Information technology tools in the practical courses of Medical Physics and Statistics

Department of Medical Physics and Informatics
University of Szeged

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Tools:
BIOPAC Student Lab data acquisition and processing system
Excel spreadsheets for calculations, reporting and tests

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Information technology tools in the practical courses of Medical Physics and Statistics

Topics:

- Electrocardiography
- Spirometry
- Electrodermal activity
- Blood pressure
- CT reconstruction
- Electromyography

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ELECTROCARDIOGRAPHY

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Electrocardiography

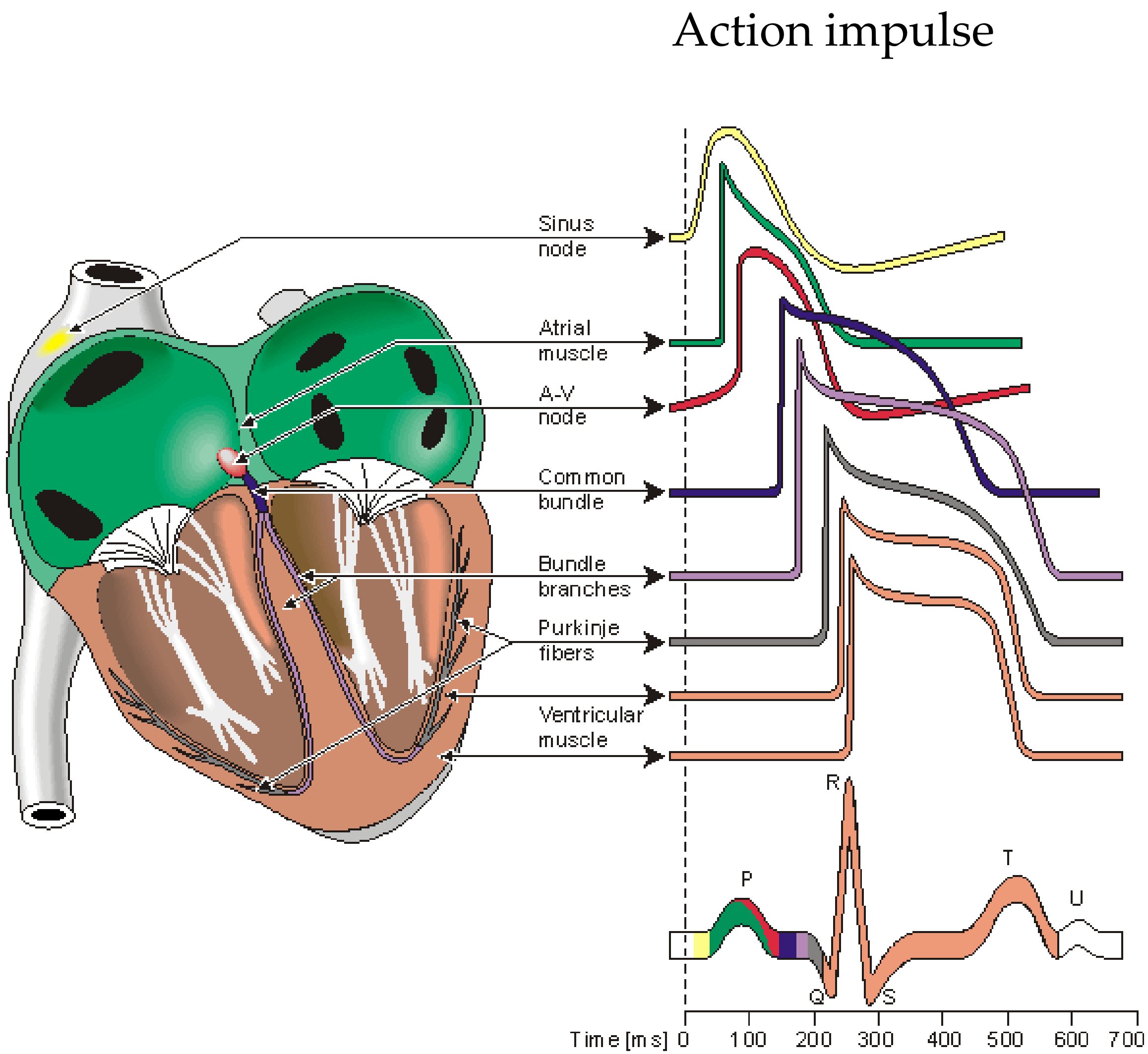
- Cyclic changes in the cardiac activity generate an electrical field
- Depolarization/repolarization leads to uneven disctribution of electrical charges around the heart
- These charges can be detected by body surface electrodes

Electrocardiogram (ECG)

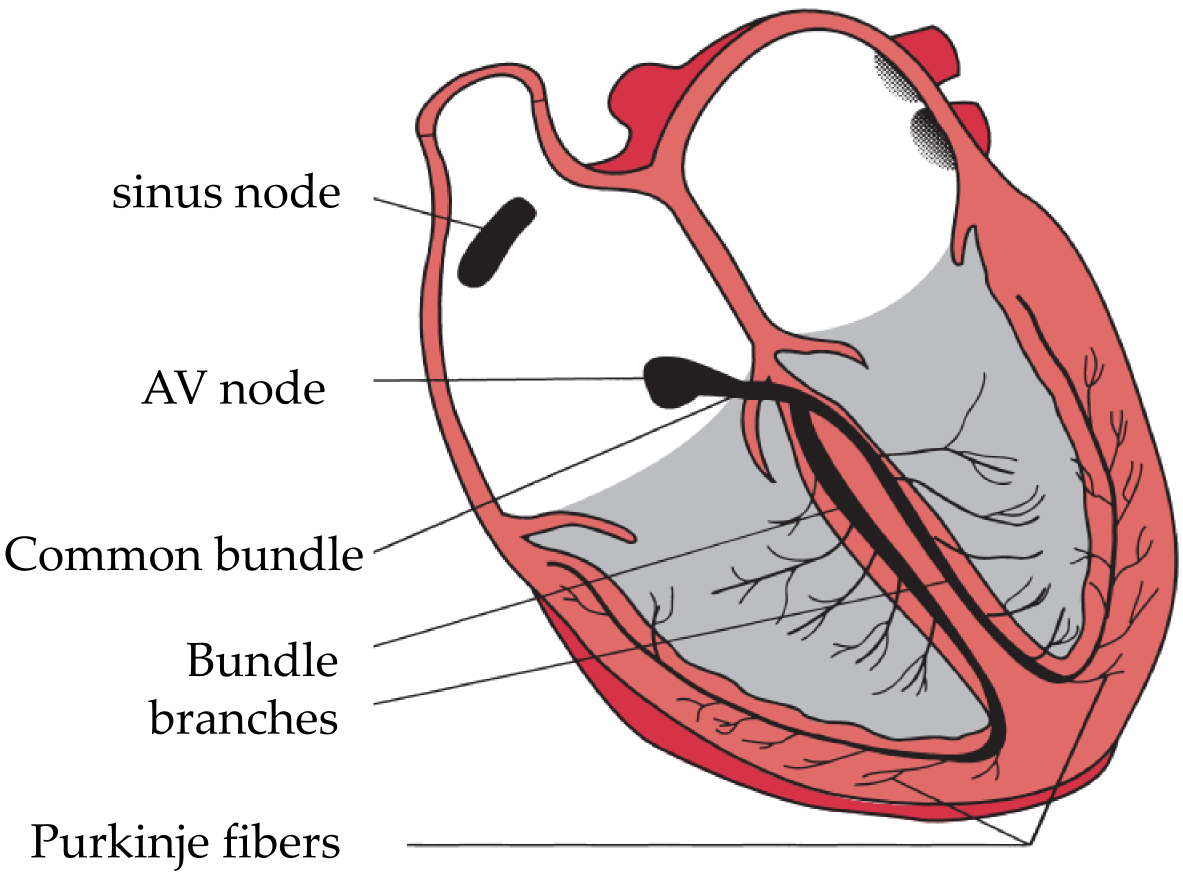
Specialized pacemaker cells start the **electrical sequence** of depolarization and repolarization

The **electrical signal** is generated by the sinoatrial (SA) node and spreads to the ventricular muscle

The **electrical activities** of the heart can be detected on the body surface via surface electrodes



Background



Electrical activity: depolarization-repolarization

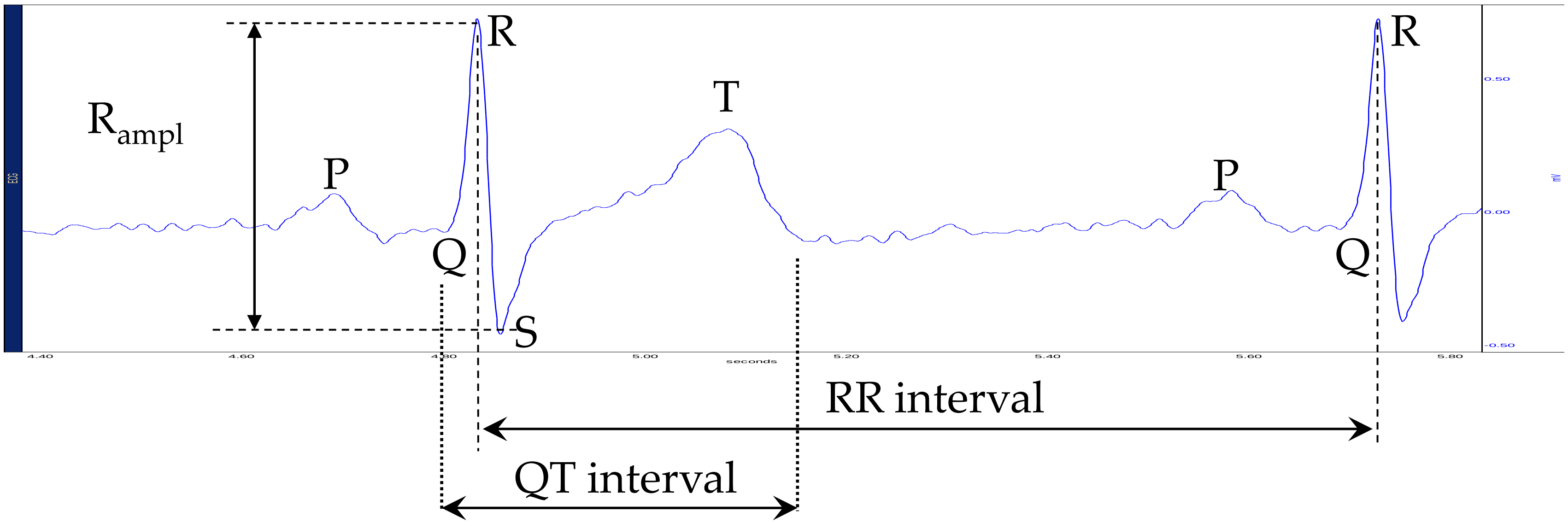
↓

Conducting system

↓

Cardiac muscle cells

ECG waves, intervals and segments



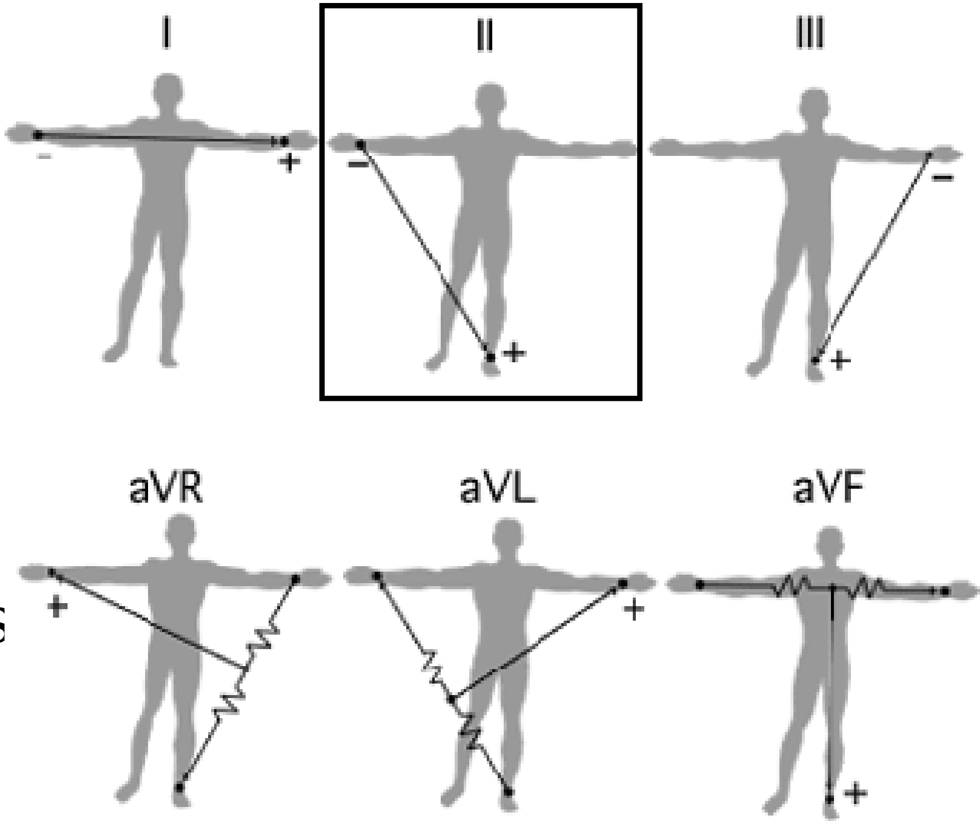
- P wave: atrial depolarization
- PQ interval: atrio-ventricular conduct
- PQ segment: impulse transmission from sinus node to AV node entering the ventricles
- QRS complex: ventricular depolarization
- T wave: ventricular repolarization

Background – Electrode leads

The arrangement of electrodes is a lead

Bipolar (Einthoven)

- Standard Lead I, II and III form a triangle where the heart electrically constitutes the null point.
- Einthoven's Triangle is used when determining the electrical axis of the heart.



Unipolar augmented leads

aVR: right arm
aVL: left arm
aVF: left foot

Experimental objectives

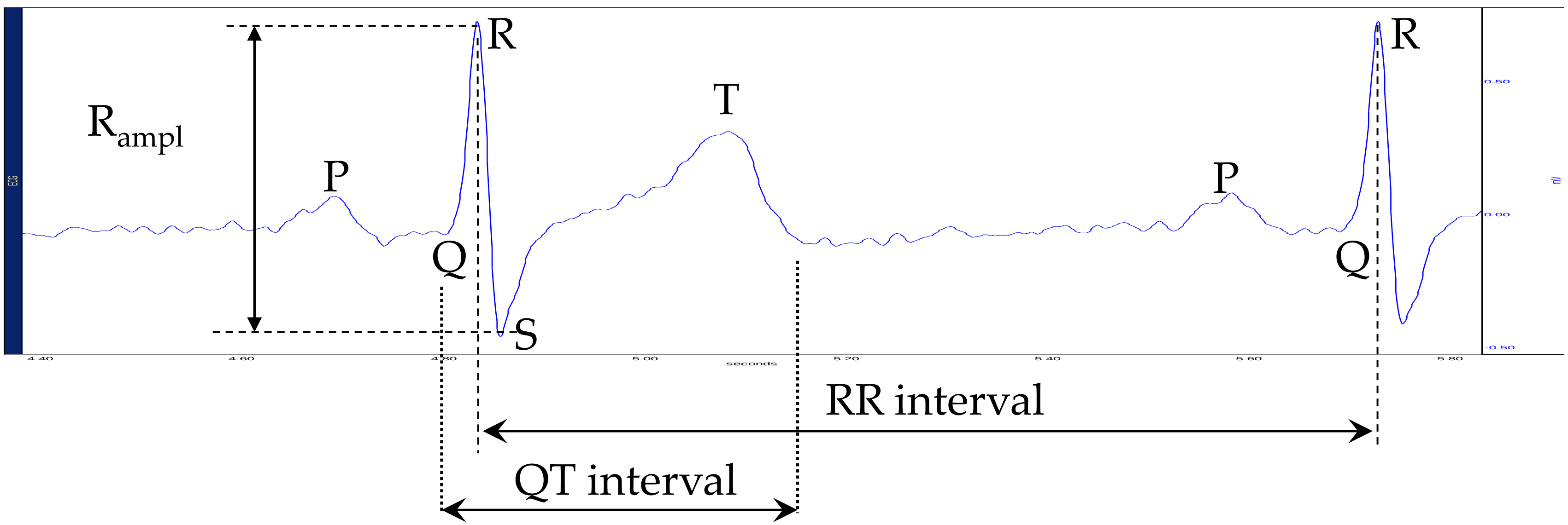
- To become familiar with the measurement of electrocardiograph
- To observe rate and rhythm changes in the ECG associated with exercise
  - Detect the current heart rate for the study period
  - Identify specific time intervals
    - Length of R-R intervals (complete heart cycle)
    - Length of QT intervals (ventricular systole)
    - Determine their ratio
  - Determine QRS amplitude

Tasks performed by the student

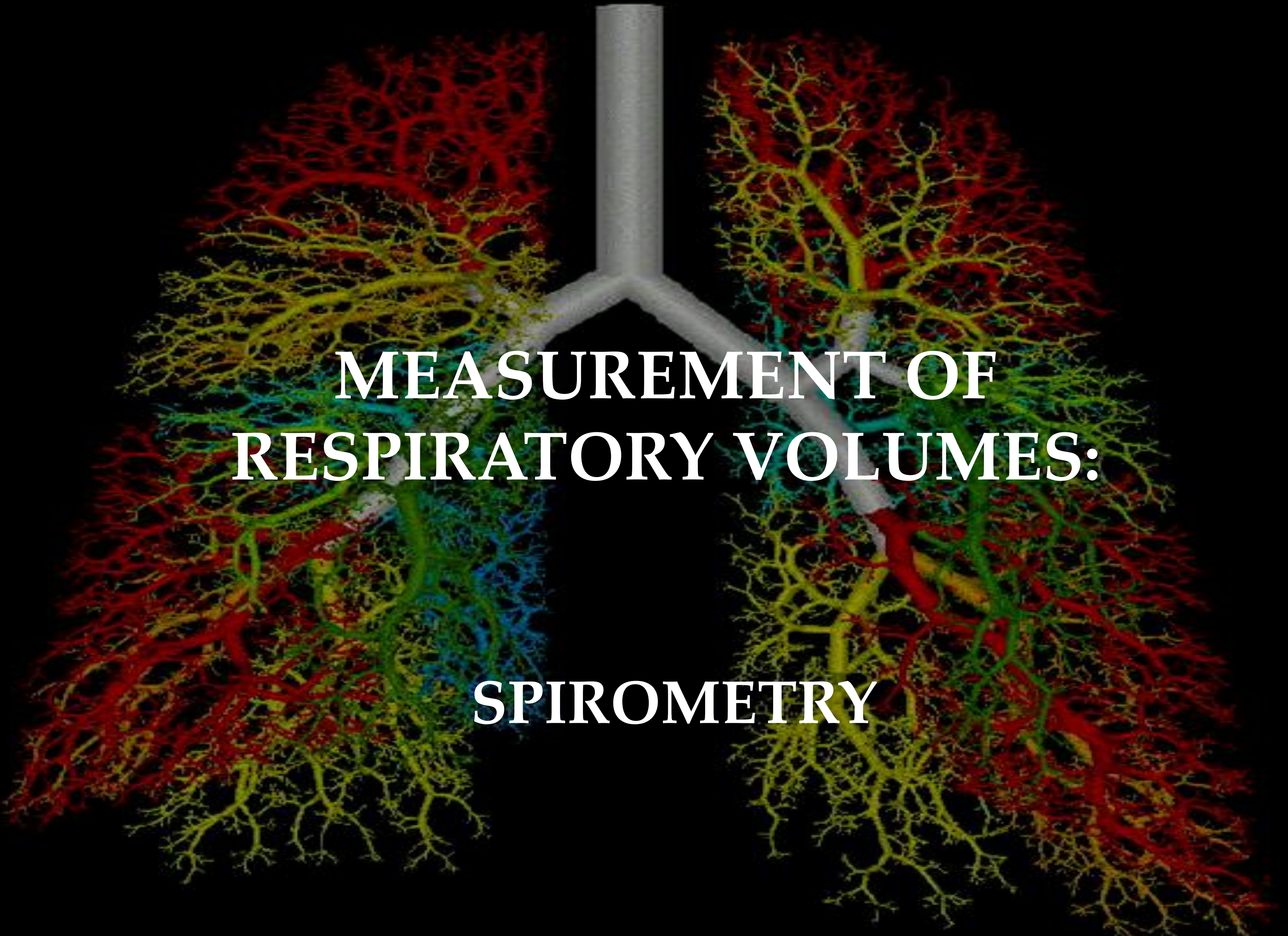
- Place the electrodes to right wrists and both ankles
- Start and set-up the BSL Lessons software
- Sit down and relax
  - record normal resting ECG for 1 min
- Perform a physical exercise
  - Record ECG after exercise for 2 min

Data analysis

- Zoom-in for a closer look at an individual ECG complex
- Determine the characteristic duration parameters in for 3 cycles each
  - QT (ventricular systole), RR interval (complete heart cycle)



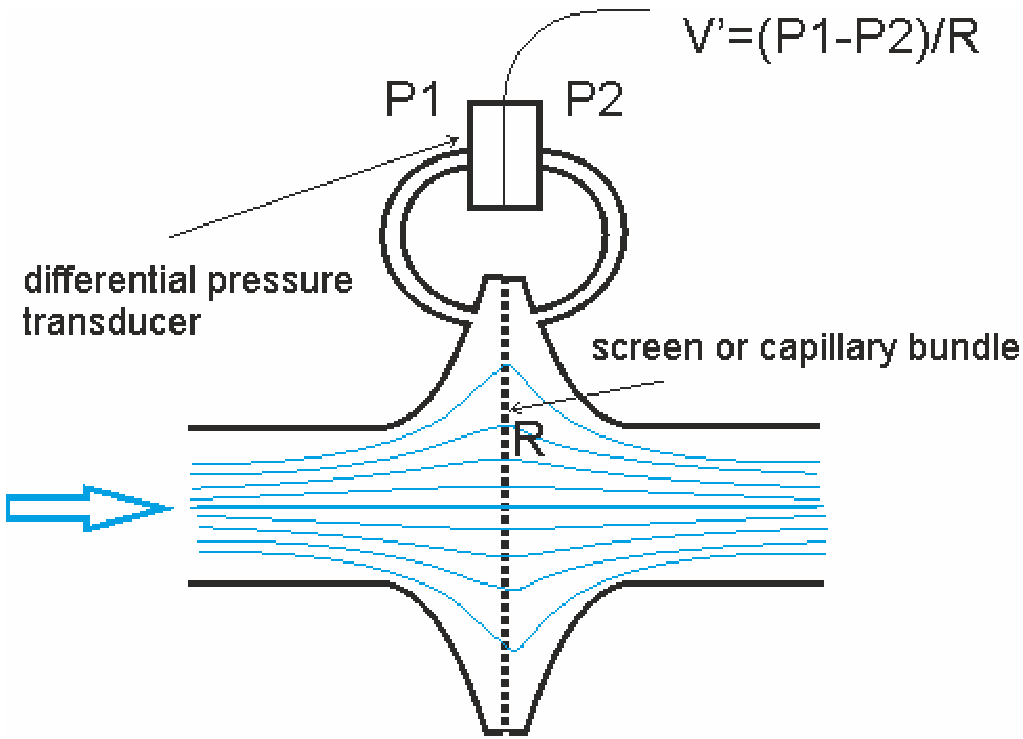
- Calculate the current heart rate in BMP for the different conditions



MEASUREMENT OF RESPIRATORY VOLUMES:

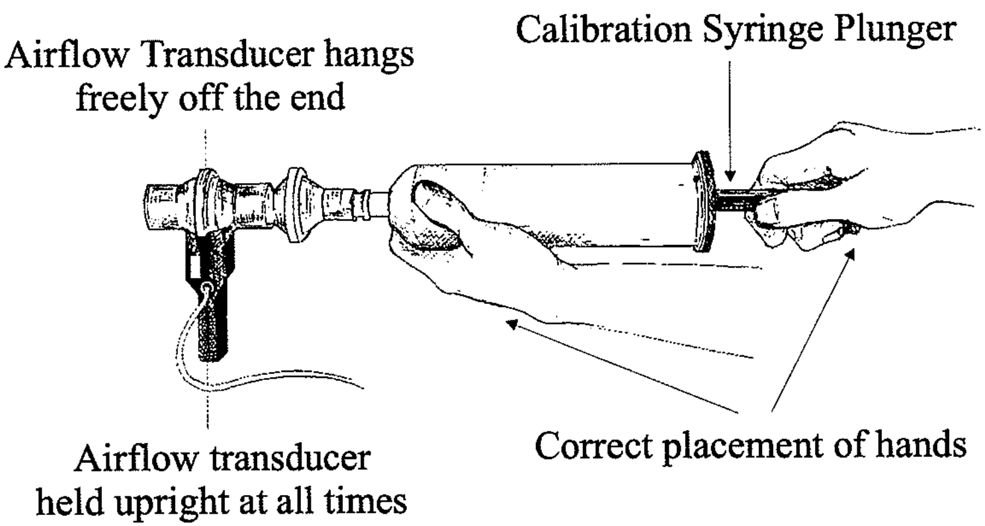
SPIROMETRY

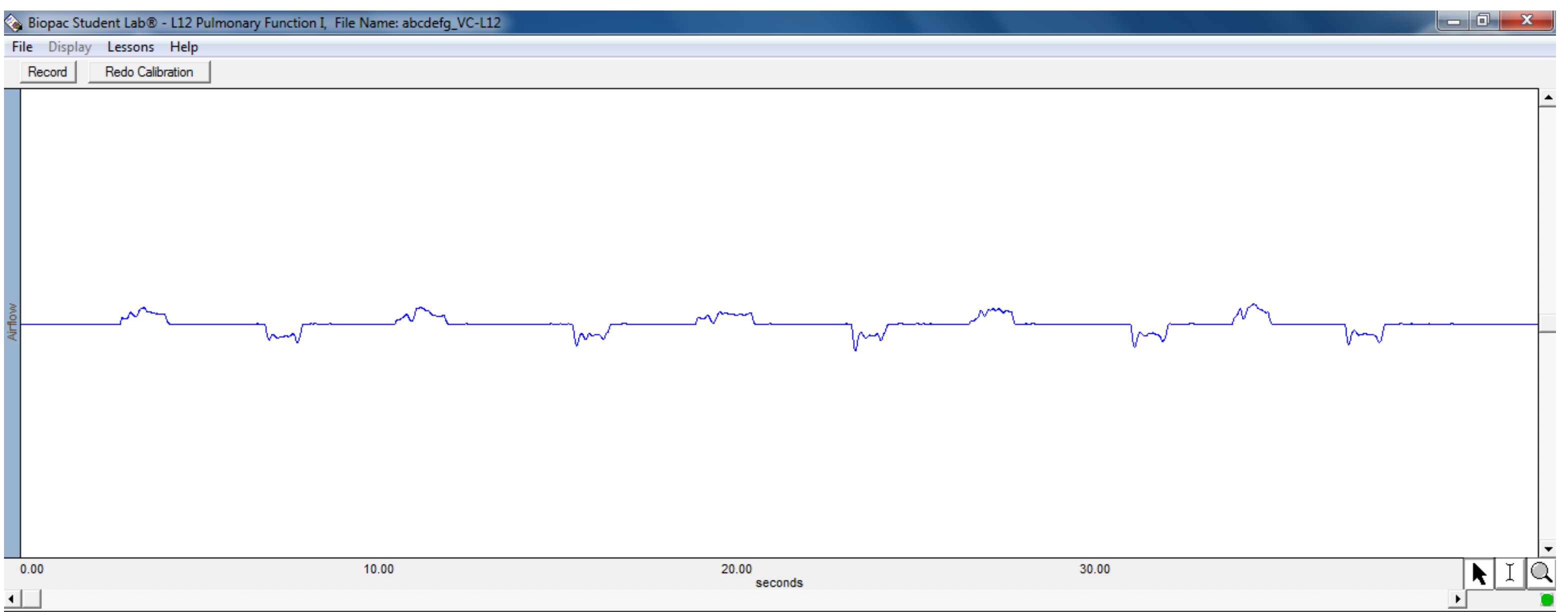
spirometer types:
open circuit



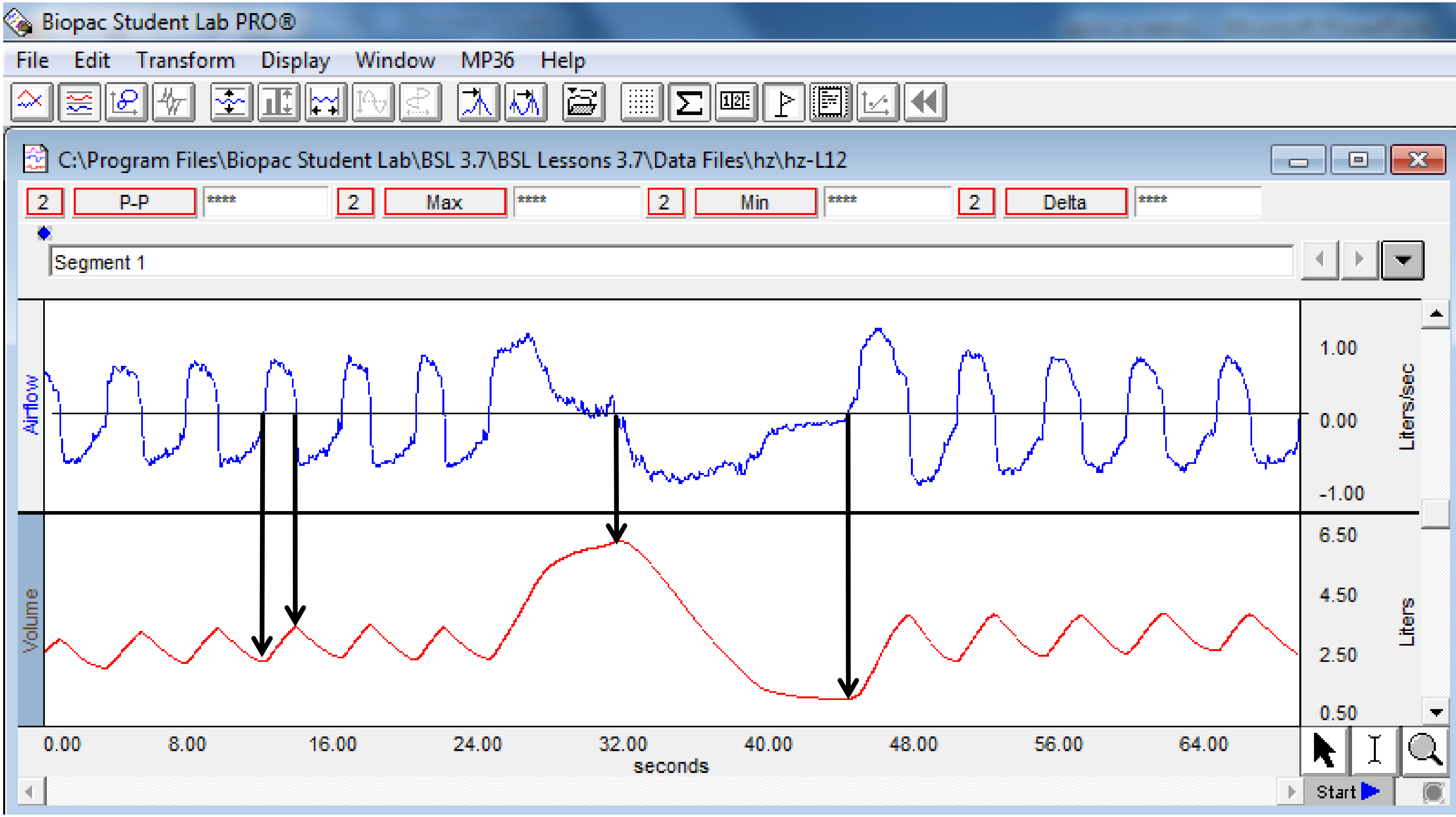
(other flowmeters: turbine, thermal, ultrasound, etc.)

volume (flow) calibration

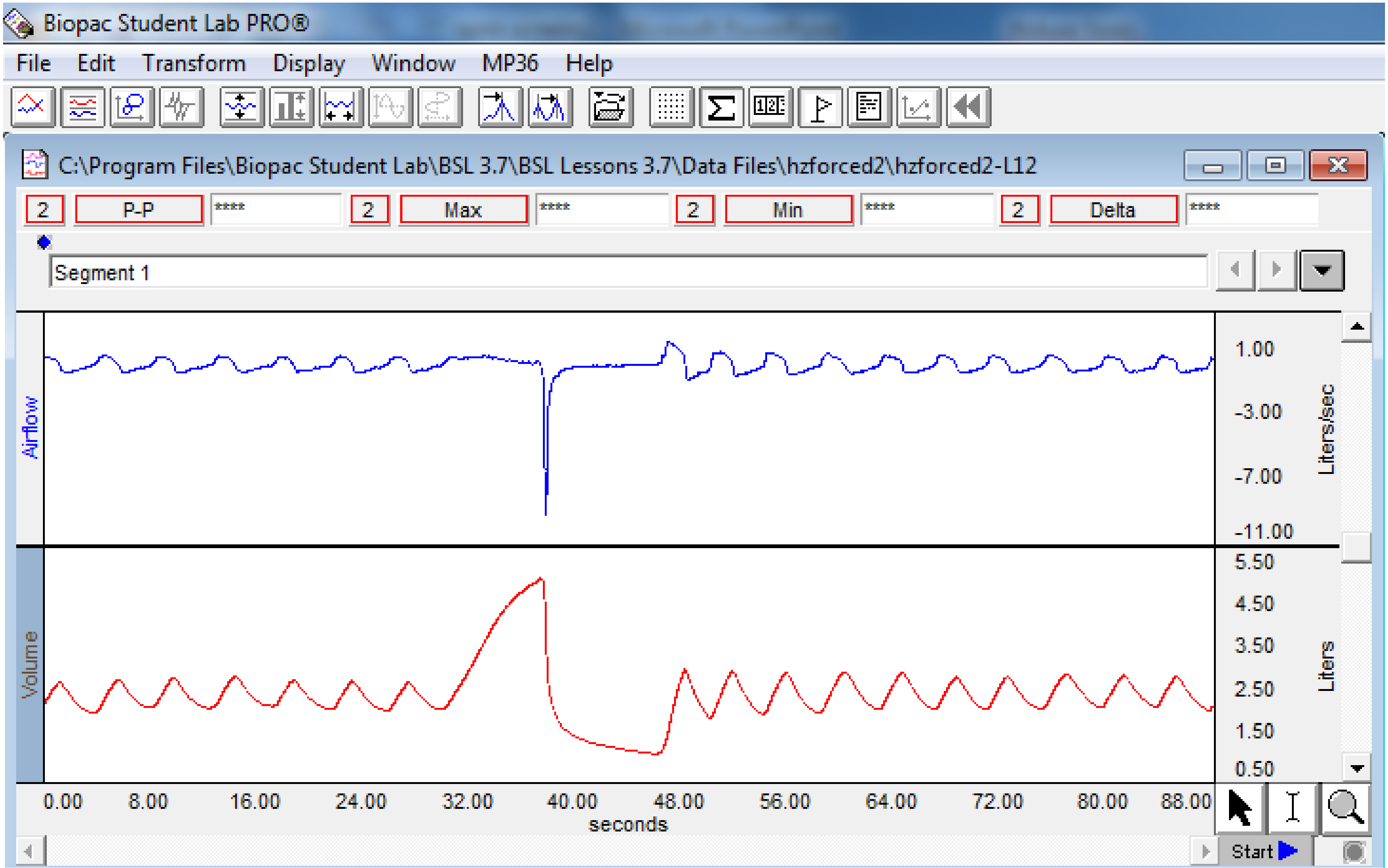




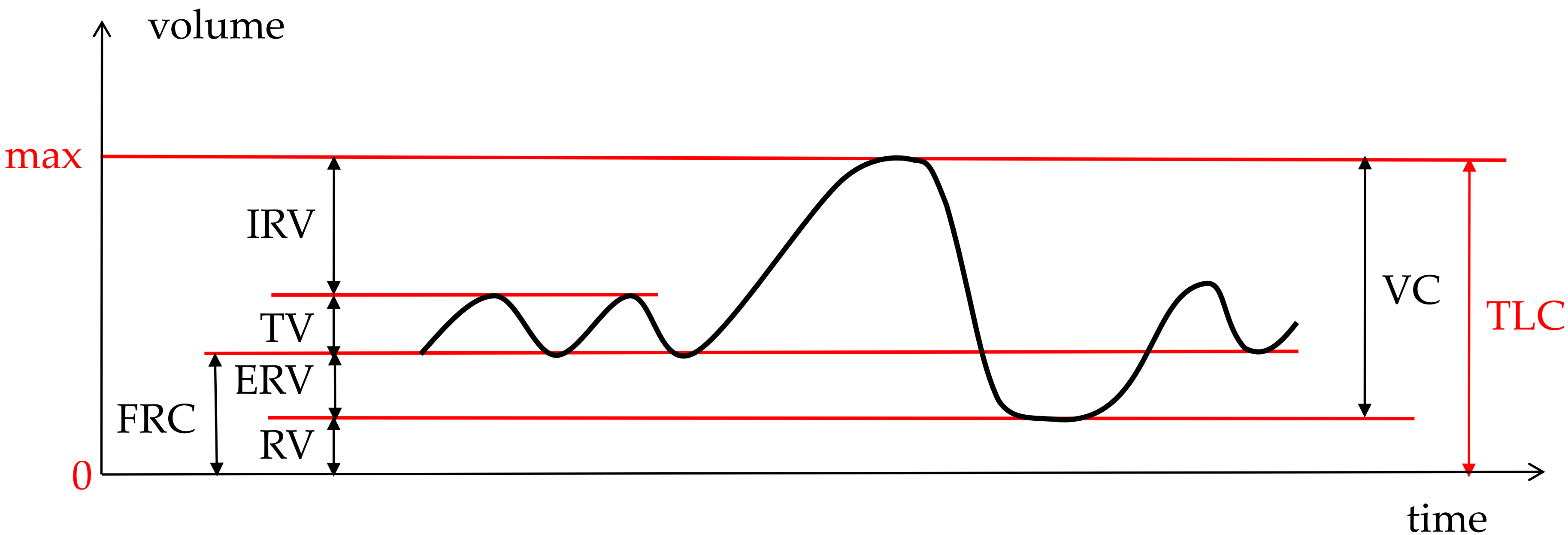
flow and volume: VC



flow and volume: FVC

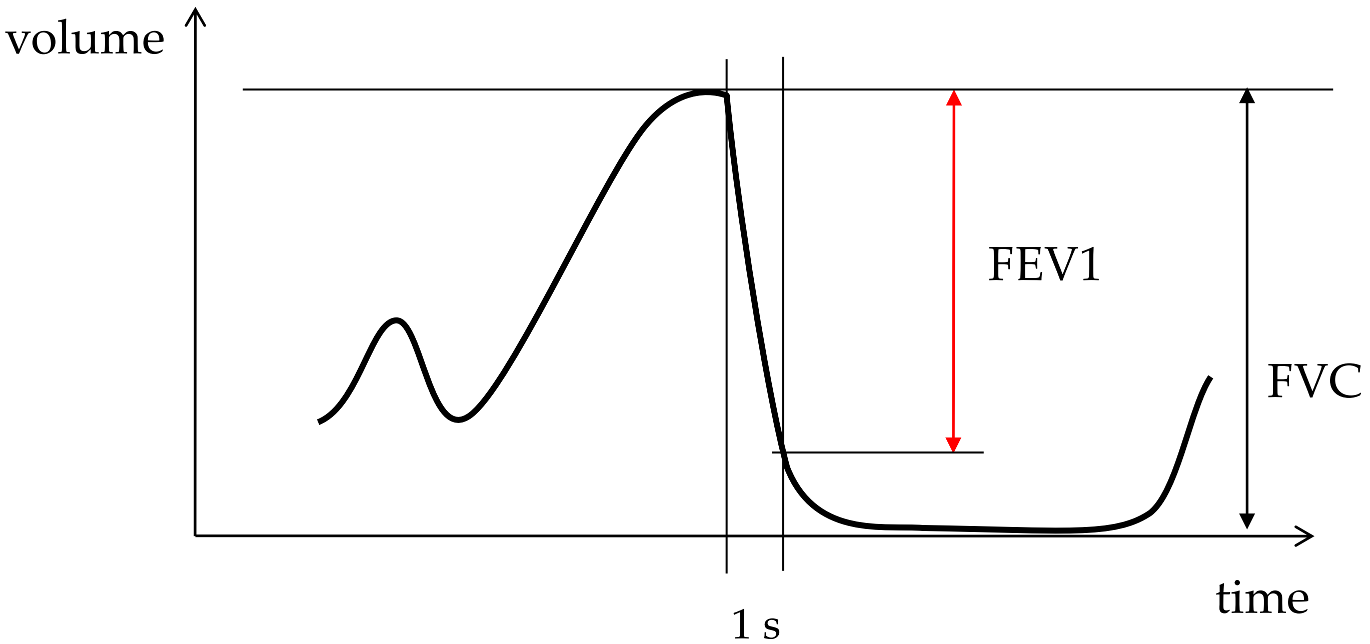


"static" lung volumes



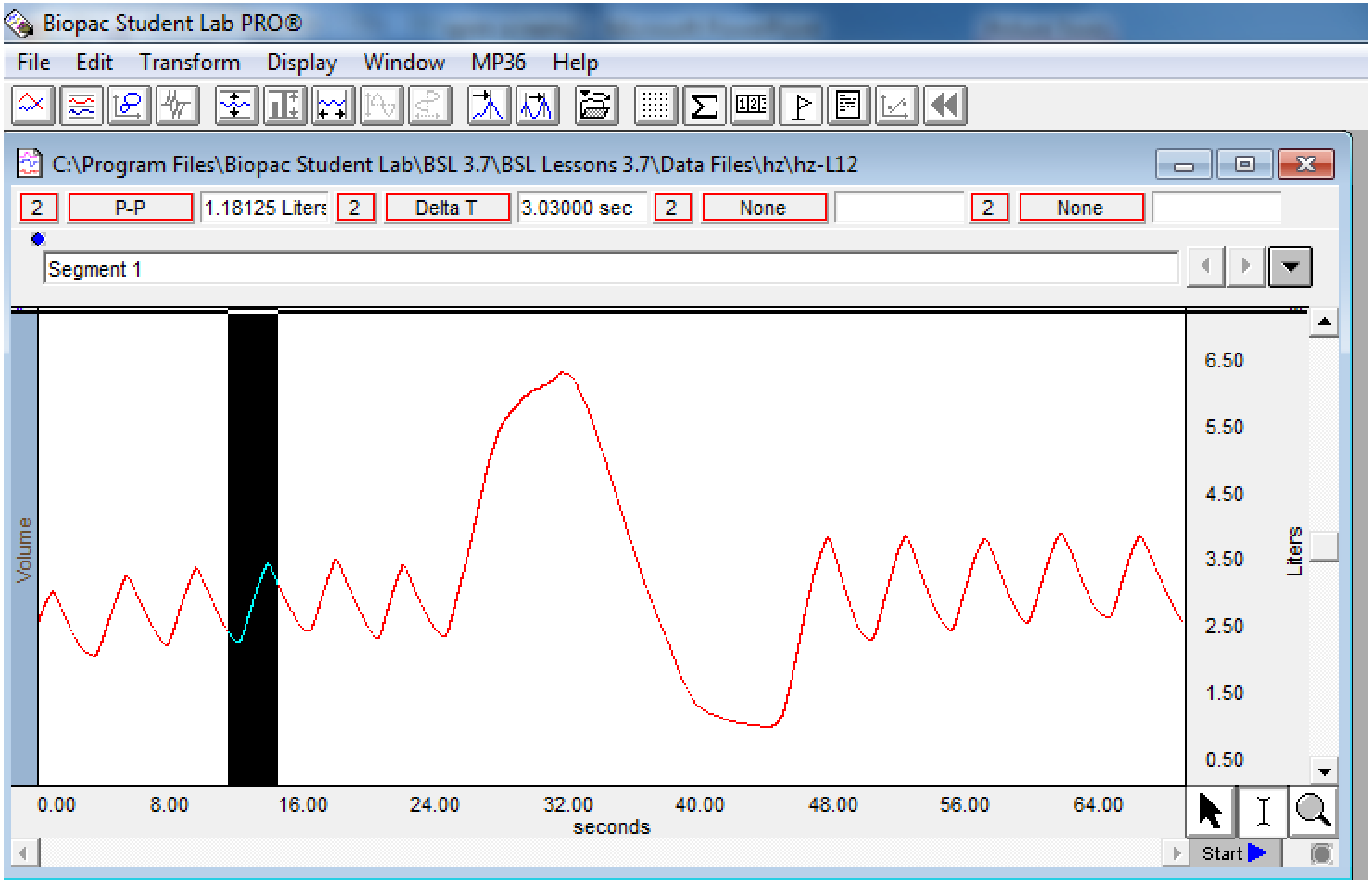
TV:	tidal volume	FRC:	functional residual capacity
IRV:	inspiratory reserve	VC:	vital capacity
ERV:	expiratory reserve	TLC:	total lung capacity
RV:	residual volume		

”dynamic” lung volumes

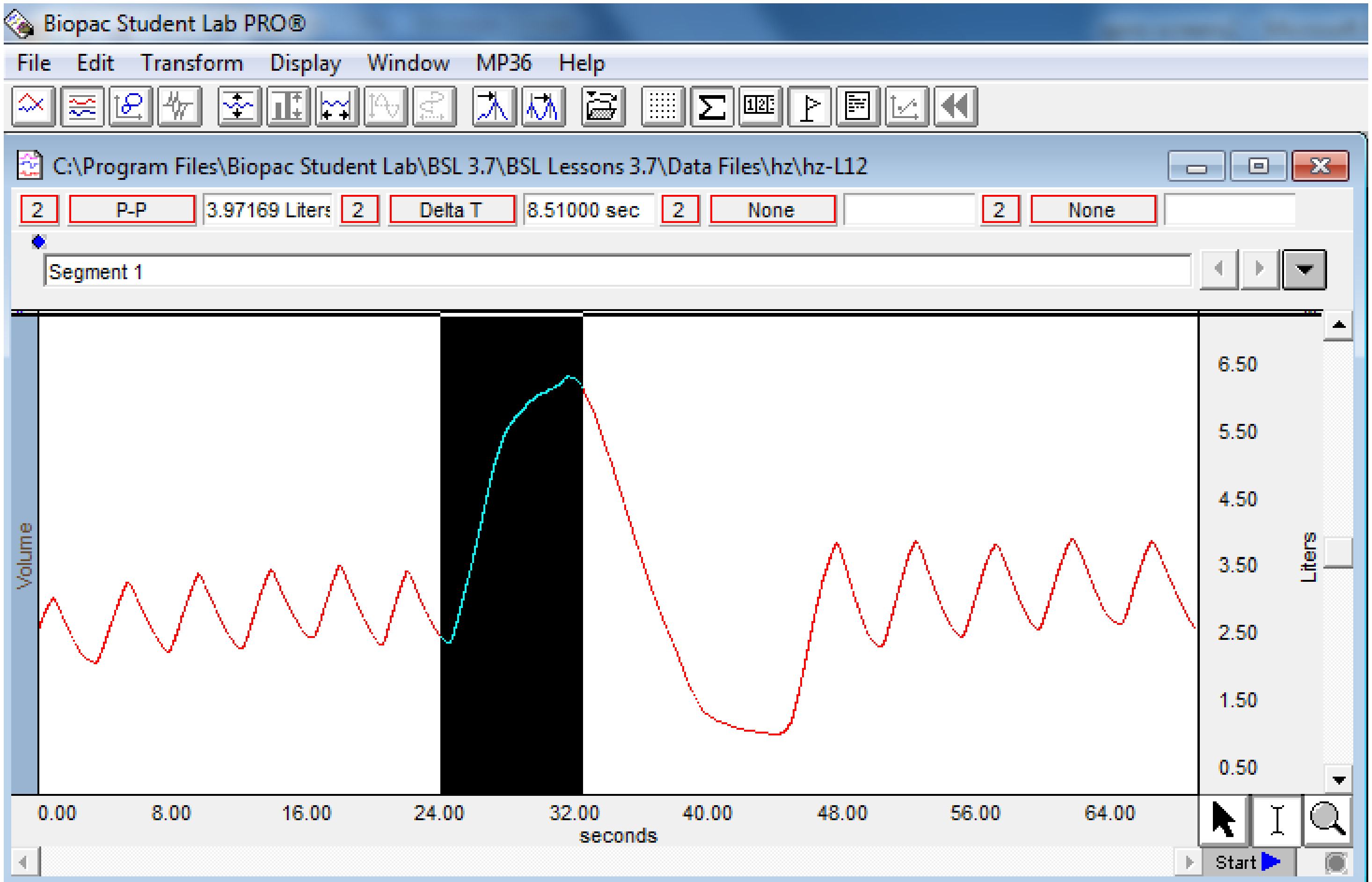


FVC: forced expiratory vital capacity
FEV1: forced expiratory volume in 1 s

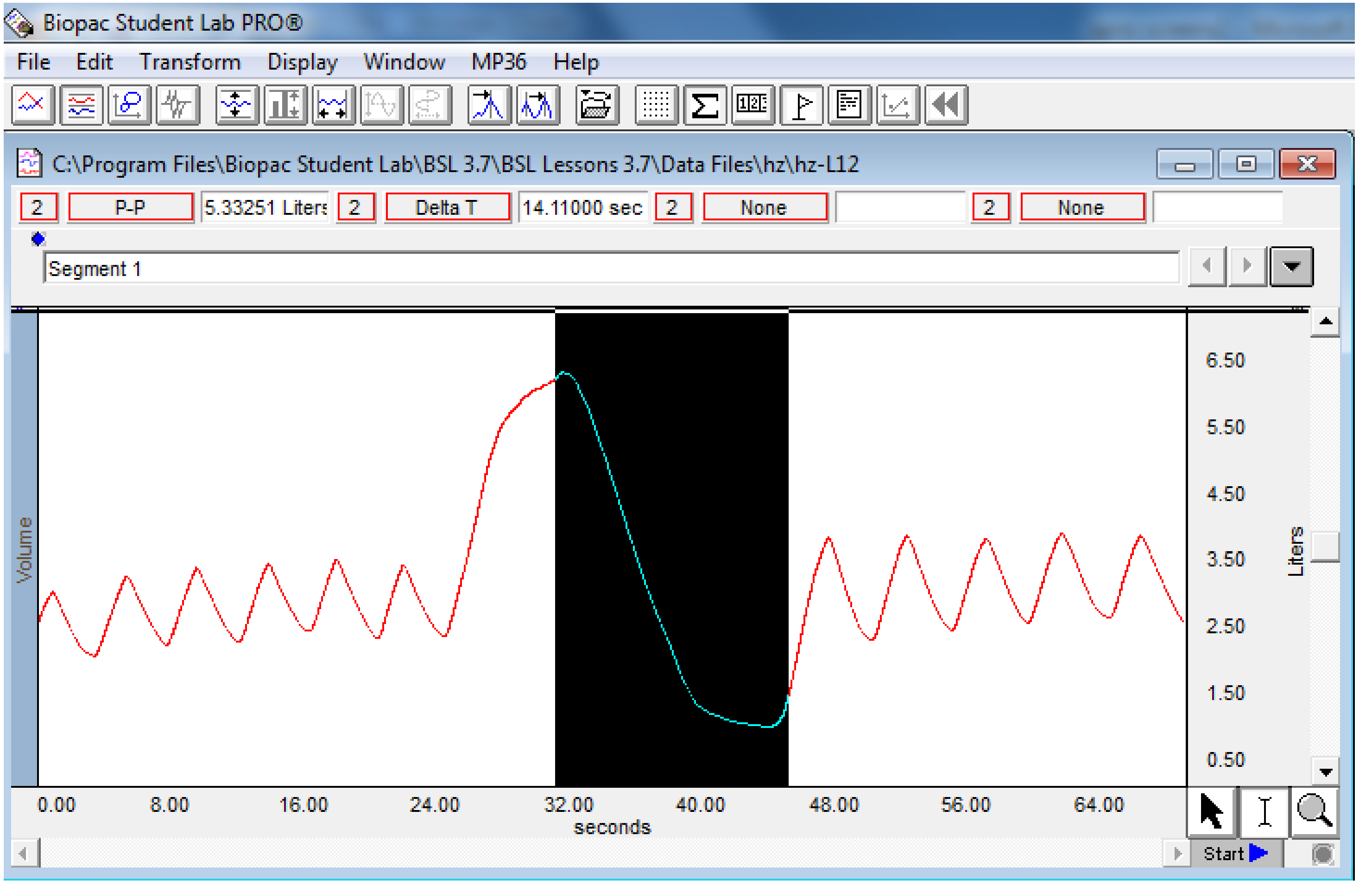
measurement of tidal volume (TV)



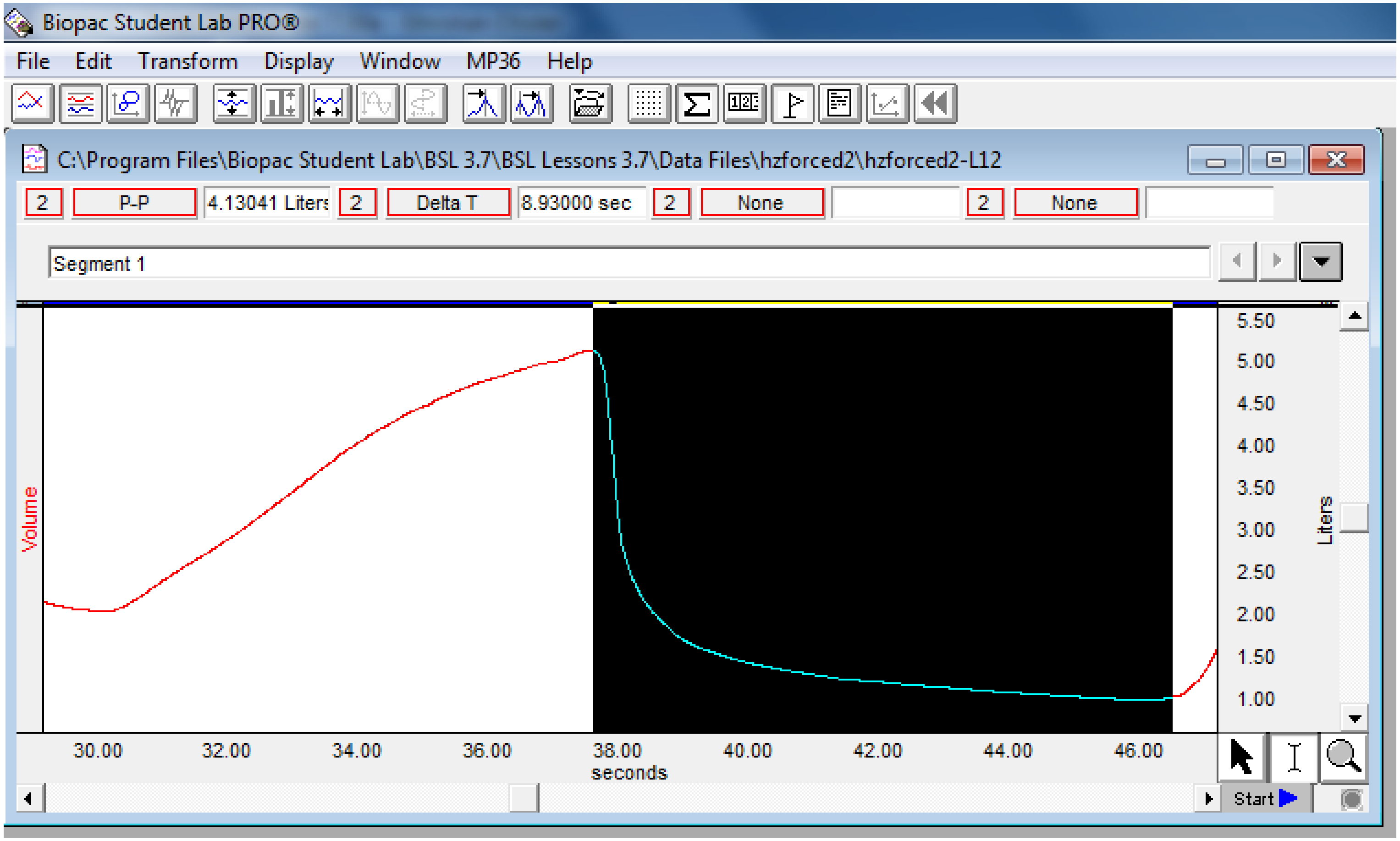
volume of maximum inspiration (TV+IC)



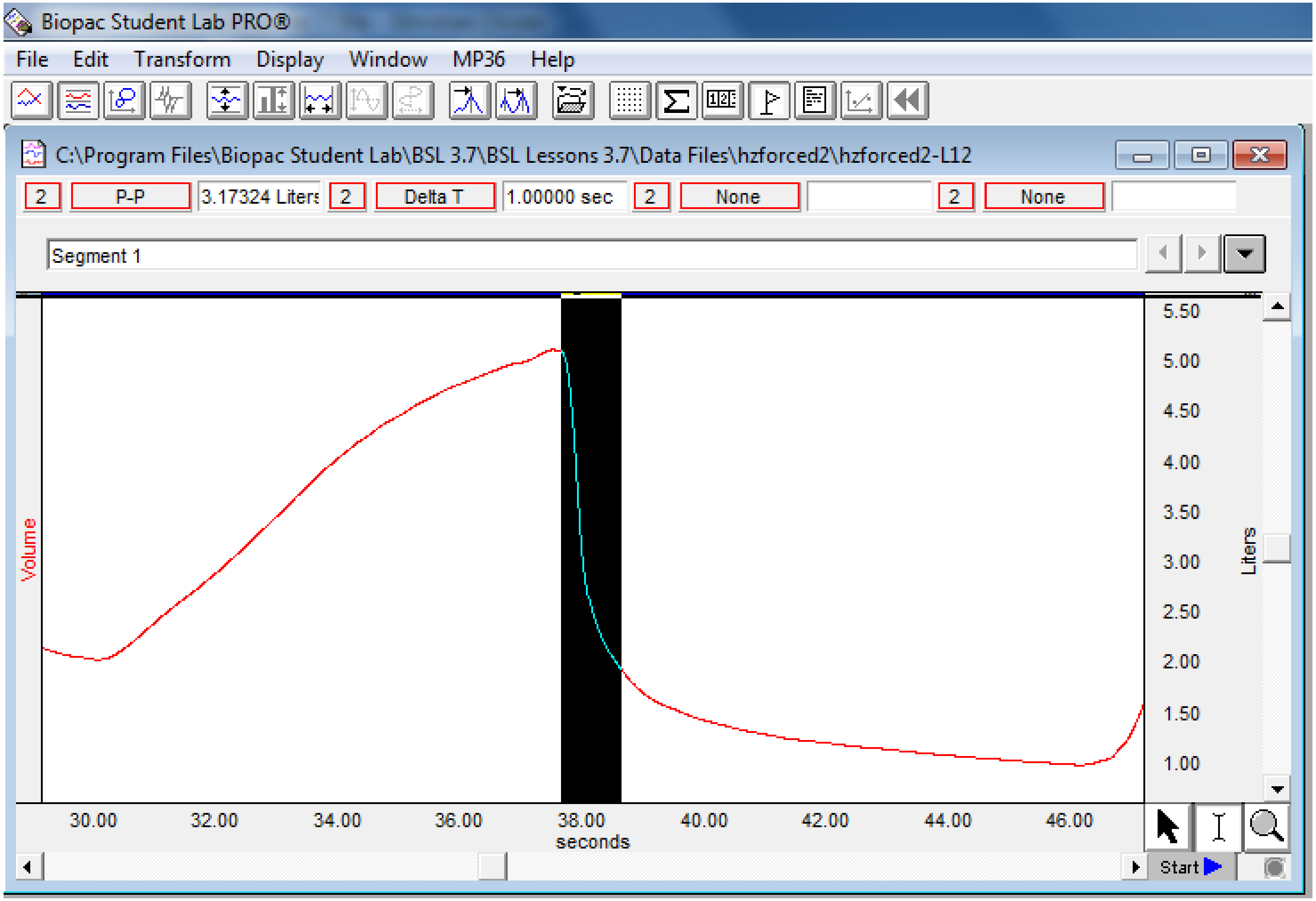
measurement of vital capacity (VC)



measurement of forced vital capacity (FVC)



forced expiratory volume in the 1st second (FEV1)



reference values for vital capacity

males:

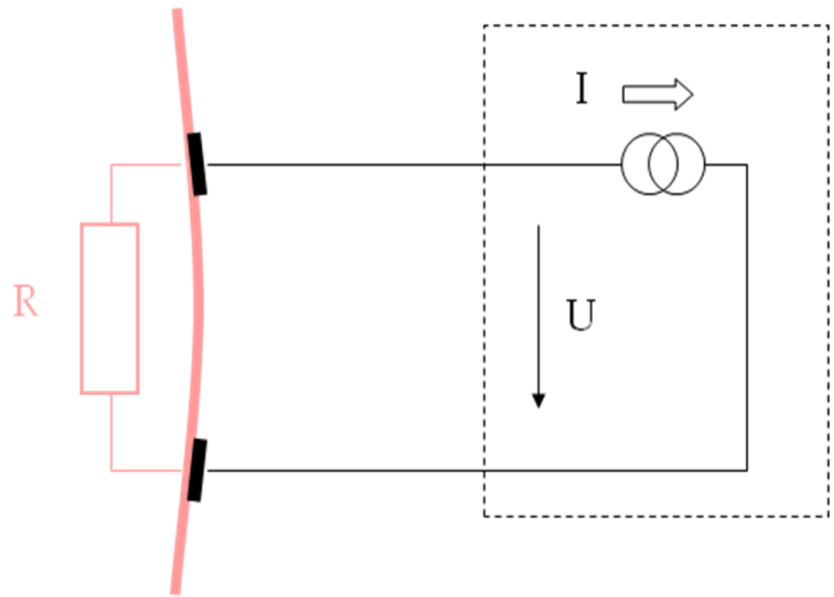
$$VC_{[L]} = 0.052H_{[cm]} - 0.022A_{[yr]} - 3.60$$

females:

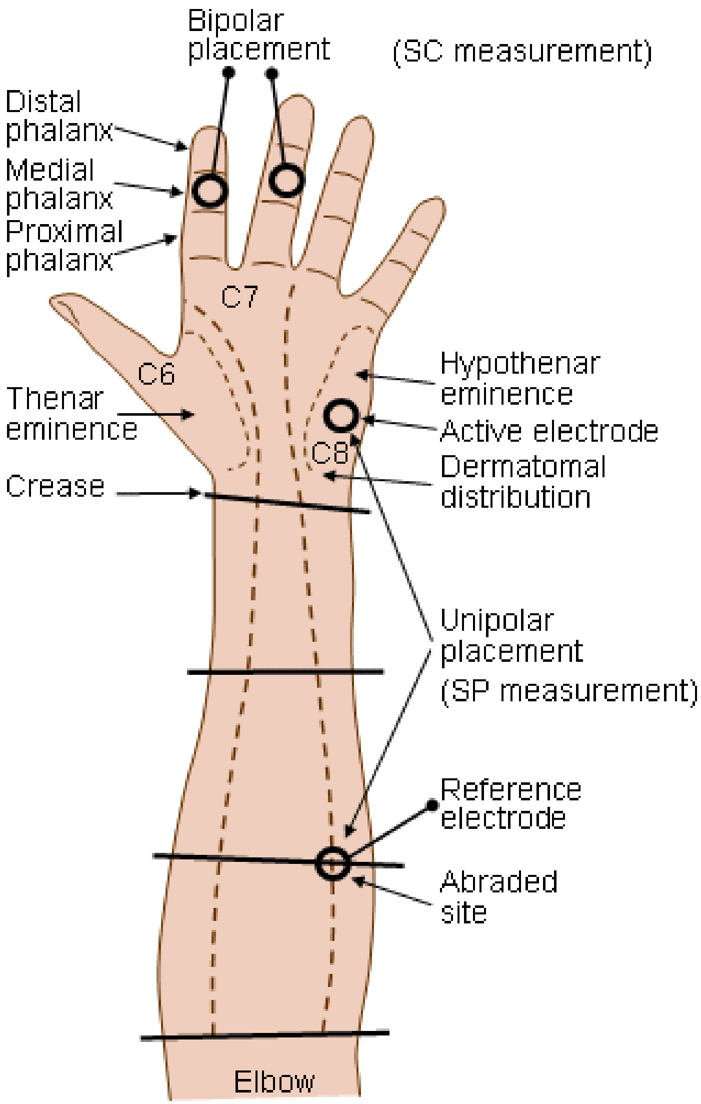
$$VC_{[L]} = 0.041H_{[cm]} - 0.018A_{[yr]} - 2.69$$

MEASUREMENT OF ELECTRODERMAL ACTIVITY

Galvanic skin resistance (GSR): a low-intensity current (I) is steadily applied between two electrodes and the voltage difference (U) is recorded between them, the resistance (R) can be calculated this is called galvanic skin resistance.



Conductivity: G=1/R [1/Ohm or Siemens (S)]

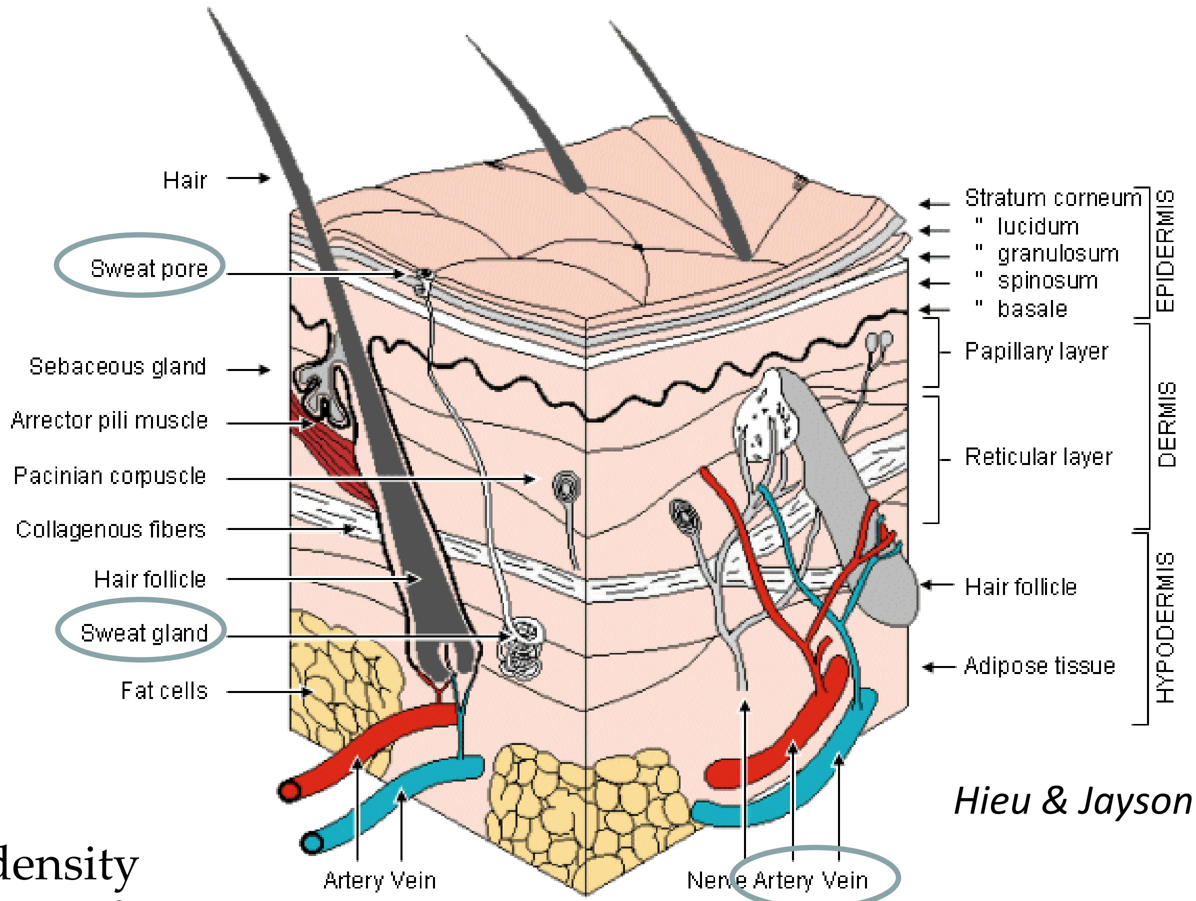


<u>Galvanic skin potential</u> (GSP): without externally applied current, electric potential difference can be measured between an active and a passive (reference) electrode.

The combined changes in GSR and GSP constitute the galvanic skin response and are collectively called electrodermal activity (EDA).

Hieu & Jayson

The physiological basis of the EDA is the change in the cutaneous blood flow and the sweat gland activity. EDA is the response of the skin to changes in the autonomic (largely sympathetic) tone, and it *reflects changes in the emotional state* and *responses to external stimuli*.



Hieu & Jayson

gland density
100-2000/cm^2

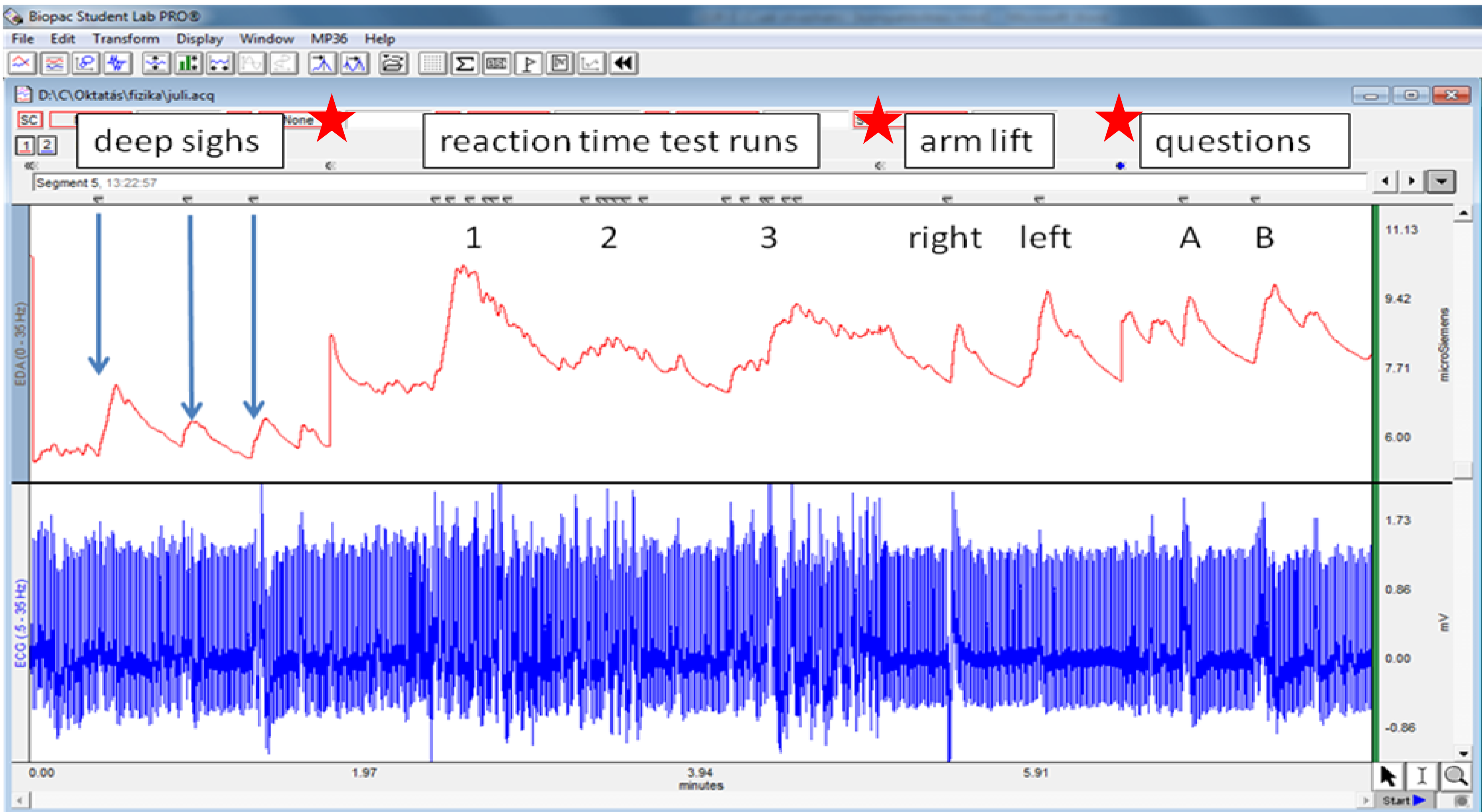
Experimental objectives

Recording and evaluation of EDA and ECG responses to

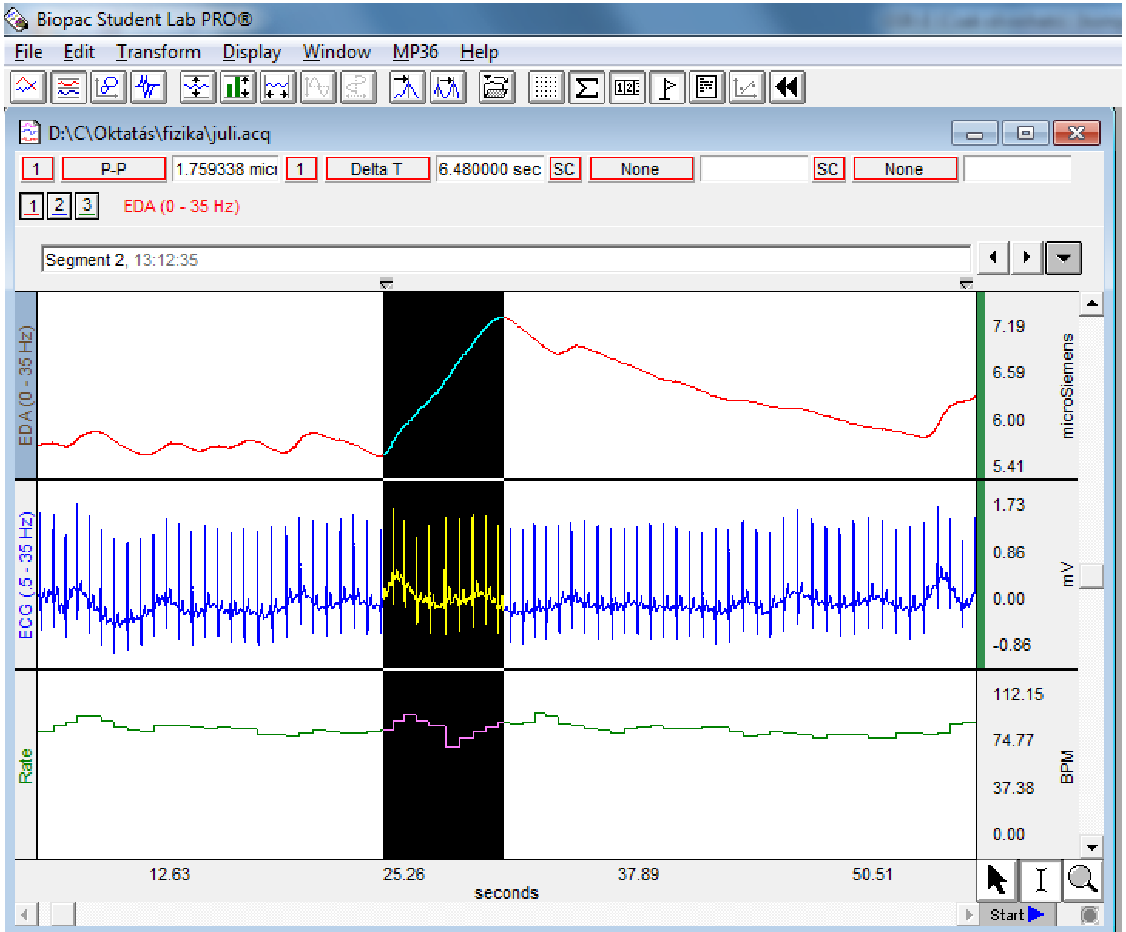
1. three deep breaths
2. three short trials of reaction time measurements
3. 5-s elevations of the right and left arms
4. answers to questions (optional)

with 20-s relaxed intervals (baseline) before each manoeuvre

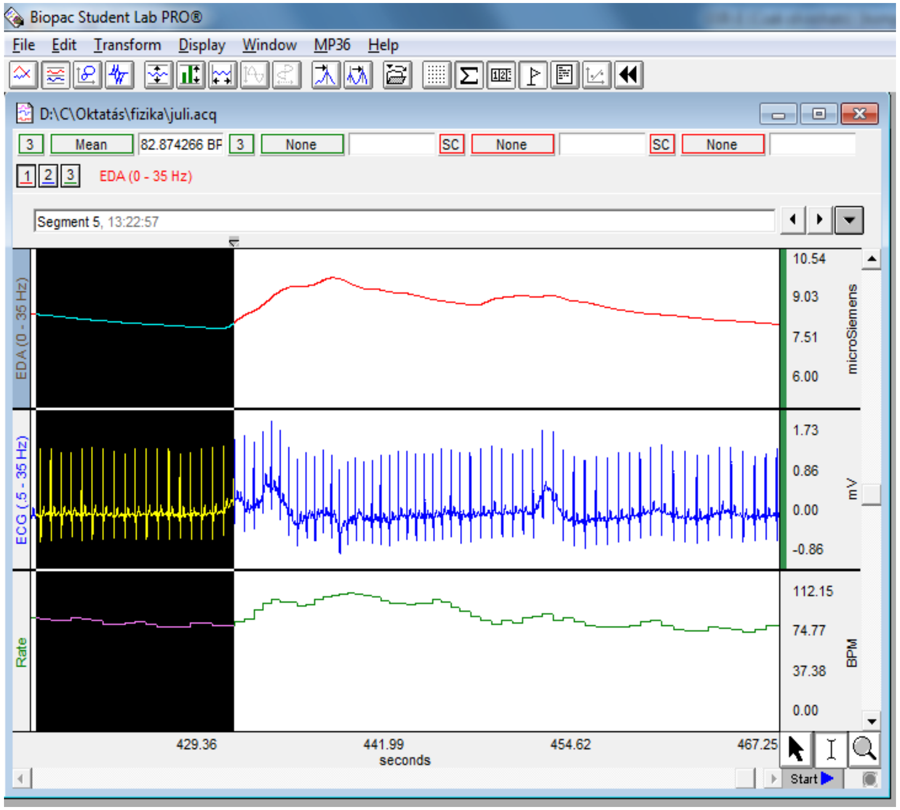
Structure of EDA recording

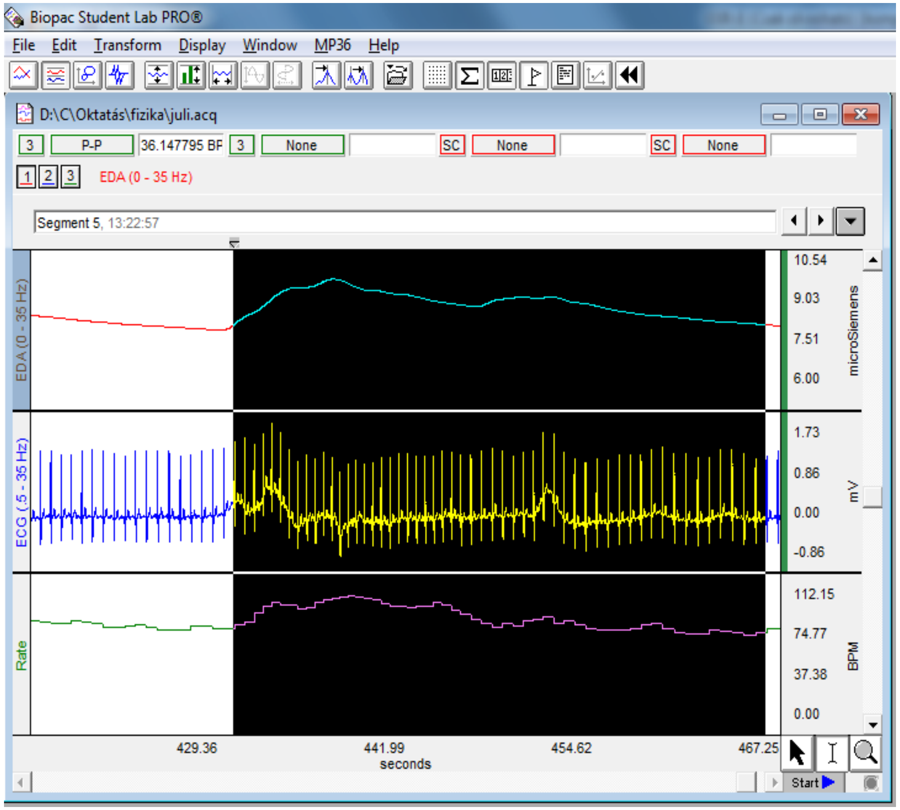


Measurement of peak response (ΔG) and latency time (ΔT) to a stimulus

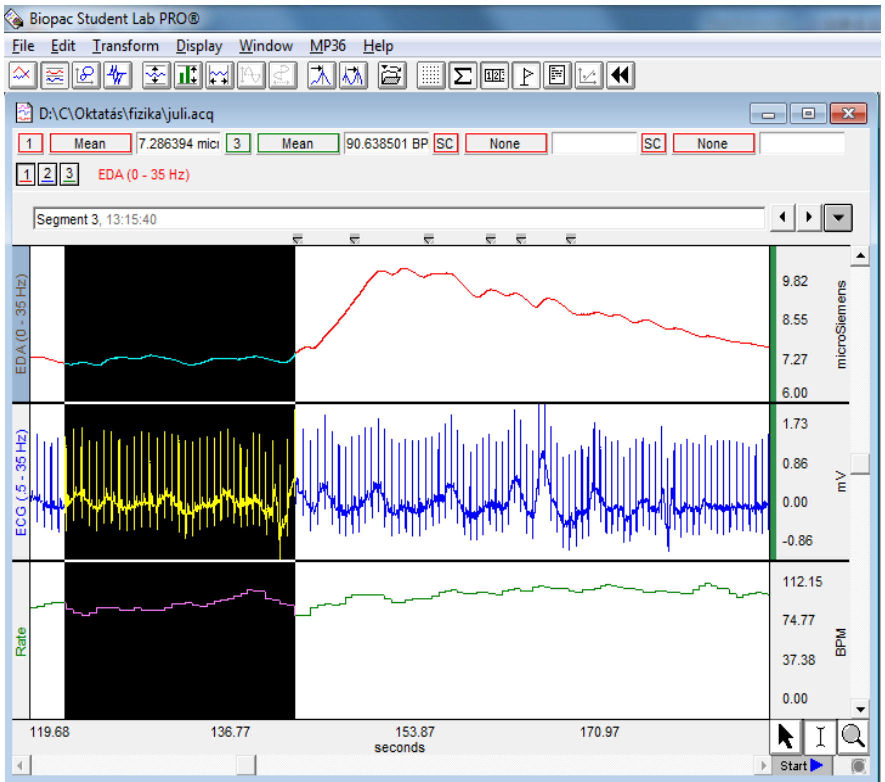


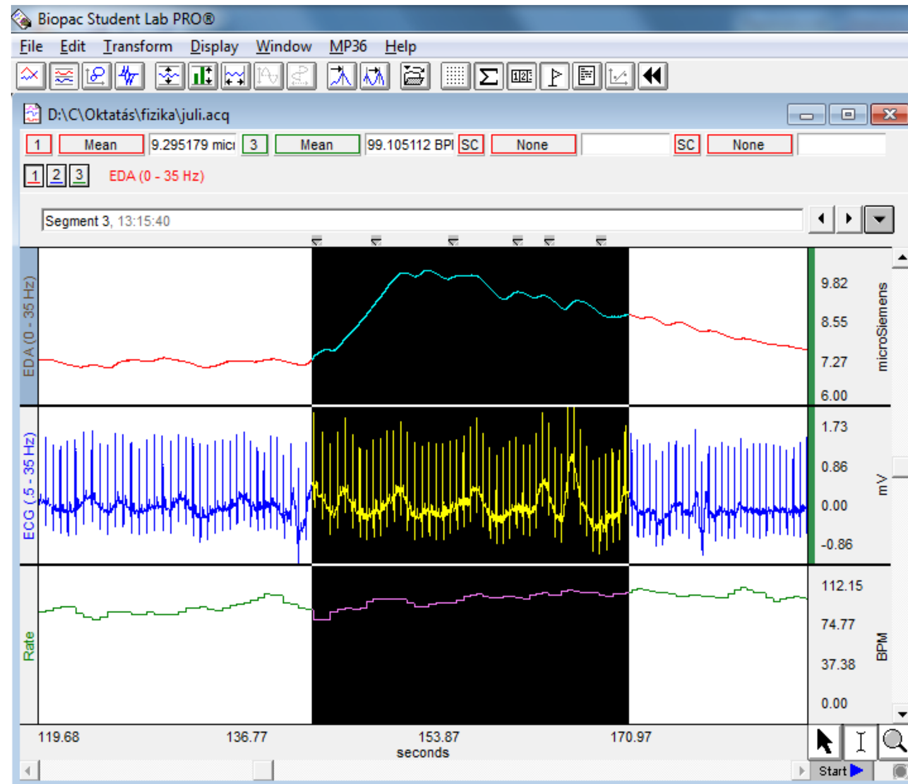
Measurement of mean heart rate (HRmean) before and peak-to-peak change in heart rate (ΔHR) after a stimulus





Mean values of GSR and HR before (baseline) and during the test trials





Noninvasive measurement of arterial pressure

Pressure in fluids

Pressure in a fluid at rest varies with vertical position (only).

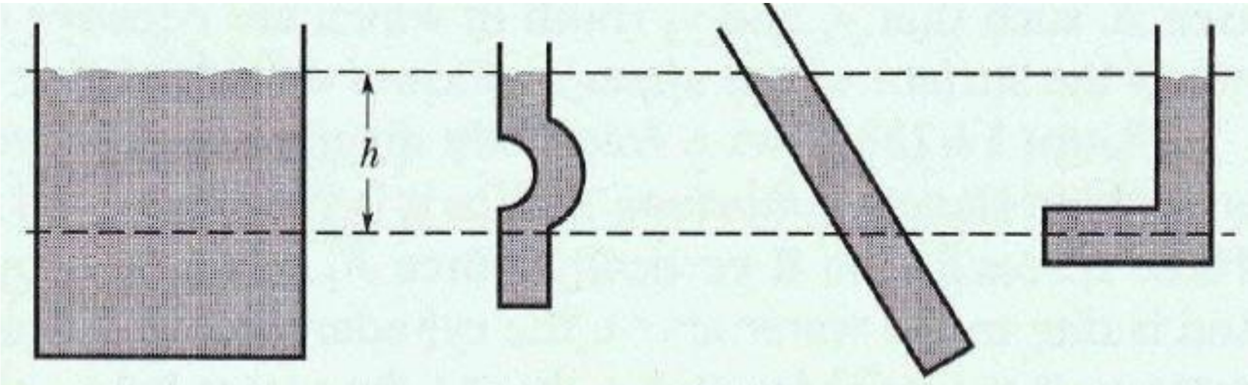
If h is the depth of a fluid sample below a reference point where the pressure is p_0, the pressure is:

height difference

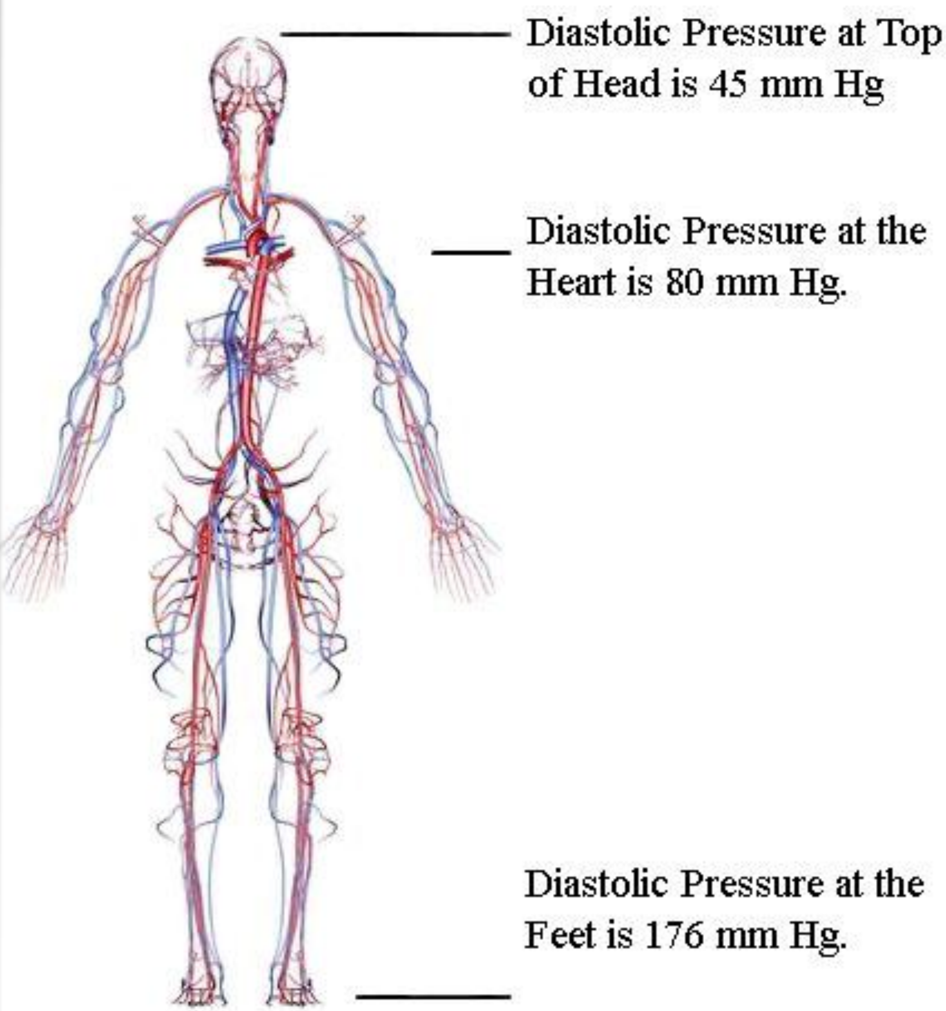
$$p = p_0 + \rho g h$$

density

gravitational acceleration (9.81 m/s^2)



Always measure blood pressure at heart level!



170 cm tall man with a normal blood pressure of 120 / 80. At elevations below the heart the blood pressure is greater while at elevations above the heart the pressure is less.

giraffe has valves in the veins and arteries of its neck, so the extreme pressure does not break the blood vessels when the giraffe lowers its head

Pressure units

The hydrostatic pressure formula converts pressure measurement to height measurement:

$$p=\rho g h$$

Measuring fluid: mercury (ρ=13 600 kg/m^3) $\rightarrow$ pressure unit: mmHg

water (ρ=1000 kg/m^3) $\rightarrow$ pressure unit: cmH_2O

(SI Unit: 1 Pa = 1 N/m^2)

Conversion??

Conversion

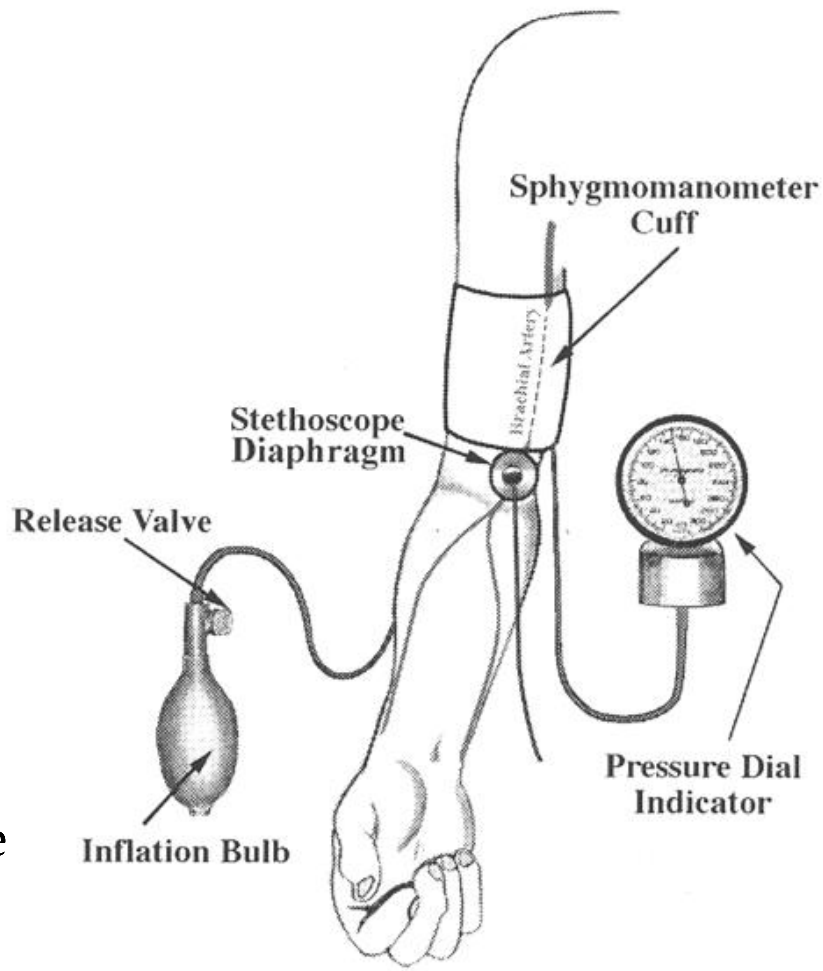
The pressure exerted by 1 cm of H_2O column is:

$$1\,\mathrm{cmH_2O} = 1000\,\frac{\mathrm{kg}}{\mathrm{m}^3} \cdot 9.81\,\frac{\mathrm{m}}{\mathrm{s}^2} \cdot 0.01\,\mathrm{m} = 98.1\,\mathrm{Pa} \approx 100\,\mathrm{Pa} = 0.1\,\mathrm{kPa}$$

The pressure exerted by 1 mm of Hg column is:

$$1\,\mathrm{mmHg} = 13\,600\,\frac{\mathrm{kg}}{\mathrm{m}^3} \cdot 9.81\,\frac{\mathrm{m}}{\mathrm{s}^2} \cdot 0.001\,\mathrm{m} = 133.4\,\mathrm{Pa} = 1.36\,\mathrm{cmH_2O}$$

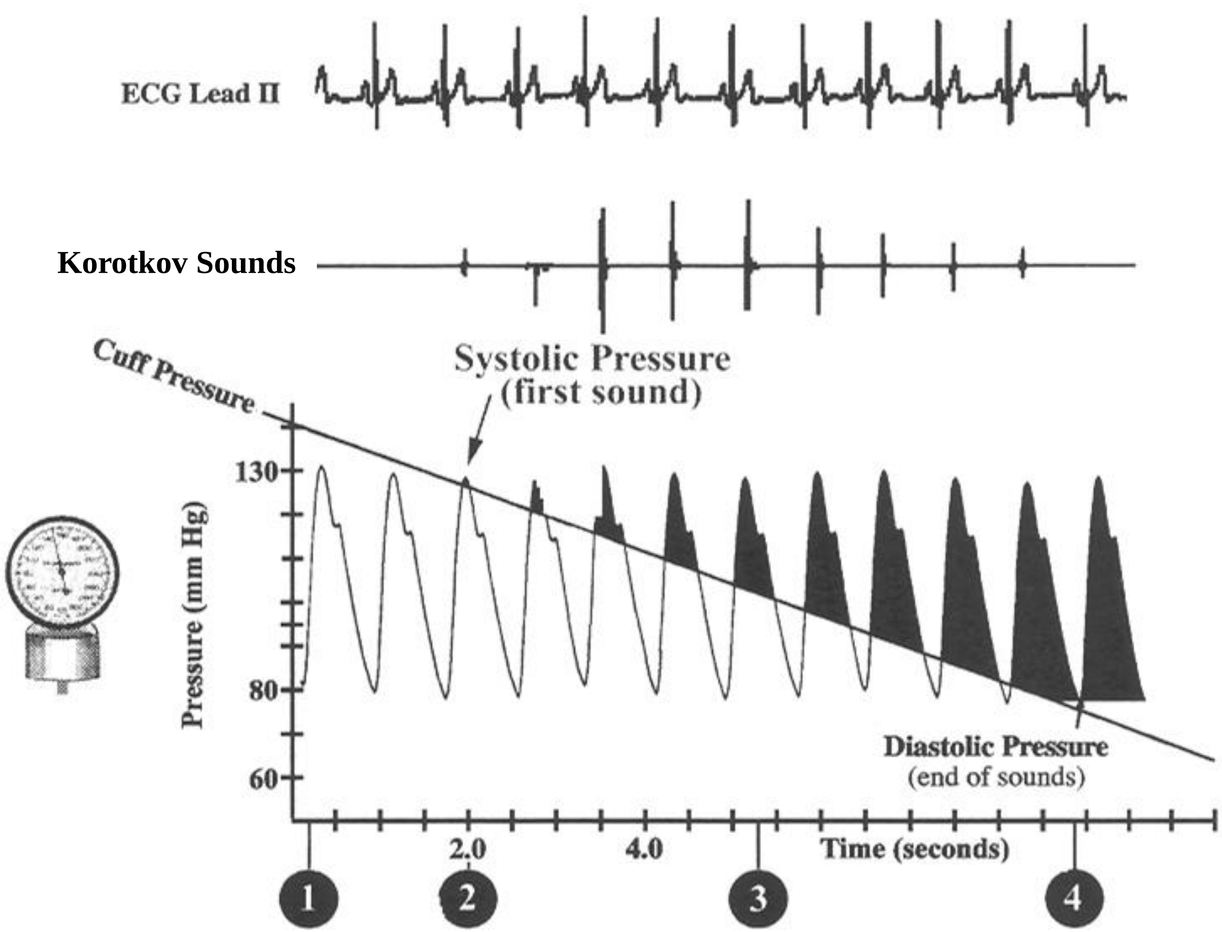
Noninvasive measurement of arterial pressure



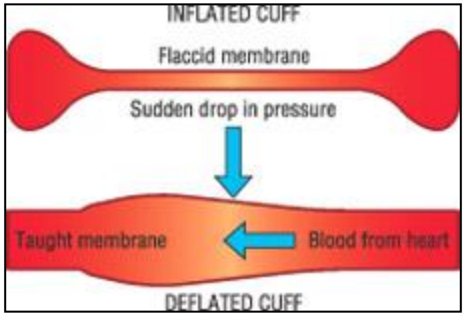
the auscultatory technique
(Korotkov, 1905)

Noninvasive measurement of arterial pressure: the principle

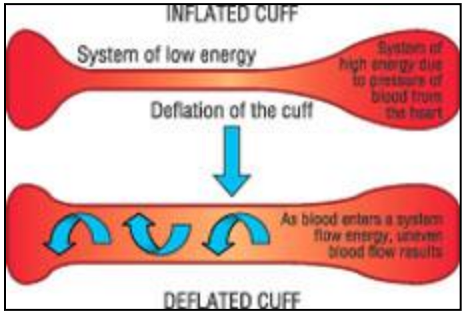
Nikolai Szergeievitch Korotkov



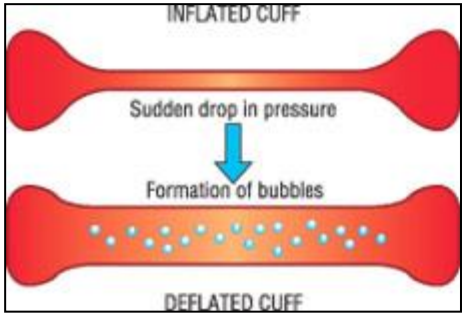
Noninvasive measurement of arterial pressure: mechanisms of the sounds



wall detachment



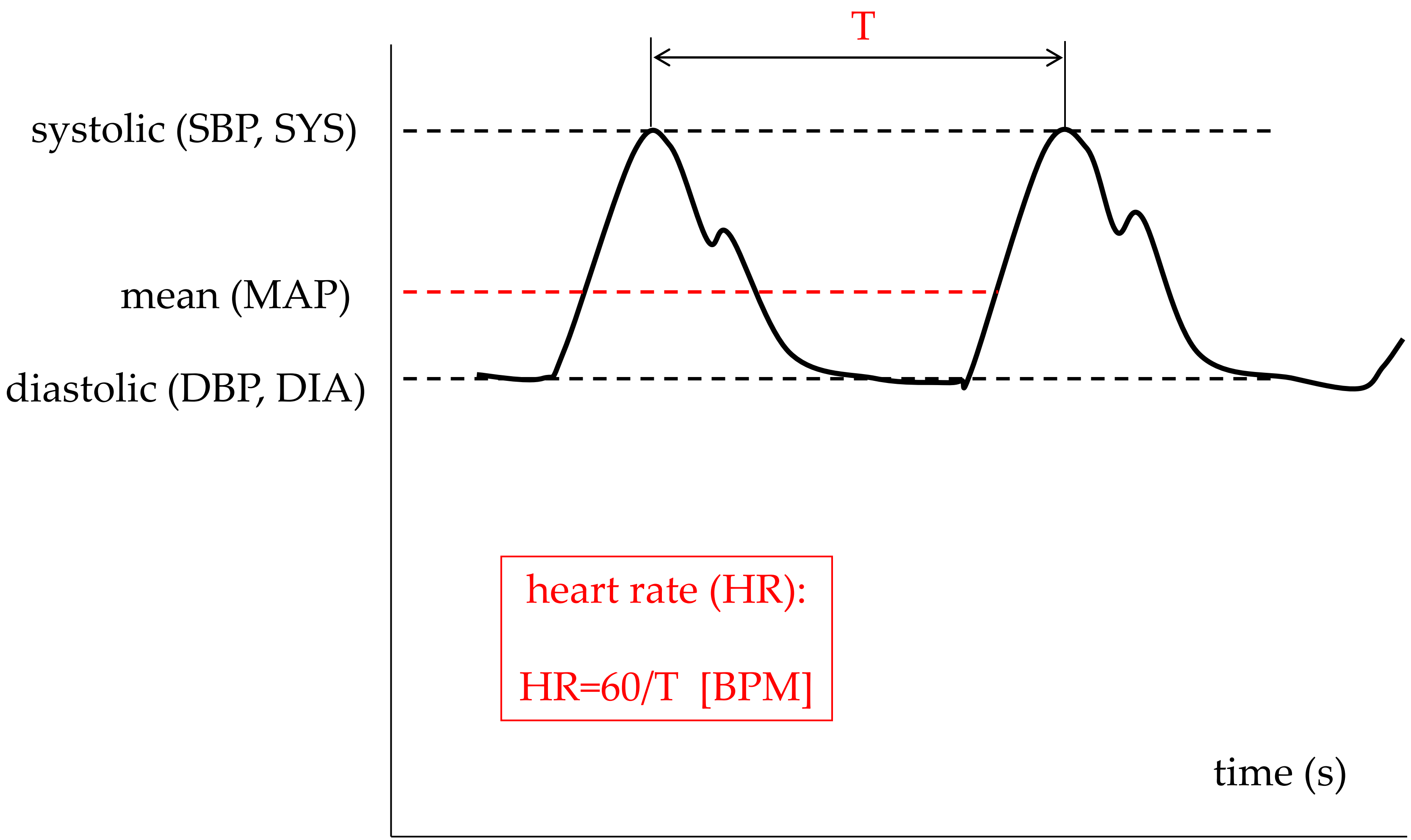
turbulence



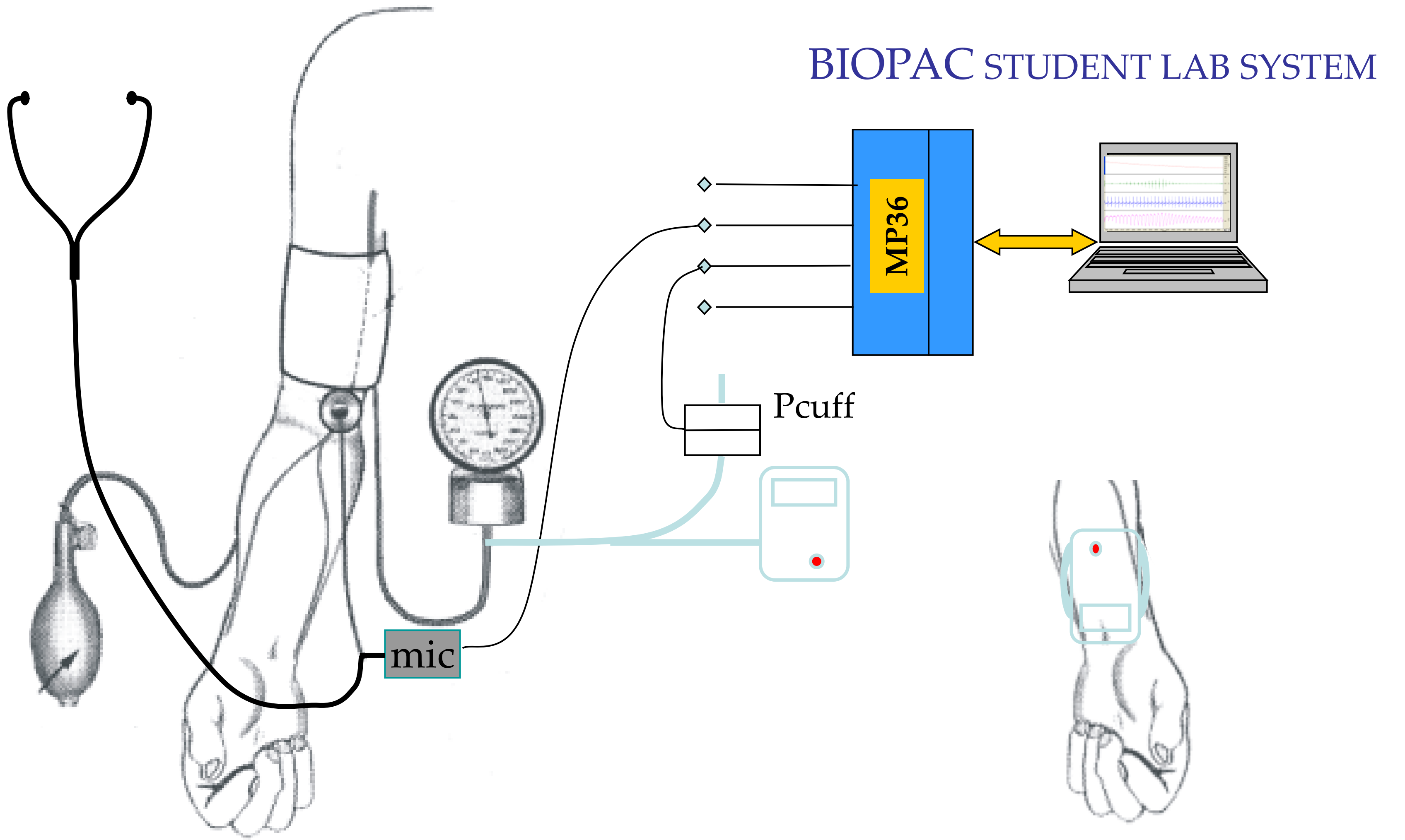
cavitation

other theories and combinations

Noninvasive measurement of arterial pressure: blood pressure measures



Laboratory practical: the setup



Measurement protocol I.

Open the lab report in Excel

I. COMPARISON OF BLOOD PRESSURE MEASUREMENT METHODS

Start BSL Lessons $\Rightarrow$ open Lesson 16: Blood pressure

Do the calibration procedure

Position the measurement devices as indicated

Turn on the Upper Arm Blood Pressure Meter
Start the recording in the BSL system (Record)
Start the Wrist Pressure Meter
Pump the cuff up to about 160 mmHg
The pressure in the cuff will automatically deflate when the pumping is stopped.
While continously looking at the pressure gauge on the screen read the pressure values when you start hearing the Korotkoff sounds, and when they stop
Fully deflate the cuff by pressing the button on the side of the pump
Stop recording (Suspend)

Measurement protocol II.

Enter the measured data into the lab report.

Repeat the measurement 3 times on one arm, then move the blood pressure monitors onto the other arms.

If any of the data is missing in a manoeuvre, mark it as FAILED in the logbook. Enter all data into the logbook, and press SUBMIT. (After each patient you start a new logbook.)

Repeat the procedures for a second patient.

II. PRESSURE – HEIGHT DEPENDENCE MEASUREMENT:
For this study, use only the wrist BP monitor.

Position your wrist at two different heights (e.g. top of computer house and table), **while keeping the upper body (heart) in the same position**. Record the readings from the BP monitor, and the height difference between the two positions.
Make min. 3 measurements.

Logbook

BP_measurement.xls

H35

Patient's ETR code without .SZE, like ABCSAAX

ABCSAAX

SUBMIT

	Korotkov		UPPER ARM			WRIST			
	SYS	DIA	SYS	DIA	PULSE	SYS	DIA	PULSE	NOTES
Maneouvre1	120	70	120	70	65	120	70	65	
Maneouvre2	120	70	120	70	65	120	70	65	
Maneouvre3									FAILED
Maneouvre4	120	70	120	70	65	120	70	65	
Maneouvre5	120	70	120	70	65	120	70	65	
Maneouvre6	120	70	120	70	65	120	70	65	
Maneouvre7									FAILED
Maneouvre8									FAILED
Maneouvre9	120	70	120	70	65	120	70	65	
Maneouvre10									

PRESSURE - HEIGHT dependence

	RAISED POSITION			LOWERED POSITION		
	SYS	DIA	PULSE	SYS	DIA	PULSE
Maneouvre1	100	65	65	140	80	65
Maneouvre2	100	65	65	140	80	65
Maneouvre3	100	65	65	140	80	65
Maneouvre4	100	65	65	140	80	65

Height difference (cm): 40

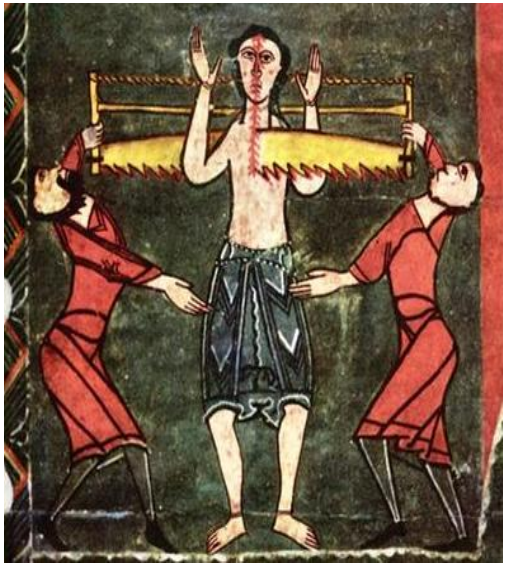
Vérnyomás

Kész

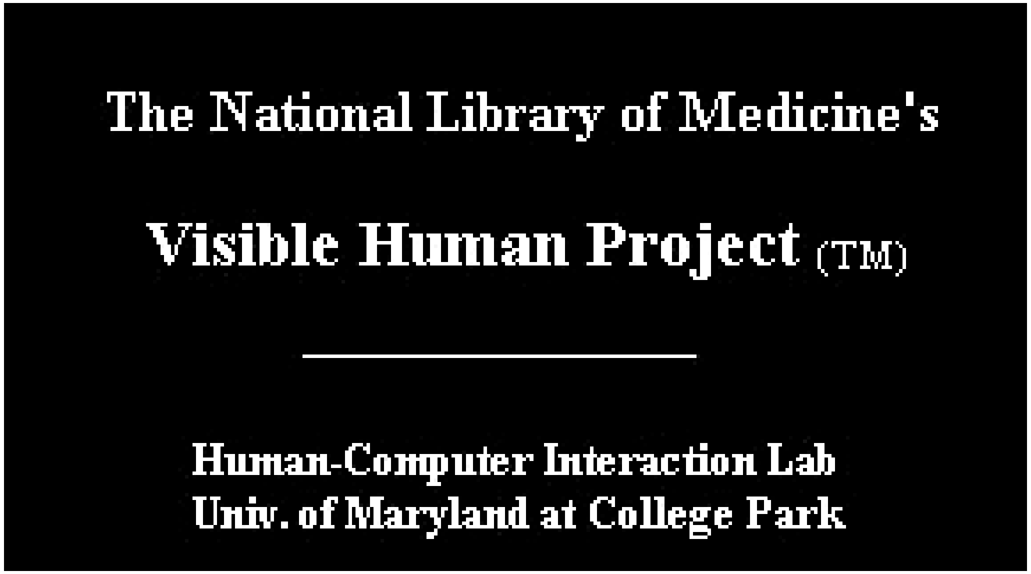
CT reconstruction

backprojection

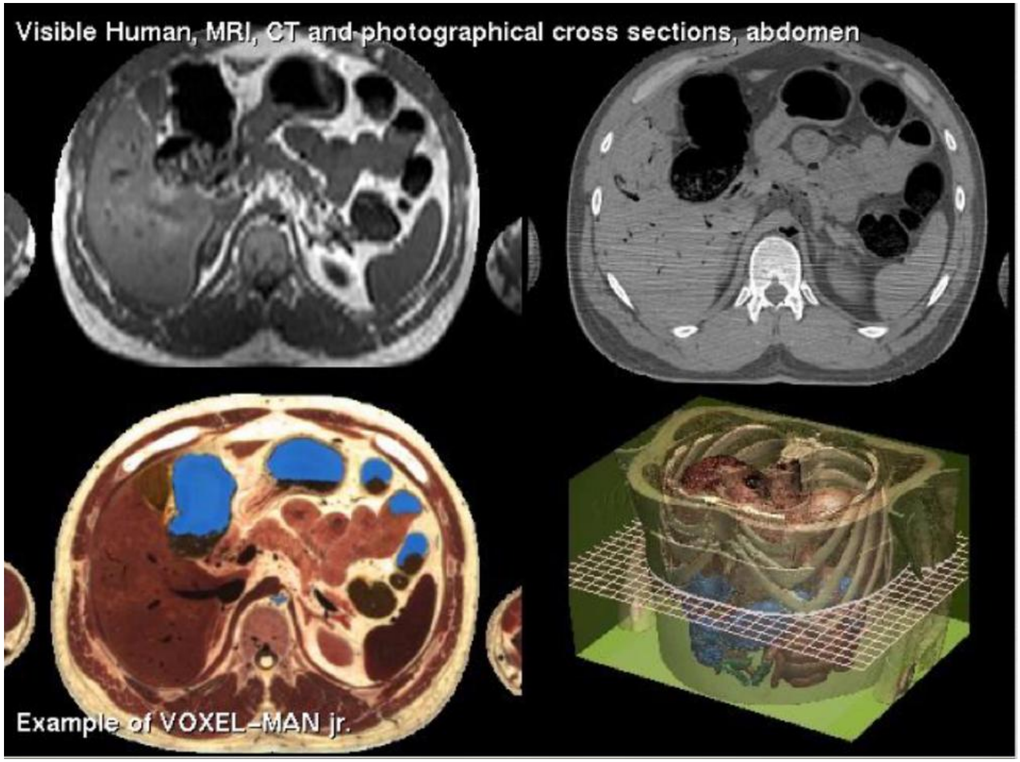
How can we get a picture of a slice of something without cutting it apart?

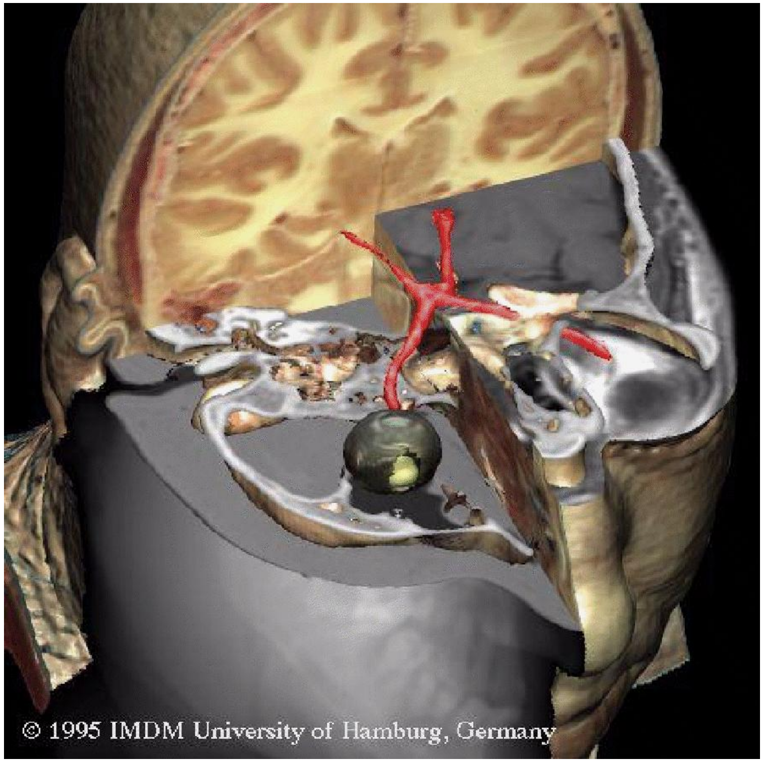


(Visible Human Project)

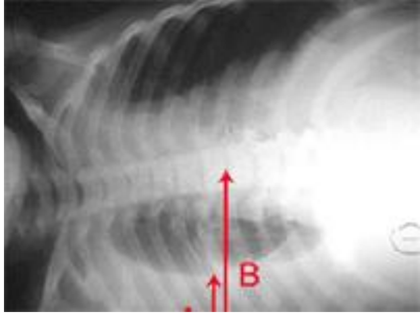


Visible Human Project





CT-Background



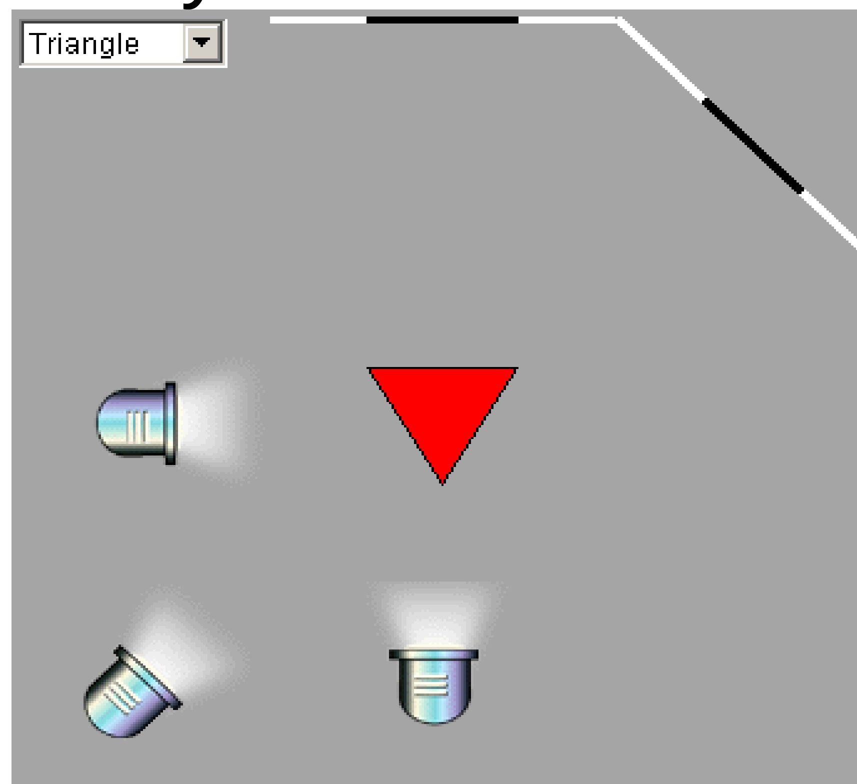
- **The computed tomography (CT)** is a medical imaging method using tomography created by computer processing
- Based on the work Johann Radon in 1917: An image can be created from the scattering data associated to cross-sectional scans of an object.
- In 1972 G.N. Hounsfield and J. Ambrose made the first clinical CT examination

Properties:

- The CT Scan is an extension of the X-Ray technology
- CT Scan uses multiple X-Ray images to create the final image
- A CT Scan can focus on the target area better than an X-ray
- Advanced CT Scan equipment can produce a 3d representation of the target while X-ray is strictly two dimensional
- Equipment for CT Scan costs considerably more than X-ray equipment
- CT Scan exposes the patient to a lot more radiation than X-ray

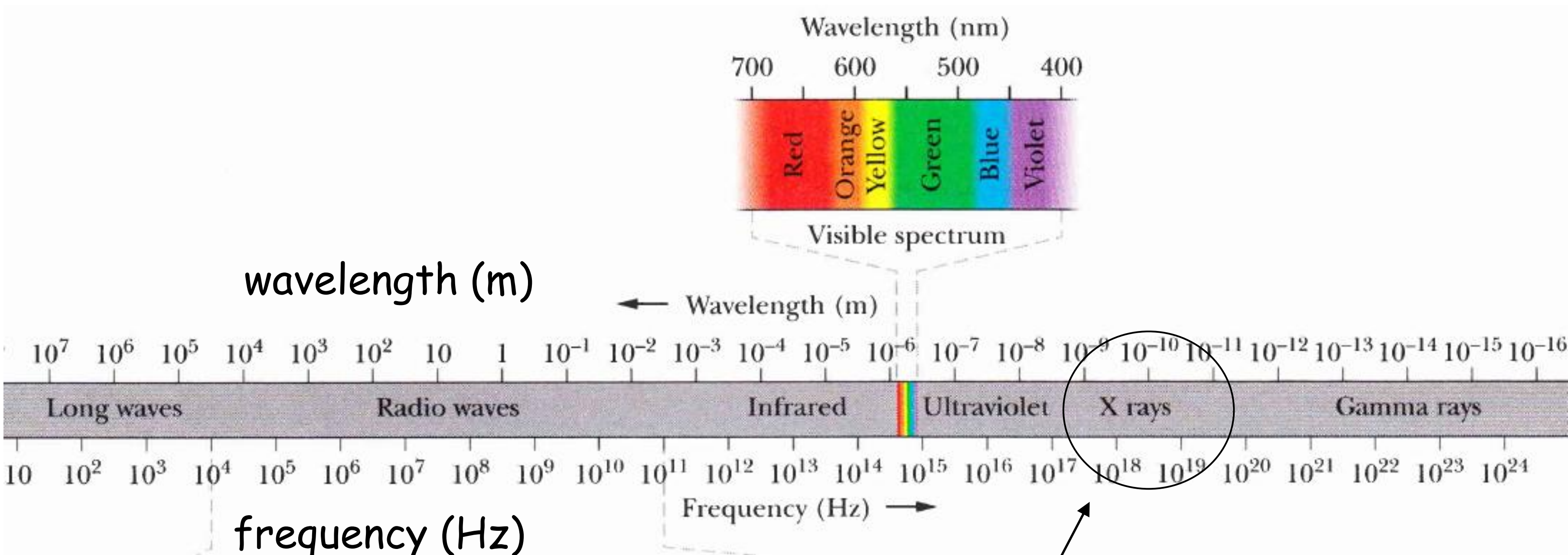
CT-Principle

- At first (keeping it simple) let’s see the shape of something by looking at shadows.
- Shine spotlights on some different shapes and look at the shadows they make.
- The more directions we us the more exact shape we can „calculate”.



Let’s start the **„projections_L.html”**, Click on the spotlights to turn them on and off. Choose different shapes from the menu.

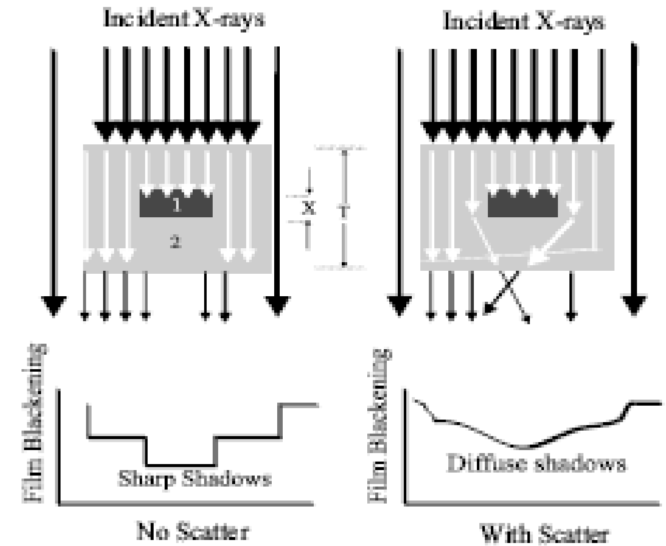
The electromagnetic spectrum



The properties of electromagnetic ray we should use:

- Goes through the human body
- The different tissue absorbs the X-rays on a different manner
- No scattering

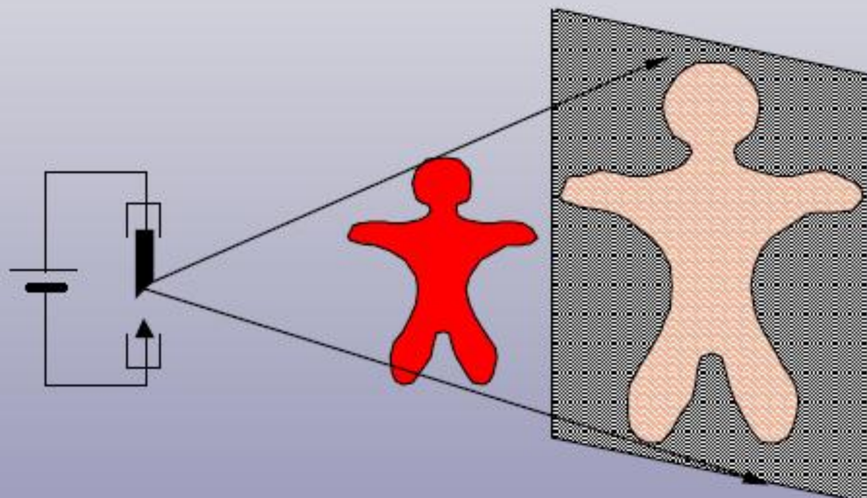
Importance of avoiding scattering: higher contrast

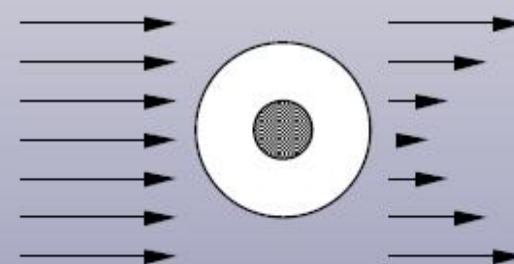


Imaging relies on the fact that different tissues of the human body absorb the X-rays at a different rate.

Substance	$\mu(cm^{-1})$ (100 keV X-rays)
Air	0.0001
Water	0.1687
Saline	0.1695
Muscle	0.18
Blood	0.178
Bone	0.48
White matter	0.1720
Grey matter	0.1727

Instead of light: X-ray

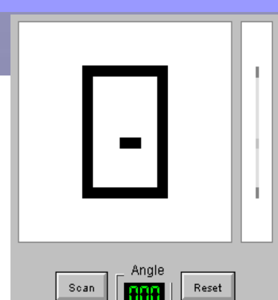




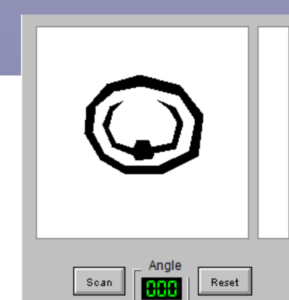
X-ray passing through the human body produces a shadow.

The darkness of the shadow depends on the density and thickness of the object.

Let’s start the „**projections_X.html.** Rotate the object.



Then the „**tomography.html.** Which resembles a human chest.



Transmission

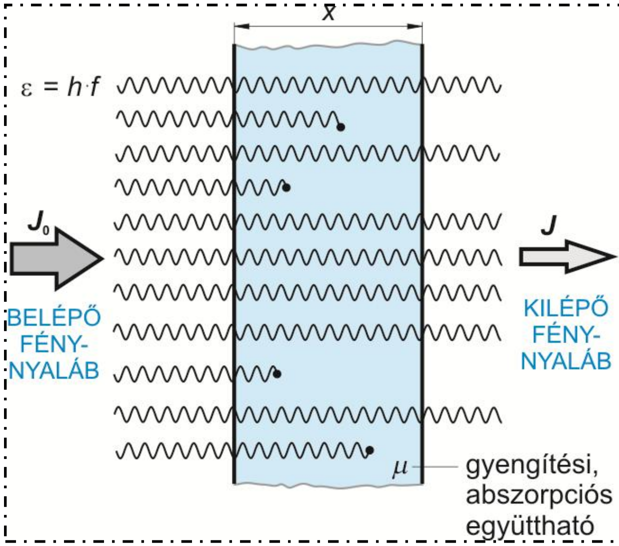
Attenuation of light passing through matter:

Beer's Law

$$I = I_0 \cdot e^{-\mu \cdot x}$$

Attenuation Coefficient

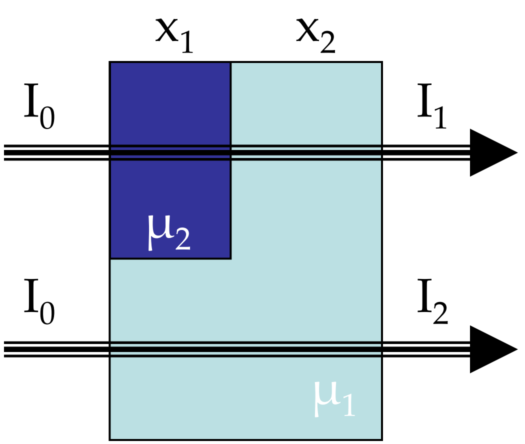
Sample Thickness



The addition of multiple layers

$$T_1 = e^{-\mu_1 \cdot x_1} \cdot e^{-\mu_2 \cdot x_2} = e^{-(\mu_1 \cdot x_1 + \mu_2 \cdot x_2)}$$

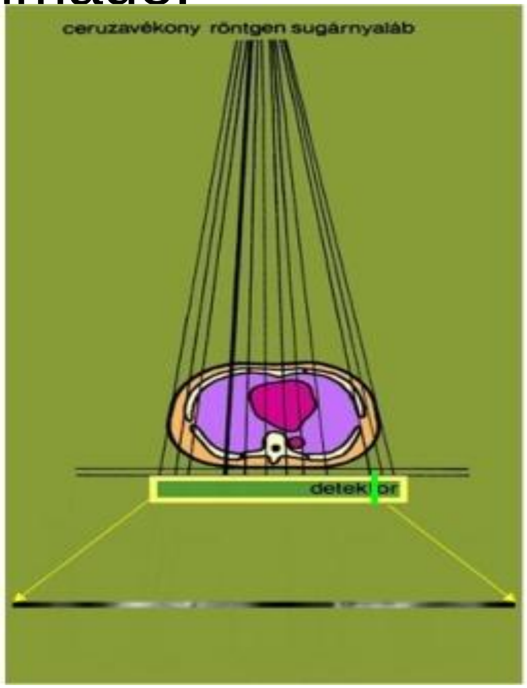
$$T_1 = e^{-\mu_1 \cdot x_1} \cdot e^{-\mu_1 \cdot x_2} = e^{-\mu_1 (x_1 + x_2)}$$

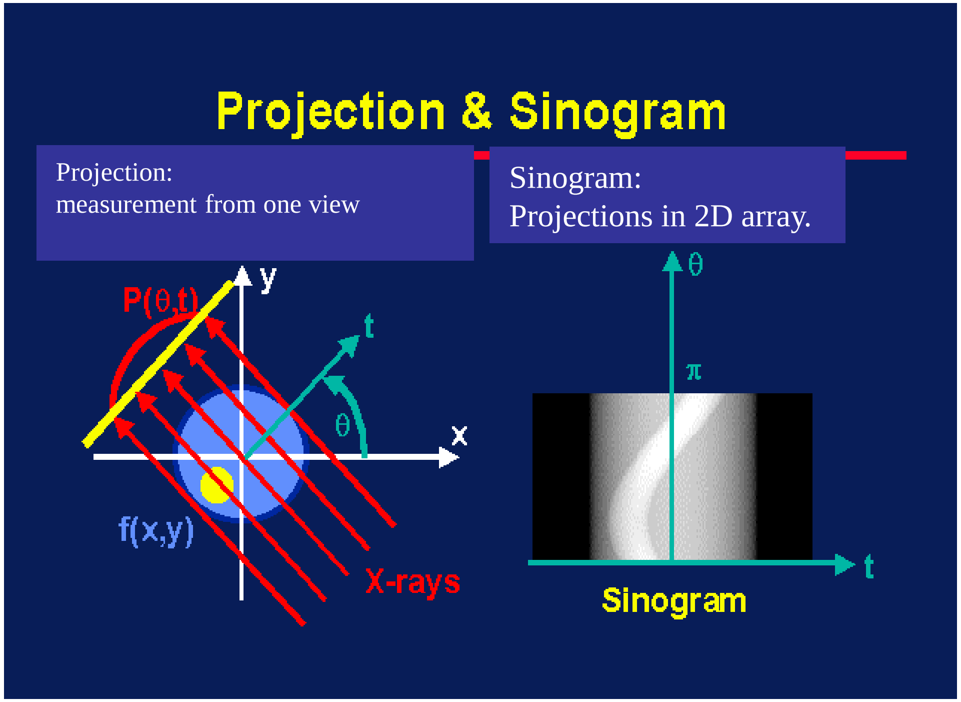


Attenuation of the (linear) layers is added together

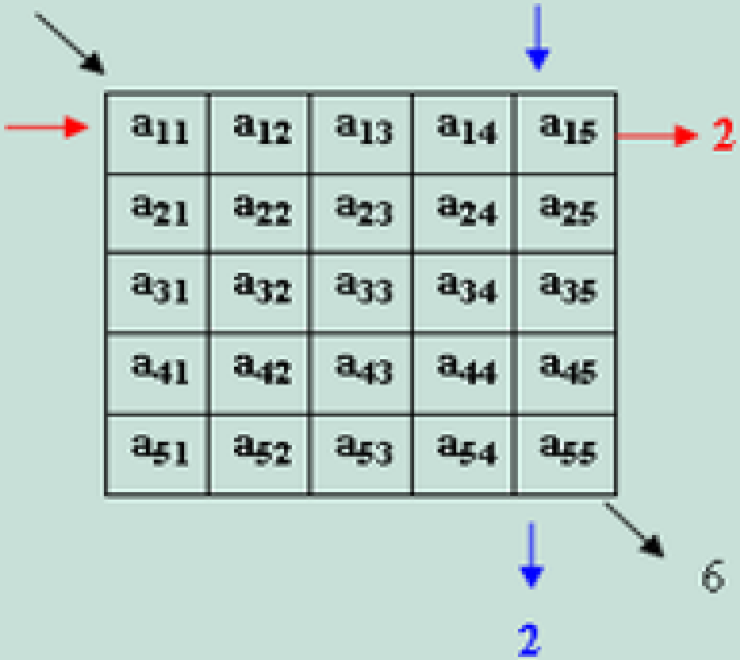
Sinogram

- In clinical use, the object (human body) does not turn, but the X-ray tube and it's detector (and the bed – 3D achievement).
- Projections are the measurements from different view points. Another concept is the "Sinogram", which is simply the 2-D array of data containing the projections.
- Computers do the hard work of reconstructing the slices from the x-ray shadows (projections) from many angles into one image.





Mathematical basis of tomography



$$a_{11} + a_{12} + a_{13} + a_{14} + a_{15} = 2$$
$$a_{11} + a_{22} + a_{33} + a_{44} + a_{55} = 6$$
$$a_{15} + a_{25} + a_{35} + a_{45} + a_{55} = 2$$

The task is the calculation of the elements of a matrix from the information of the sum (integrals) of lines, columns and diagonals.
The method is based upon the work of Johann Radon in 1917 (not for matrixes). The name of the method is „Invers Radon Transformation".

Open the CT.xls file, Projection0 sheet:

1	2	
2	0	

- Calculate the projections to the coloured cells
- Calculate the (reconstructed slice) values.
- Do we have only one solution?
- Calculate again but let's use the third projection of 45^0.

Calculating the projections from 1 and 2 directions

CT.xls excel file: Projection1 sheet:

Calculate the projections to the coloured cells.
Make the sinogram.

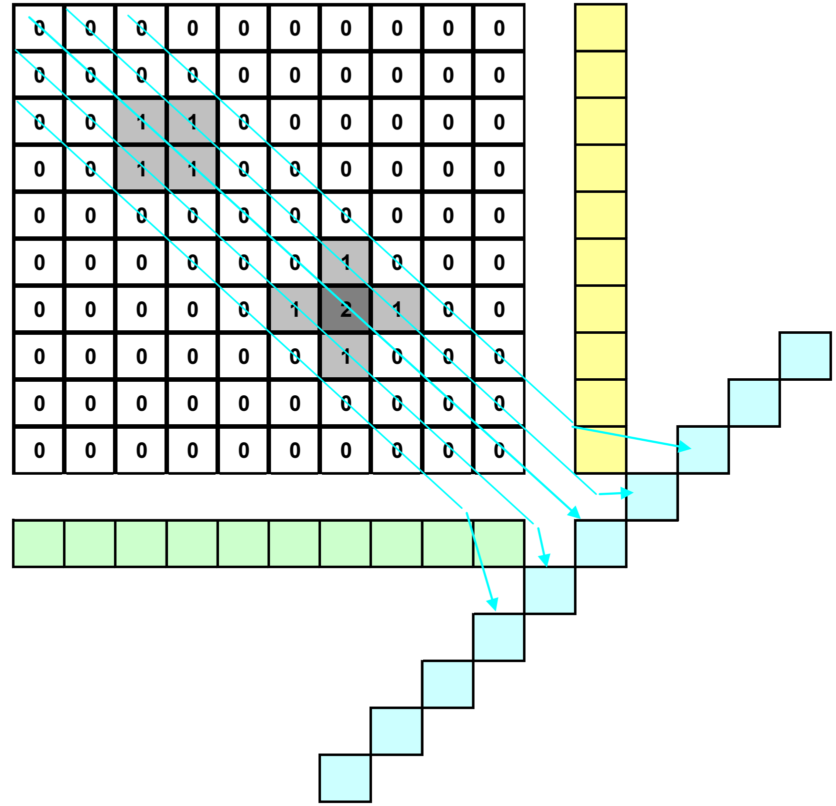
0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	
0	0	1	1	0	0	0	0	0	0	
0	0	1	1	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	1	0	0	0	
0	0	0	0	0	1	2	1	0	0	
0	0	0	0	0	0	1	0	0	0	
0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	

sinogram

0									
90									

Calculating the projections from 1, 2 and 3 directions

CT.xls excel file: Projection1, 2 sheet:

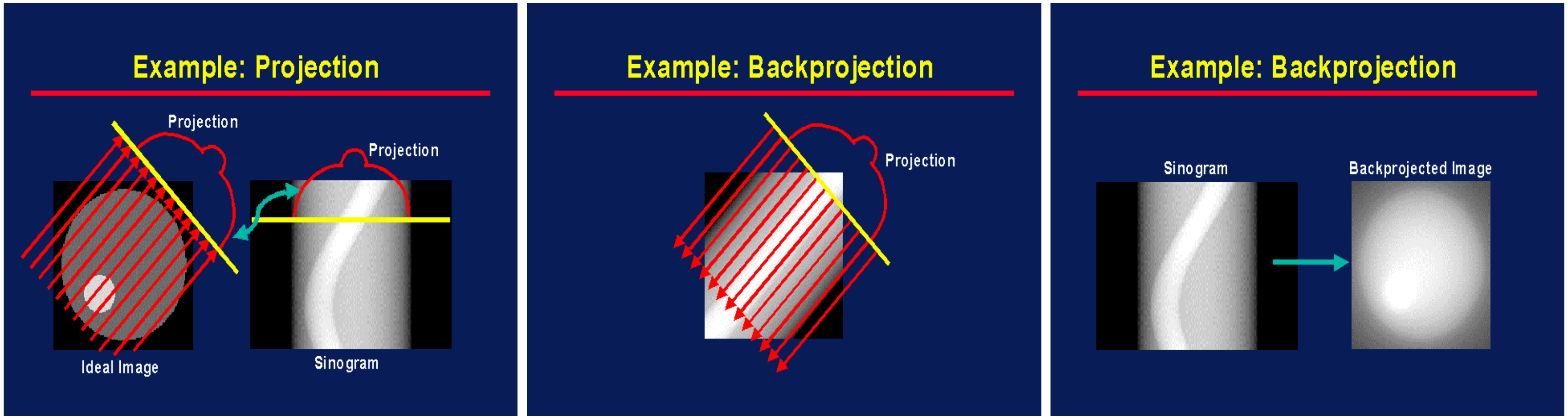


Calculate the projections to the coloured cells.
Look at the sinogram (making automatically).

synogram

0	0	0	0	0	0	0	0	0	0	0
45	0	0	0	0	0	0	0	0	0	0
90	0	0	0	0	0	0	0	0	0	0

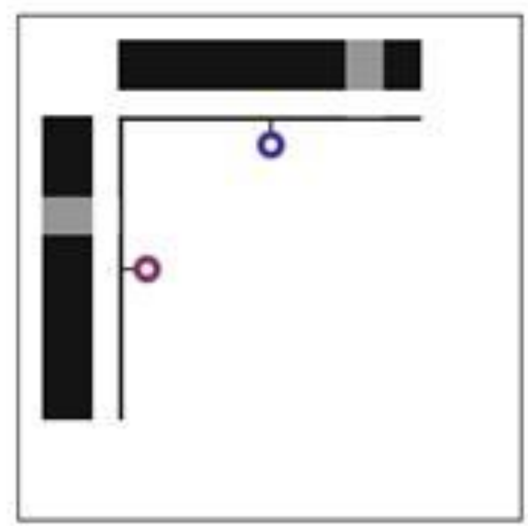
Backprojection



Start the „**backprojection.html**"

Altough thhe CT scanners nowdays use highly complex programs to calculate the slices, but this simple method for two X-ray projections gives an idea of how it works.

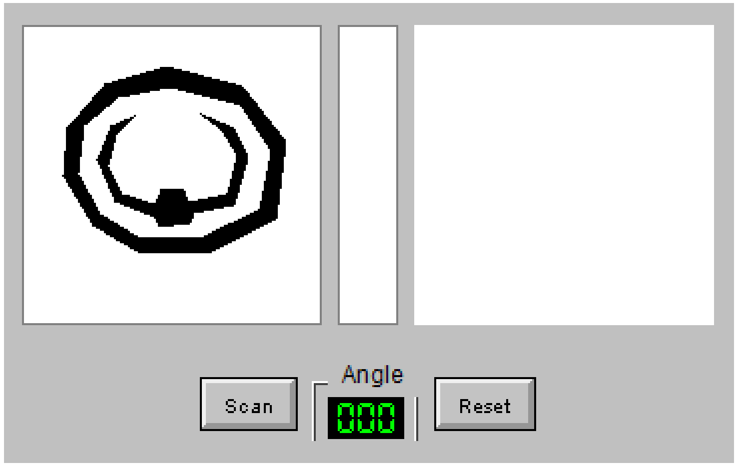
The „random scan" button sets the 2 projections, the backprojection can be made by pulling the red and blue rings. (Of course from 2 directions we cannot see weather the object is a square or a circle shaped, to this we need projections from more directions.)



Backprojections

Start the „**final_rib_cage.html**"

1. Press the "Scan" button to make a single scan.
2. Now click and drag the figure on the left to turn it.
3. Press "Scan" again...this time the new scan gets averaged into the previous one.
4. Continue to turn and scan. If you space your scans evenly you will get the clearest results.
5. Let's see from how many directions we receive a good slice.



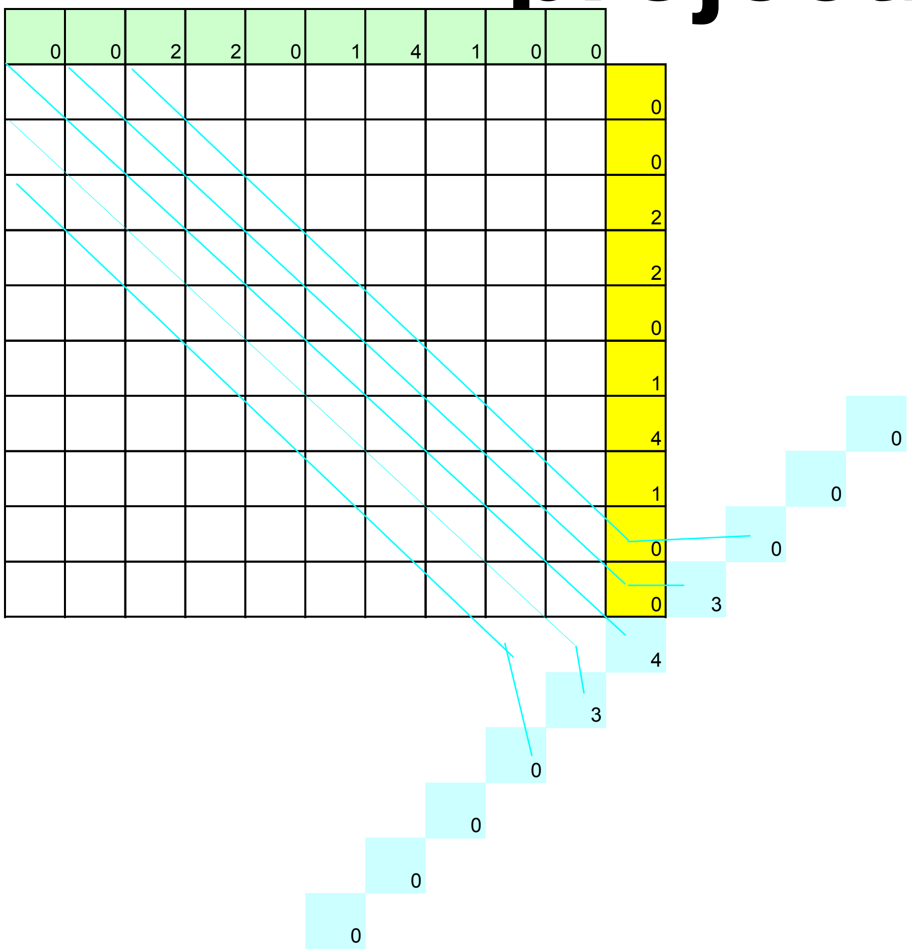
When we make a scan, the projetion (in the middle window) gets "projected back" or "smeared out" in the window on the right.
When we turn our object, the window on the right turns, too.
Then, when we make another scan the new projection gets **averaged** in with whatever is already there.

Slice calculation from 1 and 2 projections

0	0	2	2	0	1	4	1	0	0	
										0
										0
										2
										2
										0
										1
										4
										1
										0
										0

Calculate the values of the slice from the projections with the the backprojection method from two directions.

Slice calculation from 3 projections

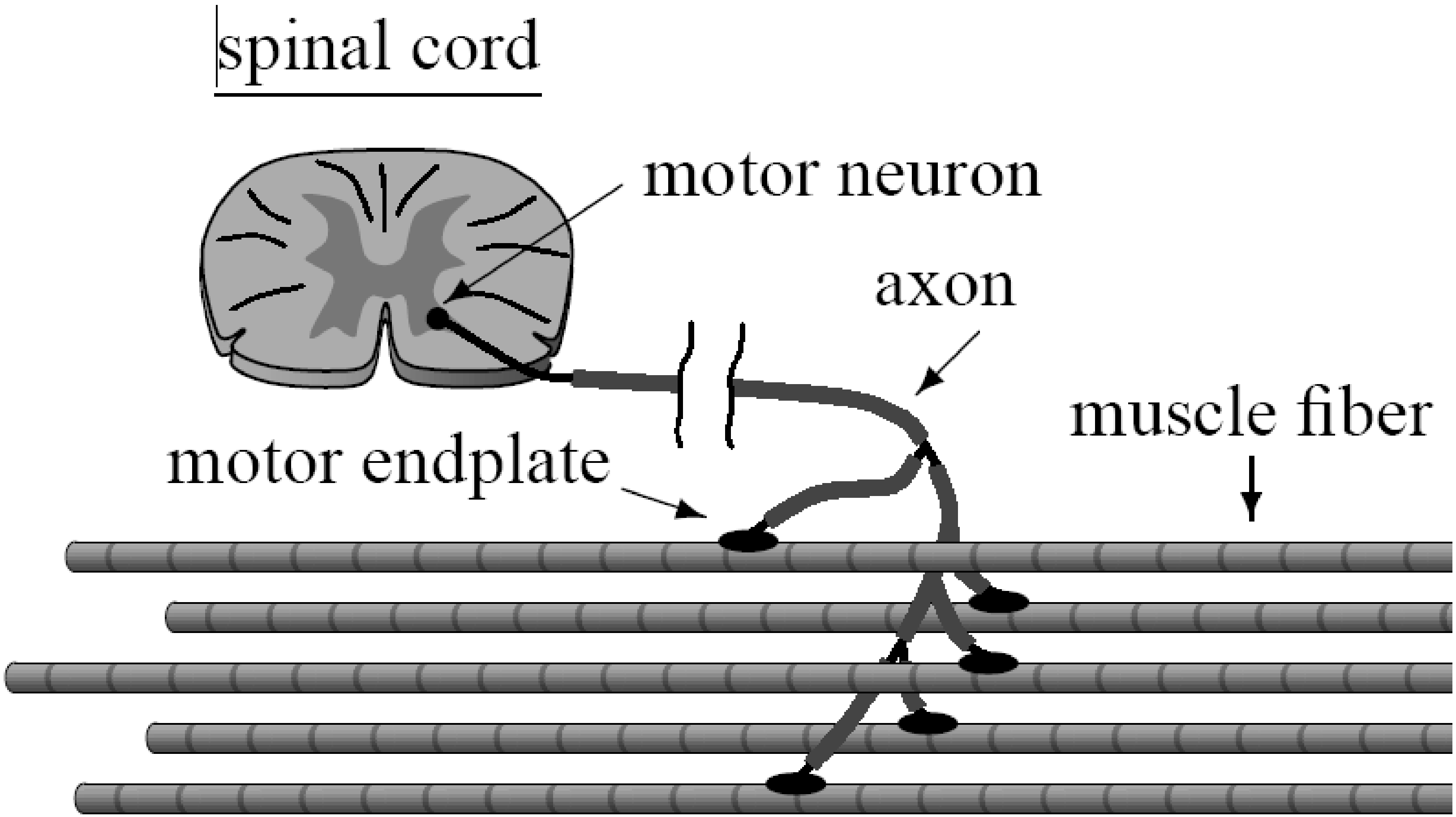


Calculate the values of the slice from the projections with the backprojection method from three directions.

electromyography

basics

background

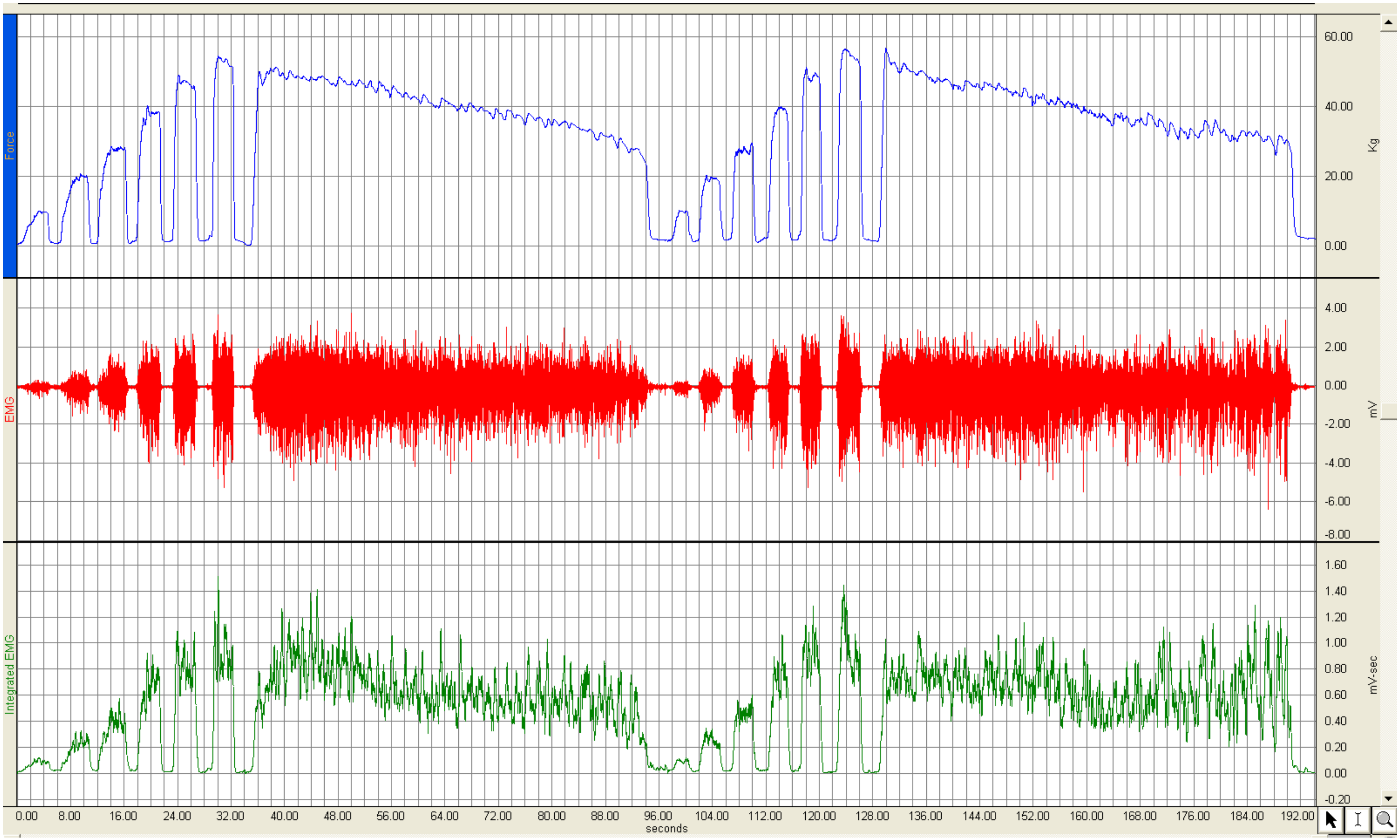


measurement tasks

- measurement of EMG during stepwise changes in grip force
- computation of EMG intensity
- correlation analysis between grip force and EMG activity
- relationship between grip force and EMG intensity during maximum effort

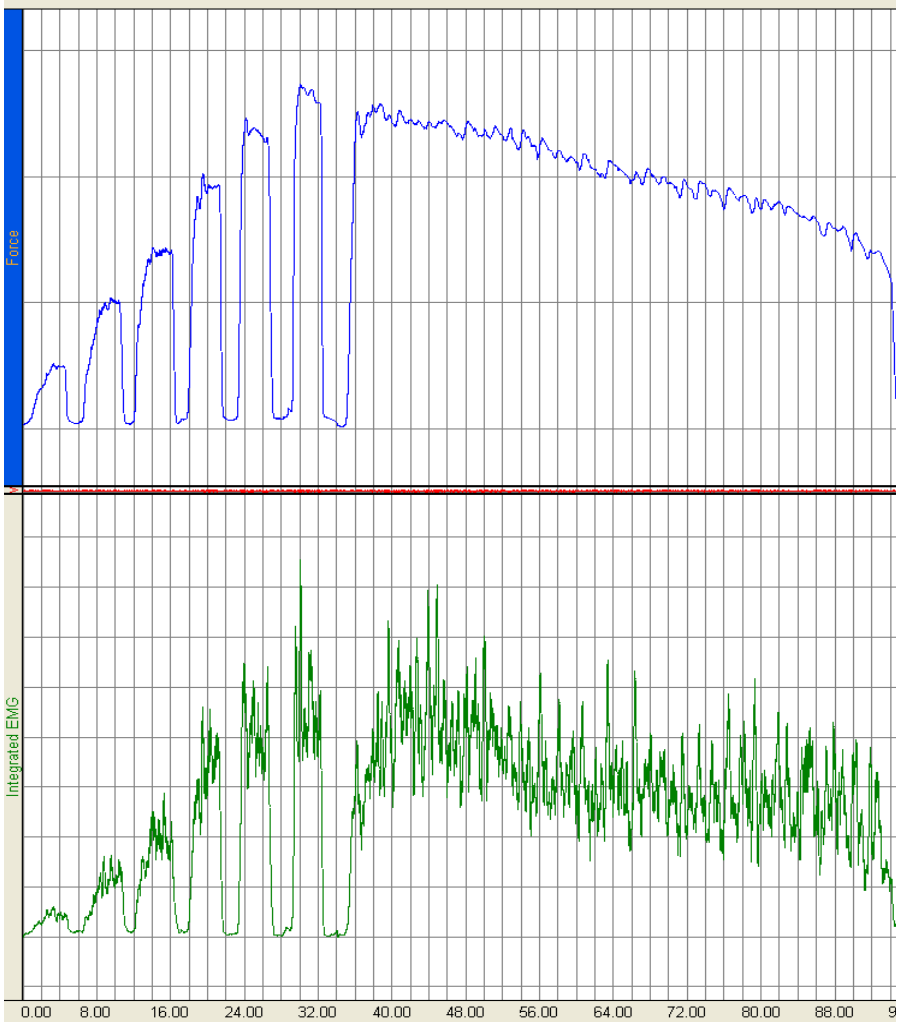
computer-aided measurements: EMG

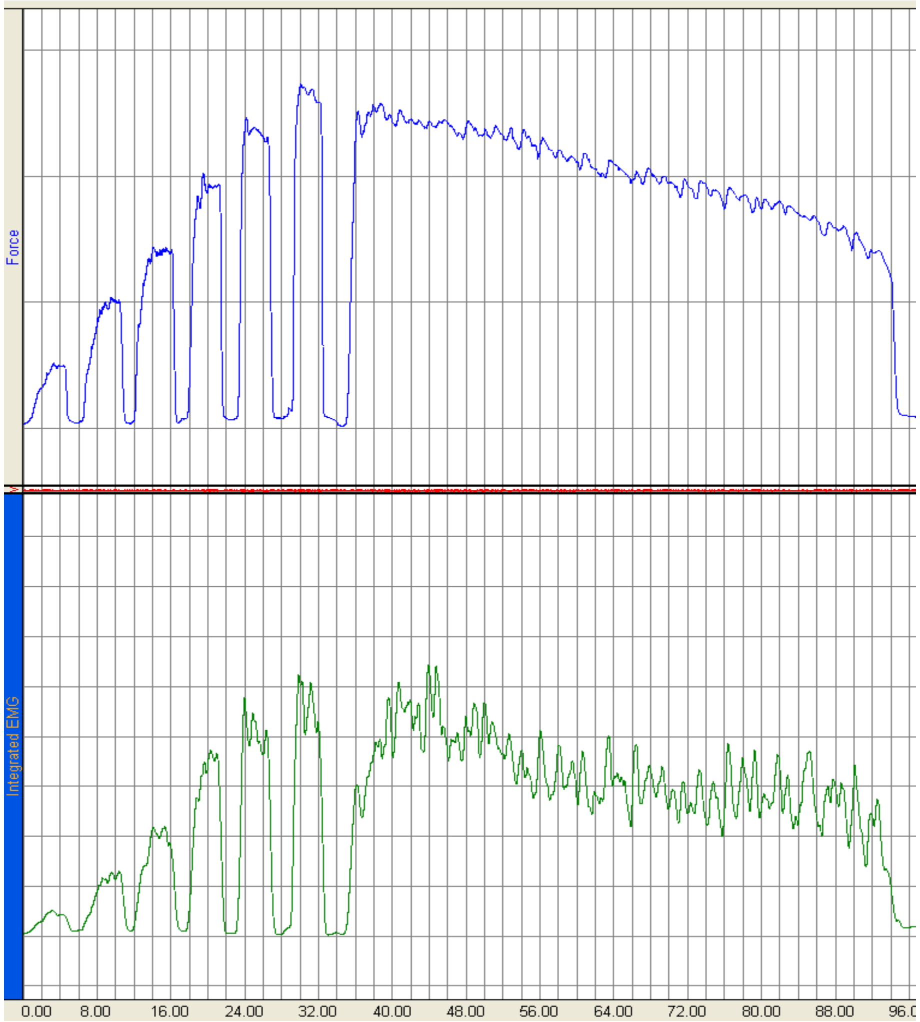
measurement protocol



computer-aided meassurements: EMG

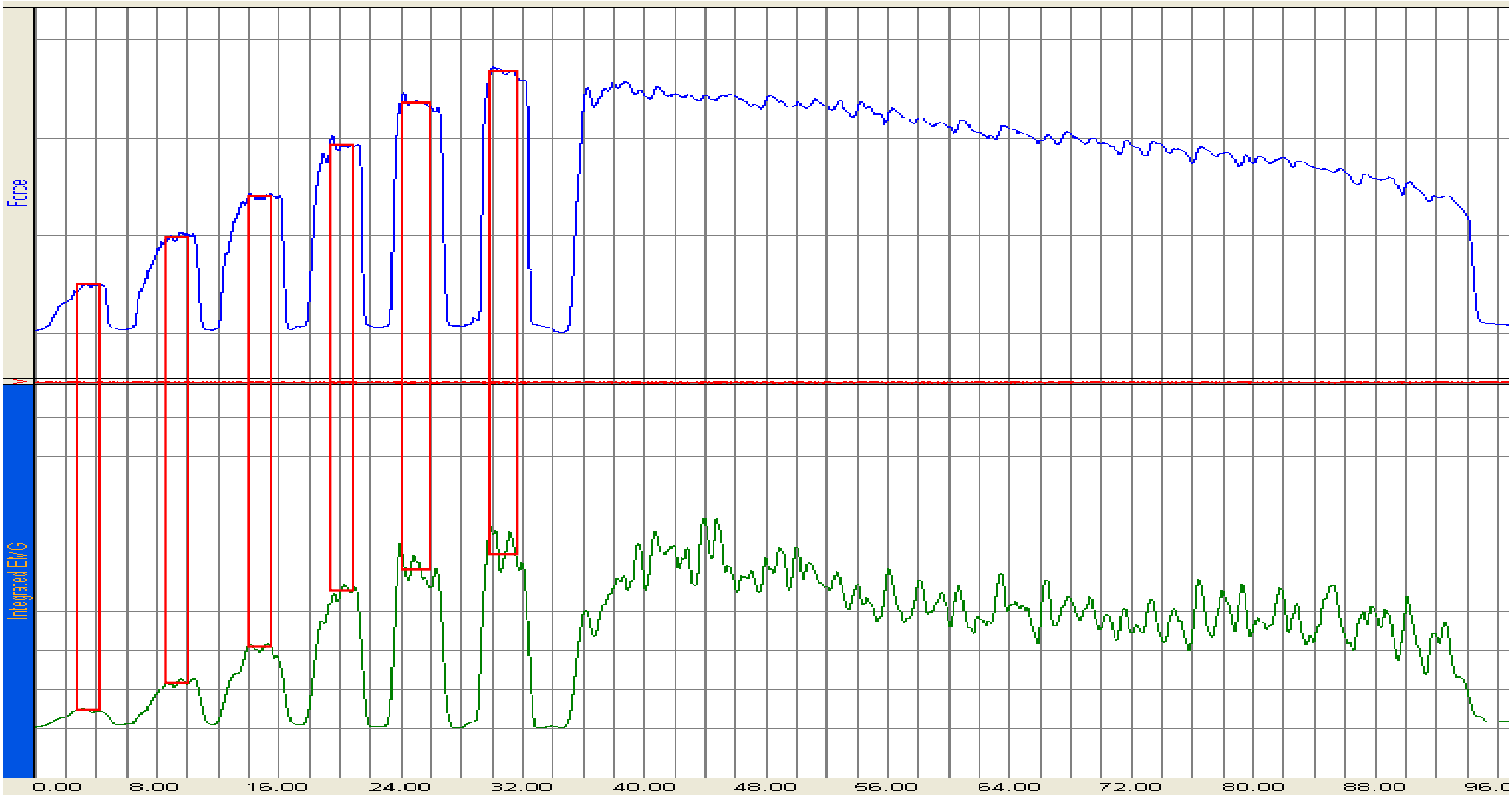
preprocessing



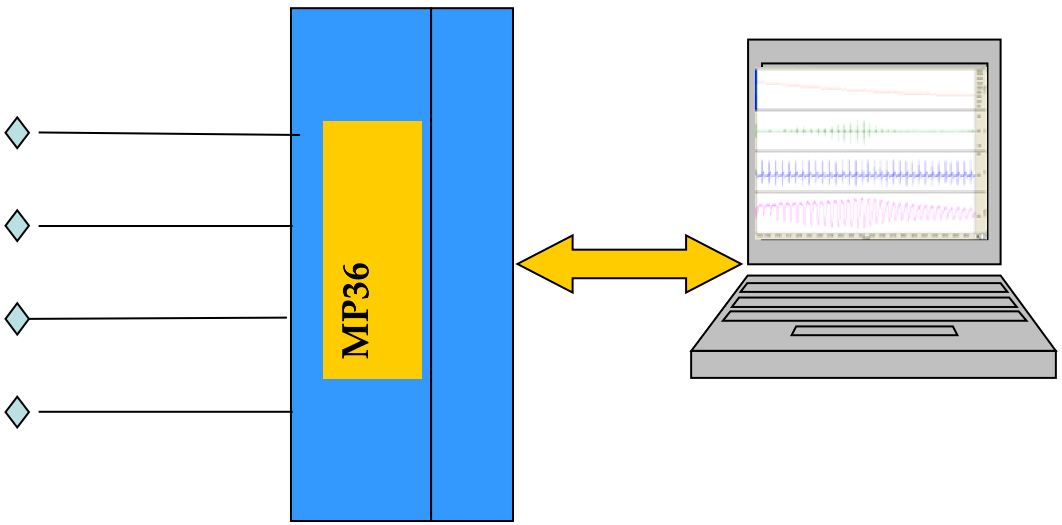


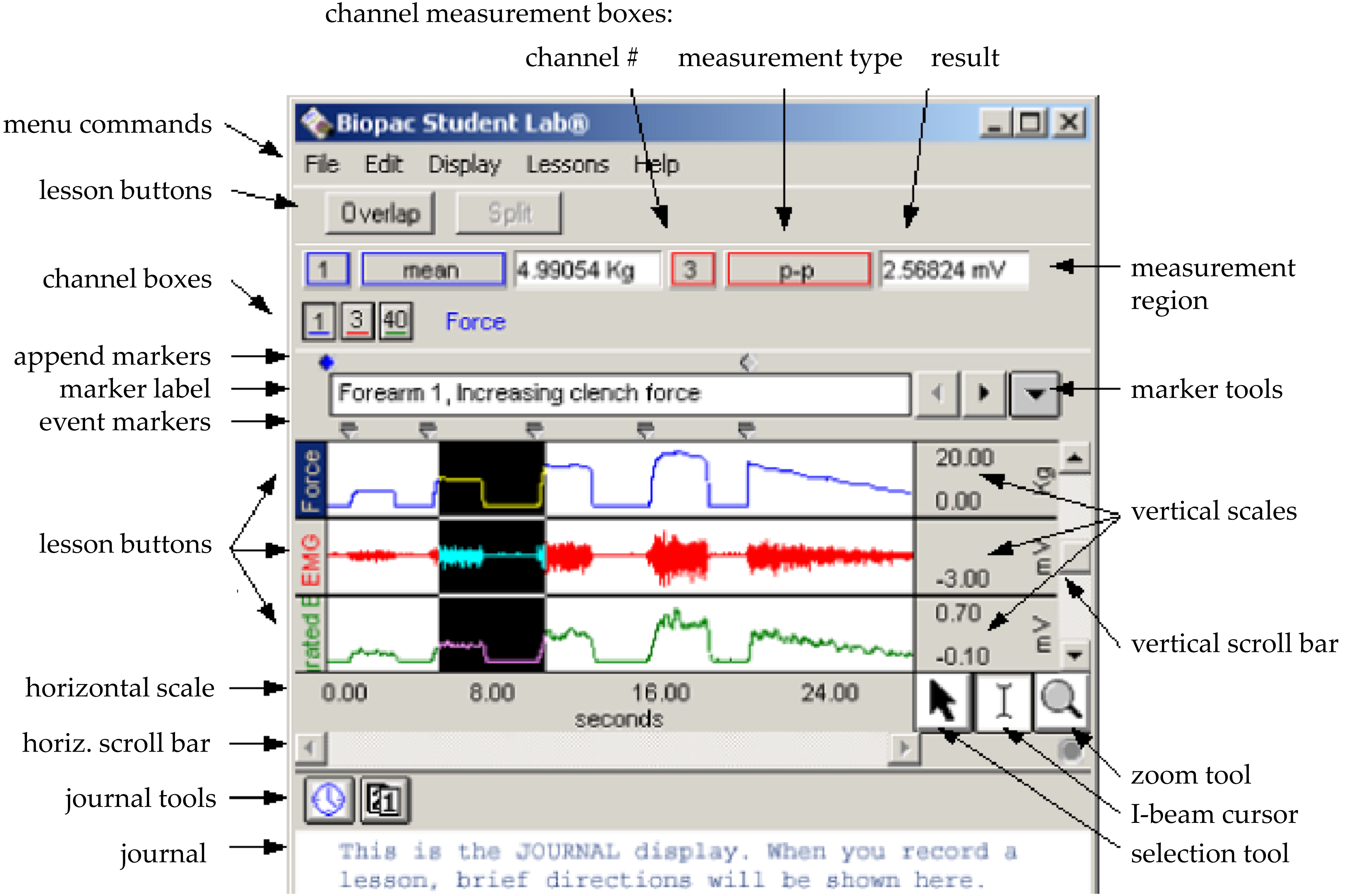
computer-aided meassurements: EMG

evaluations (1)



BIOPAC STUDENT LAB SYSTEM




channel measurement boxes:
channel #
measurement type
result
menu commands
lesson buttons
channel boxes
append markers
marker label
event markers
lesson buttons
horizontal scale
horiz. scroll bar
journal tools
journal
measurement region
marker tools
vertical scales
vertical scroll bar
zoom tool
I-beam cursor
selection tool
Biopac Student Lab®
File Edit Display Lessons Help
Overlap
Split
1
mean
4.99054 Kg
3
p-p
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Force
Forearm 1, Increasing clench force
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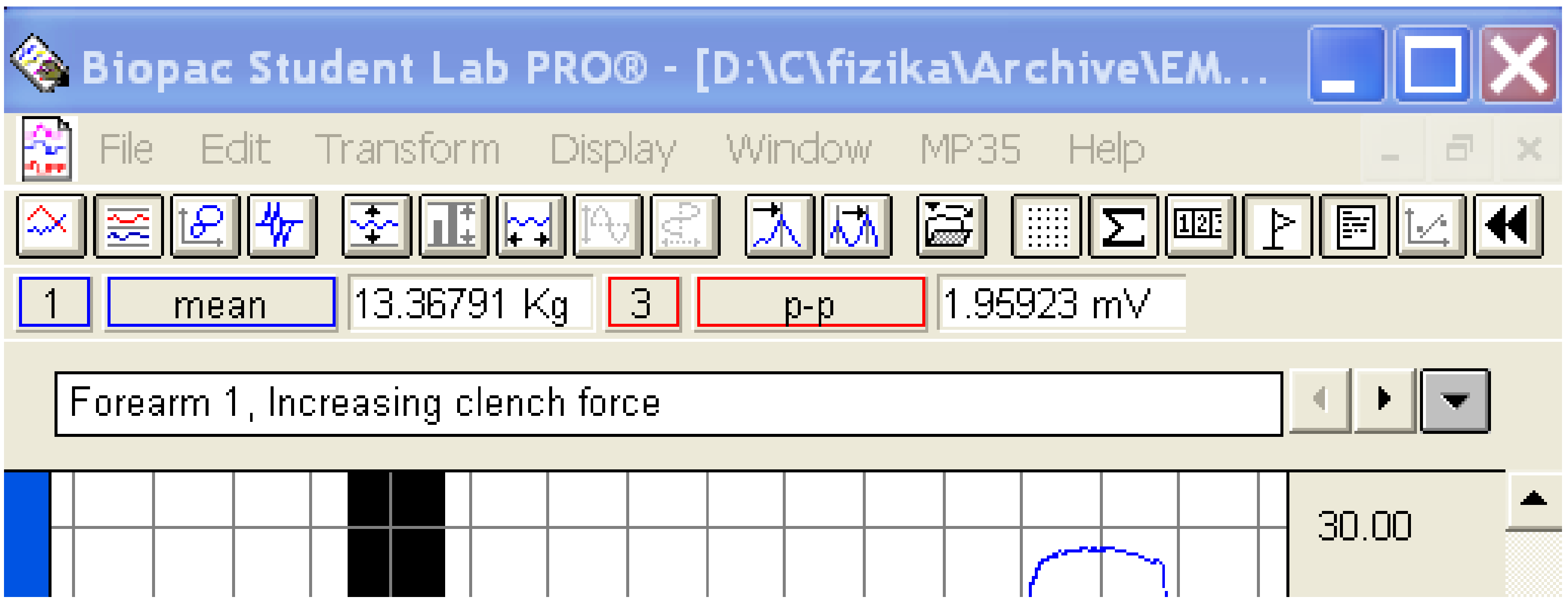
seconds
This is the JOURNAL display. When you record a lesson, brief directions will be shown here.

The toolbar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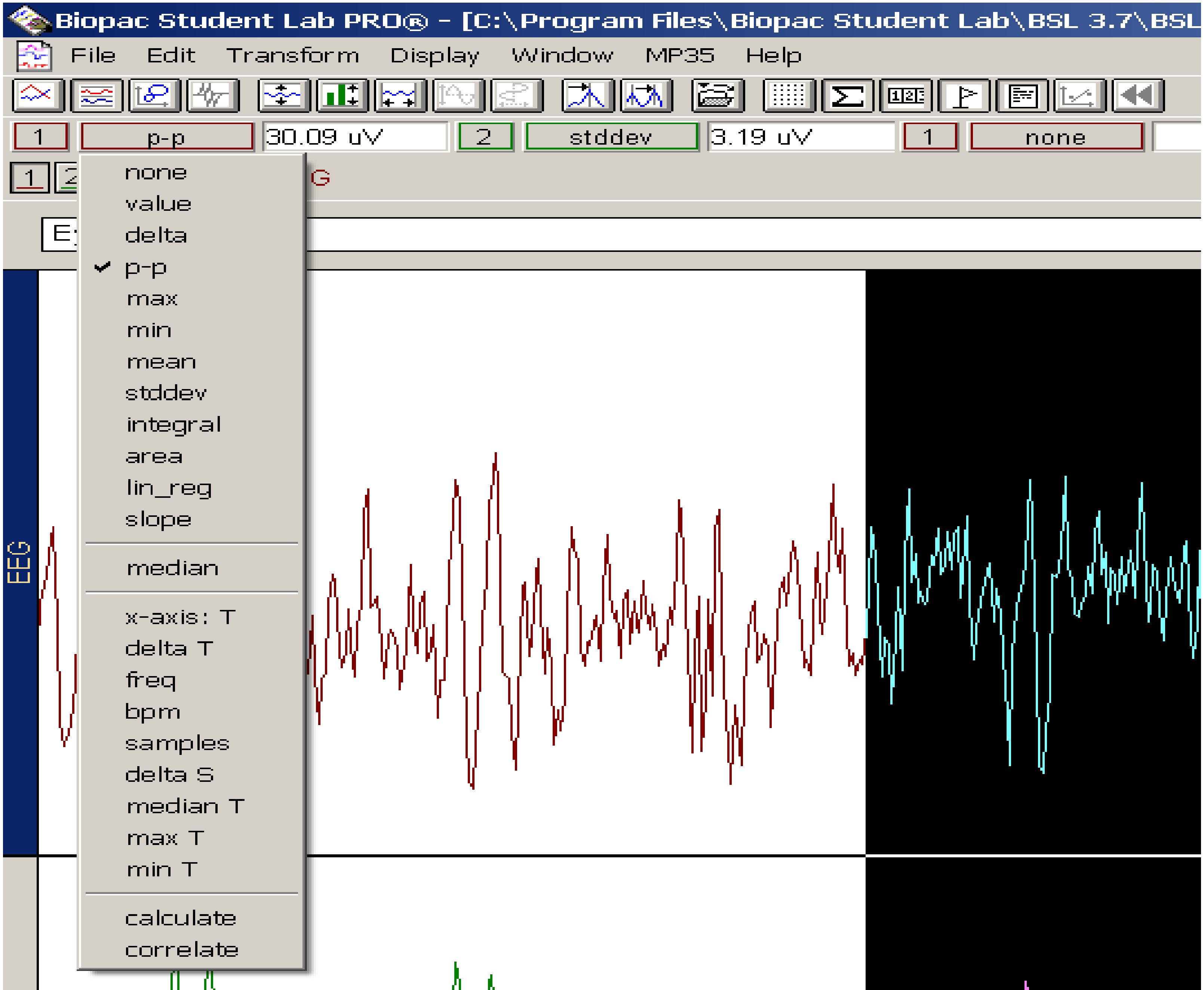
BIOPAC Student Lab (BSL)



Setting of channels