UNIVERSITÀ DI PISA

Centro E. Piaggio
bioengineering and robotics research center

INGEGNERIA DEI TESSUTI BIOLOGICI:

STRESS-STRAIN TEST

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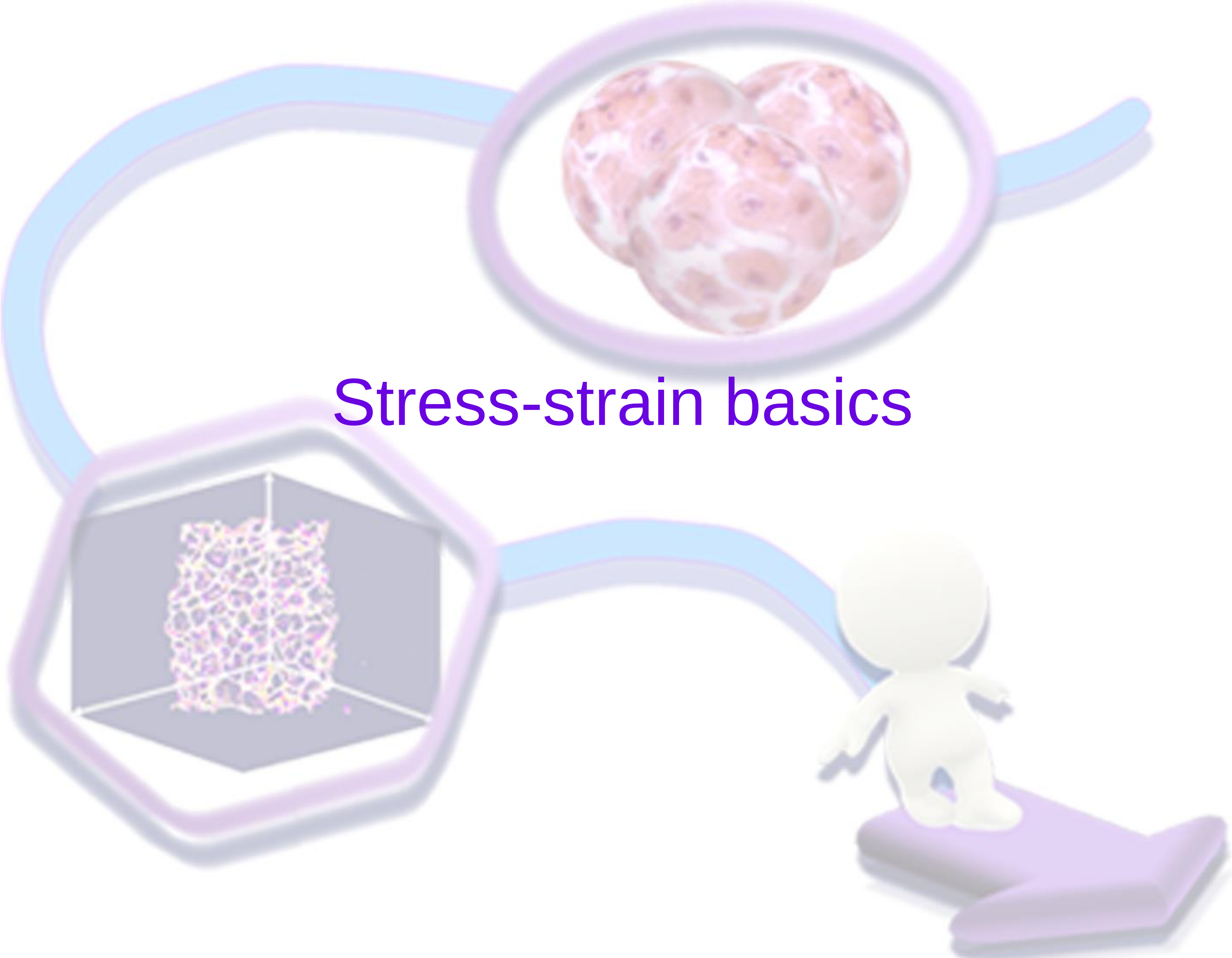
Stress-strain basics

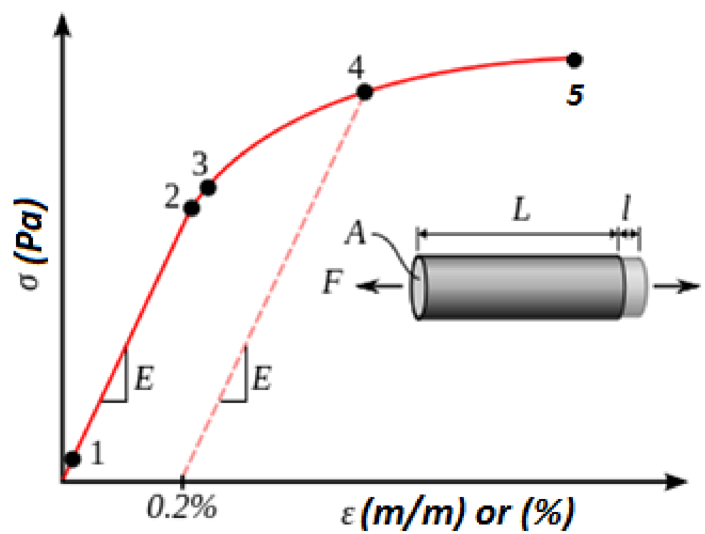


Stress-Strain: *Definition*

Stress-Strain curve is the relationship between the stress and the strain that a particular material displays. It is *unique* for each material and is found by recording the amount of deformation (strain) at distinct intervals of tensile or compressive loading (stress). [Wikipedia]

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

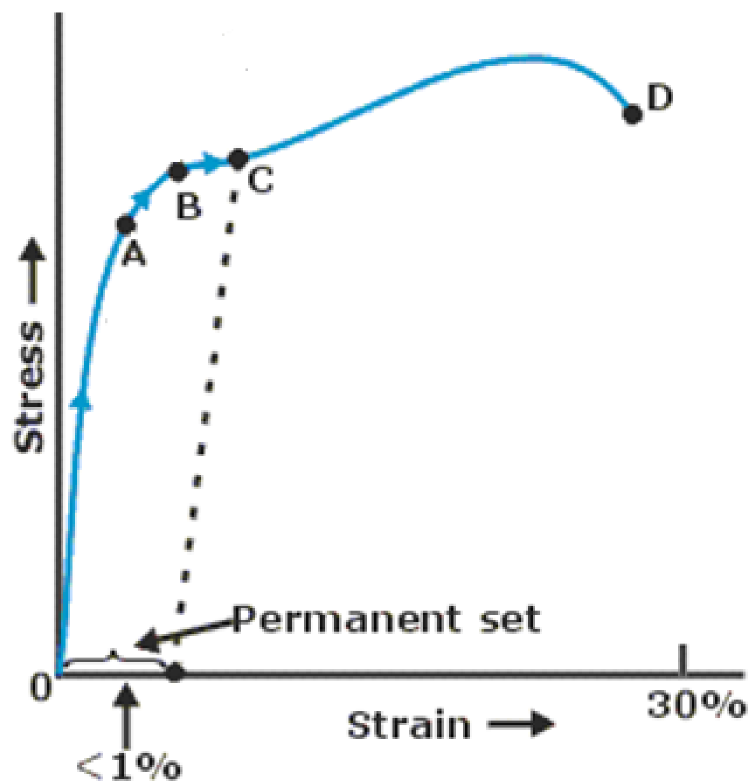
$$\varepsilon = \frac{\Delta L}{L}$$



Stress-Strain: *why do we use it?*

Allow you to evaluate material properties

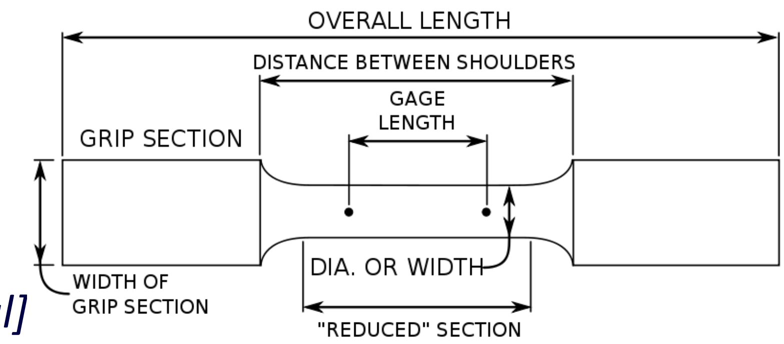
- ***Young Modulus (slope)***
- ***Yield strength (B)***
- ***Breaking point (D)***
- ***Permanent Set***



Stress-Strain: *standard vs real sample*

Standard «dog-bone» shaped sample

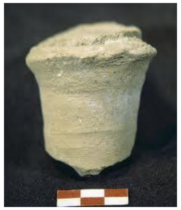
"…It has two shoulders and a gauge (section) in between. The shoulders are large so they can be readily gripped, whereas the gauge section has a smaller cross-section so that the deformation and failure can occur in this area…" [Davis, Joseph R. (2004). Tensile testing (2nd ed.). ASM International]



Real Sample

It depends on what you are working on…it is not standard!!

- *No sufficient material*
- *Heterogeneous (especially tissue or natural material)*



Obtaining experimental data

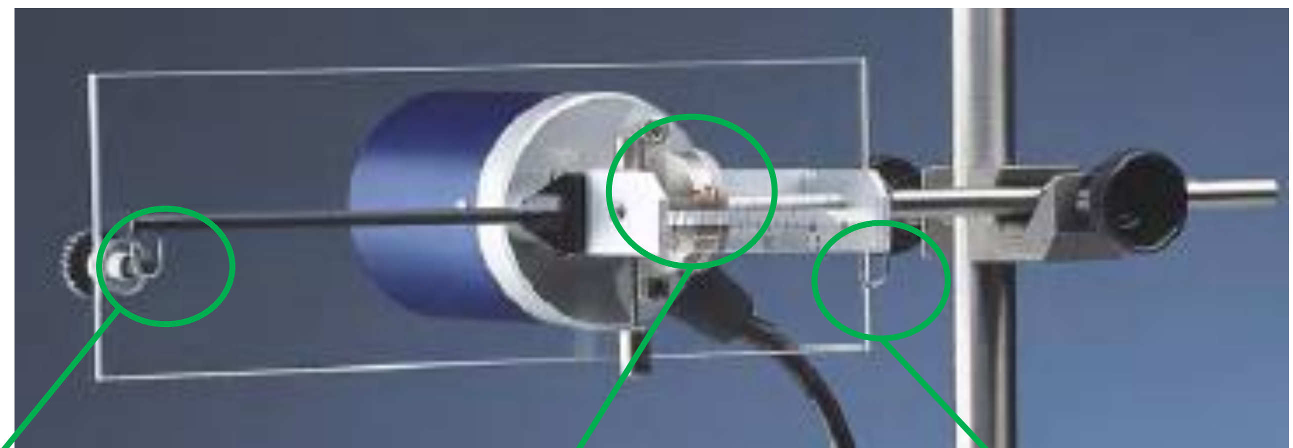
Biopac
How to get data from tests

Ugo Basile Isotonic Transducer is specially designed for investigating isotonic contractions in isolated organs, particularly smooth muscle, amphibian hearts, etc.

An Isotonic Transducer is basically a ***displacement meter under constant load***, whereas an isometric transducer measures changes in force at constant length

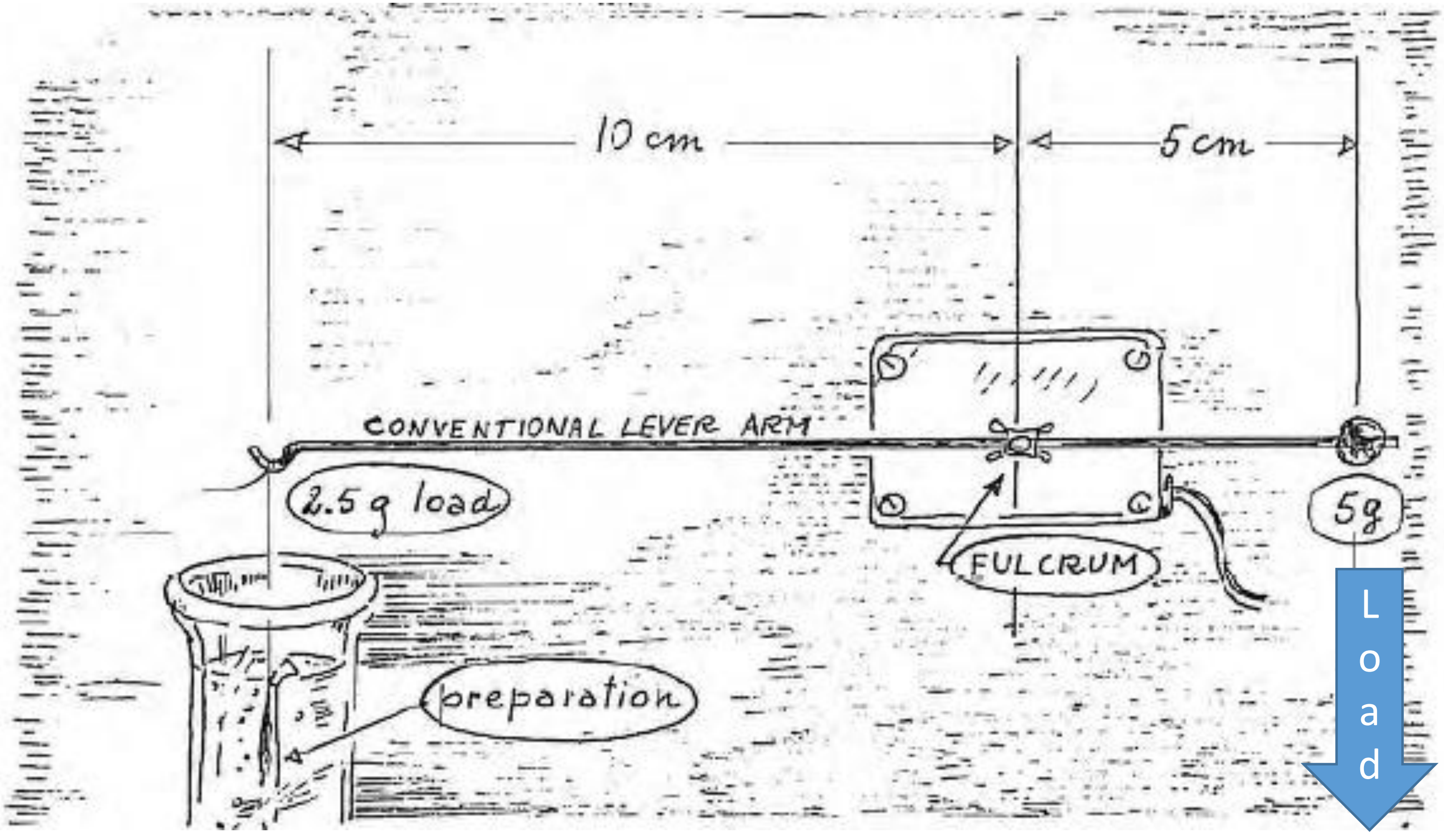
Biopac
Ugo Basile Isotonic Transducer

- Based on Hall Effect Transducer



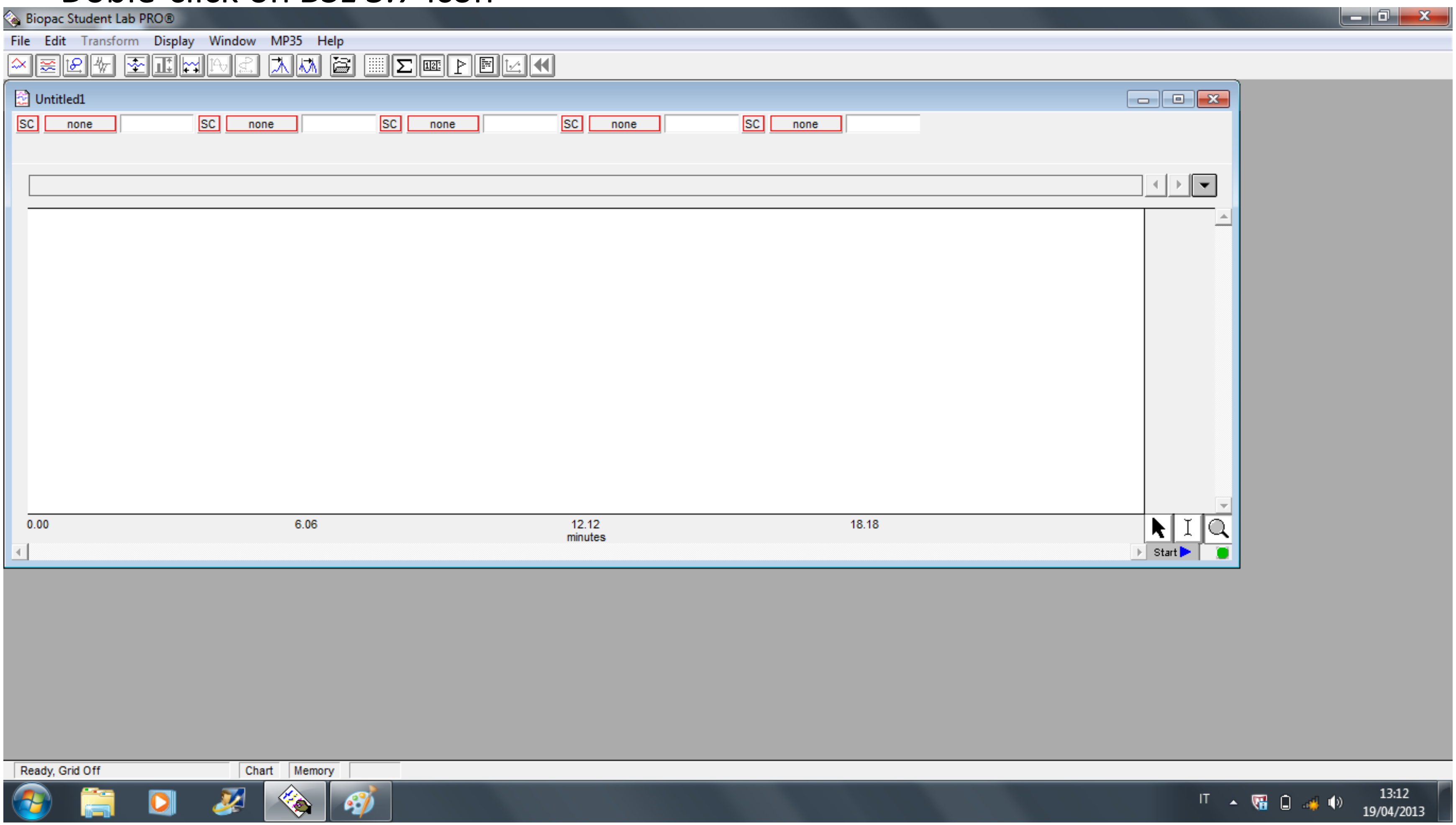
Biopac
Test protocol

N.B. sample load = applied load/2



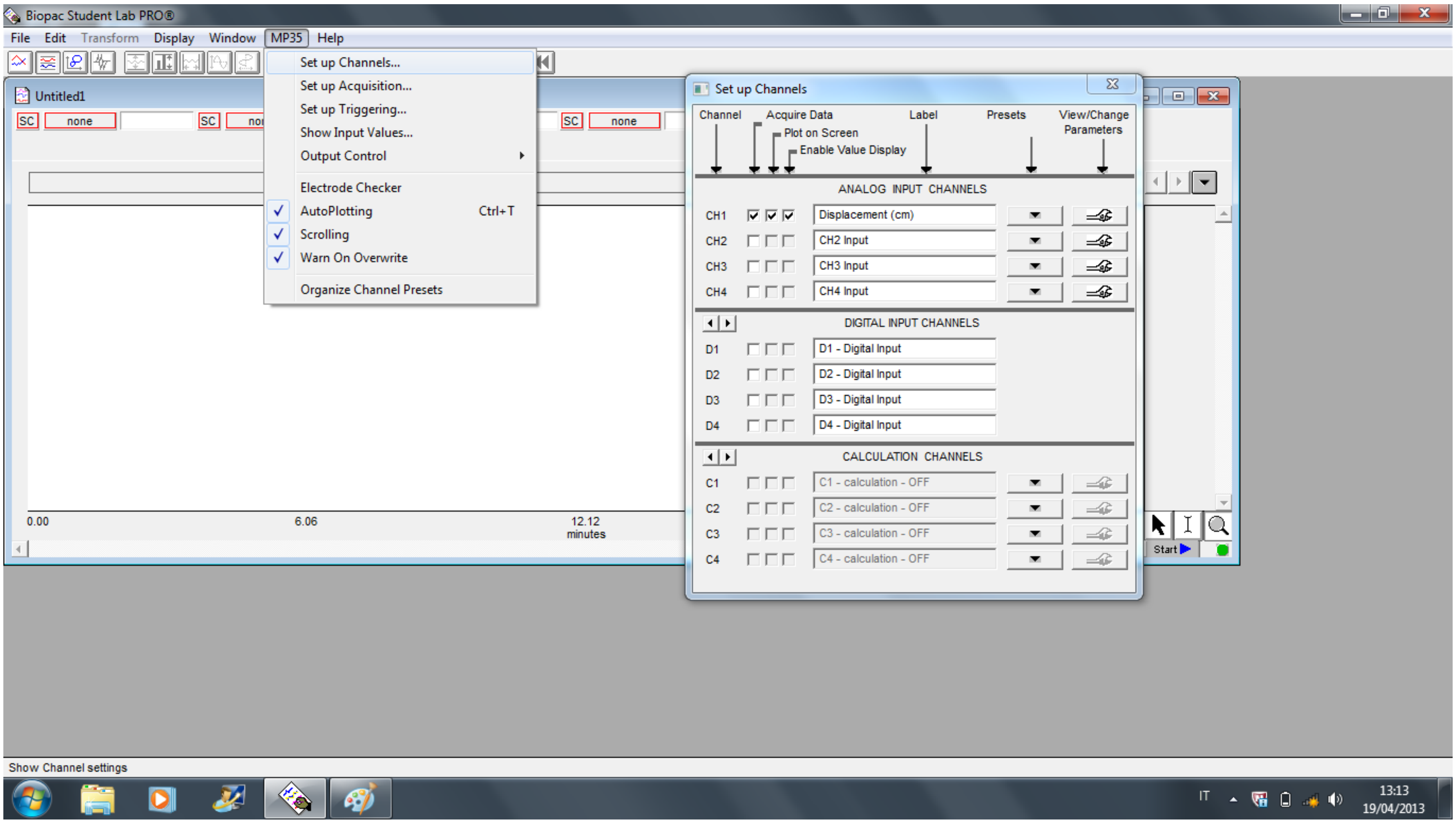
Biopac
Test protocol

- Connect *Biopac* device with Ugo Basile Isotonic Transducer
- Doble-click on *BSL 3.7* icon



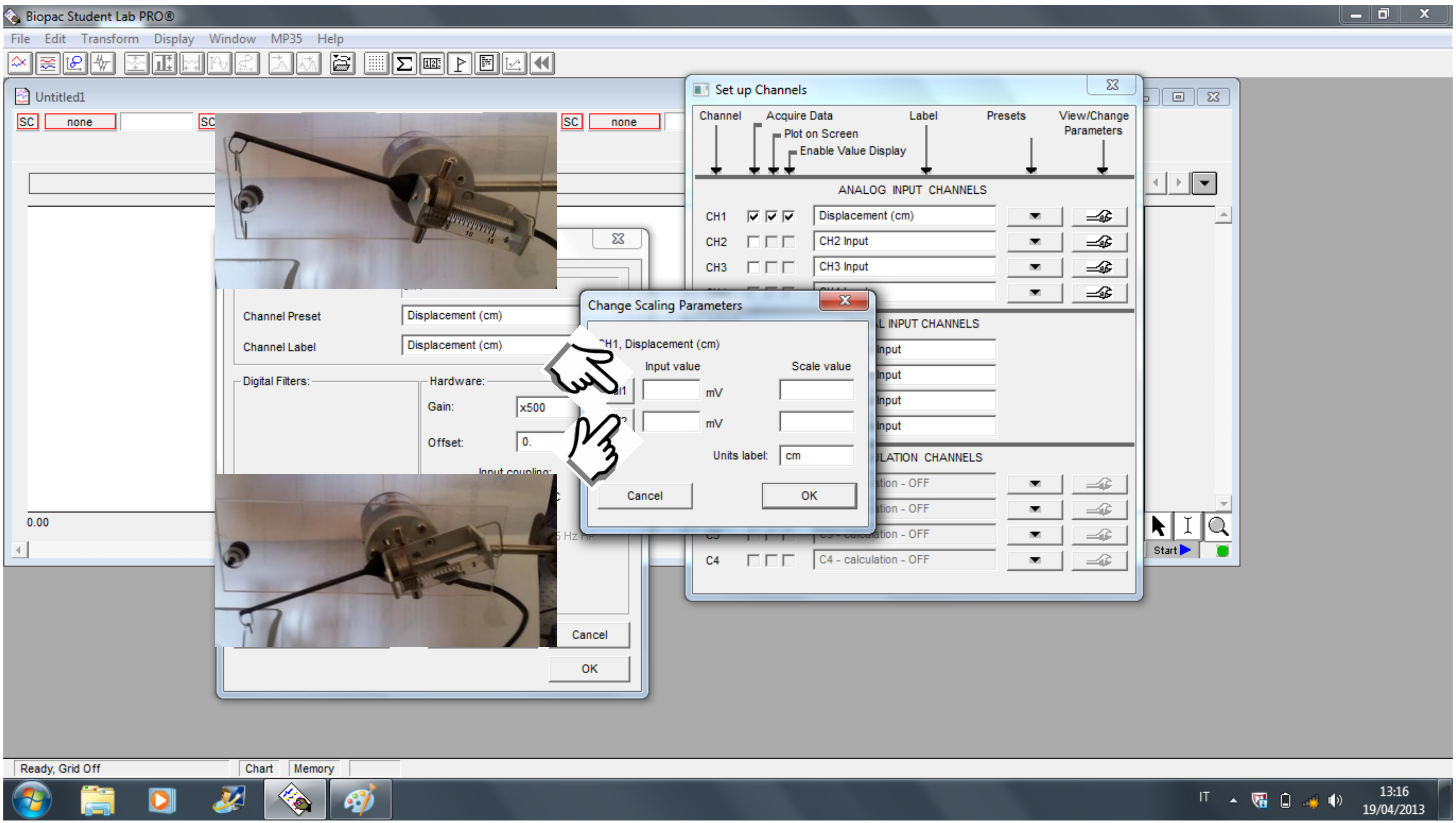
Biopac
Test protocol

- MP35-->*setup channel* □*set label Displacement (cm)*



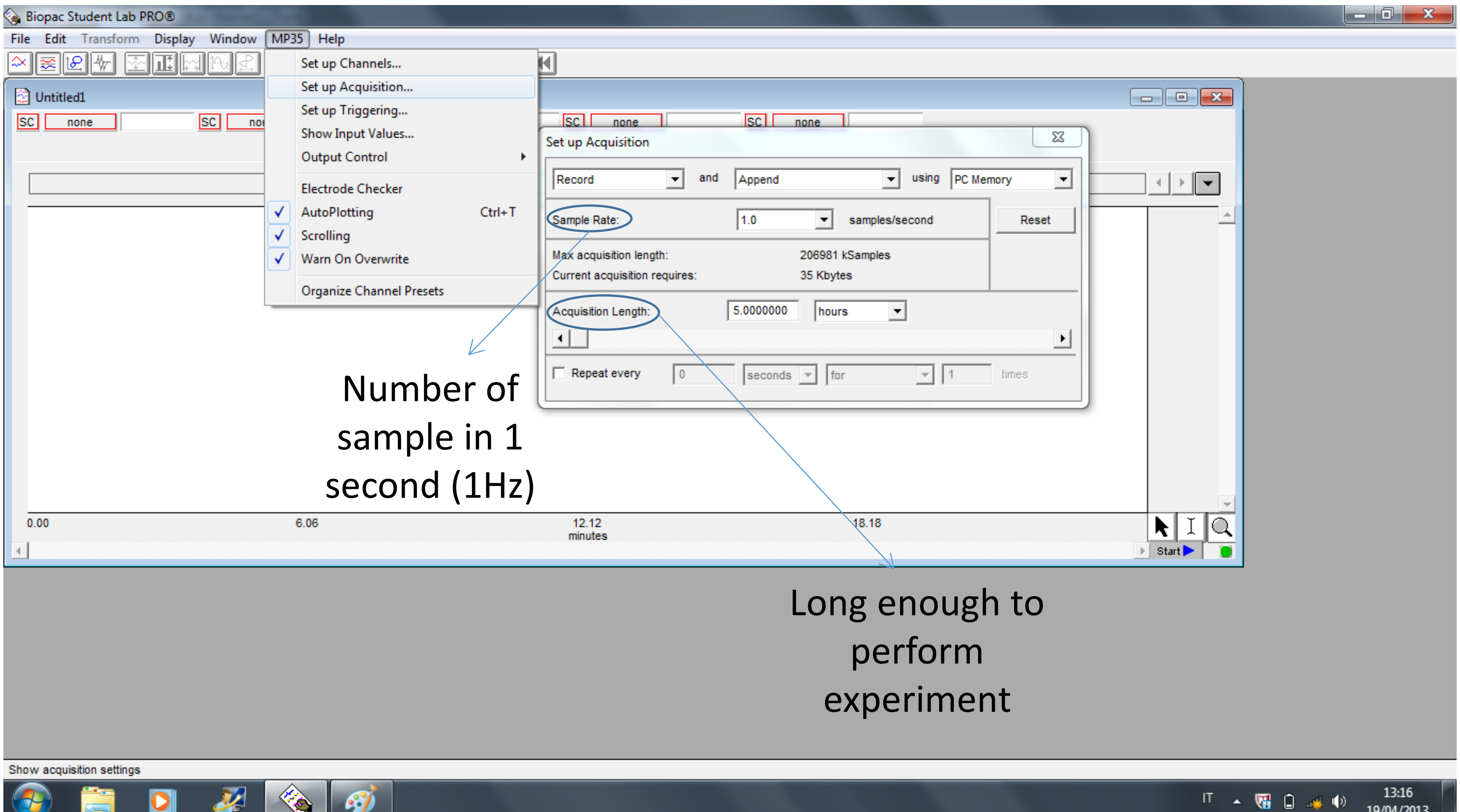
Biopac
Test protocol

- MP35-->*setup channel change parameters scaling*

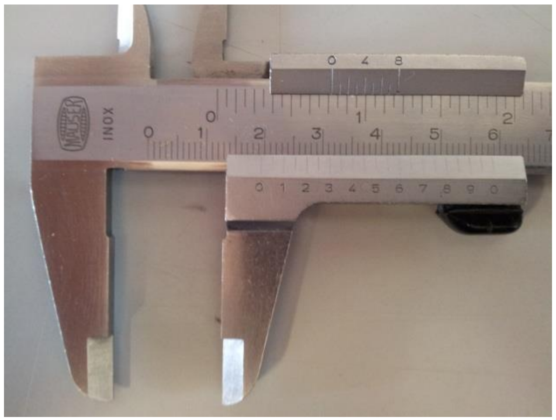


Biopac
Test protocol

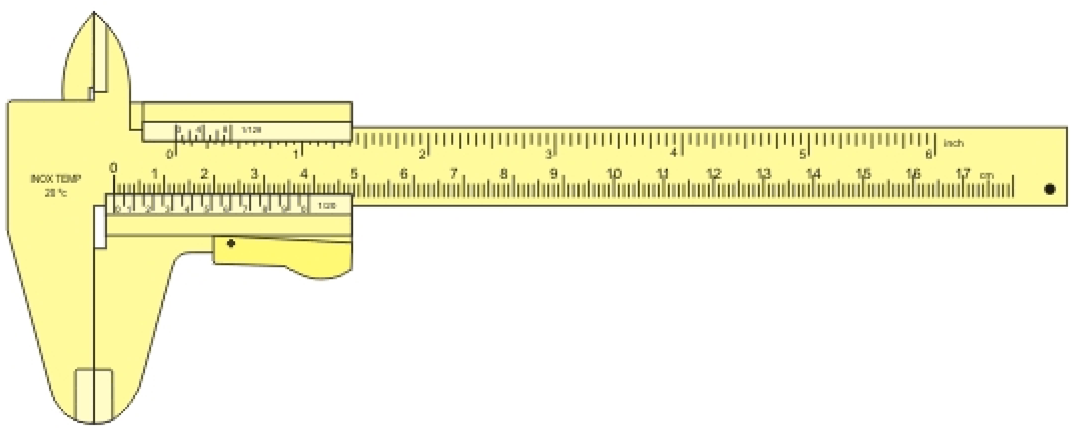
- MP35-->*setup acquisition sample rate & acquisition lenght*



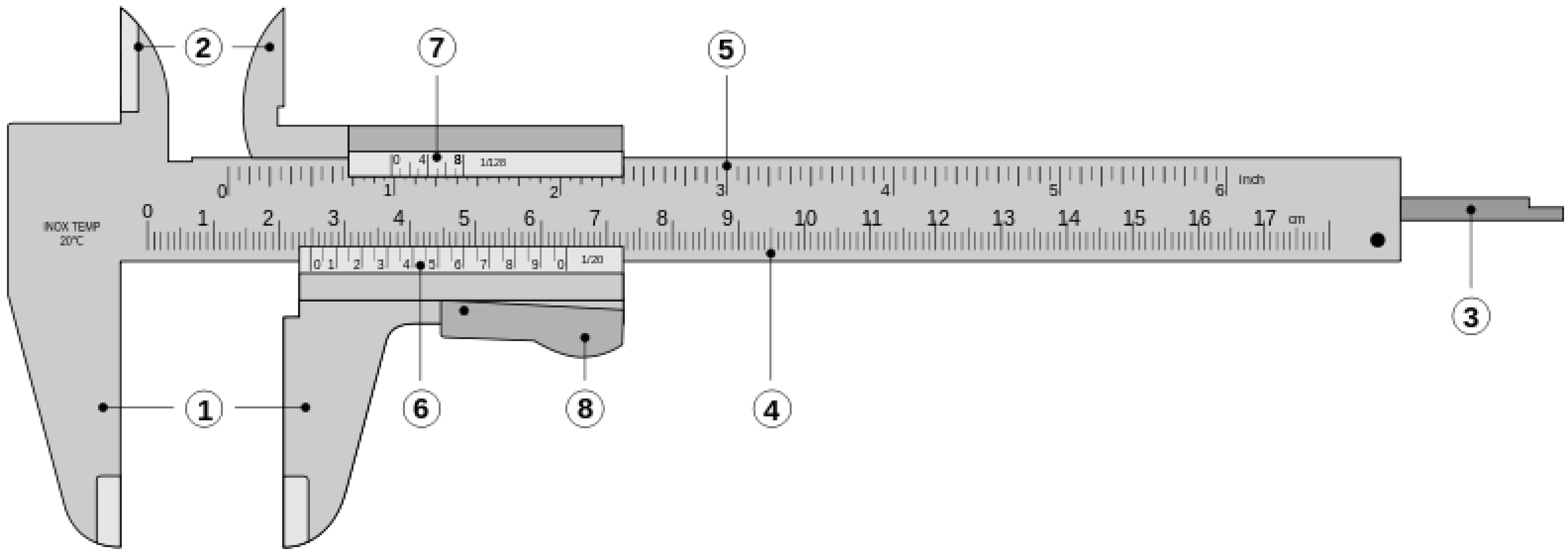
Caliper
how to use it



- direct reading of the distance measured with high accuracy and precision
- 0.1mm resolution



Caliper
how to use it



1. Outside jaws: used to measure external diameter or width of an object

2. Inside jaws: used to measure internal diameter of an object

3. Depth probe: used to measure depths of an object or a hole

4. Main scale: scale marked every mm

5. Main scale: scale marked in inches and fractions

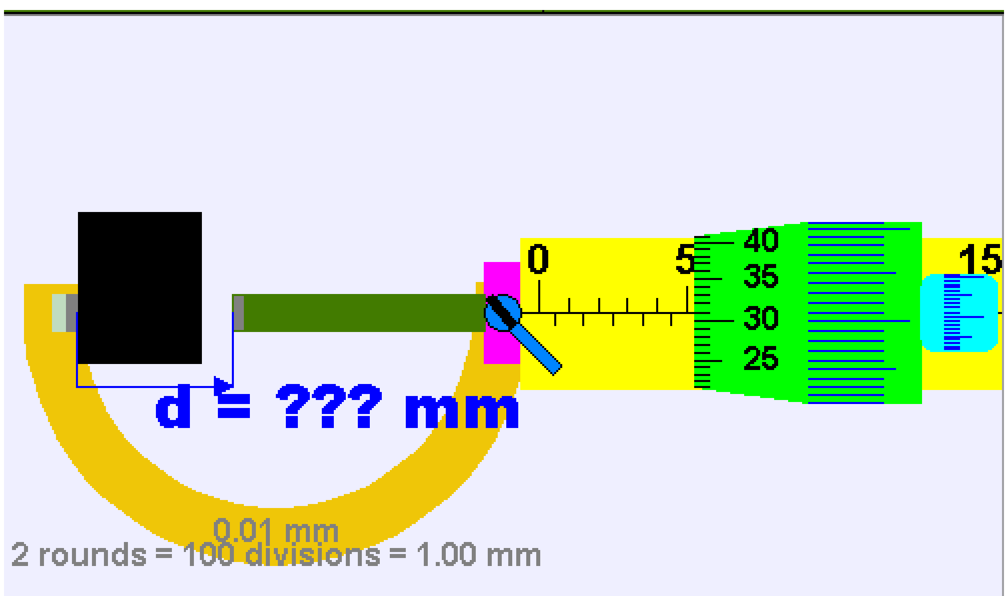
6. Vernier scale gives interpolated measurements to 0.1 mm or better

7. Vernier scale gives interpolated measurements in fractions of an inch

8. Retainer: used to block movable part to allow the easy transferring of a measurement

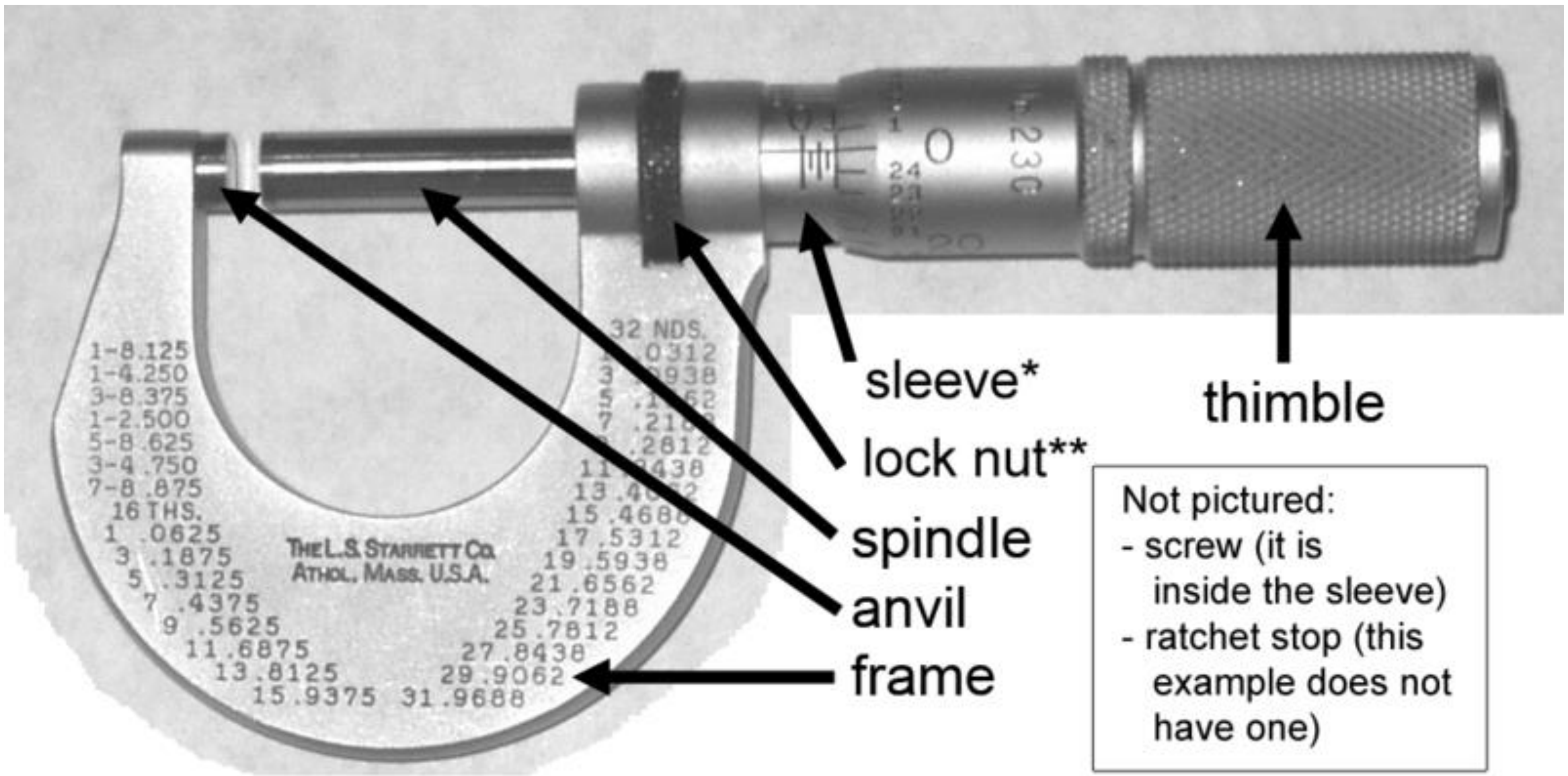
Micrometer
how to use it

- Micrometers use the principle of a screw to amplify small distances (that are too small to measure directly) into large rotations of the screw that are big enough to read from a scale



- Resolution 0.01mm (10um)

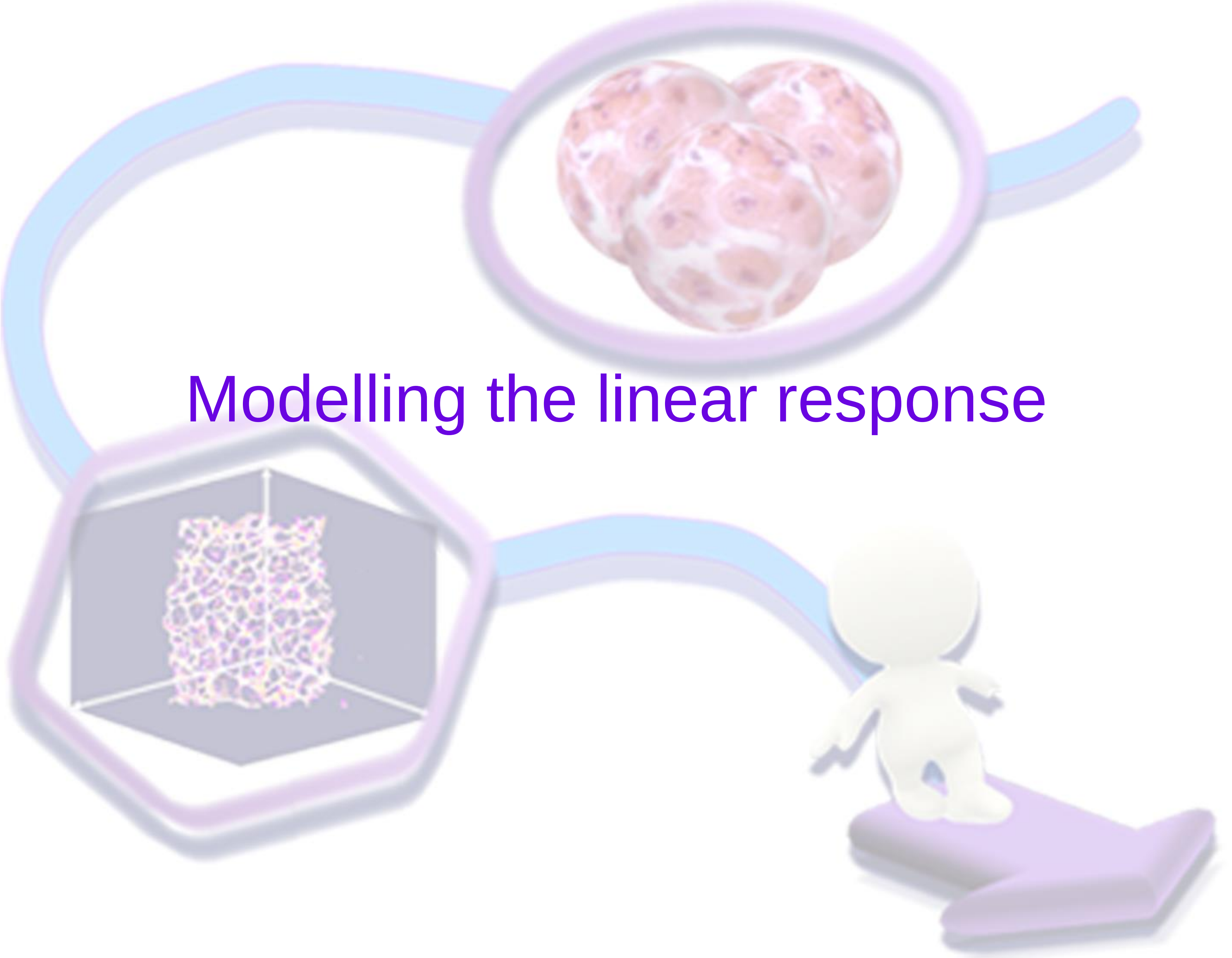
Micrometer
how to use it



**Sleeve* is the most prevalent name. May also be called the *barrel* or *stock*.

**Aka *lock-ring*. Some mics have a *lock lever* instead.

Modelling the linear response



Linear Regression: *Definition*

In statistics, **linear regression** is an approach to modeling the ***relationship*** between a dependent variable y and one or more independent variables denoted x.

In linear regression, data are modeled using linear predictor functions, and unknown model parameters are estimated from the data.

Linear Regression

Relationship between ***inlet*** and ***outlet*** is assumed as:

$$y = \alpha + \beta \cdot x + e$$

y and ***x*** are, respectively, observed outlet and inlet of a test

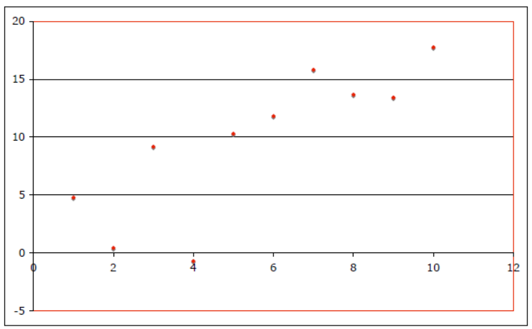
α and ***β*** are the unknown parameter of the estimation intercept and slope)

e is an error variable (normal distribution with μ=0)

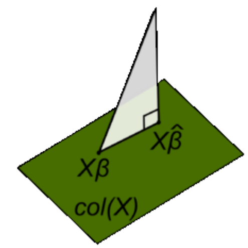
Linear Regression

Parameters are evaluated minimazing the of ***sum of squared residual*** (SS_R)

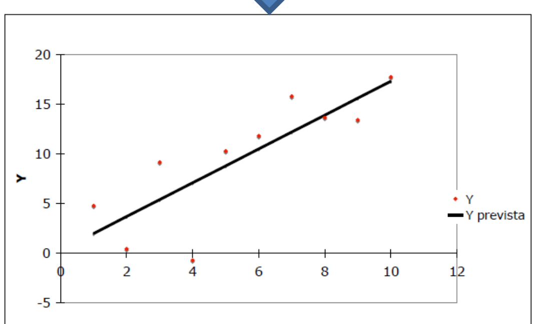
$$y = \alpha + \beta \cdot x$$



$$SS_R = \sum_{i=1}^{n} (y_i - a - bx_i)^2$$



residual = vertical distance between real data and estimated curve



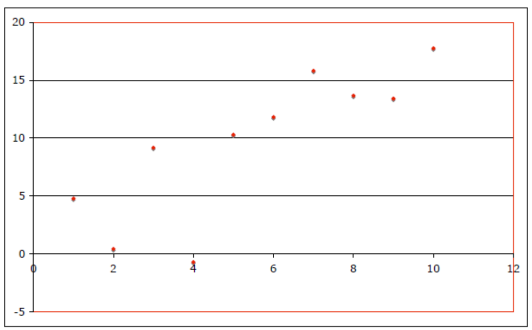
N.B.:

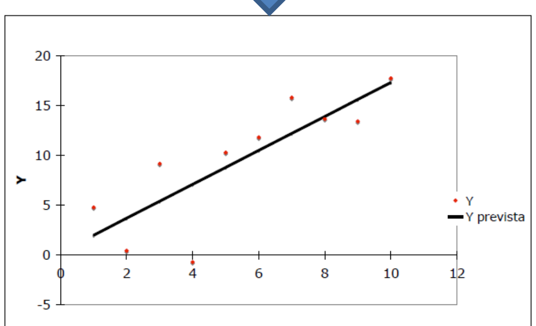
- Independent observation: (x_i, y_i) independent and identically distributed
- x_i are random and sampled together with y_i

Linear Regression

Parameters are evaluated minimazing the of ***sum of squared residual*** (SS_R)

$$y = \alpha + \beta \cdot x$$





SSR is an index of inherent variability, how line differs to real outlet due the error (e)

S_{yy} is the *total variability* of the outlet

$$S_{yy} := \sum_{i=1}^{n} (y_i - \overline{y})^2 = (n-1)s_y^2$$

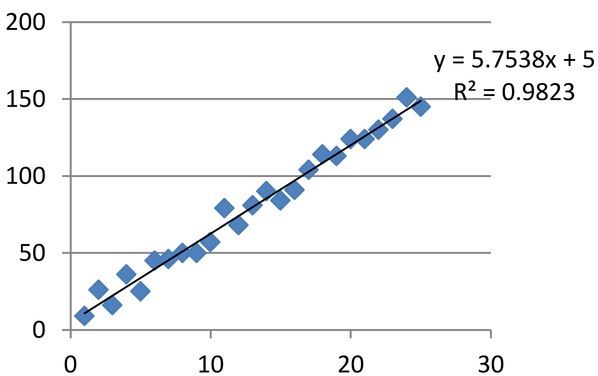
Linear Regression: *pratical example*

It is possible to evaluate fit goodness using variability index:

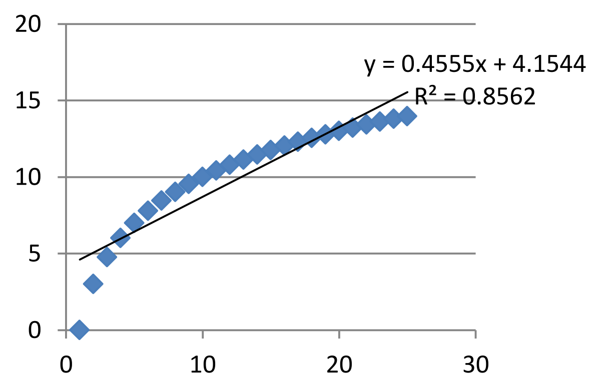
$$R^2 := 1 - \frac{SS_R}{S_{yy}}$$

$$0 < R^2 < 1$$

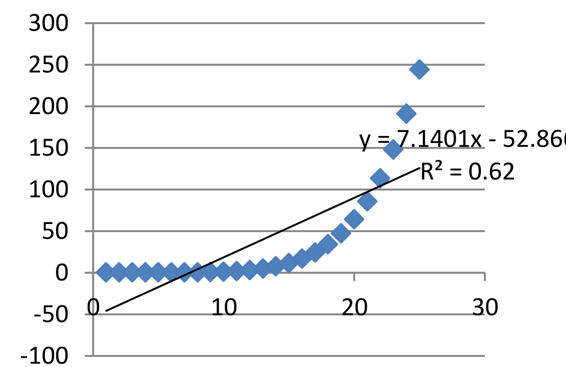
R^2 is the variability fraction due dependence between the two variable (also defined as Coefficient of determination)



Good fit (R^2 >0,9)



Not a good fit (0,9 > R^2 >0,8)

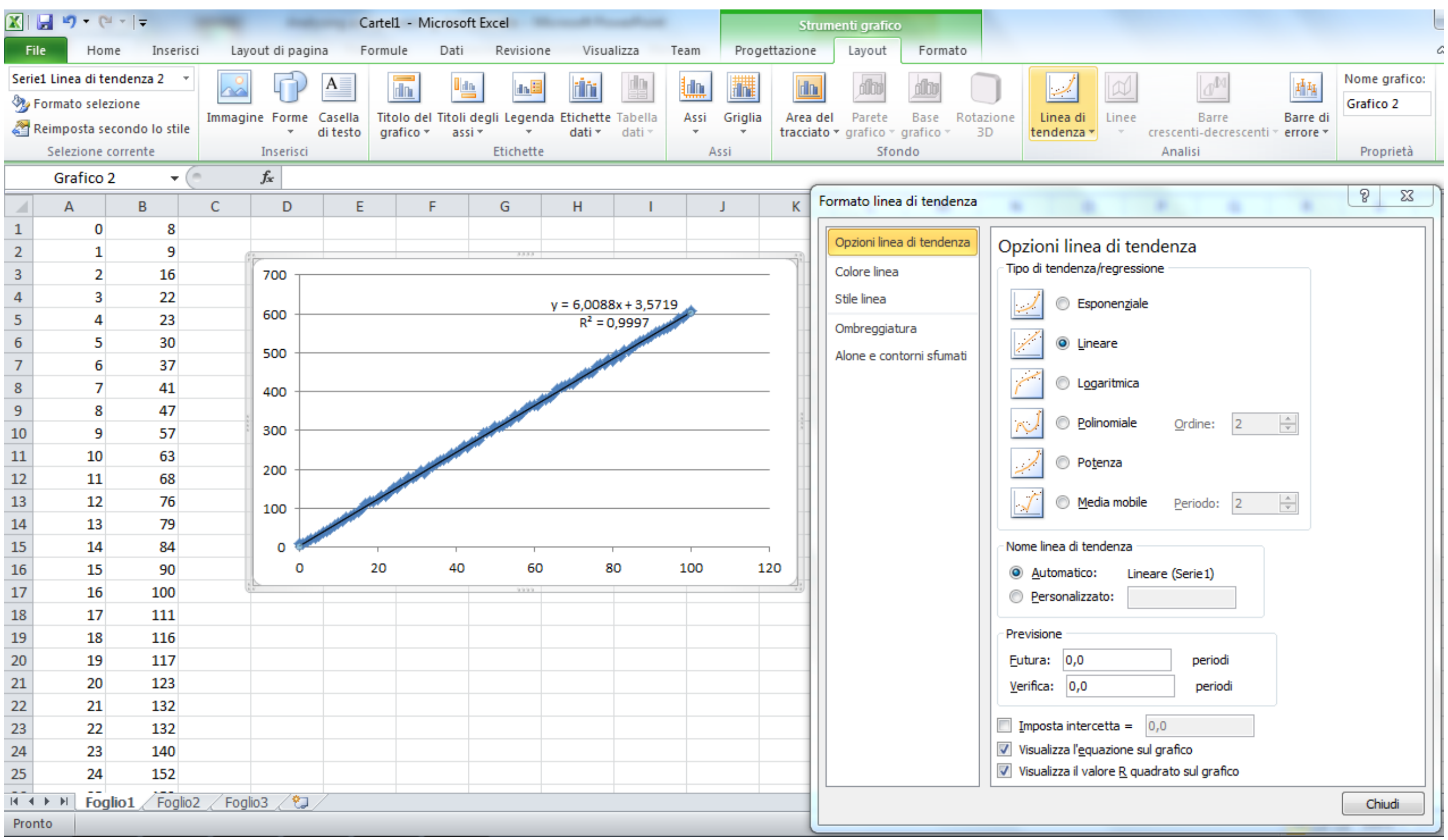


Bad fit (R^2 < 0,8)

Microsoft Excel: *Linear Regression*

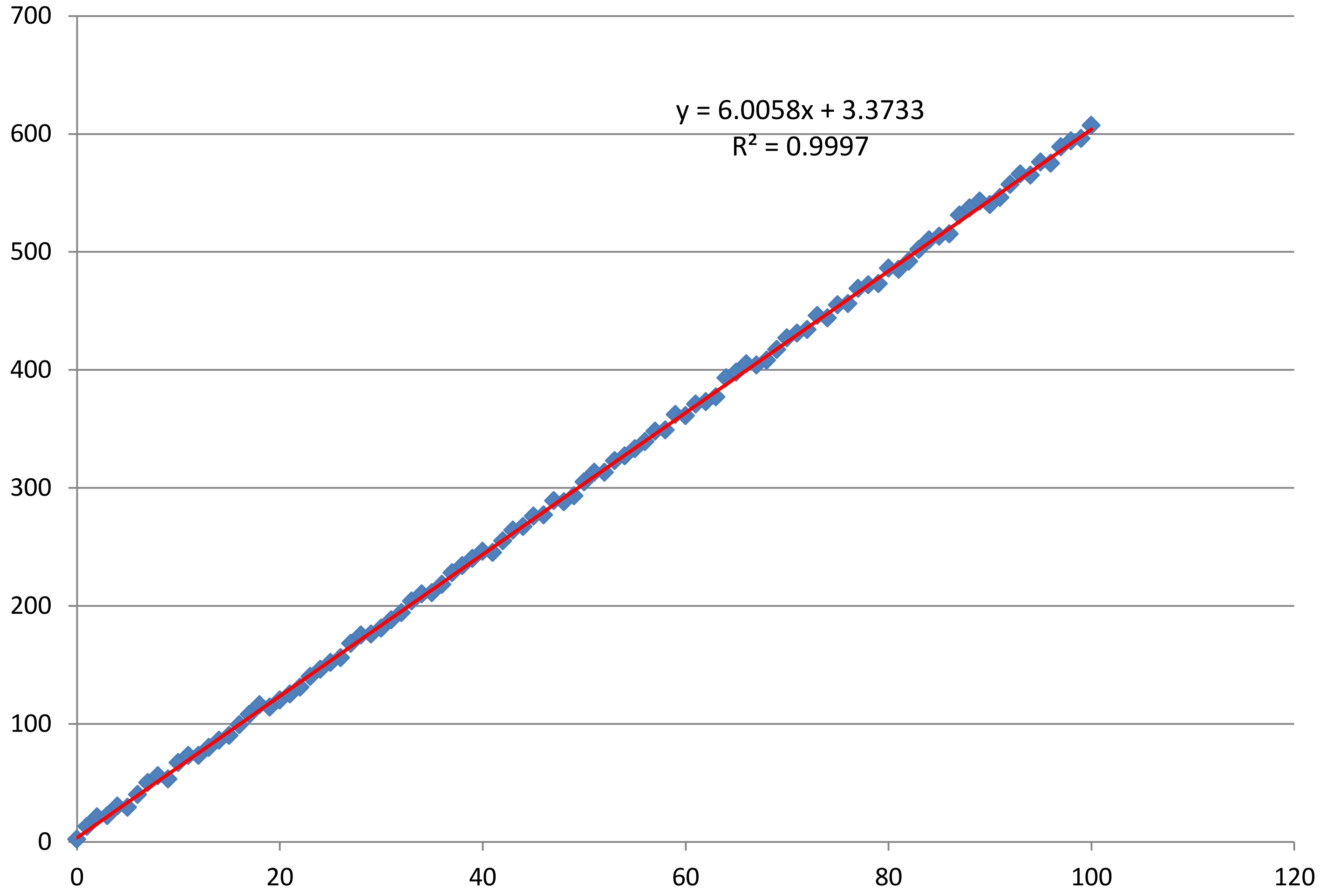
Two ways to evaluate fit parameters

- *Directly on the plot*: use trend line function (under layout)



- Easy method
- Data on plot
- GUI help

Microsoft Excel: *Linear Regression*



Microsoft Excel: *Linear Regression*

Two ways to evaluate fit parameter

- *As a cell function*: use *linear estimation* function

Known_y's is the set of y-values you already know in the relationship y = mx + b

Const is a logical value specifying whether to force the constant b to equal 0

In Italian...

=REG.LIN (known_y's, known_x's, const, stats)

Known_x's is an optional set of x-values that you may already know in the relationship y = mx + b

Stats is a logical value specifying whether to return additional regression statistics

	A	B	C	D	E	F
1	m_n	m_{n-1}	. . .	m_2	m_1	b
2	se_n	se_{n-1}	. . .	se_2	se_1	se_b
3	r_2	se_y				
4	F	d_f				
5	ss_{reg}	ss_{resid}				

Fit parameter disposition in Excel (*use CRTL+SHIFT+ENTER to fill more than one cell)*

Case of study: the hair

Typical experiment and analysis