

# 003 - Exploring Data - Part I

EPIB 607 - FALL 2020

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# Statistics in a Word

- Economics is about: *Money (and why it is good).*
- Psychology: *Why we think what we think (we think).*
- Biology: *Life.*
- Anthropology: *Who?*
- History: *What, where, and when?*
- Philosophy: *Why?*
- Engineering: *How?*
- Accounting: *How much?*

# Statistics in a Word

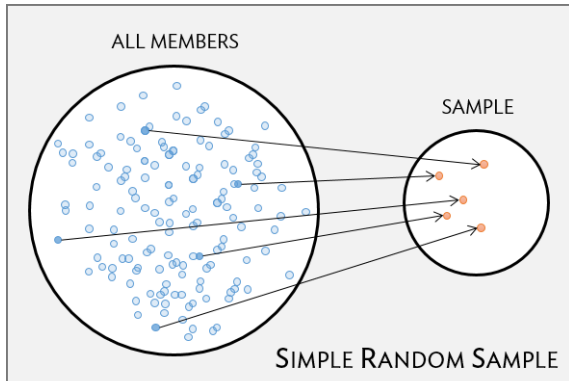
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**Statistics** is about: **Variation**

# Statistics is about quantifying uncertainty

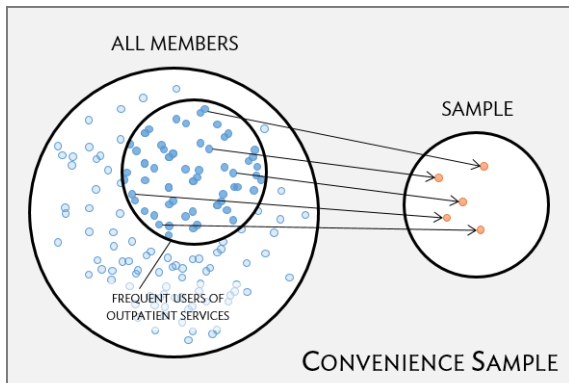
- Data vary. People are different. We can't see everything, let alone measure it all.
- Even what we do measure, we measure imperfectly.
- The data we wind up looking at and basing our decisions on provide, at best, an imperfect picture of the world.
- This fact lies at the heart of what Statistics is all about.
- How to make sense of it is a central challenge of Statistics.

# Sampling from a population



**Figure:** Random sampling is the best way to ensure that a sample reflects a population. In a simple random sample, each member of a population has the same chance of being sampled. For example, suppose we want to estimate the proportion of Montrealers who do not have a family doctor. We should randomly sample from different households in Montreal.

# Selection bias



**Figure:** Instead of sampling from different households, we simply take all individuals from the same household.

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- **Who:** Describe the individuals who were sampled (aka observations, subjects, biological samples, participants, experimental units, cases).
- **What:** Determine what is being measured. The characteristics recorded about each individual are called **variables**.

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- **Why:** What was the purpose of the survey/experiment/study?
- **When:** When was the research conducted?
- **Where:** Where was the research conducted?
- **How:** Describe how the survey/experiment/study was conducted. Simple random sample (SRS), volunteers, select population, non-representative sample ?



## Example: the *FAMuSS* study

- The Functional polymorphisms Associated with human Muscle Size and Strength study (FA- MuSS) measured a variety of demographic, phenotypic, and genetic characteristics for about 1,300 participants<sup>12</sup>.

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## Example: the *FAMuSS* study

- The Functional polymorphisms Associated with human Muscle Size and Strength study (FA- MuSS) measured a variety of demographic, phenotypic, and genetic characteristics for about 1,300 participants<sup>12</sup>.
- One goal of the study—examine the association of demographic, physiological and genetic characteristics with muscle strength.
  - ▶ In simpler terms, study the “sports gene” *ACTN3*.

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## Four rows from *FAMuSS* data matrix

```
# devtools::install_github("OI-Biostat/oi_biostat_data")
library(oibiostat)
data(famuss)
famuss %>%
  dplyr::glimpse()

## Rows: 595
## Columns: 9
## $ ndrm.ch      <dbl> 40.0, 25.0, 40.0, 125.0, 40.0, 75.0, 100.0, 57.1, 33.3,...
## $ drmm.ch      <dbl> 40.0, 0.0, 0.0, 0.0, 20.0, 0.0, 0.0, -14.3, 0.0, 0.0, 2...
## $ sex          <fct> Female, Male, Female, Female, Female, Female, Female, F...
## $ age          <int> 27, 36, 24, 40, 32, 24, 30, 28, 27, 30, 20, 23, 24, 34,...
## $ race         <fct> Caucasian, Caucasian, Caucasian, Caucasian, Caucasian, ...
## $ height       <dbl> 65.0, 71.7, 65.0, 68.0, 61.0, 62.2, 65.0, 68.0, 68.2, 6...
## $ weight       <dbl> 199, 189, 134, 171, 118, 120, 134, 162, 189, 120, 131, ...
## $ actn3.r577x  <fct> CC, CT, CT, CT, CC, CT, TT, CT, CC, CT, CT, CT, TT, CT,...
## $ bmi          <dbl> 33.112, 25.845, 22.296, 25.998, 22.293, 21.805, 22.296,...
```

## FAMuSS Variables and their descriptions

Variable	Description
ndrm.ch	Percent change in strength in the non-dominant arm, comparing strength after to before training
drm.ch	Percent change in strength in a participant's dominant arm.
sex	Sex of the participant
age	Age in years
race	Recorded as African Am (African American), Caucasian, Asian, Hispanic, Other
height	Height in inches
weight	Weight in pounds
actn3.r577x	Genotype at the location r577x in the ACTN3 gene.
bmi	The participant's body mass index



# Types of Variables

**Numerical variables** take on numerical values, such that numerical operations (sums, differences, etc.) are reasonable.

- Discrete: only take on integer values (e.g., # of family members)
- Continuous: can take on any value within a specified range (e.g., height)

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**Categorical variables** take on values that are names or labels; the possible values are called the variable's *levels*.

- Ordinal: exists some natural ordering of levels (e.g., education, likert scale)
- Nominal: no natural ordering of levels (e.g., gender)

# Types of variables

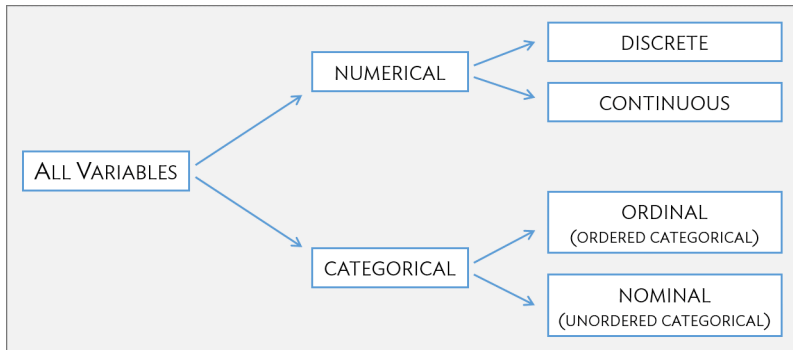


Figure: Types of variables

# Exploring data with simple tools

- Techniques for exploring and summarizing data differ for numerical versus categorical variables.
- Numerical and graphical summaries are useful for examining variables one at a time, but also for exploring the relationships between variables.



# Distributions and summary measures

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  - ▶ Center: where is the middle of the distribution?
    - ▶ Measures of center: mean, median

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- The collection of values for a numerical, continuous variable (e.g., weight) is the **distribution** for that variable.
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- Important characteristics include:
  - ▶ Center: where is the middle of the distribution?
    - ▶ Measures of center: mean, median
  - ▶ Spread: how similar or varied are the values to each other?
    - ▶ Measures of spread: standard deviation, interquartile range



## Measures of center: mean

The **sample mean** of a variable is the sum of all observations divided by the number of observations:

$$\bar{y} = \frac{y_1 + y_2 + \cdots + y_n}{n}$$

where  $y_1, y_2, \dots, y_n$  represent the  $n$  observed values in a sample.  
The mean weight in `famuss` is 155.65 pounds:

```
mean(famuss$weight)
```

```
## [1] 155.6479
```

# Measures of center: median

The **median** is the value of the middle observation in a sample.

If the number of observations is

- Odd, the median is the middle observation
- Even, the median is the average of the two middle observations

The median is the 50<sup>th</sup> percentile; 50% of observations lie below/above the median.

```
median(famuss$weight)

## [1] 150

quantile(famuss$weight, probs = 0.50)

## 50%
## 150
```

## Measures of spread

The *standard deviation* measures (approximately) the distance between a typical observation and the mean.

- An observation's *deviation* is the distance between its value  $y$  and the sample mean  $\bar{y}$ :  $y - \bar{y}$ .
- The *sample variance*  $s^2$  is the sum of squared deviations divided by the number of observations minus 1.

$$s^2 = \frac{(y_1 - \bar{y})^2 + (y_2 - \bar{y})^2 + \cdots + (y_n - \bar{y})^2}{n - 1},$$

where  $y_1, y_2, \dots, y_n$  represent the  $n$  observed values.

- The *standard deviation*  $s$  is the square root of the variance.

$$s = \sqrt{\frac{(y_1 - \bar{y})^2 + (y_2 - \bar{y})^2 + \cdots + (y_n - \bar{y})^2}{n - 1}}$$

```
sd(famuss$weight)
```

```
## [1] 34.58999
```

# Measures of Spread: Percentiles/Quartiles

The  $p^{th}$  percentile is the observation such that  $p\%$  of the remaining observations fall below this observation.

- The *first quartile* ( $Q_1$ ) is the 25<sup>th</sup> percentile.
- The *second quartile* ( $Q_2$ ), i.e., the median, is the 50<sup>th</sup> percentile.
- The *third quartile* ( $Q_3$ ) is the 75<sup>th</sup> percentile.

The *interquartile range* ( $IQR$ ) is the distance between the third and first quartiles.

$$IQR = Q_3 - Q_1$$

```
IQR(famuss$weight)

## [1] 42

diff(quantile(famuss$weight, probs = c(0.25, 0.75)))

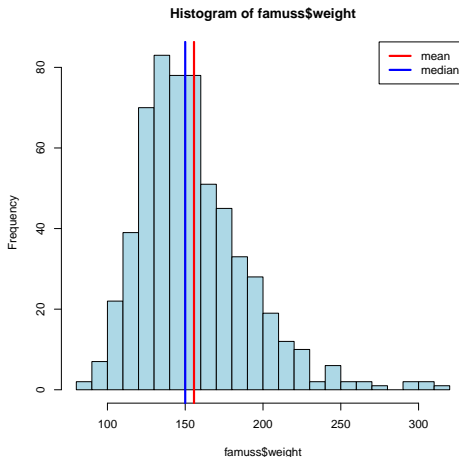
## 75%
## 42
```

# Robust estimates

- The median and IQR are called **robust estimates** because they are less likely to be affected by extreme values than the mean and standard deviation.
- For distributions containing extreme observations, the median and IQR provide a more accurate sense of center and spread.

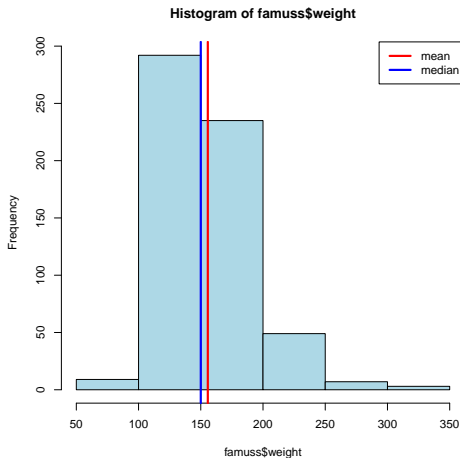
# Histograms

```
hist(famuss$weight, breaks = 30, col = 'lightblue')  
abline(v = mean(famuss$weight), lwd = 3, col = "red")  
abline(v = median(famuss$weight), lwd = 3, col = "blue")  
legend("topright", legend = c("mean", "median"), col = c("red", "blue"), lwd = 3)
```



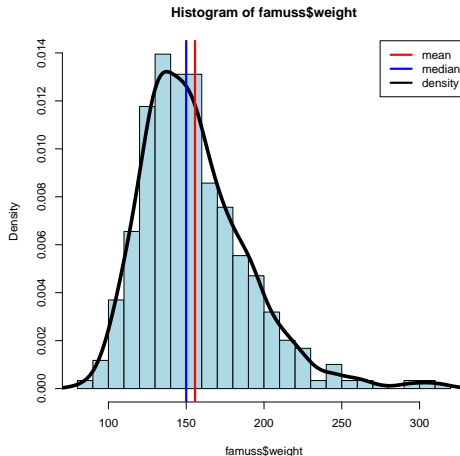
# Histograms

```
hist(famuss$weight, breaks = 5, col = 'lightblue')
abline(v = mean(famuss$weight), lwd = 3, col = "red")
abline(v = median(famuss$weight), lwd = 3, col = "blue")
legend("topright", legend = c("mean", "median"), col = c("red", "blue"), lwd = 3)
```



# Density plots

```
hist(famuss$weight, breaks = 30, col = 'lightblue', probability = TRUE)
openintro::densityPlot(famuss$weight, add = TRUE, lwd = 5)
abline(v = mean(famuss$weight), lwd = 3, col = "red")
abline(v = median(famuss$weight), lwd = 3, col = "blue")
legend("topright", legend = c("mean", "median", "density"),
      col = c("red", "blue", "black"), lwd = 3)
```





# Histograms ...

- Histograms show important features of the shape of a distribution:
  - ▶ Symmetry, or lack of it (skew)
  - ▶ Minimum and maximum values
  - ▶ Regions of high frequency (modes)

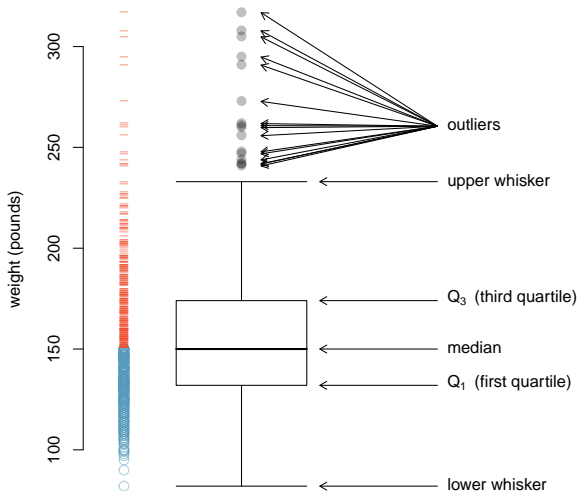
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  - ▶ Identifying extreme values

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  - ▶ Identifying extreme values
- Remember that histograms are sensitive to the number of bins!

# Boxplot for weight



# Boxplots

A boxplot indicates the positions of the first, second, and third quartiles of a distribution in addition to potential **outliers**, observations that are far from the center of a distribution.

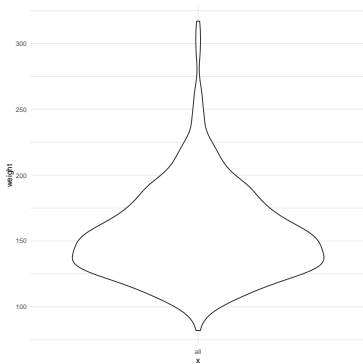
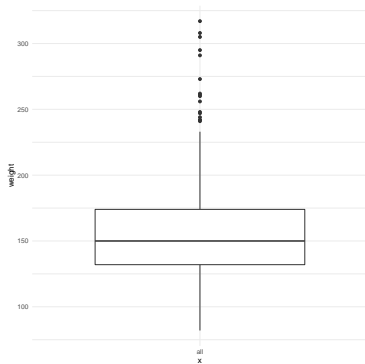
- Large outliers: values  $> Q_3 + (1.5 \times IQR)$
- Small outliers: values  $< Q_1 - (1.5 \times IQR)$

On a boxplot...

- The rectangle extends from the first quartile to the third quartile, with a line at the second quartile (median).
- Whiskers capture data between  $Q_1 - (1.5 \times IQR)$  and  $Q_3 + (1.5 \times IQR)$  ; whiskers must end at data points.
- Potential outliers shown with dots.

# Boxplots vs. Violin plots

```
p1 <- ggplot(data = famuss, mapping = aes(x = "all", y = weight)) + theme_minimal()
p1 + geom_boxplot()
p1 + geom_violin()
```





# Tables

A table for a single variable, a *frequency table* or *one-way table*, summarizes the distribution of observations among categories.

Based on the table, describe the distribution of genotype at the location *actn3.r577x* among the study participants.

```
table(famuss$actn3.r577x)
```

```
##  
##  CC  CT  TT  
## 173 261 161
```



# Bar plots for categorical data

A bar plot is a common way to display a single categorical variable.

```
graphics::barplot(table(famuss$actn3.r577x))  
sjPlot::plot_frq(famuss$actn3.r577x)
```

