# Hypothesis Testing and t-tests

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# A Few Important Definitions.

- Population: all of the individual units of interest (what we want to know about)
- Sample: a subset of the population that is studied (what we can actually observe).
- Descriptive statistics: values calculated from samples that describe the sample. Examples include the mean, median, and standard deviation.
- Inferential statistics: values calculated from samples that let you learn something about the data. One example is a P-value.

# Hypothesis Testing.

- Ho : The Null Hypothesis.
- $H_A$ : The Alternative Hypothesis

We collect evidence to see if we can or cannot reject the null hypothesis. We never accept the null or the alternative hypothesis.

The null and alternative hypothesis should be decided before you start the experiment.

# Error in Hypothesis Testing

What you conclude

| Reality | Ho CANNOT be rejected | Ho is rejected |
|---|---|---|
| Ho True | ✓ | Type 1 error |
| Ho False | Type 2 error | ✓ |

# Using Statistics to Test Our Hypothesis

- In order to actually test our hypothesis, we need statistics.
- We need to know how likely it is that we would see our results (results we get from our samples) if the null hypothesis was true so we can decide if it is reasonable to reject it or not.
- The scientific body has decided that there needs to be less than a 5% chance that your results are different from the null due to random chance.
- This is the infamous $P < 0.05$
- How do we use statistics to figure out if $P < 0.05$?

# A Tale of Two Distributions

- Population distribution.
  - Distribution of all the different values of a variable in a population.
  - Effectively impossible to know in most situations.
- Sampling distribution.
  - Distribution of all the different sample statistic values you could theoretically get when you randomly draw a sample from a population.
  - Many different ways to estimate or make an educated guess about the sampling distribution.

# Sampling Distribution Example.

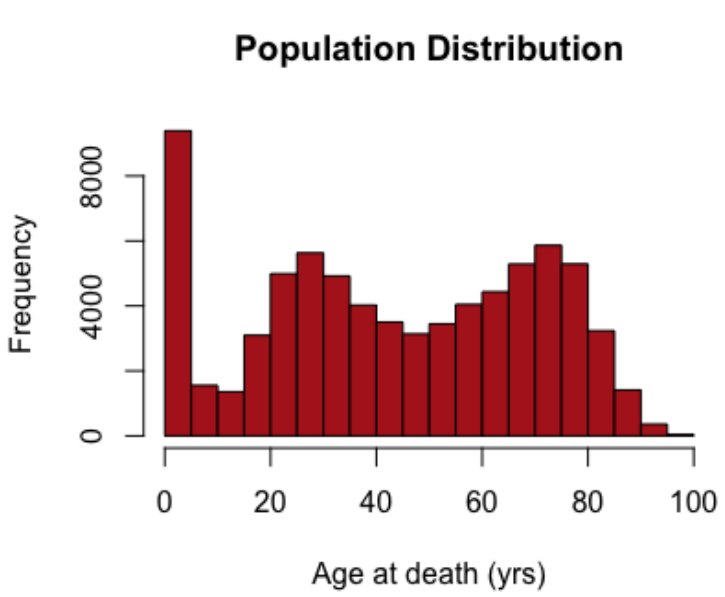
To open the proper R file, got to the Stats workshop folder that you should have downloaded from GitHub (or download the folder now from https://github.com/ubcbraincircuits/BCCHRI-DBC-ICORD-Stats-Workshop-2021 by clicking code and download zip)

Go into the t-test_work subfolder and open up the t-test_script_working rmd file with Rstudio.

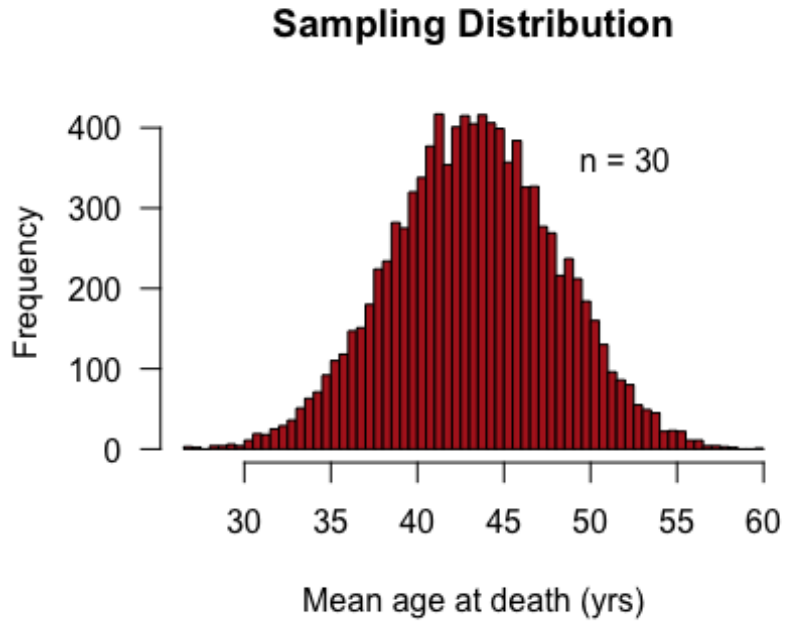
Now you are ready to start working.

# The Central Limit Theorem

- The sampling distribution of a sample mean is approximately normal for large sample sizes.




Take a sample of 30 individuals from the population and calculate the mean age. Repeat 10,000 times and put means in histogram.




Example using data of the age of death in Switzerland during the Spanish Flu Pandemic.

# The Student's t-statistic.

$$t = \frac{\bar{X} - \mu}{\frac{s}{\sqrt{N}}}$$

X = Sample Mean μ = mean under the null hypothesis

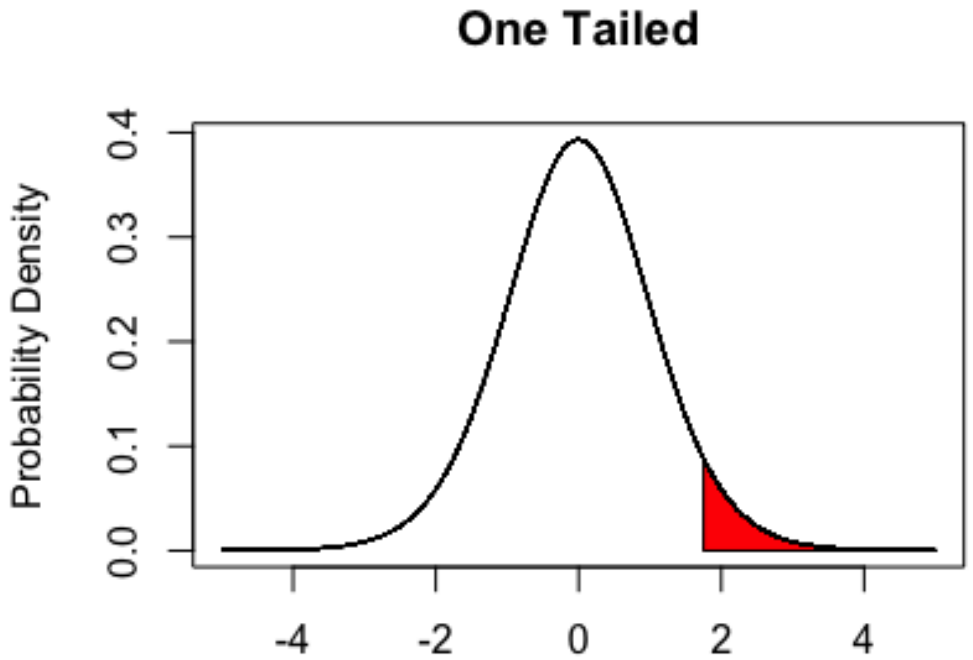
s/sqrt(N) = Standard error of the sample

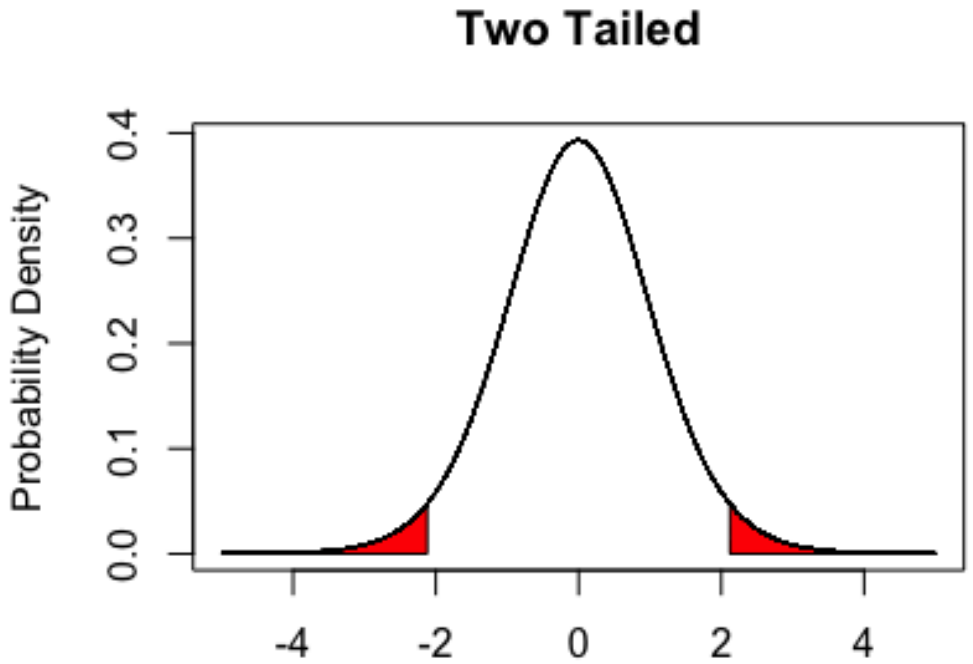
- Two major points to take from this equation
  - The student's t statistic is a measure of the difference between the sample mean and the mean under the null hypothesis.
  - The t statistic changes depending on the sample size.

# One Tail vs Two Tail.

- One tail and two tailed tests are referring to the rejection region
- Deciding between these two is entirely a function of how you are wording your alternative hypothesis.
  - Greater than the null?
  - Less than the null?
  - More extreme than the null?

Note: How you word your alternative hypothesis should be based on what results you are interested in.



# Three Different Kinds of t-tests.

- One sample t-test
  - Used to test if the sample statistic is significantly different from what we would expect if the null hypothesis was true.
- Two sample t-test
  - Used to test if two independent populations are significantly different from each other.
- Paired t-test.
  - Used to test if a population undergoes a significant change after a certain treatment.

# Assumptions of the different t-tests

- One sample t-test
  - Random sampling
  - The variable is normally distributed. Robust to this assumption if the sample size is very large (central limit theory).
- Two sample t-test
  - Random sampling in both populations
  - The variable is normally distributed in both populations. Robust to this assumption if the sample size is very large (central limit theory).
  - The standard deviation of the variable is the same in both populations.
- Paired t-test.
  - Random sampling
  - The variable is normally distributed. Robust to this assumption if the sample size is very large (central limit theory).

# When The t-test Won't Work and What You Should Do.

- What do we do if our sample statistic does not seem to be normally distributed and our sample size is small? What if we want to look at a statistic other than the mean? Bootstrapping and permutation testing.

- What if we have more than two groups we need to compare? ANOVA and multiple comparisons.

# Additional Resources.

- The Analysis of biological data by Whitlock and Schlutler
- An introductory R tutorial made by the Brain Circuits Research Cluster (link here)