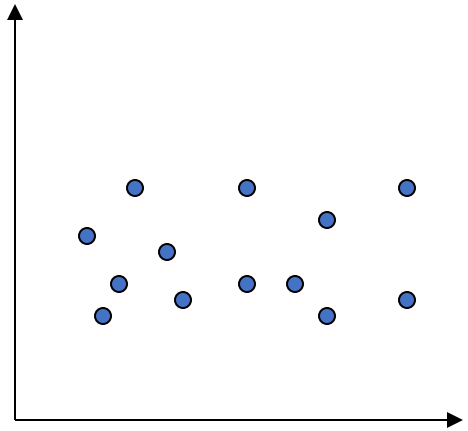
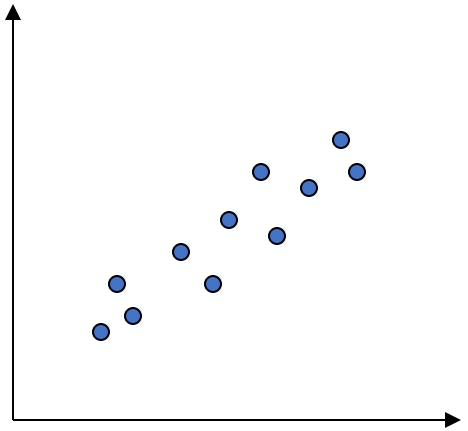
- x – independent variable (predictor, covariable)
- y – dependent variable (outcome, response)
- Sometimes not clear which variable is x or y

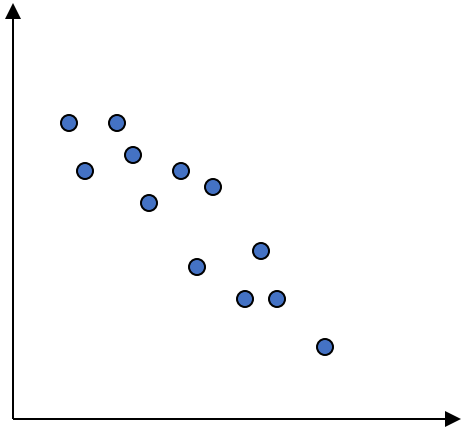
Summarizing association between continuous variables

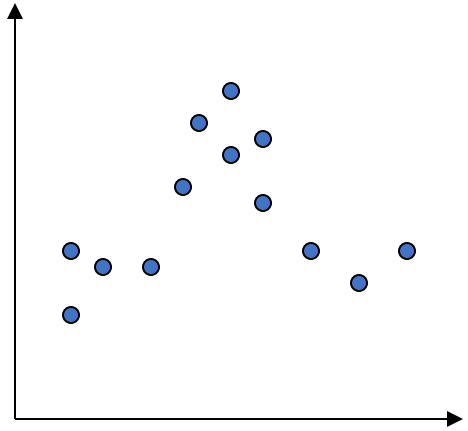
- Scatterplot
- x – independent variable (predictor, covariable)
- y – dependent variable (outcome, response)
- Sometimes not clear which variable is x or y
- Each observation is represented by one point
- Pattern of the points → relationship between variables

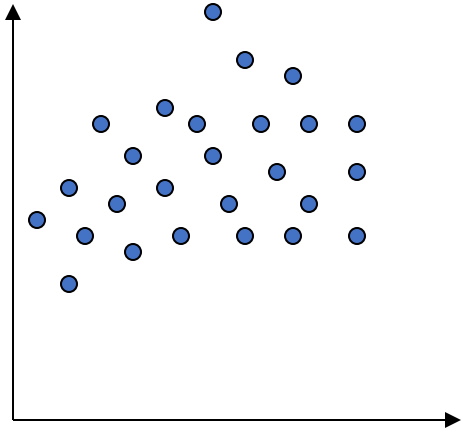
Scatterplot











No relationship

Positive correlation

Negative correlation

Linear relationship

Non-linear relationship

Scatterplot

- Scatter plots are easier to interpret if variables are approximately normally distributed
- Transform data appropriately before plotting

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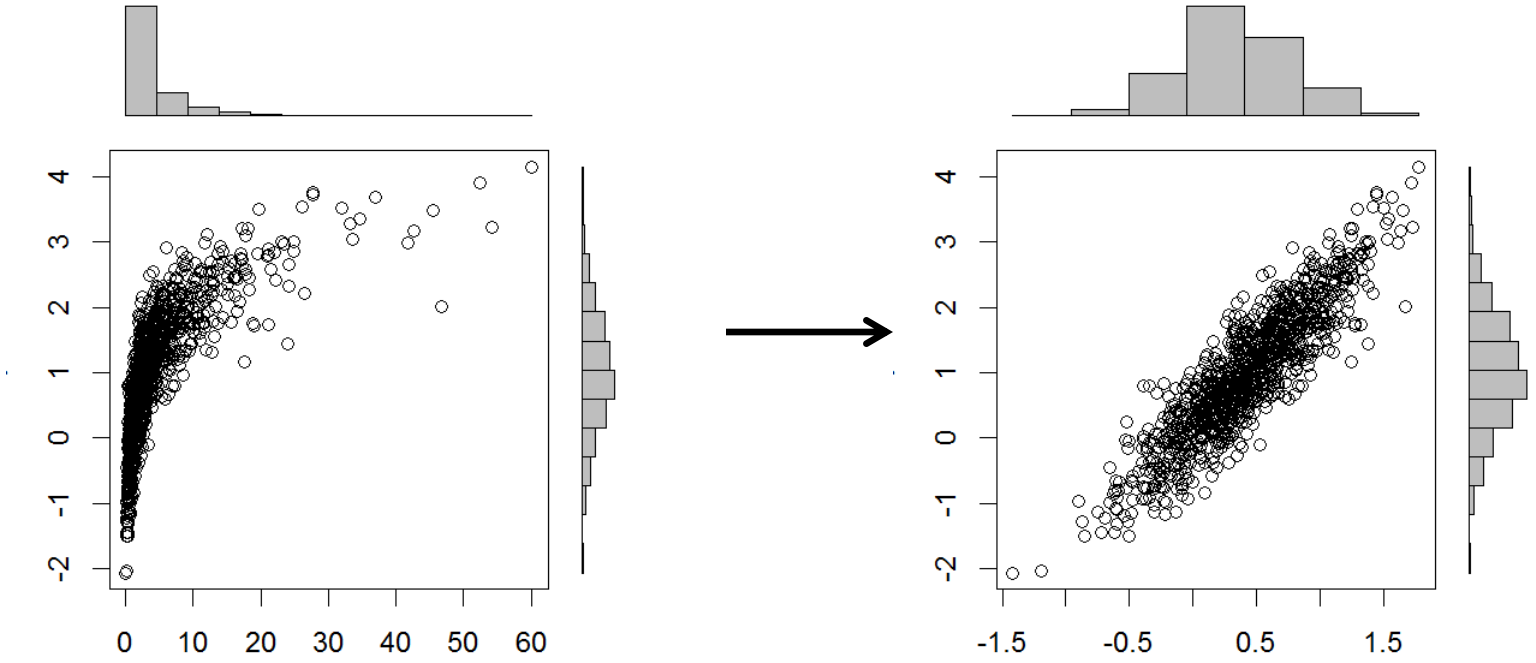
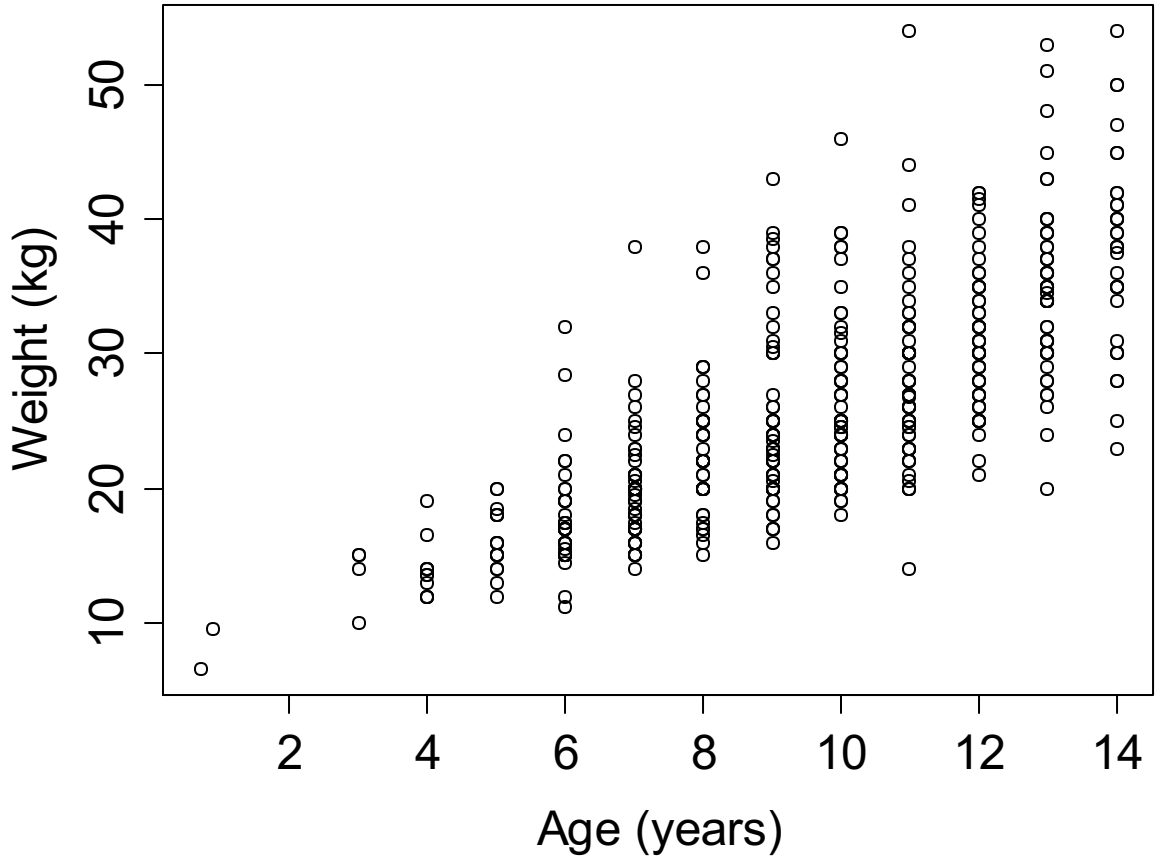


Quiz: age vs. weight for dengue shock dataset



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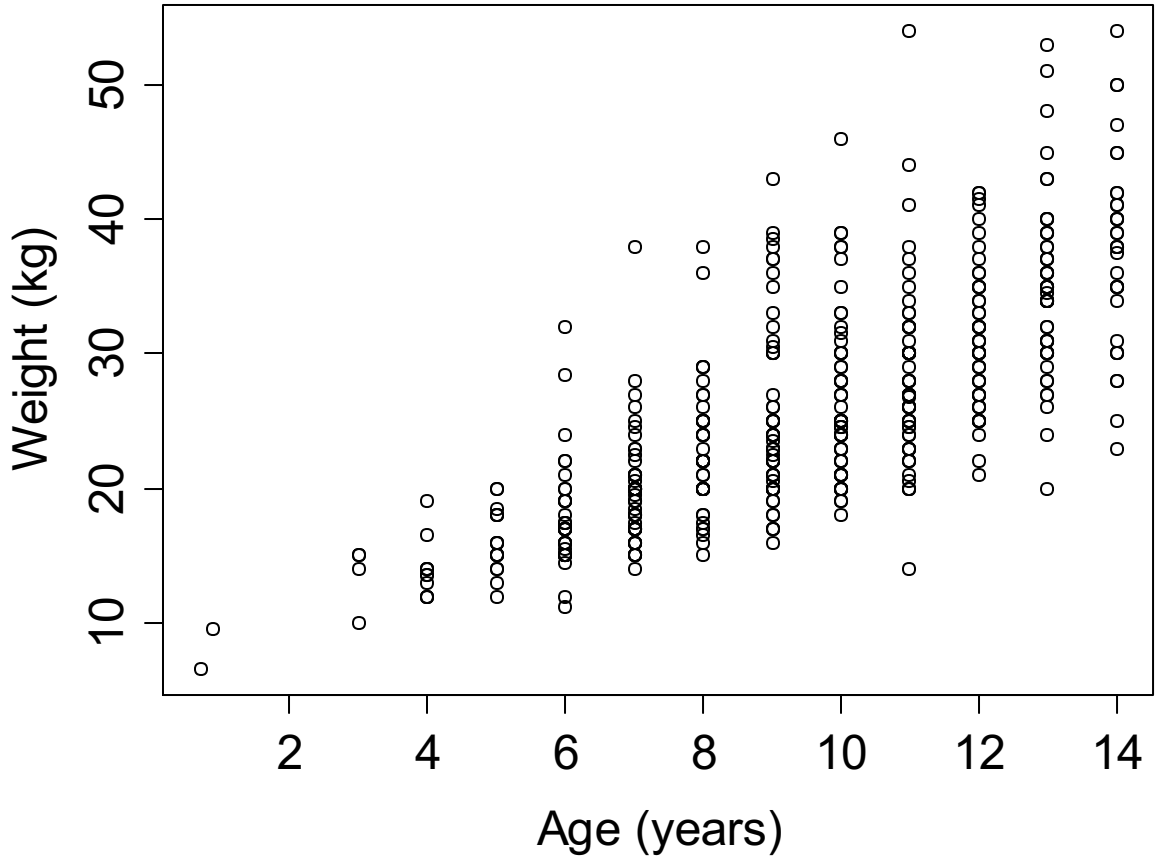


- Roughly linear increase of weight with age
- A lot of variability, especially for higher age

Summary

- Data structure
- Data types: categorical/continuous
- Data summary
  - Numbers
    - Frequency, percentage, proportion
    - Location: mean, median
    - Dispersion: standard deviation, range, IQR
  - Graphs
    - Pie chart, bar chart, dotplots
    - Histogram, boxplot
    - Scatterplot

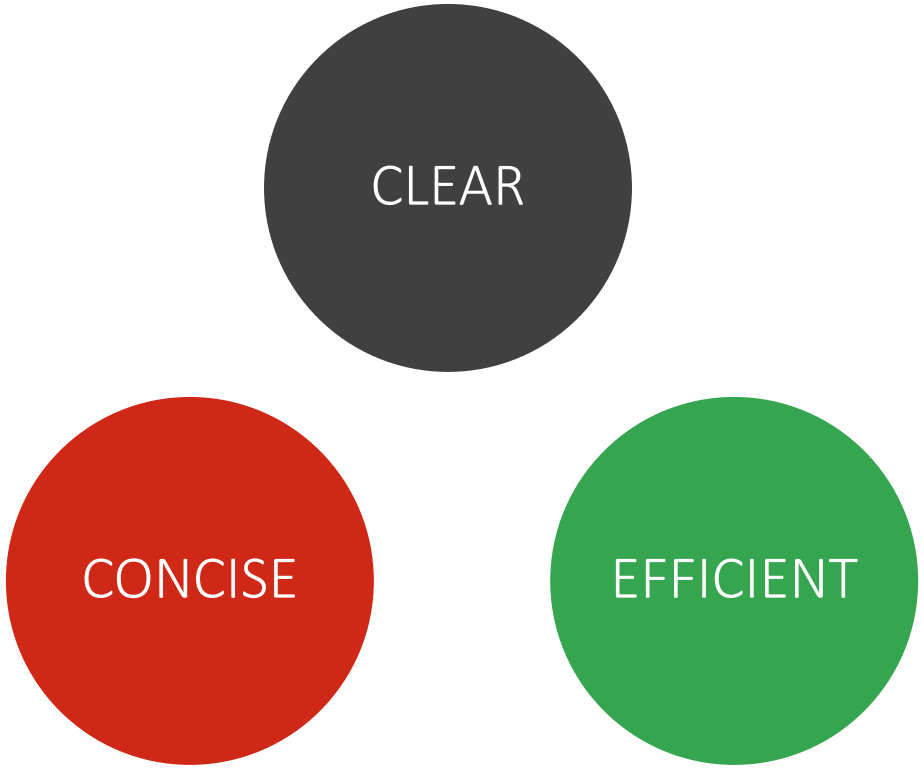
Making effective graphs and tables

Graphs and tables can be

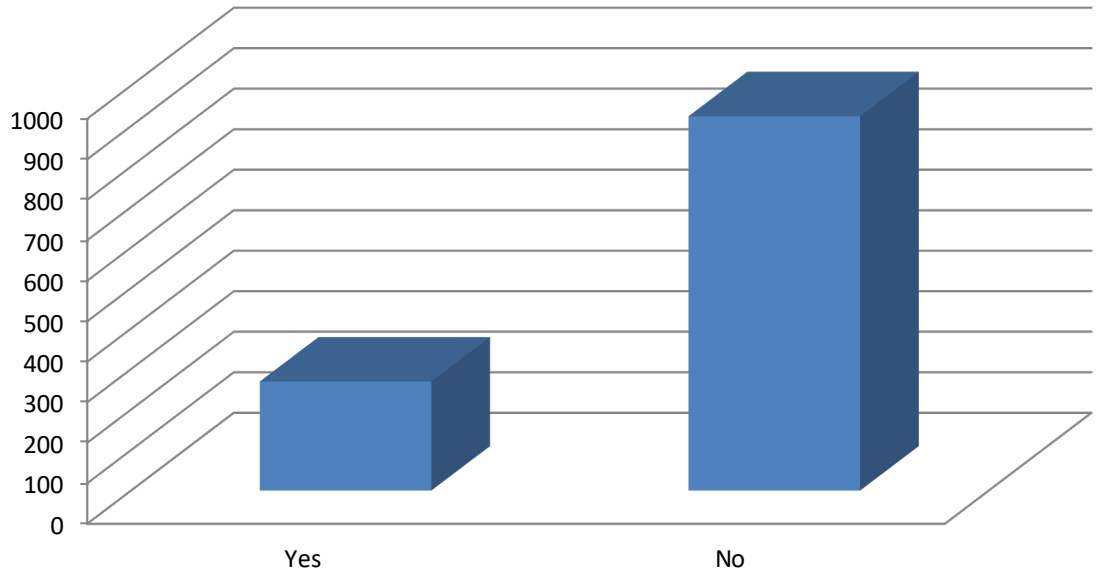
GOOD

BAD

Graphs and tables should be



What is wrong with this graph?



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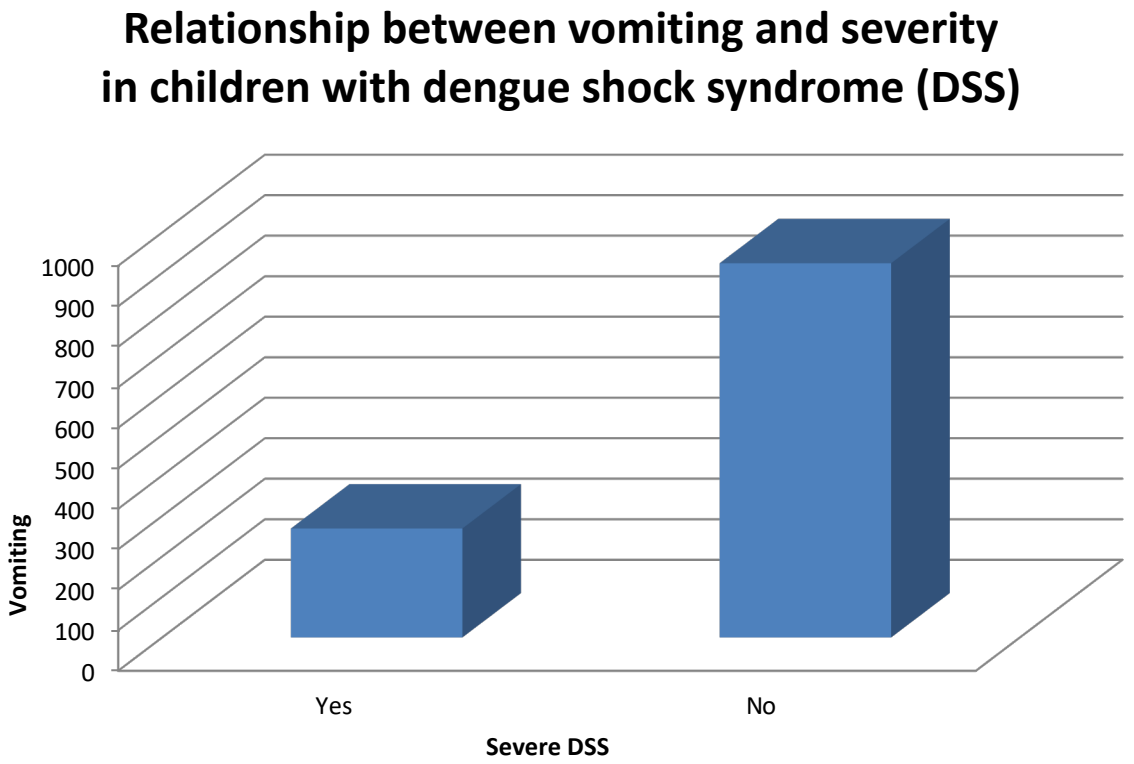

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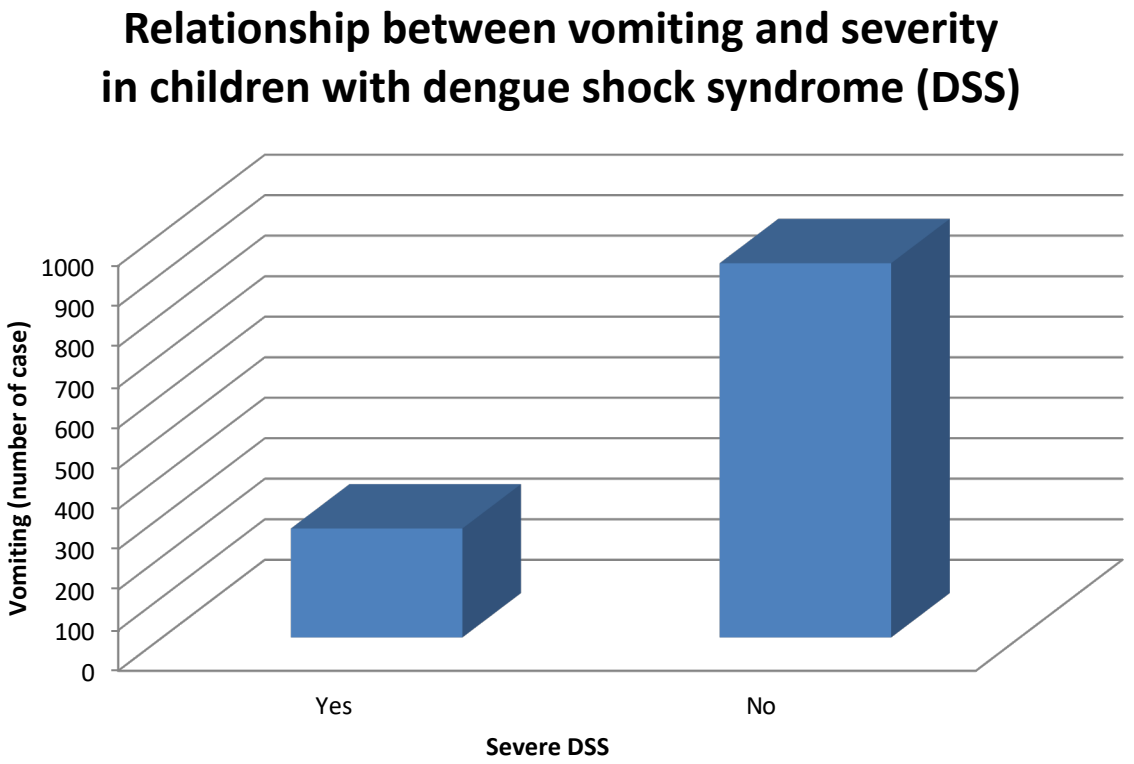

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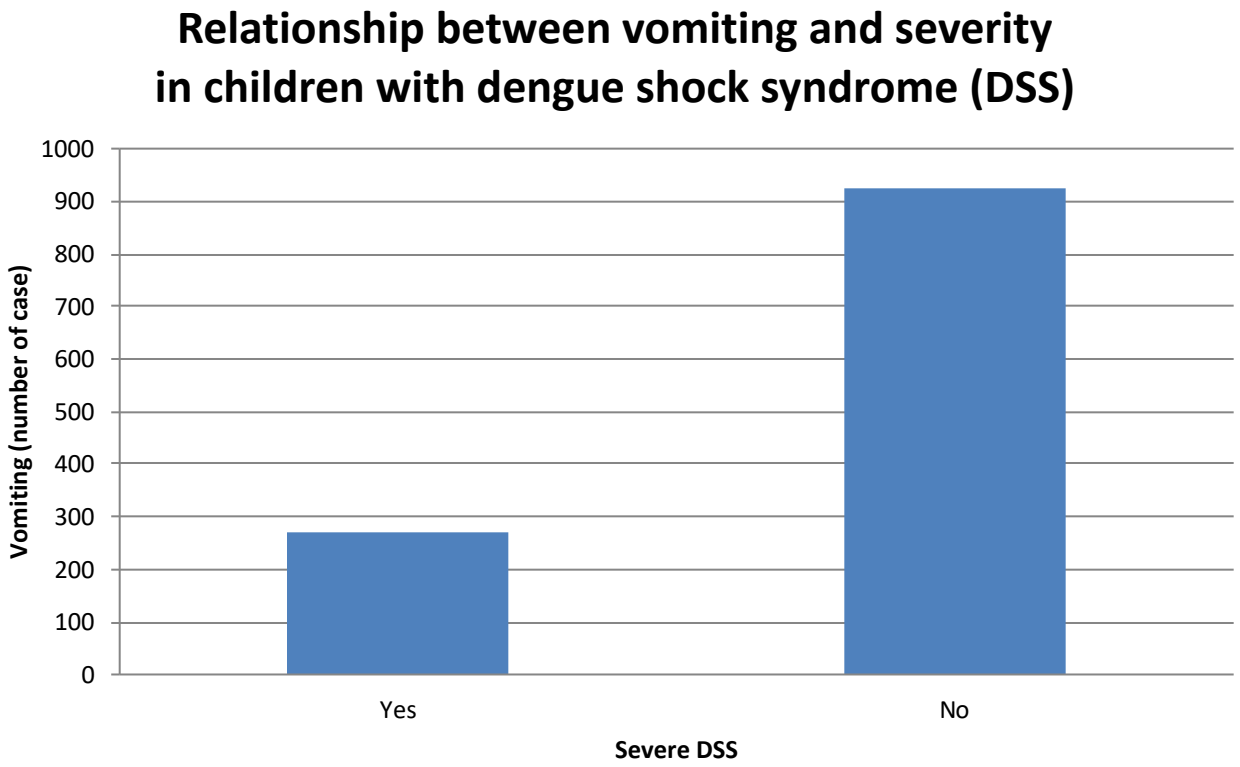

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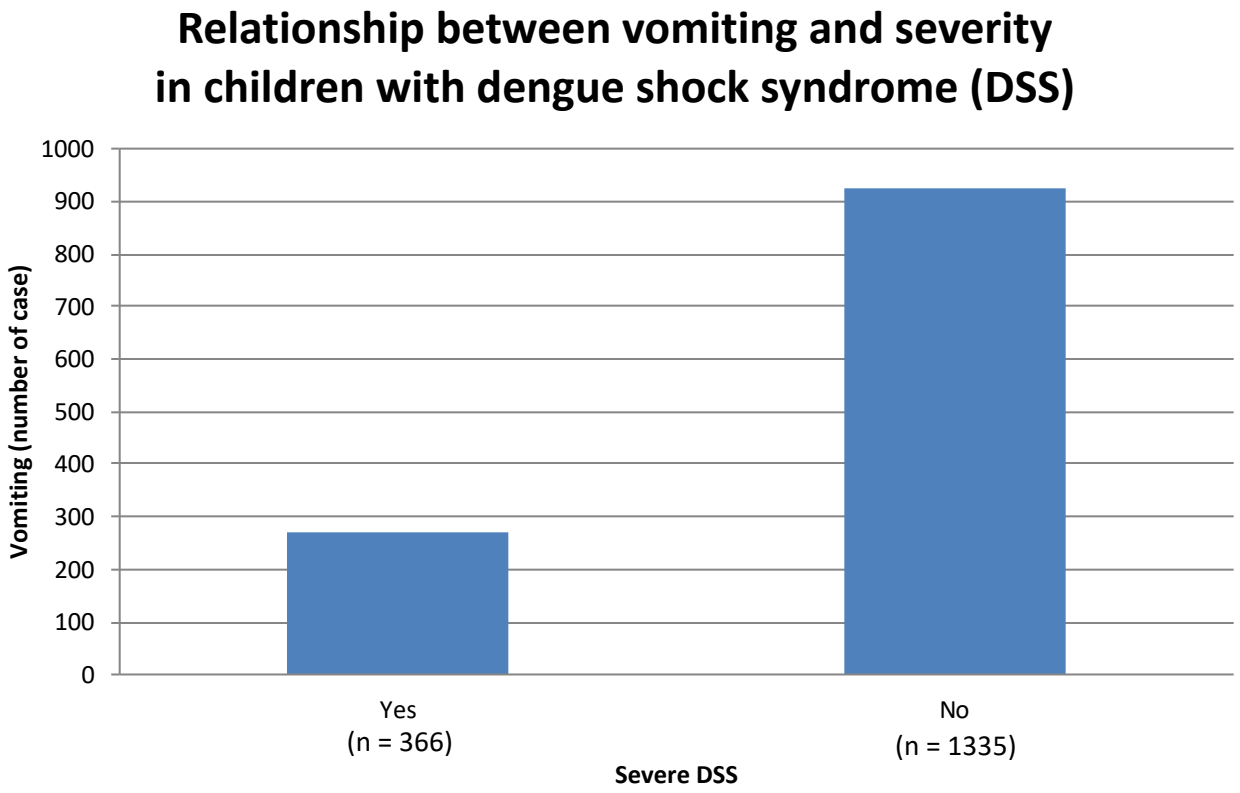

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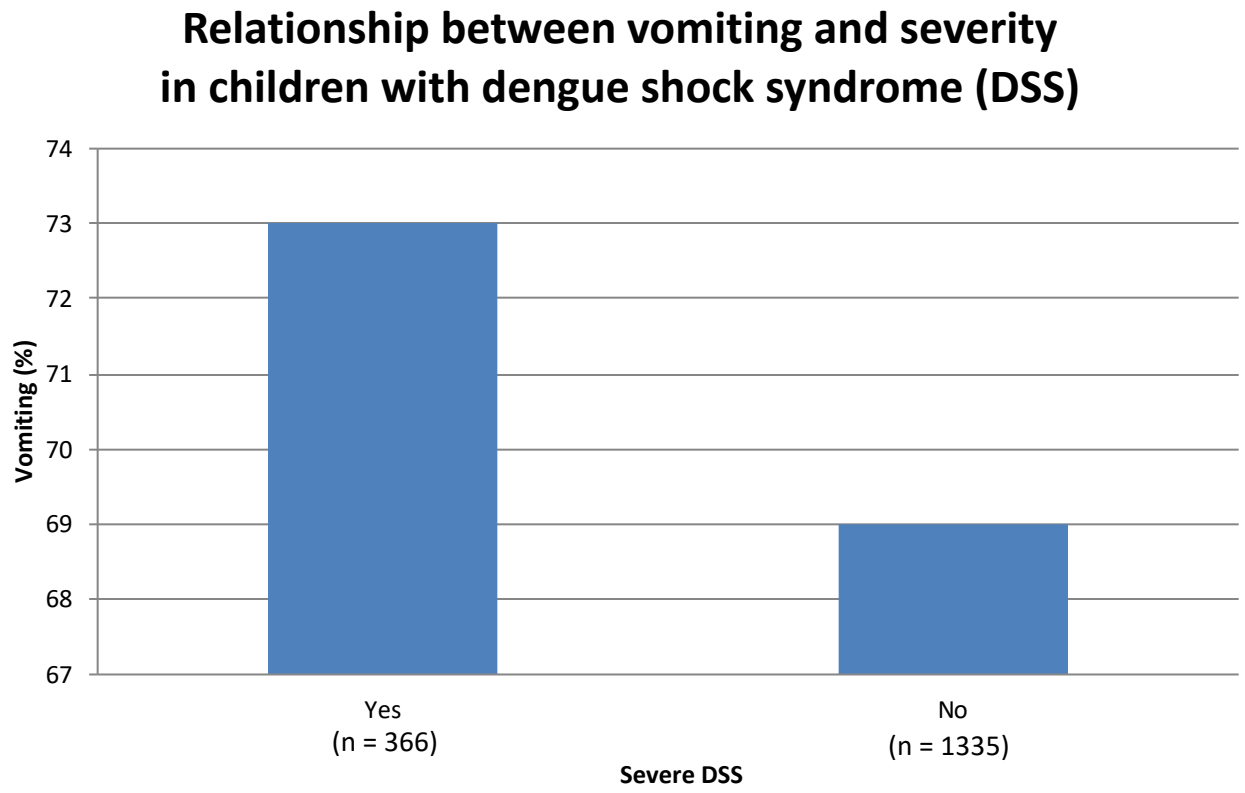

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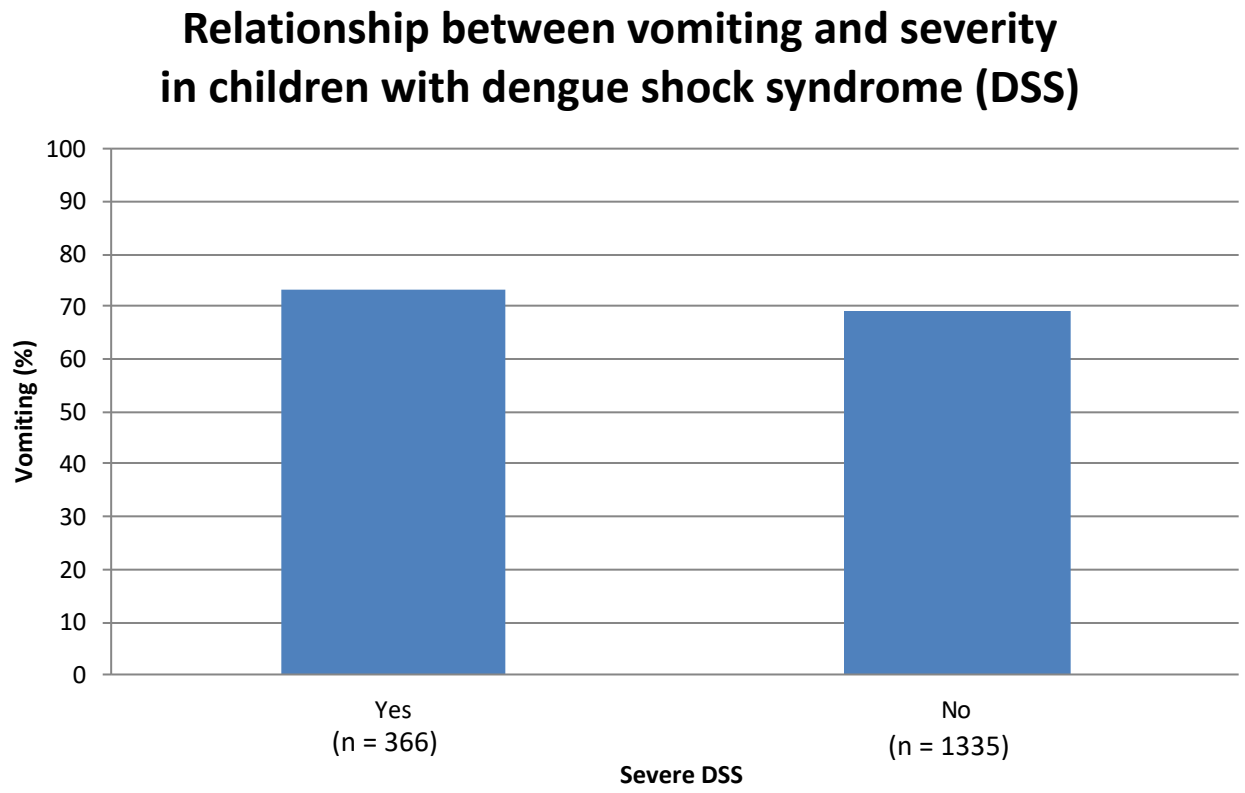

What is wrong with this table?

Characteristics	Summary statistics	
Age	9.753	(7.012 – 12.18)
Weight	27.2	(20.14 – 35.26)
Hemorrhage		
None	493	(29.1)
Skin only	1153	(67.35)
Mucosal	73	(3.55)

What is wrong with this table?

Table 1. Baseline characteristics of the study participants

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Summary

- How to make an effective graph or table?
  - Ensure its CLARITY, PRECISION, and EFFICIENCY
  - Would you like to receive a KISS? Keep It Short and Simple

RECAP

Recap

- Biostatistics
  - Descriptive and inferential statistics
- Descriptive statistics
  - Data structure: tidy data
  - Data types: categorical/continuous
  - Data summary
    - Numbers
      - Frequency, percentage, proportion
      - Location: mean, median
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    - Graphs
      - Pie chart, bar chart, dotplots
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      - Scatterplot
- Making effective graphs and tables
  - Clarity, precision, efficiency