Introduction virtual exercise 1 – Linear elasticity of bone

Orestis G. Andriotis

Institute of Lightweight Design and Structural Biomechanics
TU Wien

Objectives

- How was the experiment conducted in the lab?
- How to design your virtual experiment?
- Prepare your input ".dat" file
- Trial and error – run script using two commands
- create1op
- module1op

ILSB

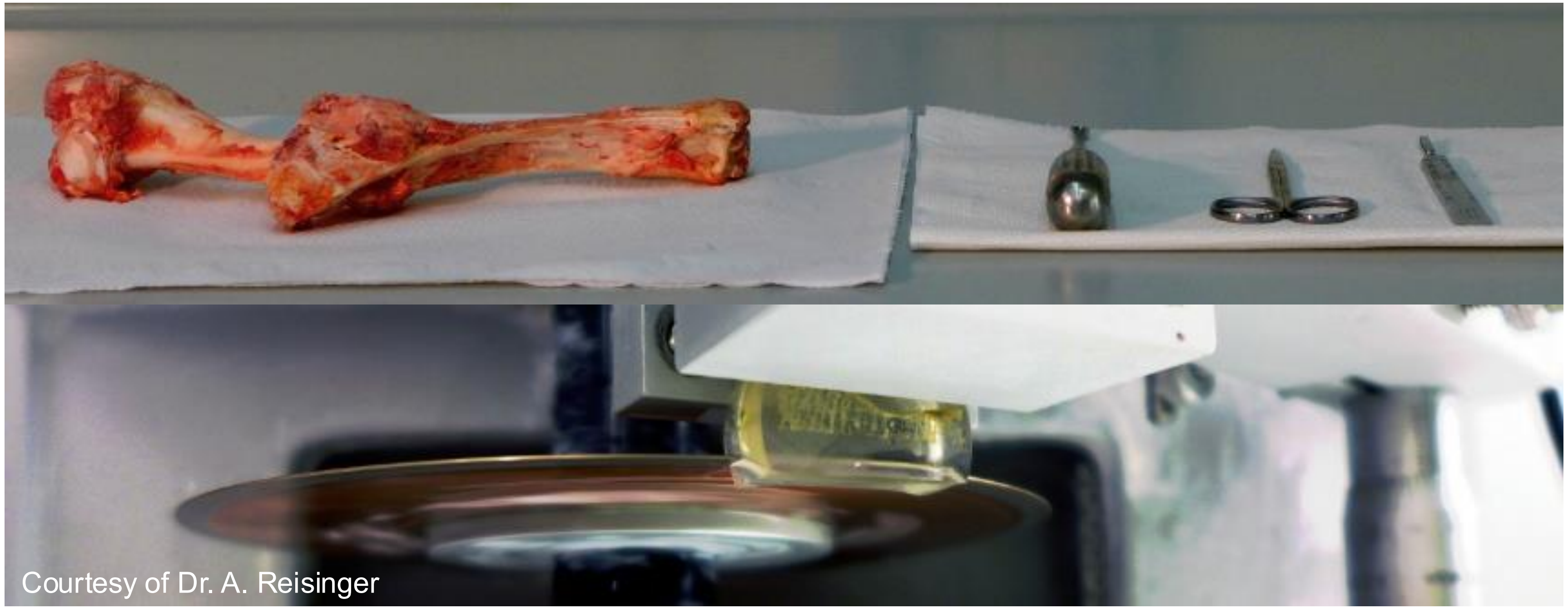
What would you do in the Laboratory?

Safety equipment and safety regulations

Sample preparation

Sample Preparation of Bone Samples

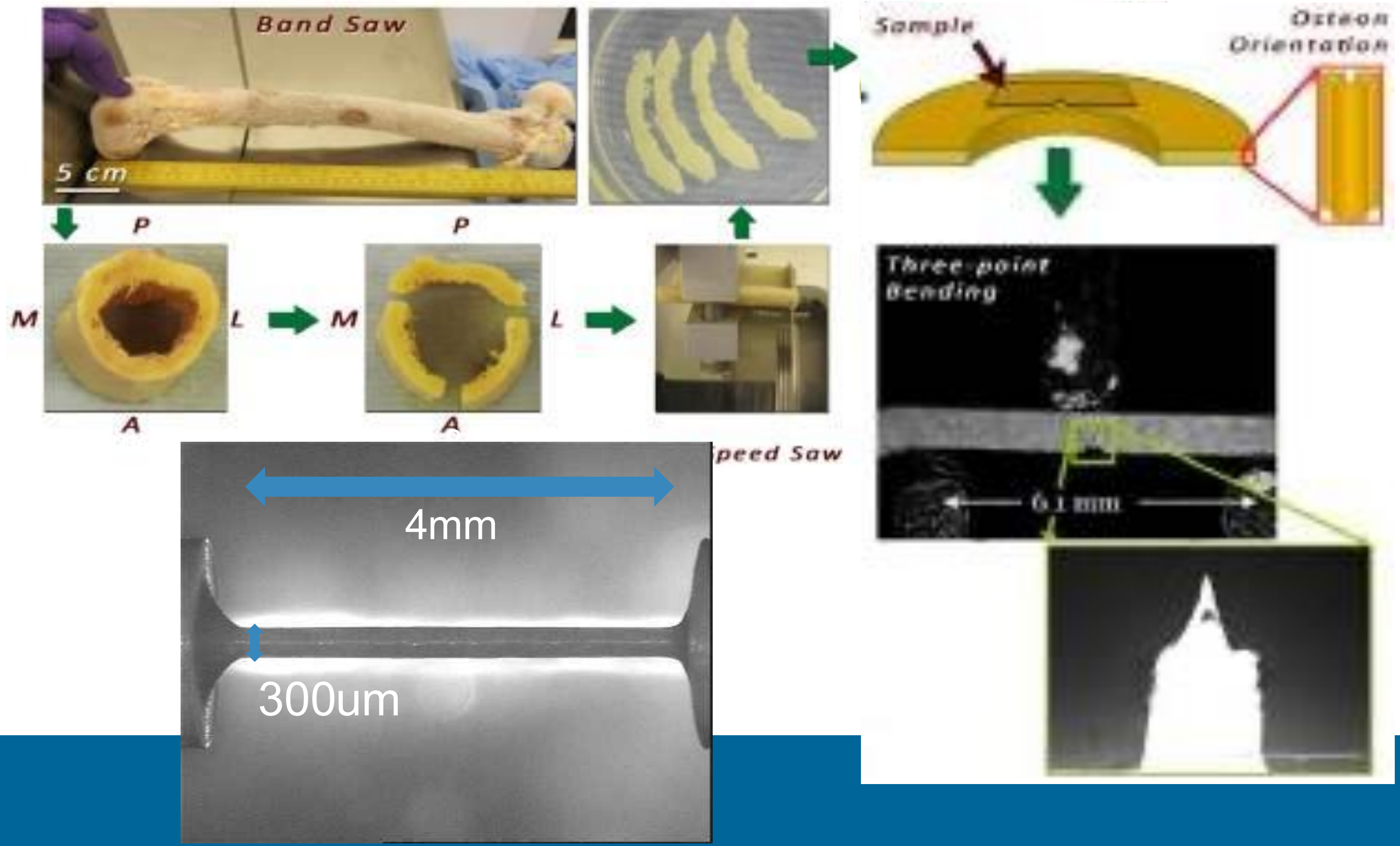
1. Using tools (scalpel, tweezers etc.) remove soft tissue from bone.
2. Cut bone in small pieces until you reach the desired geometry


Courtesy of Dr. A. Reisinger

Sample Preparation

Sample Preparation of Bone Samples

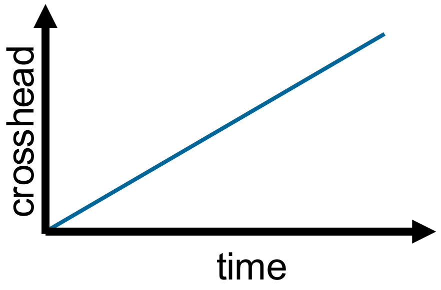
1. **Aim:** prepare samples for mechanical testing
2. Consider the hierarchical architecture of bone

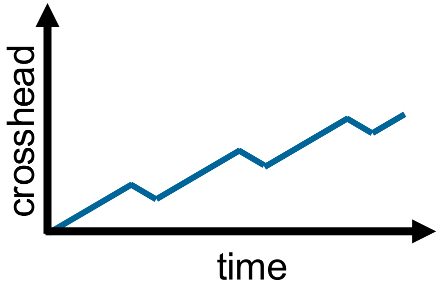


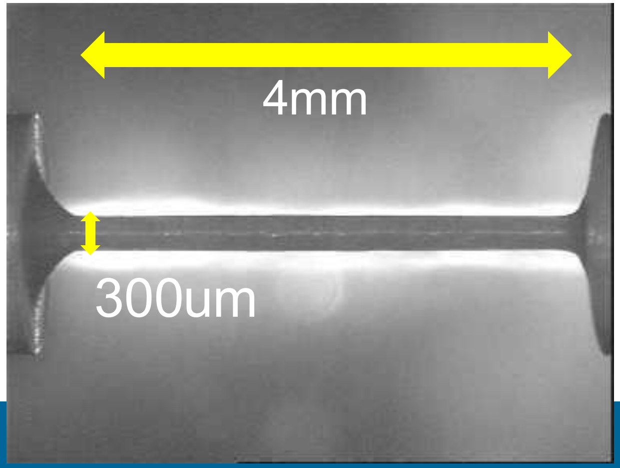
Input Parameters, Loading Scenario etc.

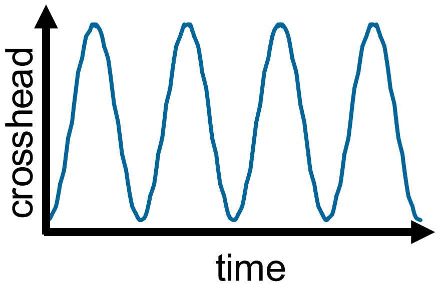
Mechanical analysis requires:

1. The sample dimensions
   A. Gauge length
   B. Diameter
   C. Cross section area
2. Define the loading scenario
   A. Quasi-static or dynamic
   B. Load or displacement control
   C. Tension, compression, bending etc.





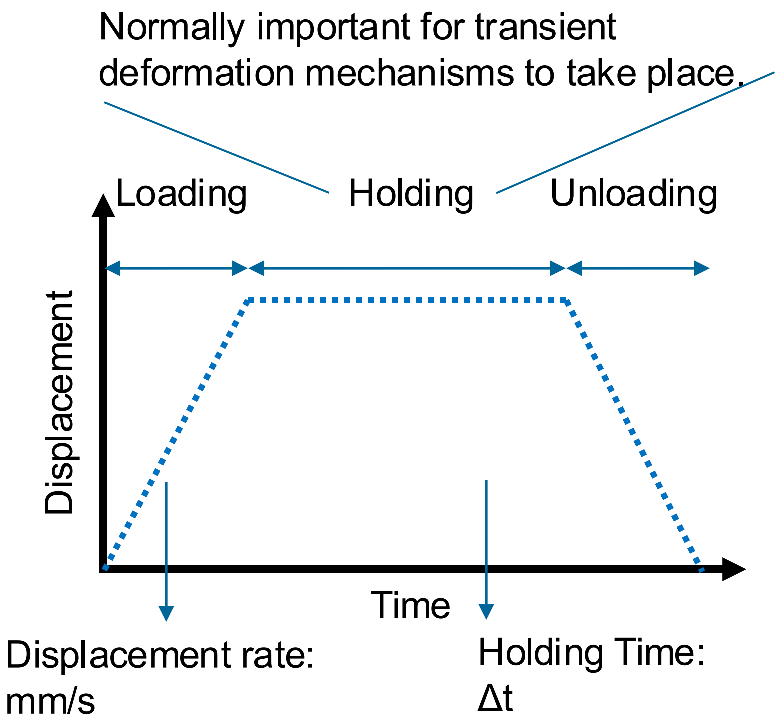




Quasi-static Loading Scenario

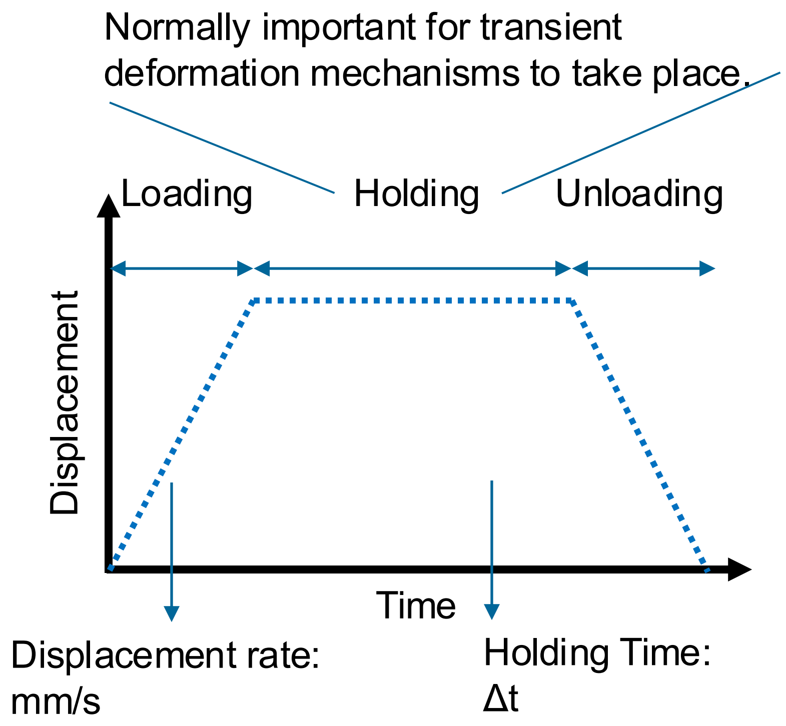
Input: Loading scenario

Output: force - displacement

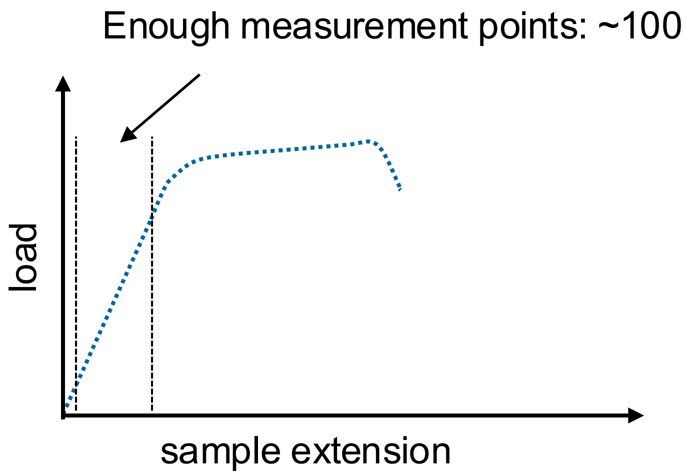


Quasi-static Loading Scenario

Input: Loading scenario



Output: force - displacement

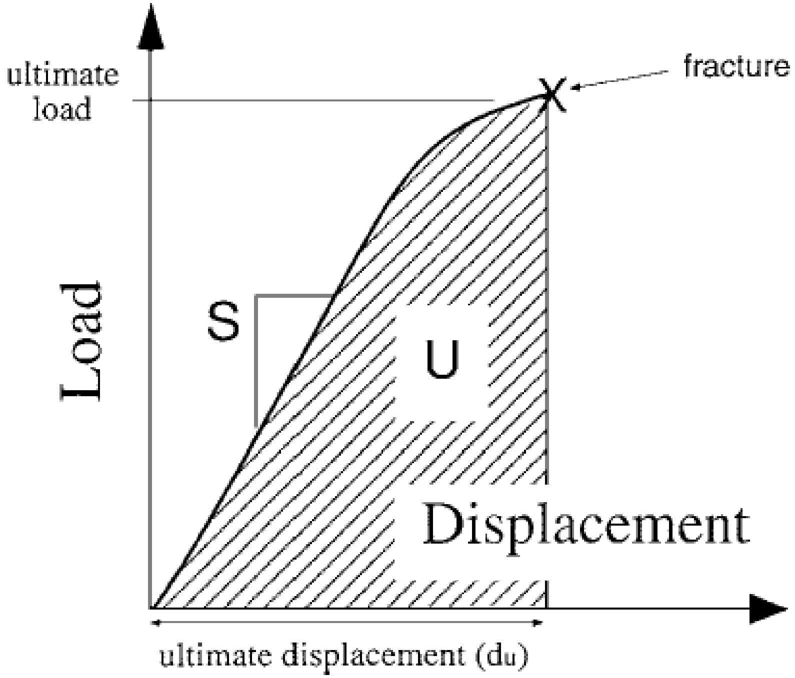


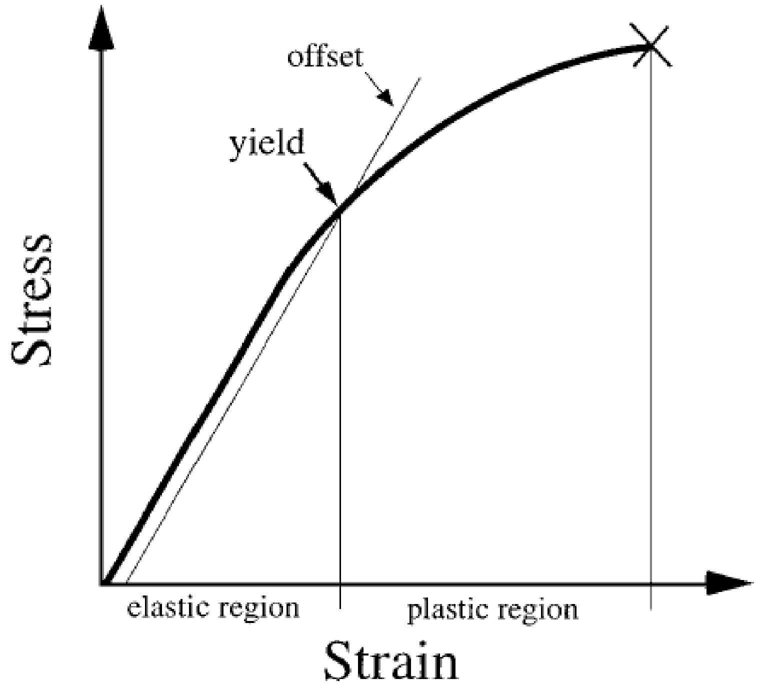
Sampling frequency

- Matched to speed and sample behaviour e.g. to determine Young's modulus -> obtain 100 measurement points in elastic regime

Mechanical Characterization – Data Analysis

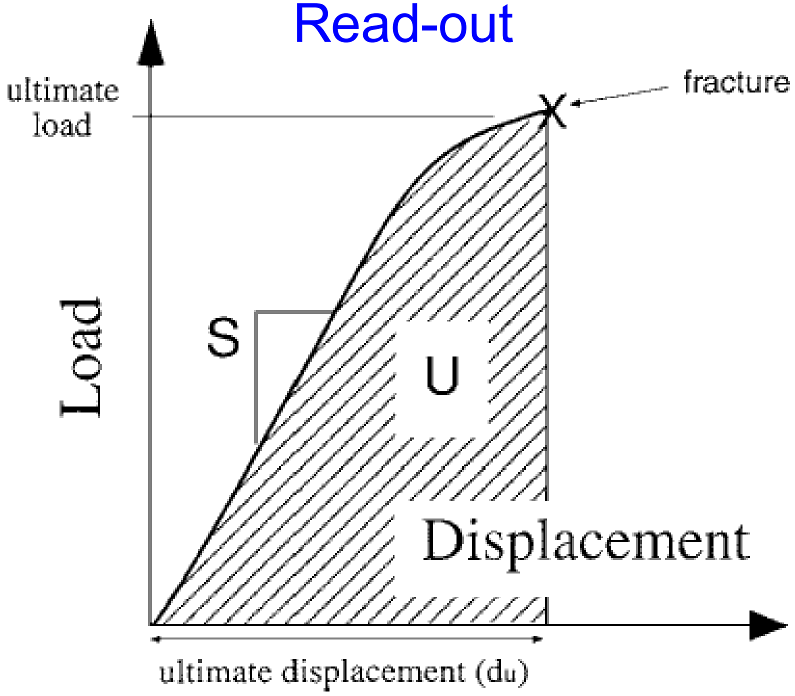
Quiz: What parameter is **measured** and which one is **calculated**?



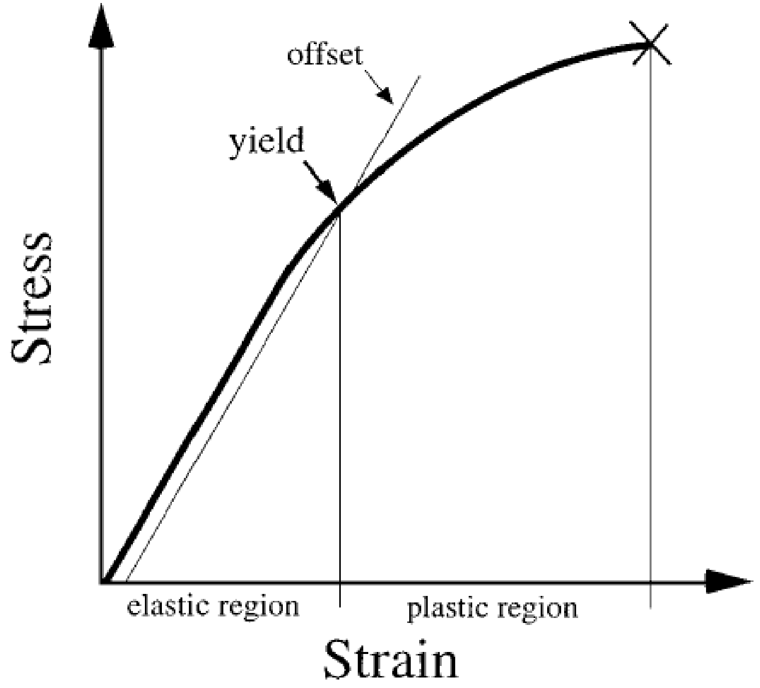


Mechanical Characterization – Data Analysis

Measured from experiment –
Read-out



Calculated (!)



- Load and Displacement are structure dependent
- Stress and Strain are material dependent – calculated based on original geometry

A larger structure of the same material can withstand larger forces but the material properties are the same.

Small vs. True Strain

For stress – uniaxial tension divide force per total cross-sectional area of sample:

$$\sigma = \frac{f}{A}$$

For strain use small strain approximation:

$$\varepsilon = \frac{l - l_0}{l_0}$$

Limitations:

- Small strain not additive use true strain:

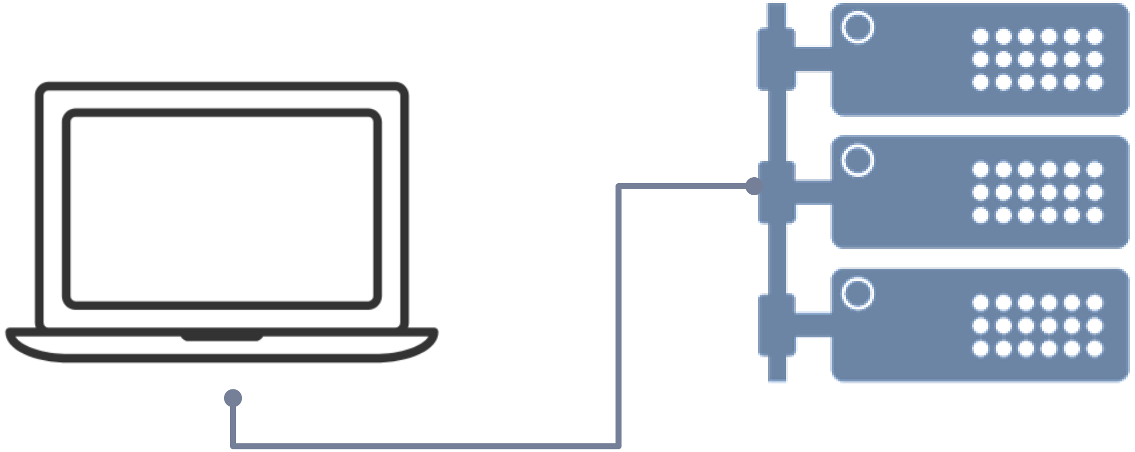
$$\varepsilon_T = \ln(1 + \varepsilon)$$

- Cross-section will change during test (Poisson's effect) use true stress:

$$\sigma_T = \frac{f}{A}\frac{A_0}{A_0} = \sigma\frac{A_0}{A} \qquad l_0 A_0 = lA \qquad \sigma_T = \sigma(1 + \varepsilon)$$

- If strains are large beyond a few % – better to use non-linear strains, e.g. Green-Lagrange (no assumptions violated)

Virtual Experiment



- Connect to server and log in to your account
- Input text file – every file is one sample
- Outputs:
  - 1x .dat file: Sample geometry (you do not need this)
  - **1x Log-file: Sample dimensions, Read-out data**
- Sample name defined by a letter **a** to **z**
- Be sure to change the sample name – otherwise files will be overwritten!

Input ".dat" file

Script already written <u>but</u> you will **create an <u>input file</u>.**

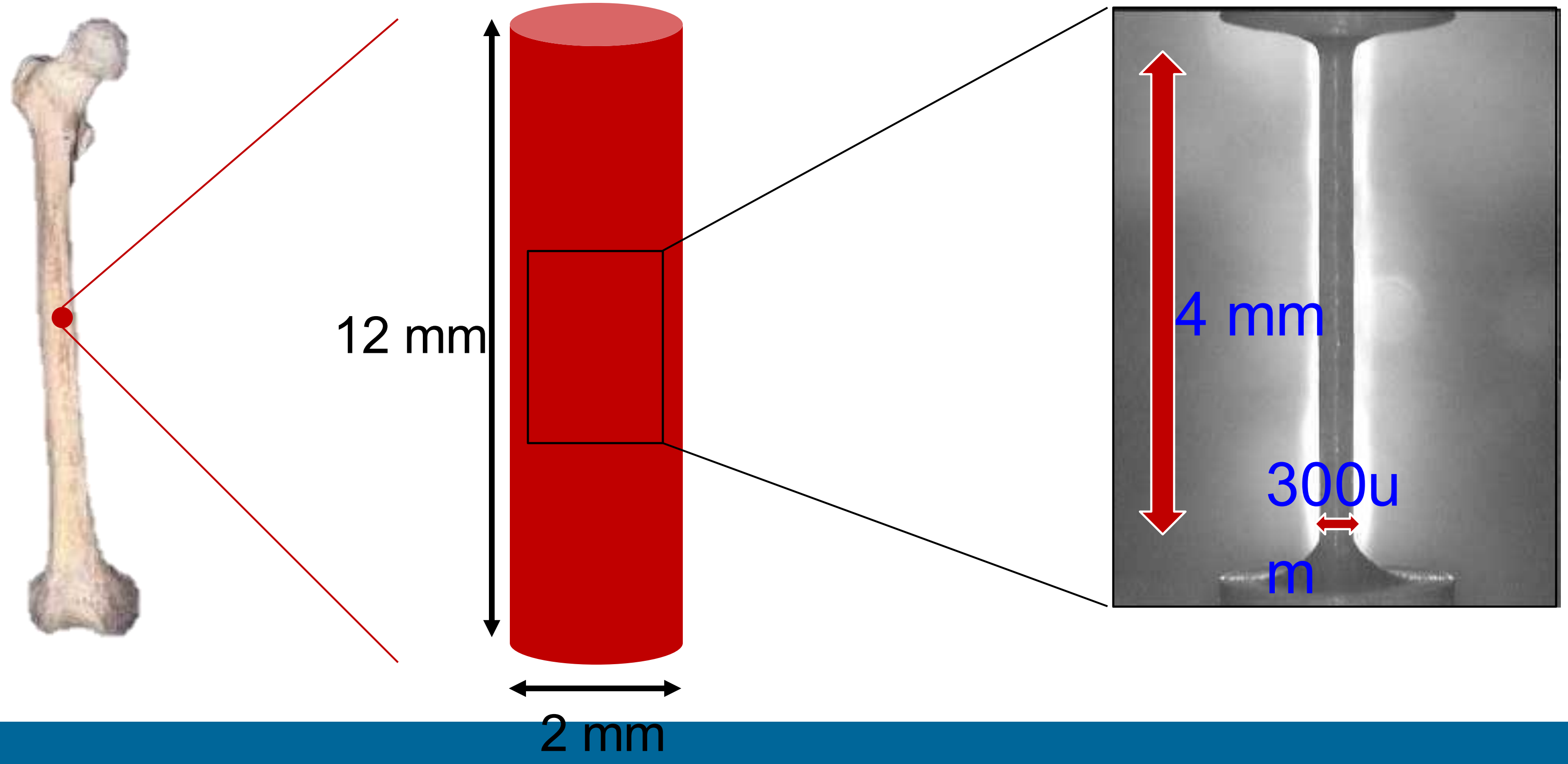
➡ Sample generator

```
namein = "module1.dat";
infile = OpenRead[namein];
username = Read[infile, String];
sample = Read[infile, String];
Close[infile];
```

Module 1 – 2D Linear Elasticity of Bone

How was the experiment performed in the lab?

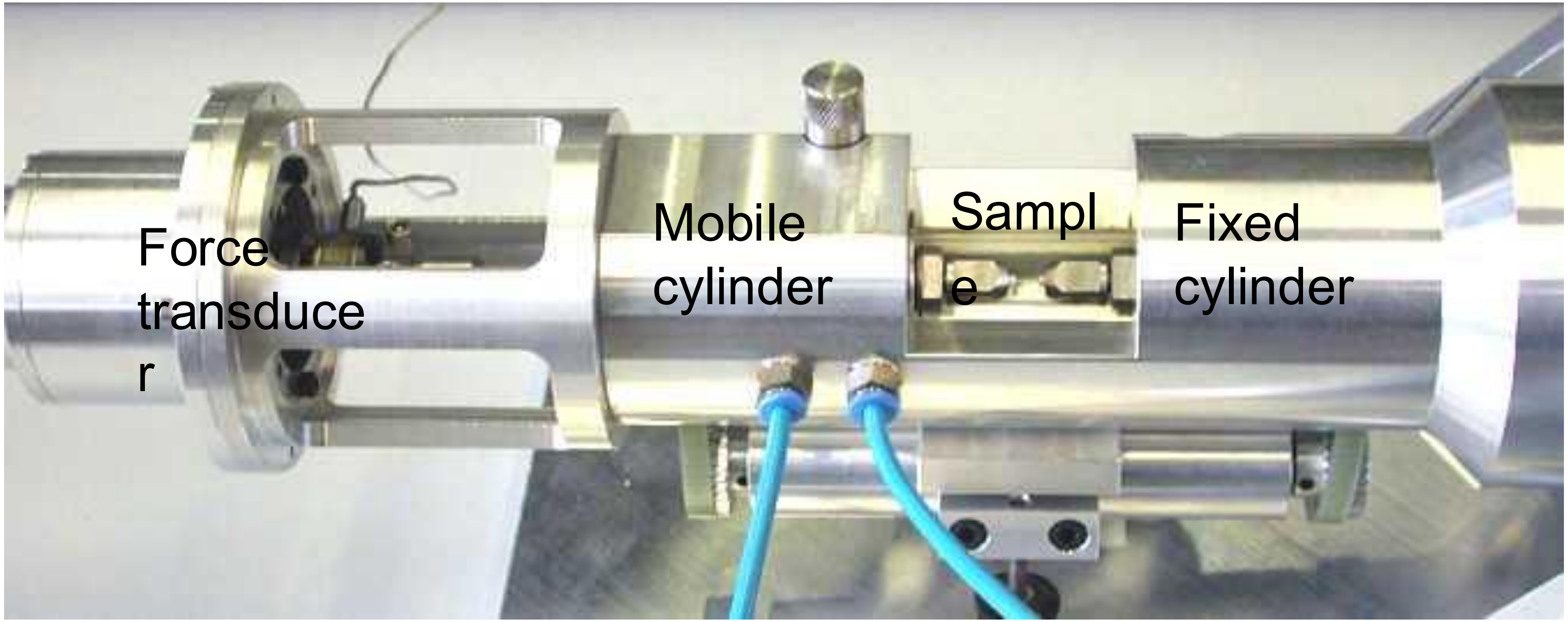
1. Micro-sample preparation.



Module 1 – 2D Linear Elasticity of Bone

How was the REAL experiment performed?

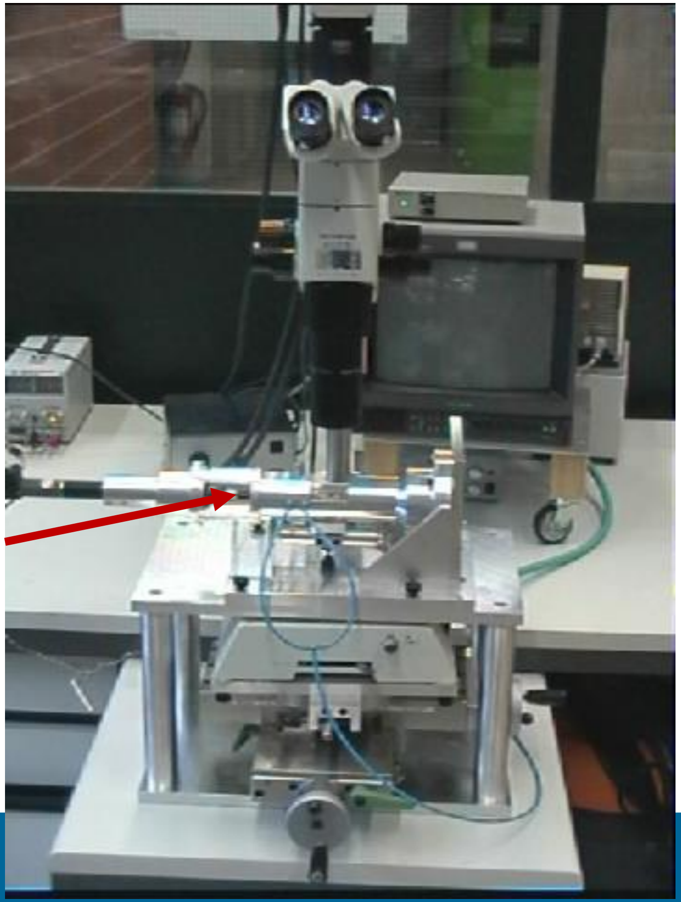
2. Mounting on testing device.



Module 1 – 2D Linear Elasticity of Bone

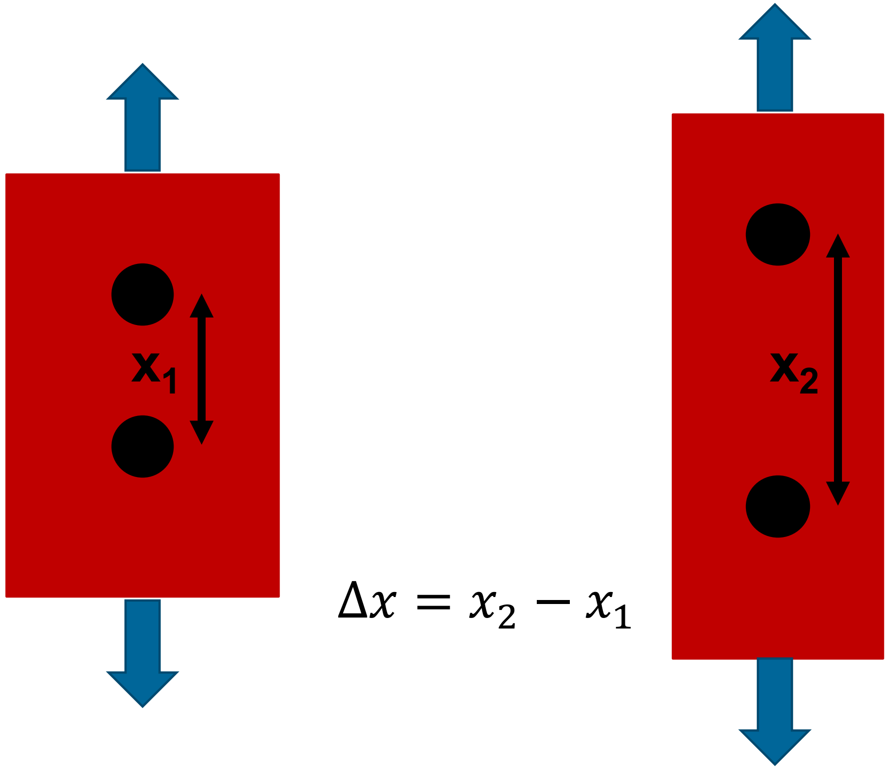
Top down view optics

Testing system



Module 1 – 2D Linear Elasticity of Bone

3. Displacement landmarks on sample.



Note:

For very **small displacement** no recognizable **difference in shape** of landmarks.

Module 1 – Tasks

ILSB

1. Check the reversible or irreversible nature of the tensile behavior of bone.
2. Test the linearity of its elasticity and measure its apparent tensile modulus.
3. Quantify the degree of variability of its apparent elastic properties over the length of the sample.
4. Write a brief report that describes the results of the previous tasks.
    a. Must include (Introduction, Materials and methods, Results, Discussion, Conclusions and References sections).

Module 1 – Run Virtual Experiments

1. Folder → module1 (or any other name that works for you)
2. Text input file in folder – Extension must be “.dat”
3. Name of DAT file: **module1.dat**
4. Open terminal in that folder
    1. Option1: Right click in folder & Select “Open terminal”
    2. Option2: Have an open terminal and navigate to the file directory that the module1.dat file is
5. Write command **create1op** & hit Enter
6. Write command **module1op** & hit Enter

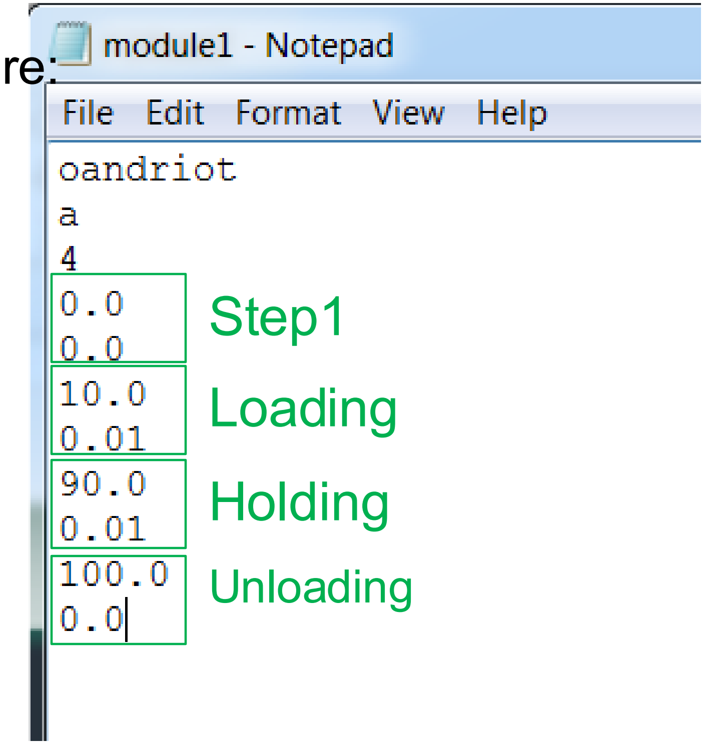
- Do analysis: use any software such as Matlab, python etc.
- Write report

Module 1 – Input file

All input files are already given

1. Create a folder with name ‘module1.dat’.
2. In folder / folder-name, create a txt file with the extension ‘.dat’
3. The txt file should have the following structure:

```
LINE1: username (eg. oandriot)
LINE2: a-z (sample ID)
LINE3: Number of steps (eg. 4)
LINES 4-11:
0.0 (time)
0.0 (displacement)
10.0
0.01
90.0
0.01
100.0
0.0
```



Module 1 – Output Files

1. File in the form “username-N-sampleID.dat”
   - Sample physical characteristics
2. File in the form “username-N-sampleID.log” in ASCII format
   - Full results