

Statistical Inference for Data Science

Dr. Anja Mühlemann

29. August 2024





Questions from Day 2

Day 3

Hypothesis Testing

Today's Topics

- Hypotheses
- p-values
- Error types
- Frequently used tests

Inferential Statistics

Inferential Statistics

With a certain degree of certainty, one would like to draw conclusions from empirical data, even if the data are subject to error or incomplete.

3 main techniques

- **Parameter estimates:** Calculation estimate for unknown parameter of underlying probability distribution
- **Confidence intervals:** Calculation of a region within which unknown parameter should lie with certain degree of certainty
- **Tests:** Tests are intended to prove that a certain effect, e.g. the effect of a vaccine, is indeed present.

Tests

- Method for deciding on the correctness of hypotheses under uncertainty

e.g., new medication is better than the old one

2 Hypotheses:

- **Working hypothesis (H1):** Motivation of the study
e.g., the new medication is **better** than the old one
- **Null hypothesis (H0):** Opposite of H1
e.g. the new medication is **not better** than the old one

Goal: reject the null hypothesis with some degree of certainty

Tests

- Statistical test rely on a **test statistic**, for which distribution under the test assumptions and H_0 is known.
- We calculate the value of the test statistic for the sample at hand (\hat{T})
- And check whether this value is **probable** for the distribution under H_0 .
- To this end the **p-value** is calculated
- If the **p-value < 1 - desired degree of certainty**, we reject H_0
- Otherwise, we cannot reject H_0 , which does **not** necessarily imply that H_1 holds

p-value

- To illustrate what a p-value is, I'll illustrate the *one sample t-test* in a little more detail
- **Assumptions:** independent observations, approx. normal
- **Possible hypotheses:**

$$H_0: \mu = \mu_0, \quad H_1: \mu \neq \mu_0,$$

$$H_0: \mu \leq \mu_0, \quad H_1: \mu > \mu_0,$$

$$H_0: \mu \geq \mu_0, \quad H_1: \mu < \mu_0,$$

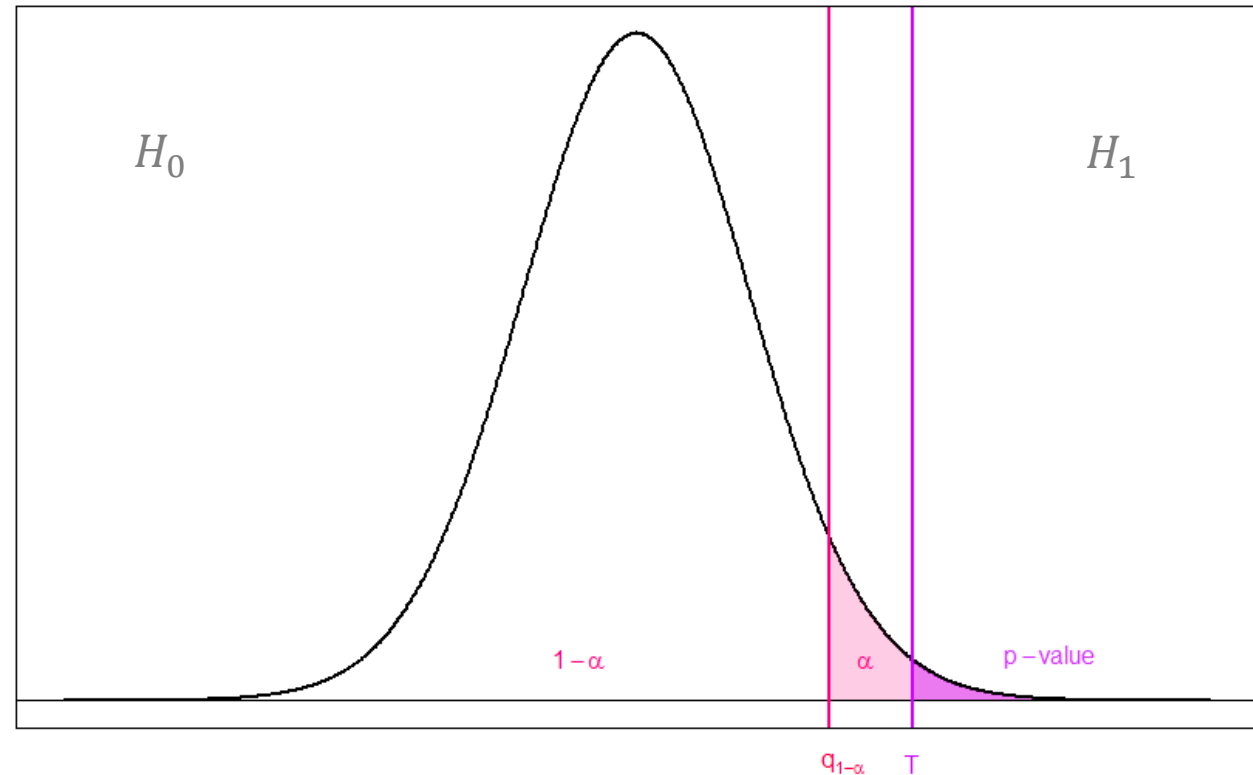
- **Test statistic:**

$$T = \frac{\hat{\mu} - \mu_0}{\hat{\sigma}} \sqrt{n}$$

- Thus, T is large (≥ 0) if H_1 holds, and T is small (< 0) if H_0 holds

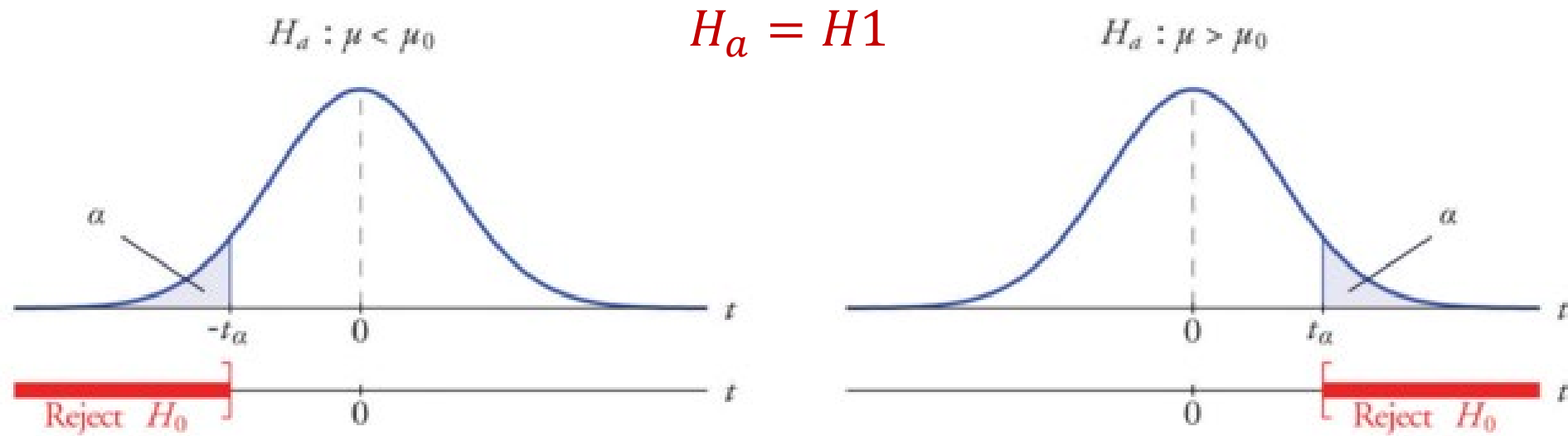
p-value

- **Distribution:** One can show that if H_0 holds, then T follows a t-distribution with $n - 1$ degrees of freedom

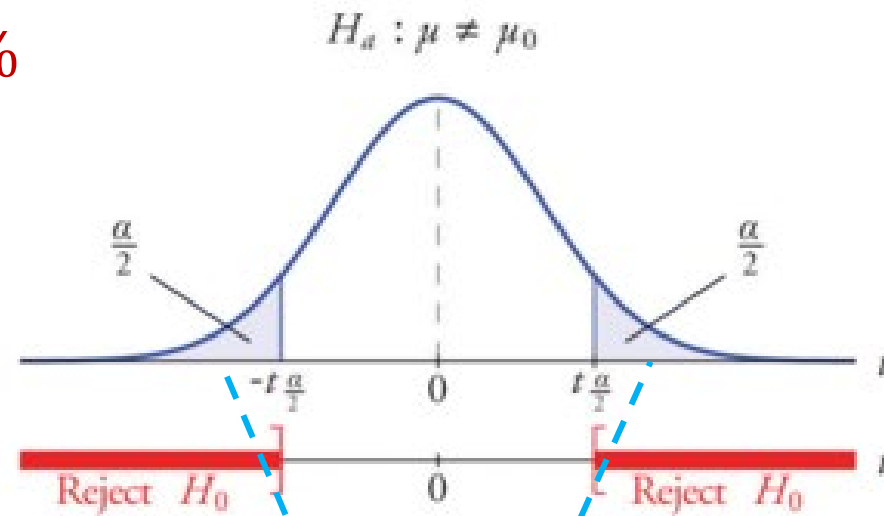


- Thus, the p-value is «*the probability to observe a even more extreme value in terms of H_0 than the one at hand*»

Tests



Typically $\alpha = 5\%$



Unlikely observations under H_0

Errors

- **Type 1:** Wrongly reject the null hypothesis due to a fluctuation (**false positive**)
- **Type 2:** Wrongly keep the null hypothesis by interpreting a real effect as a fluctuation (**false negative**)

		Reality	
		True	False
Measured or Perceived	True	Correct 😊	Type 1 error False Positive
	False	Type 2 error False Negative	Correct 😊

Prison example

Innocent person set free	Innocent person jailed
Guilty person set free	Guilty person jailed

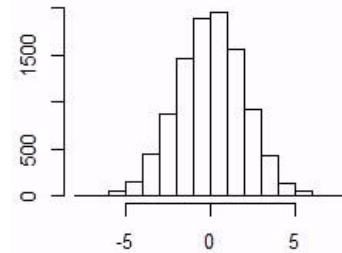
Types of Tests

- **One group:** the mean monthly income is larger than 5000.-
 - **Two groups:** the mean income of men is larger than that of women
 - **\geq Three groups:** effect of tea on weight loss (green, black, none)
- \geq Two groups:**
- **Paired:** dependent, repeated measurements on same individual, **e.g.** blood pressure before and after surgery
 - **Unpaired:** independent, from separate individuals, **e.g.** blood pressure after medication 1 vs. blood pressure after medication 2

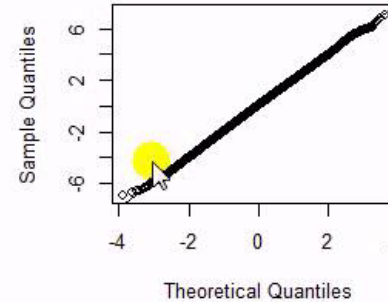
Normality

- Many test assume that the sample comes from a normal distribution
- Thus, we need to check whether this is fulfilled before performing such a test
- Shapiro-Wilk test, Shapiro-Francia test, Q-Q-Plot, ...

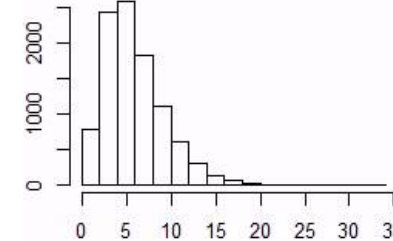
Symmetric distribution



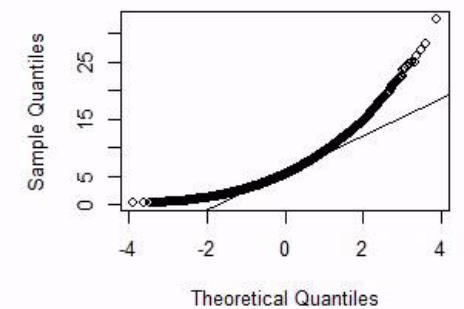
Normal Q-Q Plot



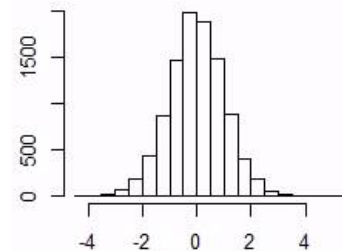
Postive skew



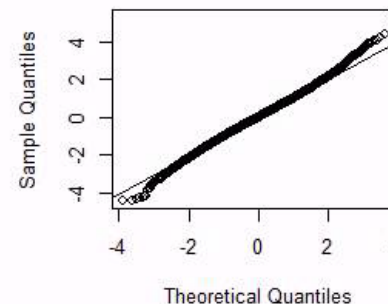
Normal Q-Q Plot



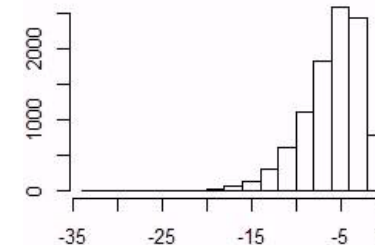
Symmetric with fat tails



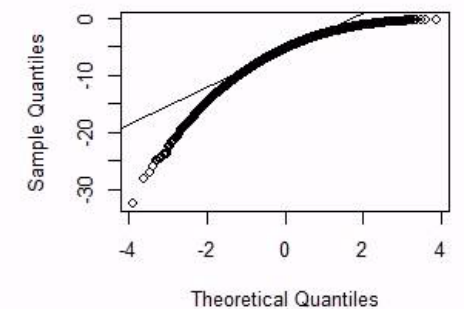
Normal Q-Q Plot

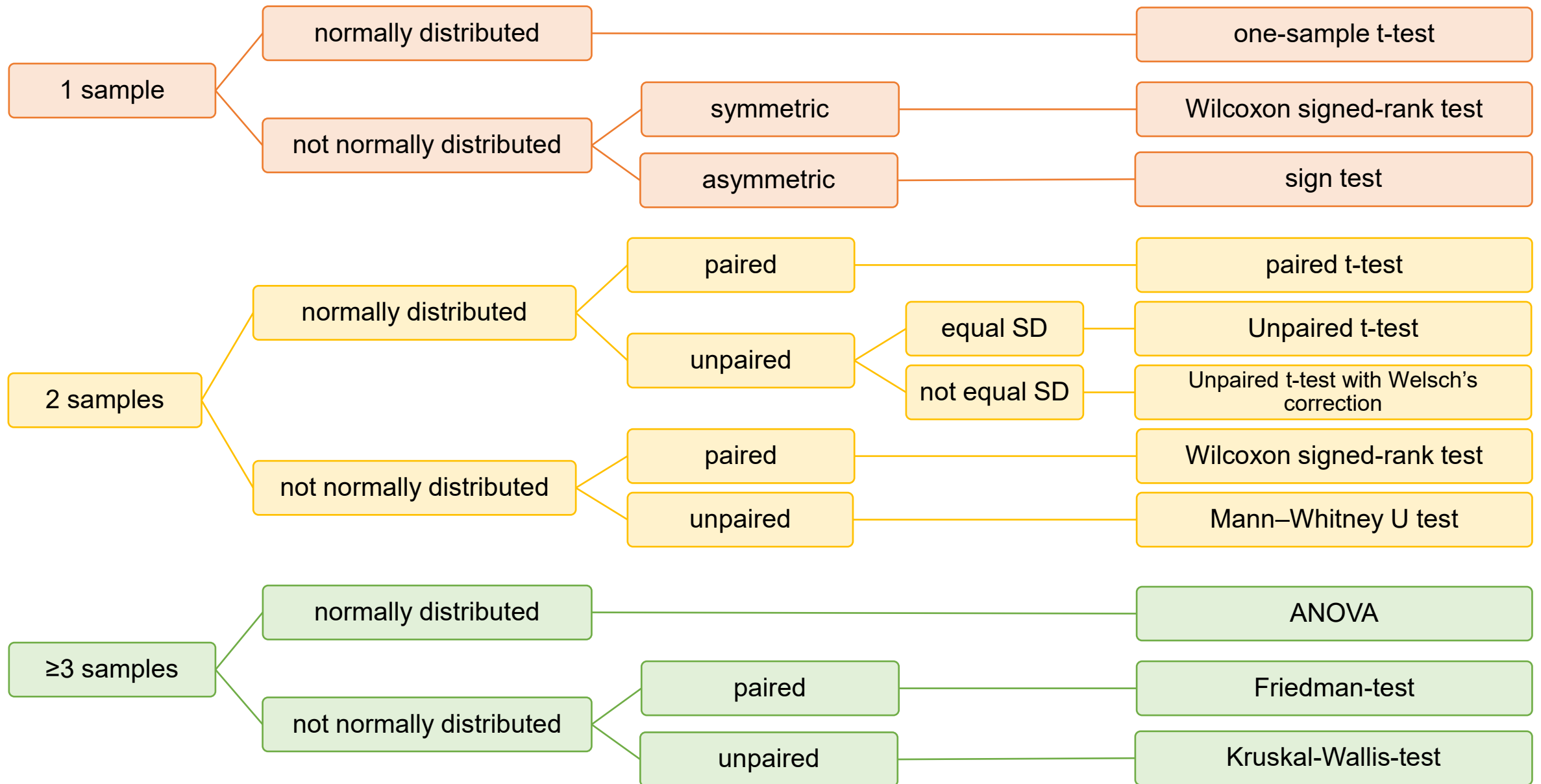


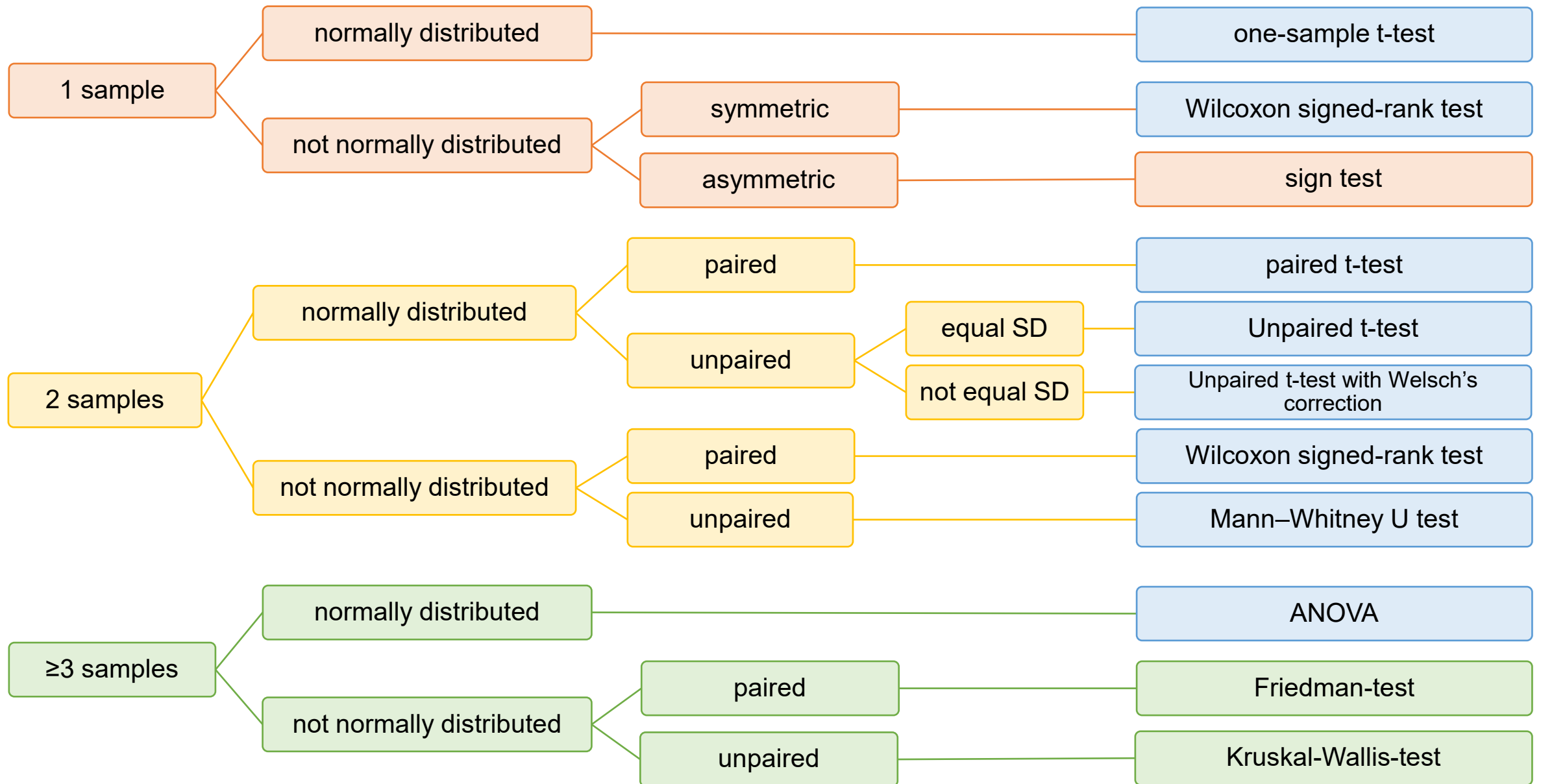
Negative skew



Normal Q-Q Plot







Exercise

- 3 Slides to be uploaded to ILIAS today
 - 1 slide: Question that the test tries to answer, assumptions on data, other details
 - 1 slide: example from “real live” (if possible)
 - 1 slide: your conclusion from the Notebook on this test
- Will be presented at tomorrow’s discussion session

Nr	Test
1	One-sample t-test
2	One-sample Wilcoxon SR test
3	Paired t-test
4	Paired Wilcoxon SR test
5	Unpaired t-test
6	Unpaired t-test with Welsch’s correction
7	Mann-Withney U test
8	One-way ANOVA