



UNIVERSITÀ DI PISA



Centro E. Piaggio
bioengineering and robotics research center

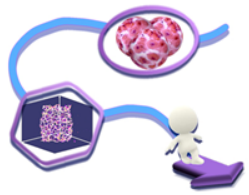
INGEGNERIA DEI TESSUTI BIOLOGICI: STRESS-STRAIN TEST

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14 Aprile 2014

Stress-strain basics

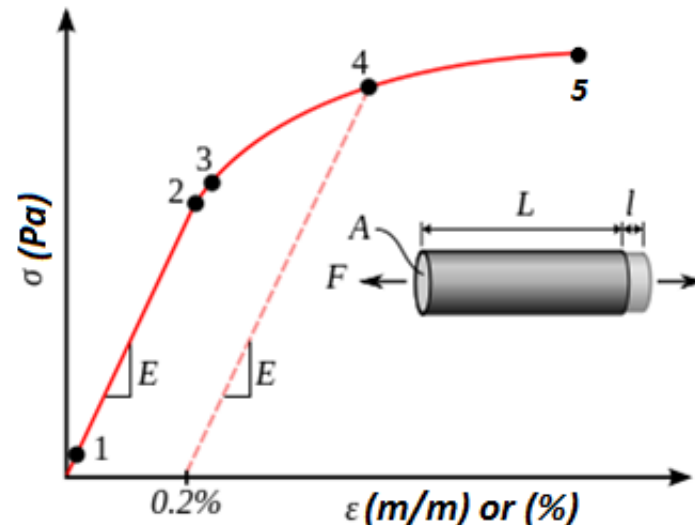


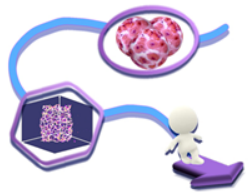


Stress-Strain: *Definition*

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]

$$\sigma = \frac{F}{A}$$
$$\varepsilon = \frac{\Delta L}{L}$$

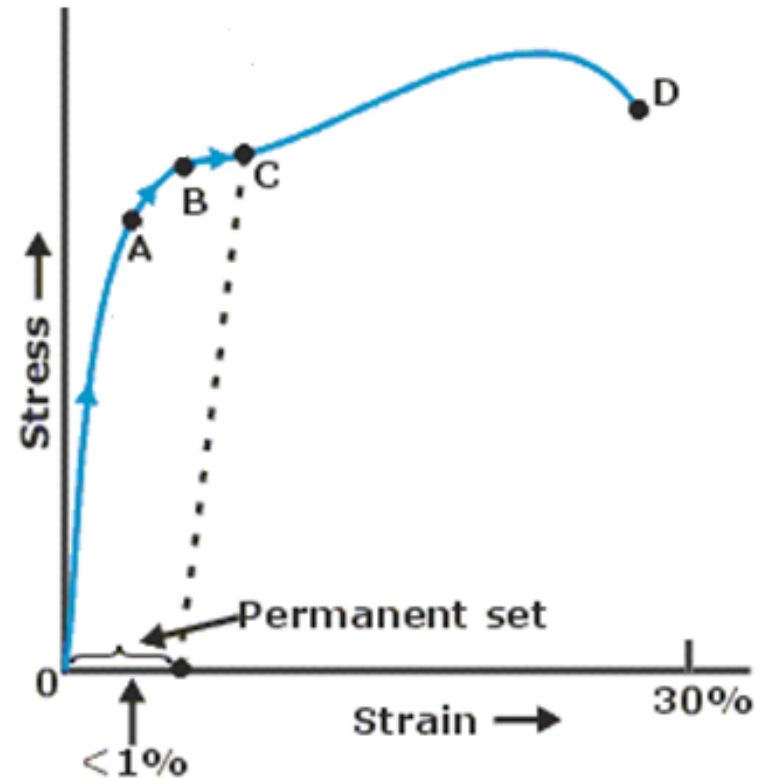


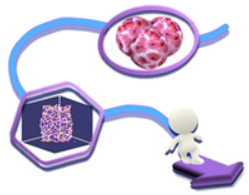


Stress-Strain: *why do we use it?*

Allow you to evaluate material properties

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

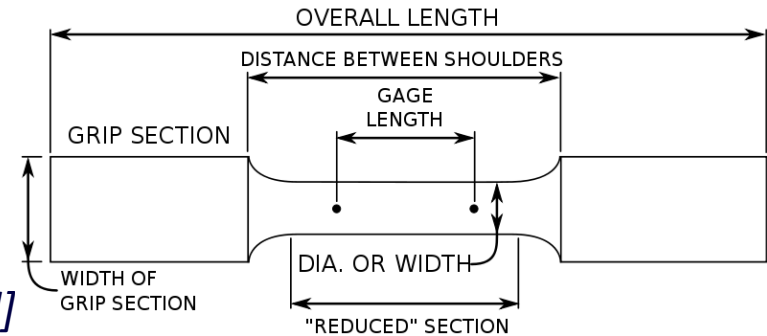




Stress-Strain: *standard vs real sample*

Standard «dog-bone» shaped sample

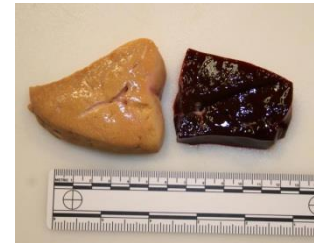
“...It has two shoulders and a gauge (section) in between. The shoulders are large so they can be readily gripped, whereas the gauge section has a smaller cross-section so that the deformation and failure can occur in this area...” [Davis, Joseph R. (2004). Tensile testing (2nd ed.). ASM International]



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.

Biopac



Isotonic Transducer
Ugo Basile

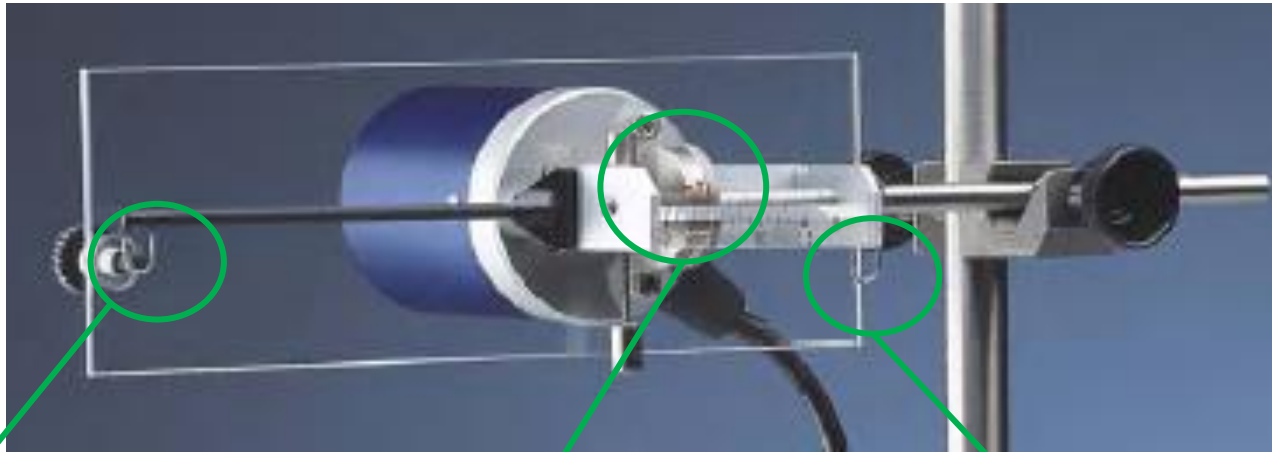
An Isotonic Transducer is basically a ***displacement meter under constant load***, whereas an isometric transducer measures changes in force at constant length



Biopac

Ugo Basile Isotonic Transducer

- Based on Hall Effect Transducer



Sample Hanging Point

Preload

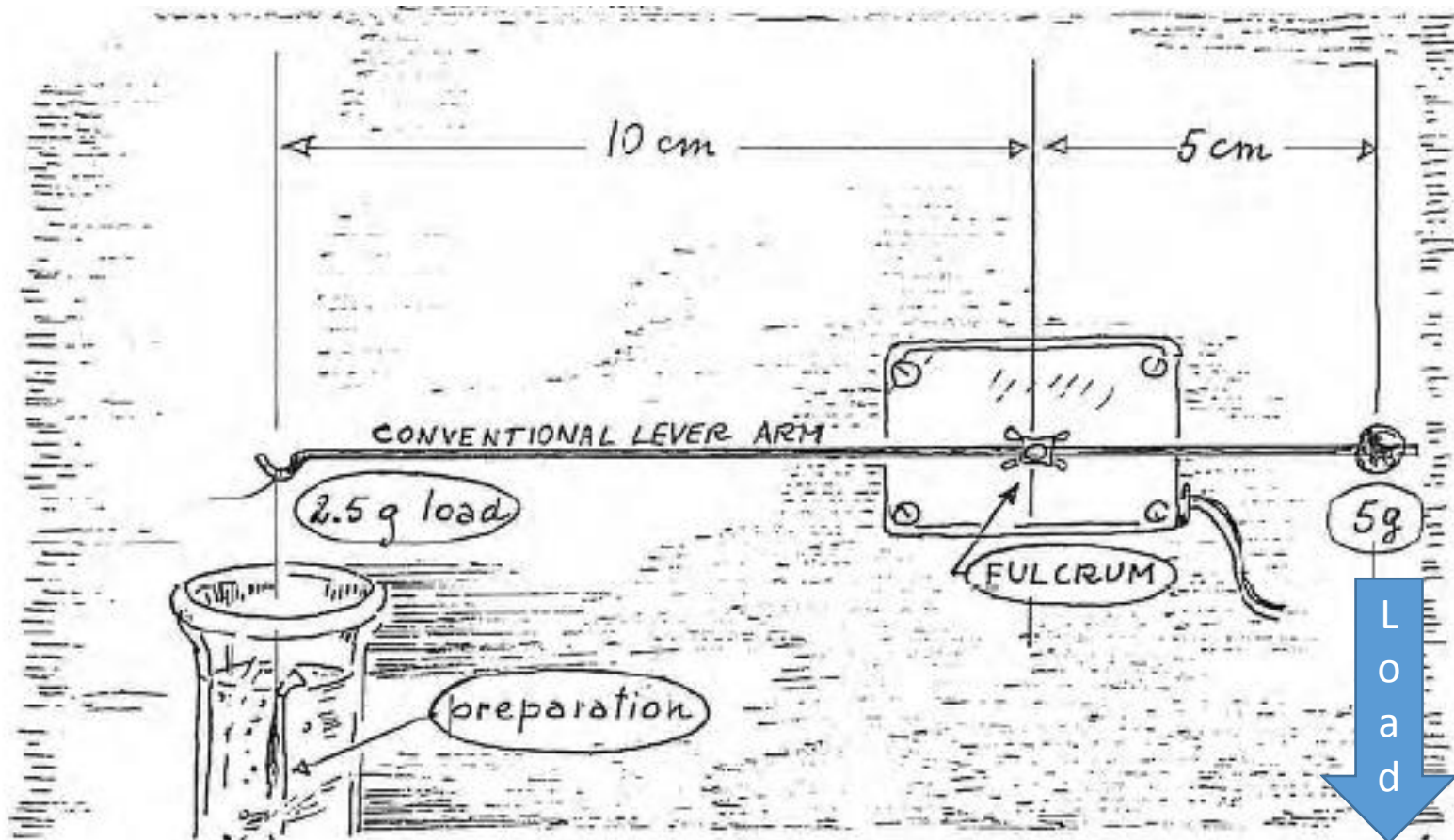
Load Hanging Point



Biopac

Test protocol

N.B. sample load = applied load/2

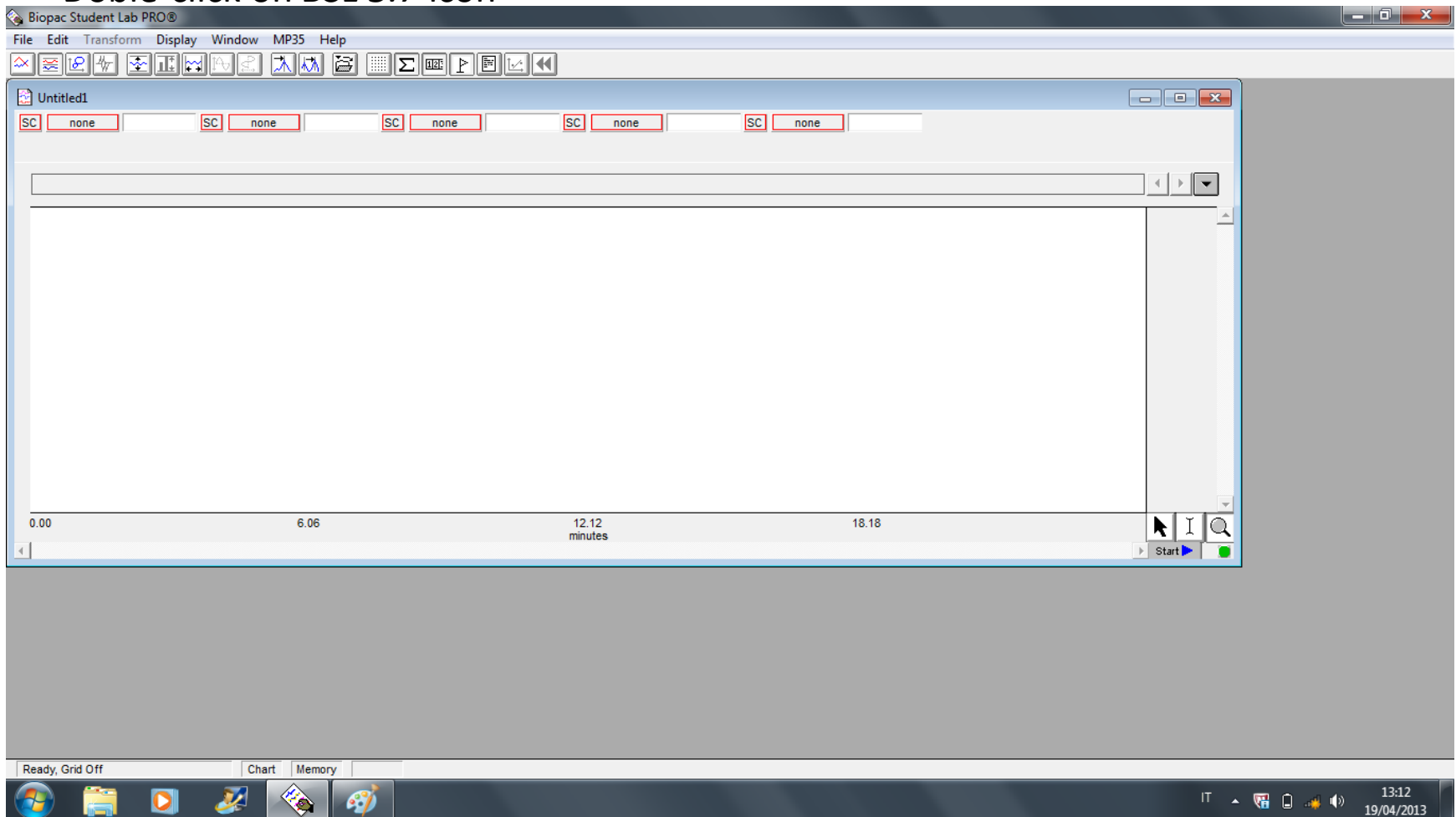




Biopac

Test protocol

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





Biopac

Test protocol

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

The screenshot displays the Biopac Student Lab PRO software interface. The main window shows a menu bar (File, Edit, Transform, Display, Window, MP35, Help) and a toolbar. The 'MP35' menu is open, showing options like 'Set up Channels...', 'Set up Acquisition...', and 'AutoPlotting'. A 'Set up Channels' dialog box is overlaid on the main window, showing the configuration for channels. The dialog box has columns for Channel, Acquire Data, Label, Presets, and View/Change Parameters. It is divided into three sections: ANALOG INPUT CHANNELS, DIGITAL INPUT CHANNELS, and CALCULATION CHANNELS.

Channel	Acquire Data	Label	Presets	View/Change Parameters
ANALOG INPUT CHANNELS				
CH1	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> <input checked="" type="checkbox"/>	Displacement (cm)	▼	🔗
CH2	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	CH2 Input	▼	🔗
CH3	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	CH3 Input	▼	🔗
CH4	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	CH4 Input	▼	🔗
DIGITAL INPUT CHANNELS				
D1	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	D1 - Digital Input		
D2	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	D2 - Digital Input		
D3	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	D3 - Digital Input		
D4	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	D4 - Digital Input		
CALCULATION CHANNELS				
C1	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	C1 - calculation - OFF	▼	🔗
C2	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	C2 - calculation - OFF	▼	🔗
C3	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	C3 - calculation - OFF	▼	🔗
C4	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	C4 - calculation - OFF	▼	🔗

The bottom of the screen shows the Windows taskbar with the time 13:13 and date 19/04/2013.



Biopac

Test protocol

- MP35-->setup channel change parameters scaling

The screenshot displays the Biopac Student Lab PRO software interface. The main window shows a video feed of a mechanical setup with a syringe and a displacement sensor. Overlaid on this are several dialog boxes:

- Set up Channels:** A dialog box with columns for Channel, Acquire Data, Label, Presets, and View/Change Parameters. Under "ANALOG INPUT CHANNELS", CH1 is selected with "Displacement (cm)" as the label. CH2 and CH3 are also listed but not selected.
- Change Scaling Parameters:** A smaller dialog box for "CH1, Displacement (cm)". It has fields for "Input value" (set to 1), "Scale value" (set to 500), and "Units label" (set to "cm"). A hand cursor is pointing at the "Input value" field.
- Channel Configuration:** A dialog box showing "Channel Preset" and "Channel Label" both set to "Displacement (cm)". It also shows "Gain" set to "x500" and "Offset" set to "0".

The bottom of the screen shows the Windows taskbar with the system clock at 13:16 on 19/04/2013.



Biopac

Test protocol

- MP35-->setup acquisition sample rate & acquisition length

Number of sample in 1 second (1Hz)

Long enough to perform experiment

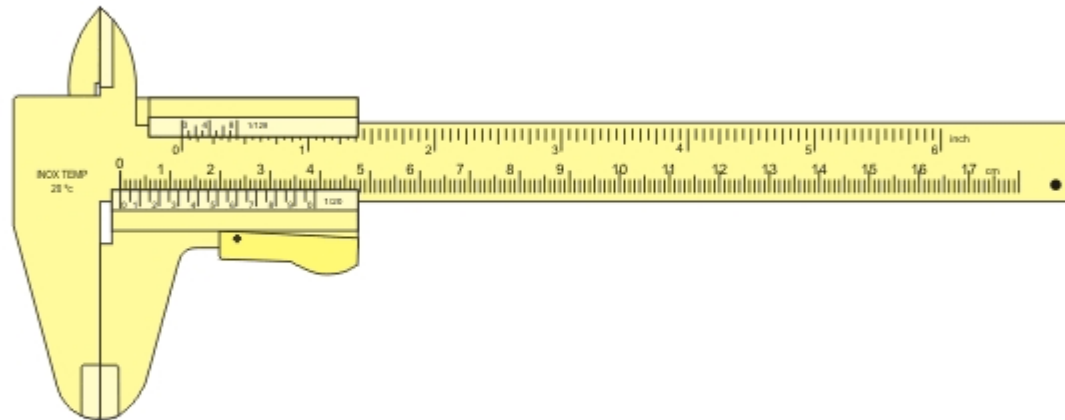


Caliper

how to use it



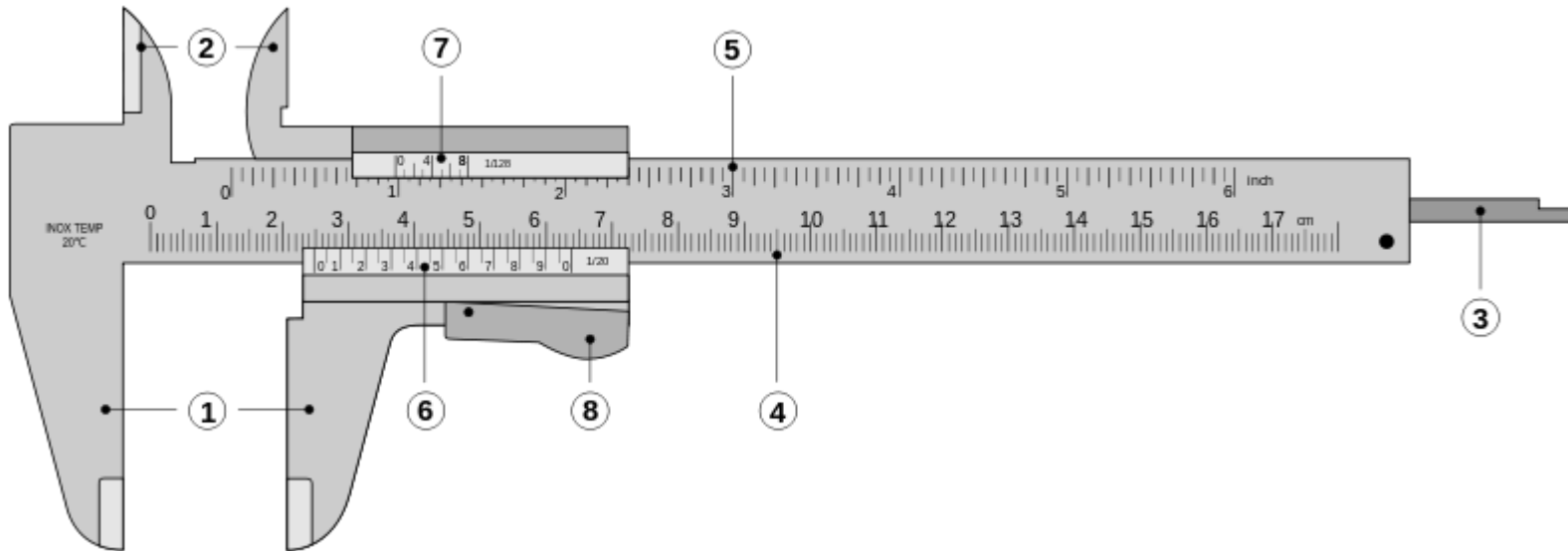
- direct reading of the distance measured with high accuracy and precision
- 0.1mm resolution





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

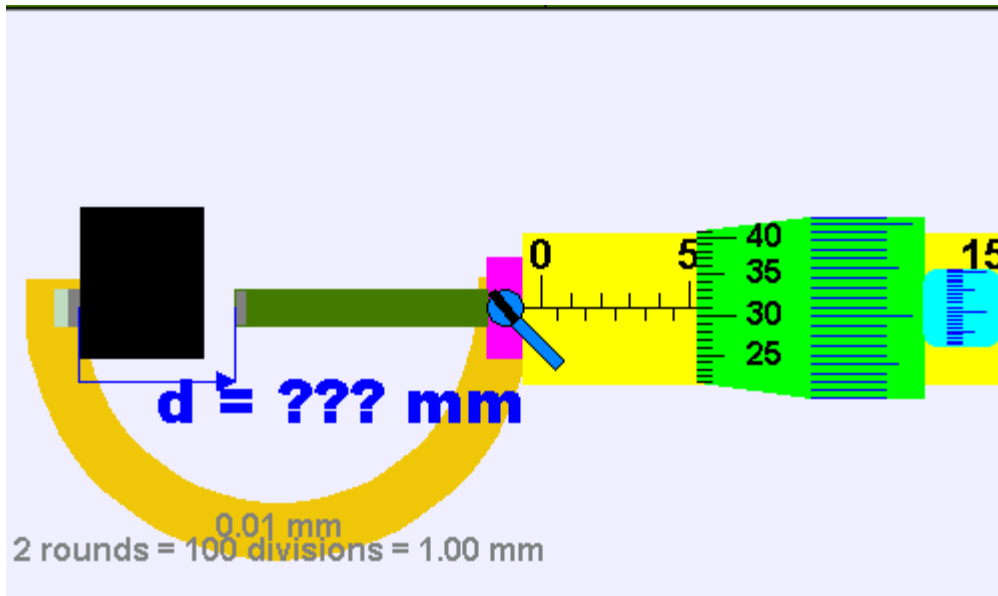


Micrometer

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

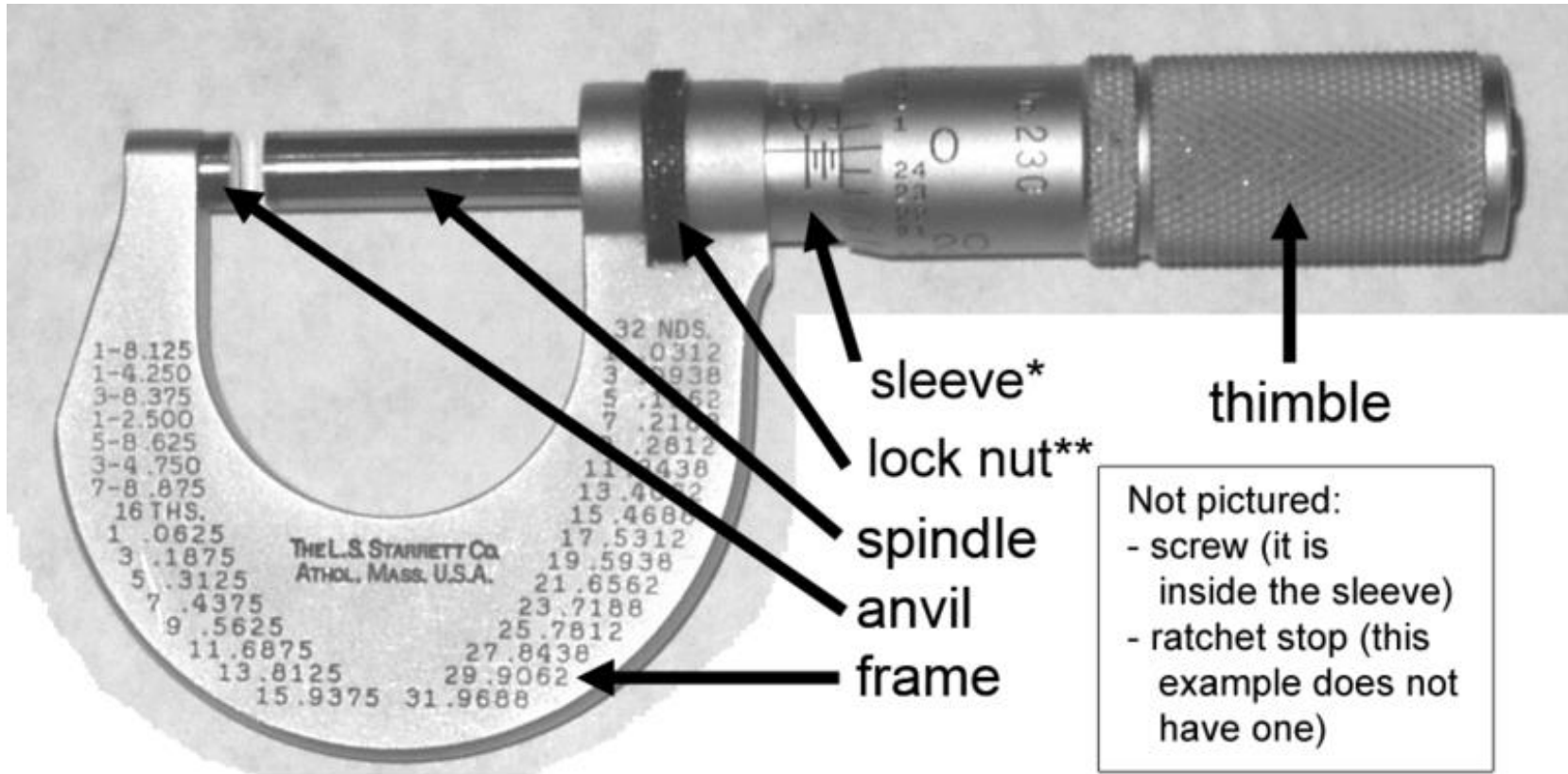


- Resolution 0.01mm
(10 μ m)



Micrometer

how to use it

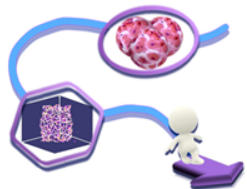


*Sleeve is the most prevalent name. May also be called the *barrel* or *stock*.

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



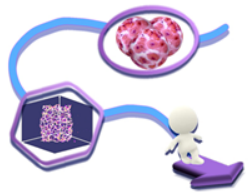
Modelling the linear response



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:

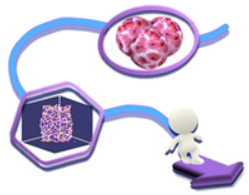
$$y = \alpha + \beta \cdot x + e$$

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)

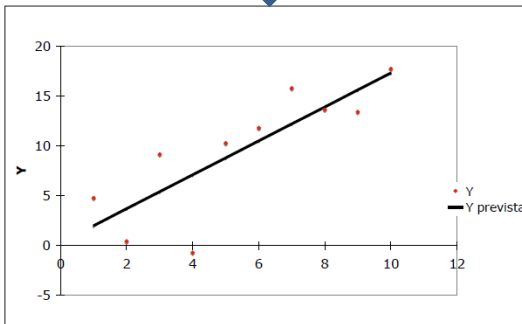
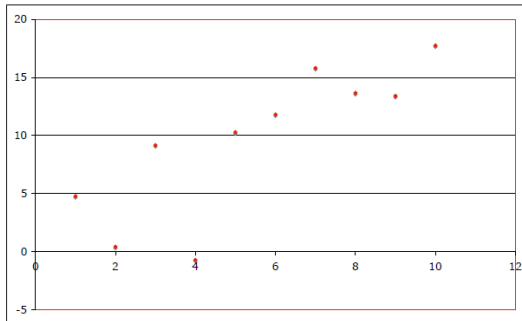
e is an error variable (normal distribution with $\mu=0$)





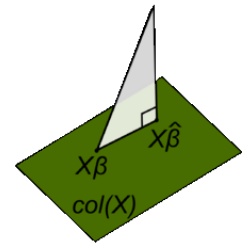
Linear Regression

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



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

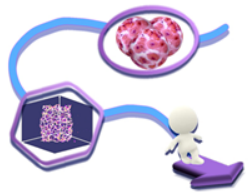
$$SS_R = \sum_{i=1}^n (y_i - a - bx_i)^2$$



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

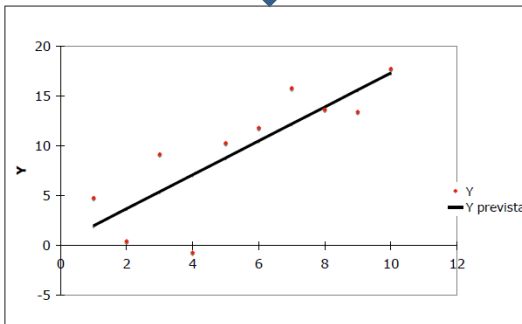
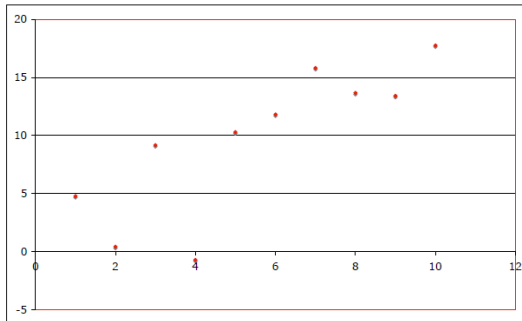


Linear Regression

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

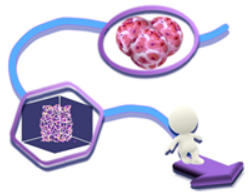
$$y = \alpha + \beta \cdot x$$

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

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



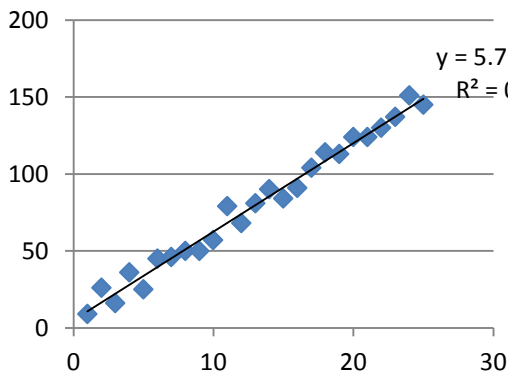
Linear Regression: *practical example*

It is possible to evaluate fit goodness using variability index:

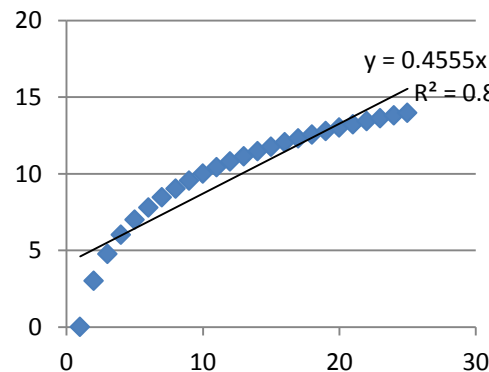
$$R^2 := 1 - \frac{SS_R}{S_{yy}}$$

$$0 < R^2 < 1$$

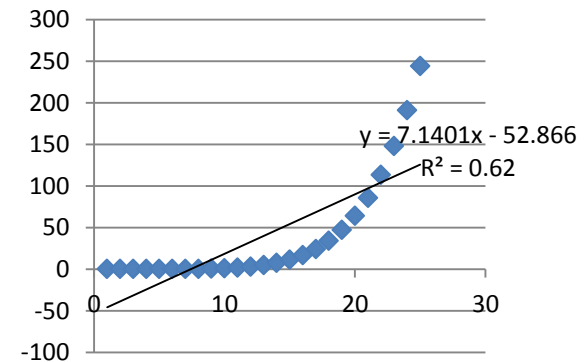
R^2 is the variability fraction due dependence between the two variable (also defined as Coefficient of determination)



Good fit ($R^2 > 0,9$)



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



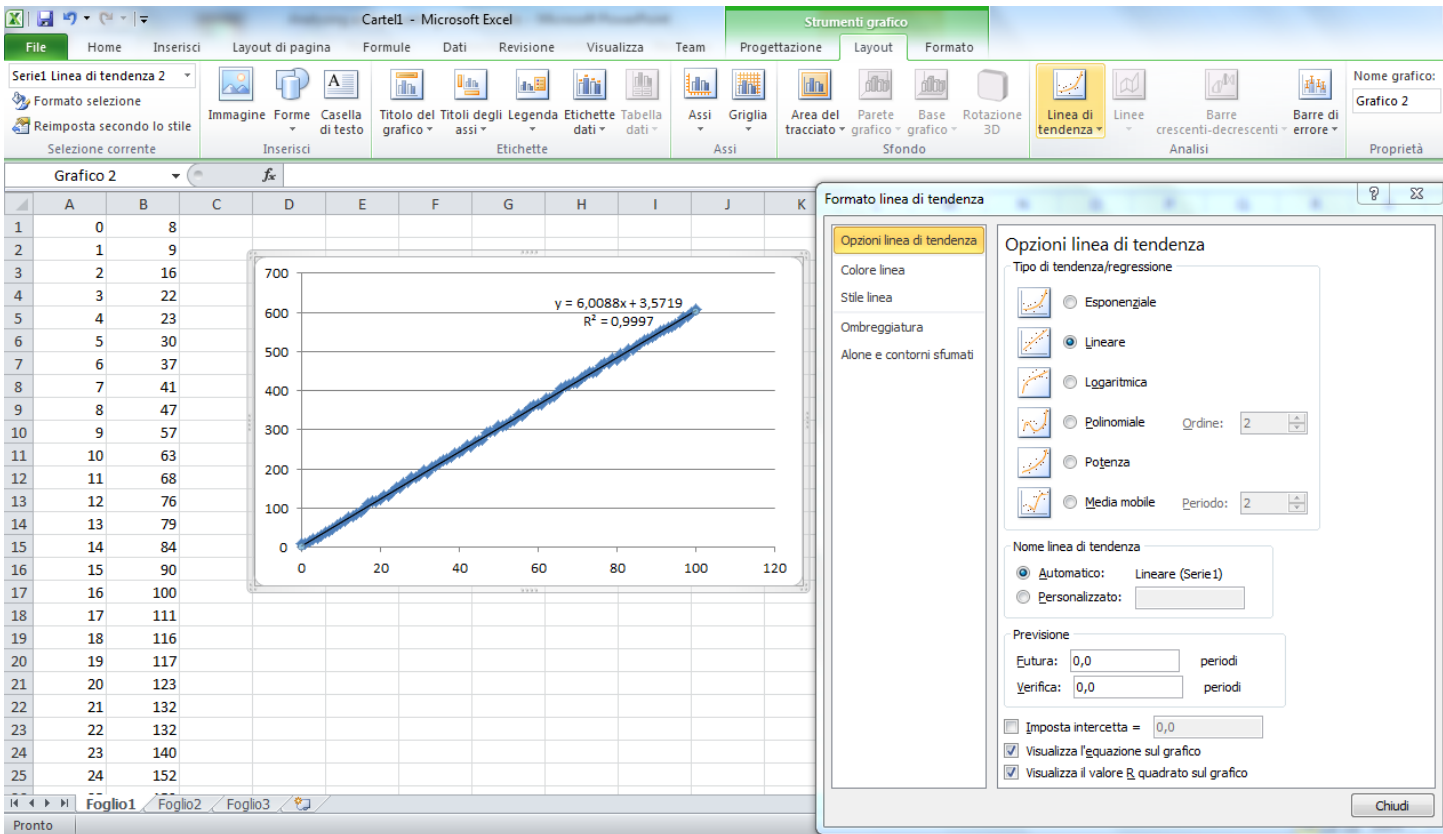
Bad fit ($R^2 < 0,8$)



Microsoft Excel: *Linear Regression*

Two ways to evaluate fit parameters

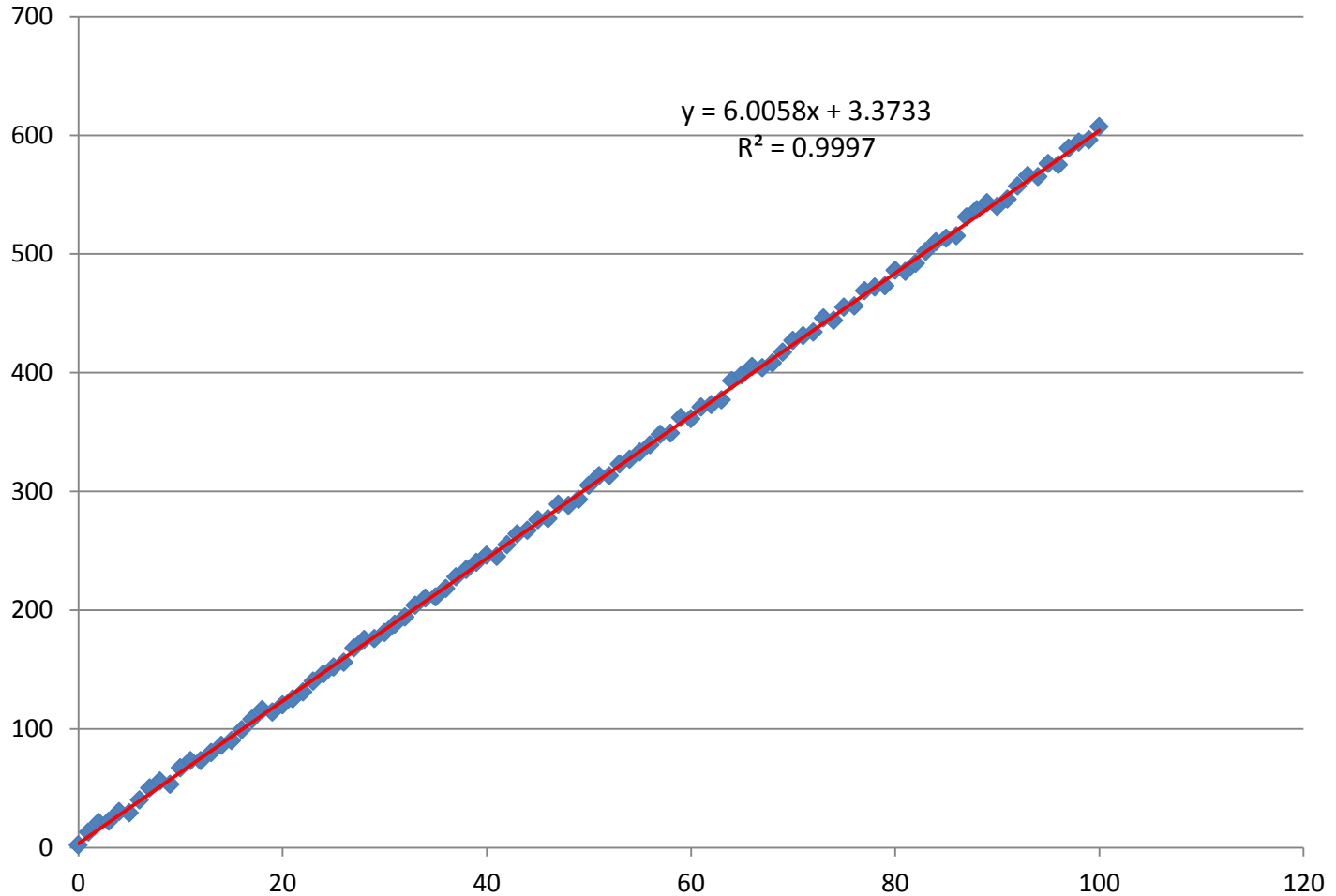
- *Directly on the plot*: use trend line function (under layout)



- 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 $y = mx + b$

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 $y = mx + b$

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

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	ssreg	ssresid				



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



Case of study: the hair

Typical experiment and analysis

