BLOOD PRESSURE

- **Blood pressure – the most important parameter in cardiovascular system – „**high-profile“ parameter

- **Blood pressure (BP)** means the force exerted by the blood against any unit area of the vessel wall

- Systolic blood pressure - SBP
- Diastolic blood pressure -SBP
- Mean arterial pressure - MAP
- Pulse pressure - PP

BP = CO x R CO – cardiac output, R – resistance

CO = SV x HR SV – stroke volume, HR – heart rate

Arterial blood pressure curve

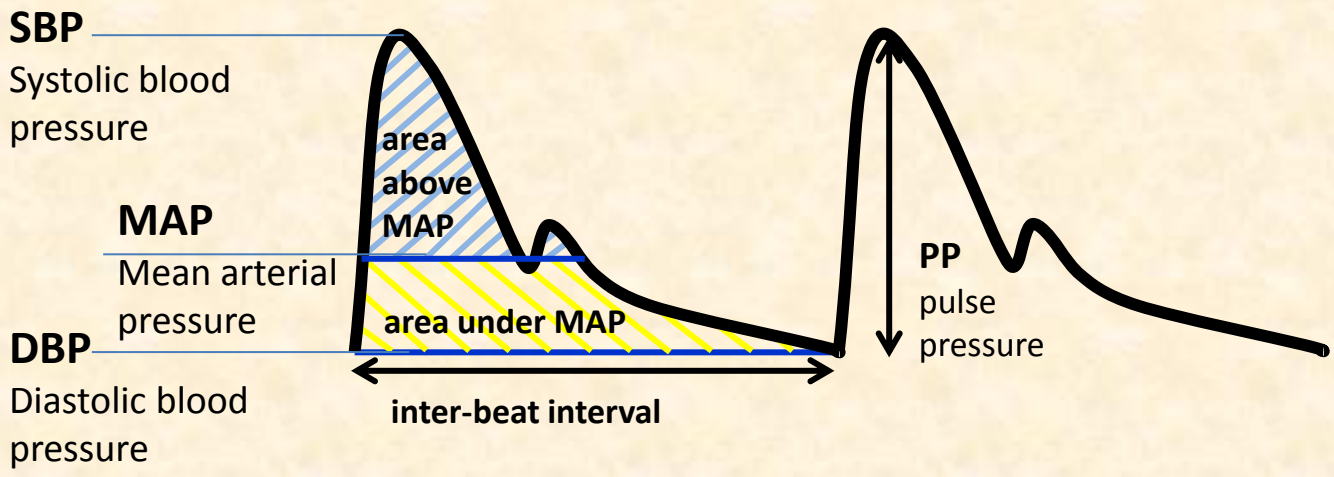
Blood pressure (BP): pressure on vascular vall (continual variable)

Mean arterial pressure (MAP) : mean value of blood pressure in the inter-beat interval (IBI)

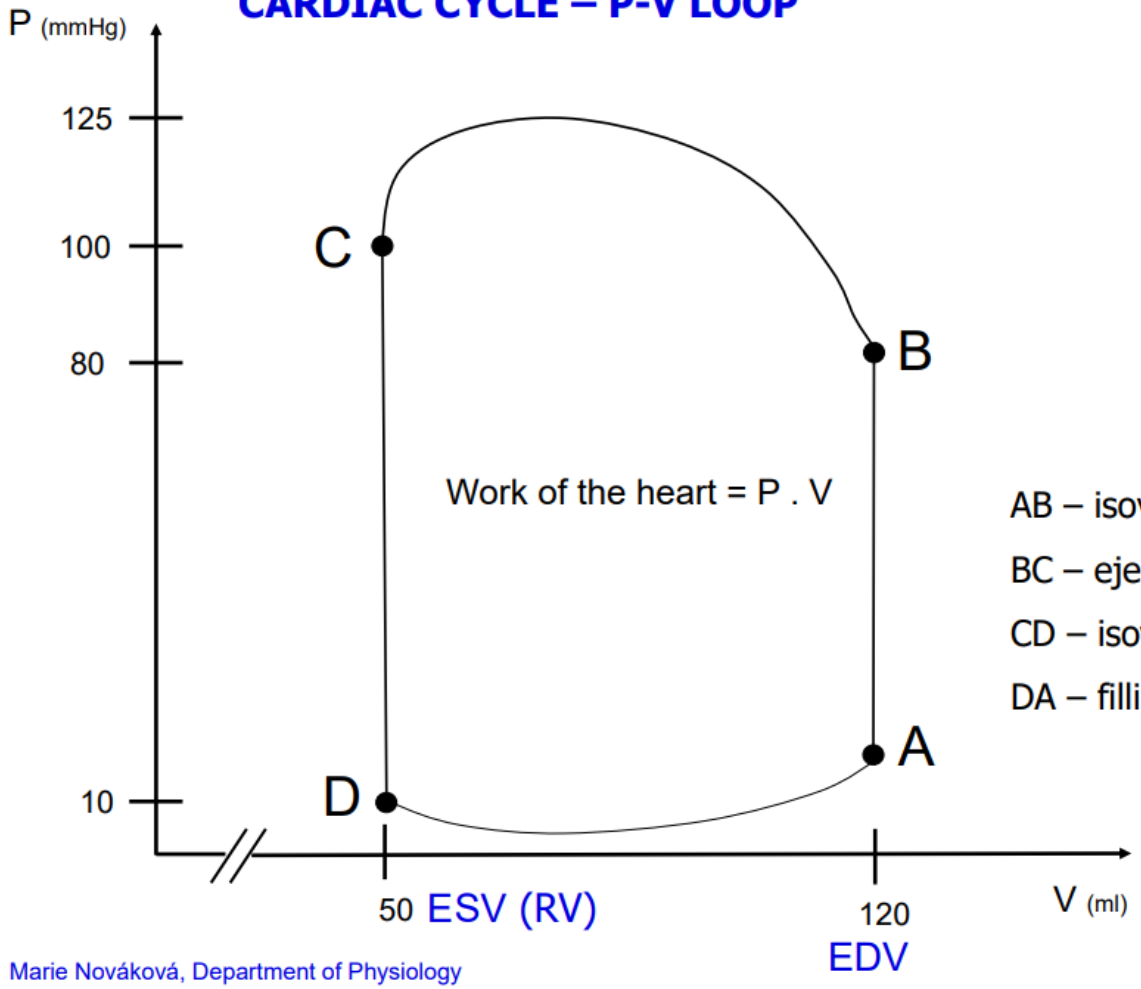
- **area under MAP = area above MAP**
- **aproximation: MAP≈ DBP + 1/3 PP (PP = SBP – DBP)**

Definition:
SBP - maximum of BP in the inter-beat interval
DBP – minimum of BP in the inter-beat interval

Attention: Values of SBP and DBP varies in different parts of cardiovascular system



CARDIAC CYCLE – P-V LOOP



LAPLACE law:

$T = P \cdot r / 2h$

$\uparrow P = T \cdot \uparrow 2h / \downarrow r$

AB – isovolumic contraction

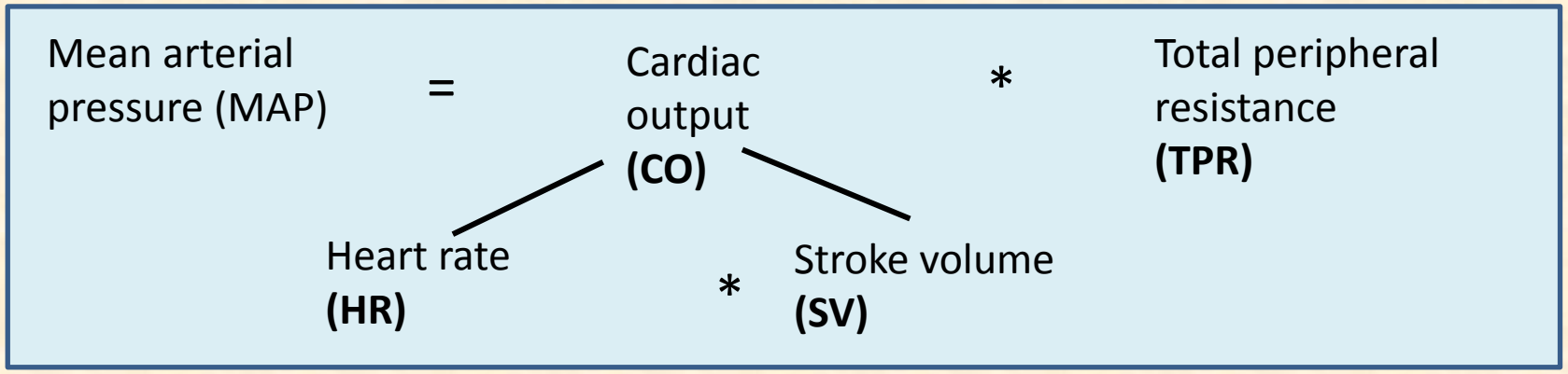
BC – ejection

CD – isovolumic relaxation

DA – filling

MUNI MED

MAP is a function of cardiac output and total peripheral resistance



- SBP is given mainly by CO
- DBP is given mainly by TPR

Classification BP values

category	Systolic BP	Diastolic BP
	(mmHg)	(mmHg)
optimal	< 120	< 80
normal	120 – 129	80 – 84
high normal pressure	130 – 139	85 – 89
Hypertension - mild	140 – 159	90 – 99
Hypertension - moderate	160 – 179	100 – 109
Hypertension - severe	≥ 180	≥ 110
Izolated systolic hypertension	≥ 140	< 90

According the Guidelines of European Society of Cardiology 2013

Classification BP values: „officer BP“

category	Systolic BP	Diastolic BP
	(mmHg)	(mmHg)
optimal	< 120	< 80
normal	120 – 129	80 – 84
high normal pressure	130 – 139	85 – 89
Hypertension – mild: grade 1	140 – 159	90 – 99
Hypertension – moderate: grade 2	160 – 179	100 – 109
Hypertension – severe: grade 3	≥ 180	≥ 110
Isolated systolic hypertension	≥ 140	< 90

According the Guidelines of European Society of Cardiology 2018

Classification of BP

- **It is recommended that BP be classified as**

optimal, normal, high–normal, or grades

1–3 hypertension, according to office BP.

2018 ESC/ESH Guidelines for the management of arterial hypertension

The Task Force for the management of arterial hypertension of the European Society of Cardiology (ESC) and the European Society of Hypertension (ESH)

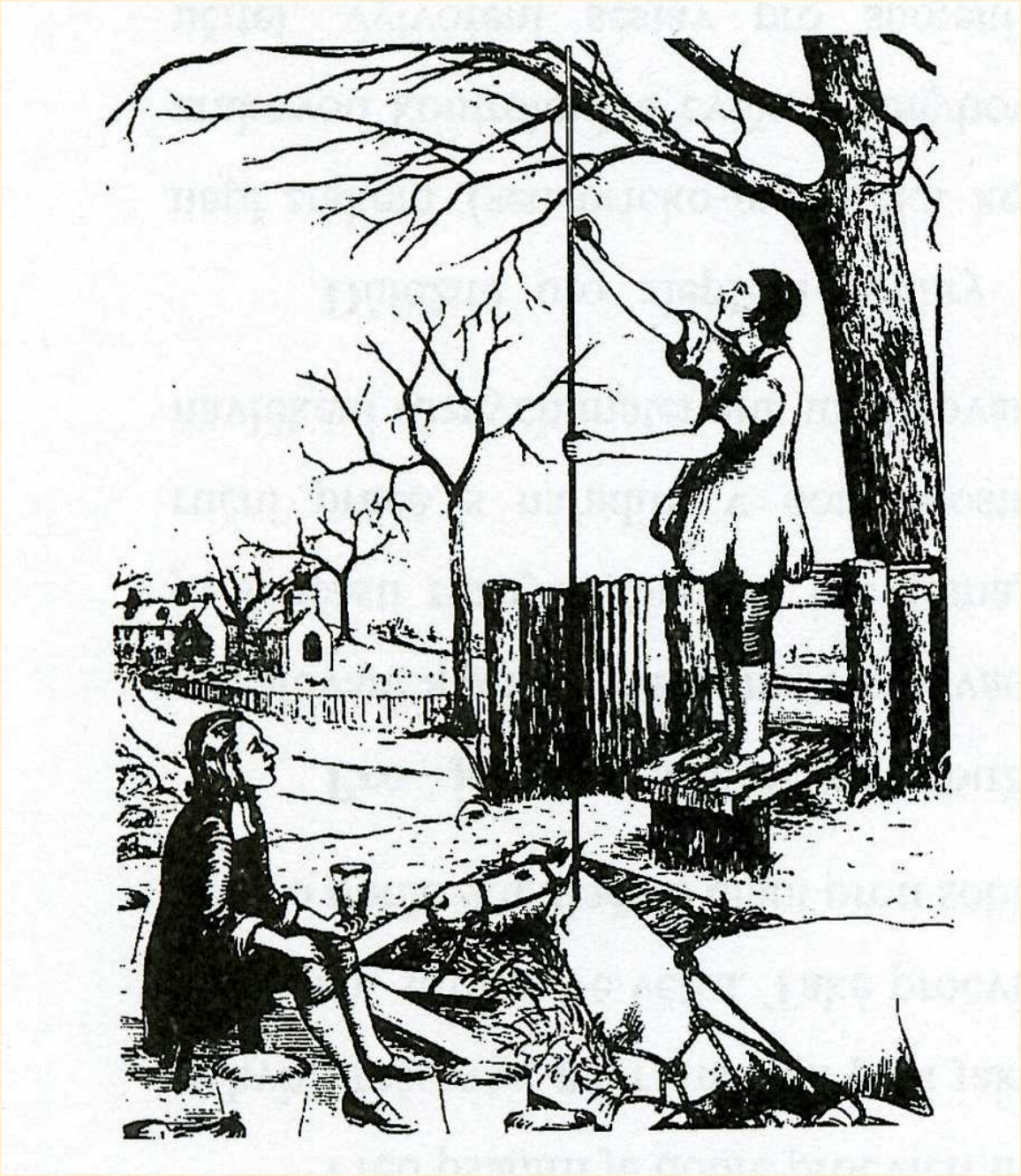
Authors/Task Force Members: **Bryan Williams* (ESC Chairperson**) (UK), **Giuseppe Mancia* (ESH Chairperson**) (Italy), Wilko Spiering (The Netherlands), Enrico Agabiti Rosei (Italy), Michel Azizi (France), Michel Burnier (Switzerland), Denis L. Clement (Belgium), Antonio Coca (Spain), Giovanni de Simone (Italy), Anna Dominiczak (UK), Thomas Kahan (Sweden), Felix Mahfoud (Germany), Josep Redon (Spain), Luis Ruilope (Spain), Alberto Zanchetti† (Italy), Mary Kerins (Ireland), Sverre E. Kjeldsen (Norway), Reinhold Kreutz (Germany), Stephane Laurent (France), Gregory Y. H. Lip (UK), Richard McManus (UK), Krzysztof Narkiewicz (Poland), Frank Ruschitzka (Switzerland), Roland E. Schmieder (Germany), Evgeny Shlyakhto (Russia), Costas Tsioufis (Greece), Victor Aboyans (France), and Ileana Desormais (France)

European Heart Journal (2018) 39, 3021–3104

BLOOD PRESSURE MEASUREMENT

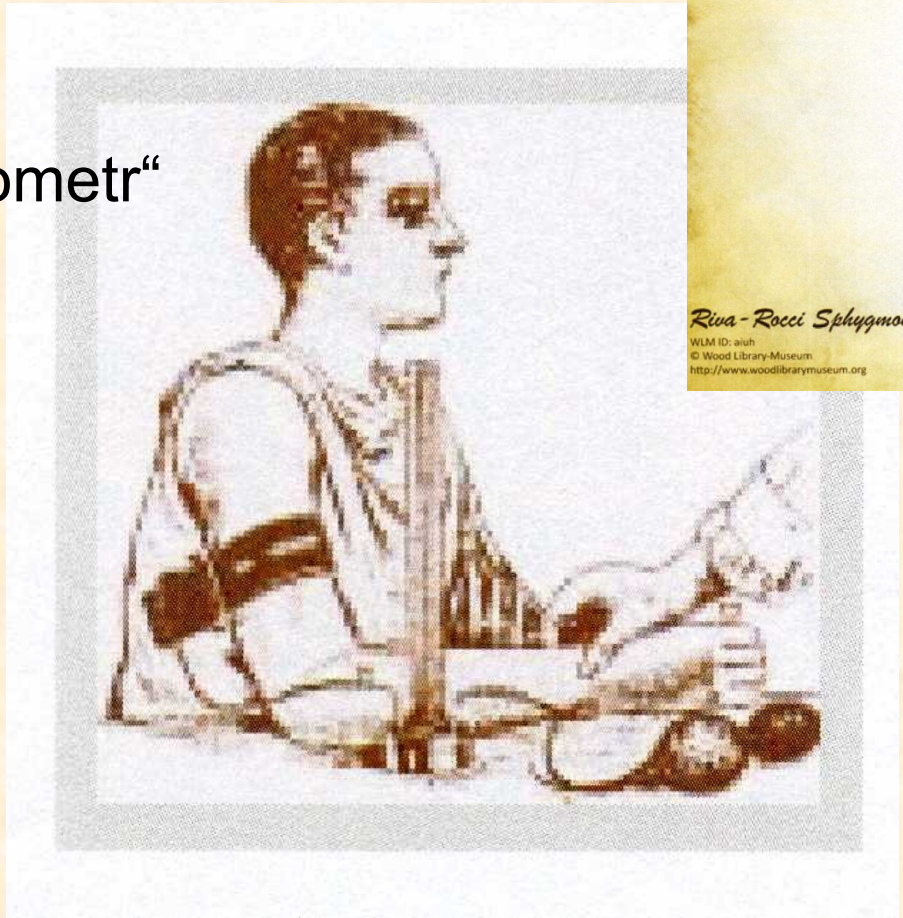
- **Direct invasive method**
  - 1726 Stephan Hales – horse
  - Today – during catheterization

- **Indirect non-invasive measurement**
  - Palpation method
  - Auscultation method
  - Oscilometric method



Palpatory methods

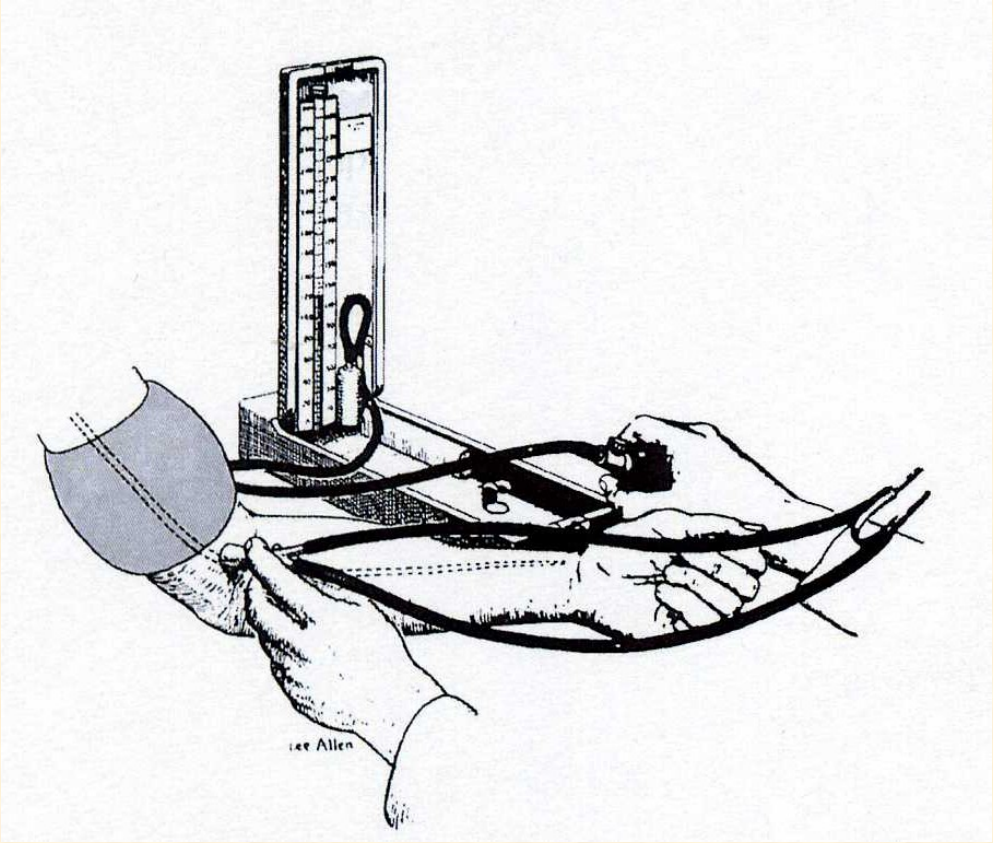
Italian physician
Riva Rocci
„mercury sfygmomanometr“
The cuff on the arm
1896



Auscultatory method

A Russian army surgeon
Nikolai Korotkoff
1904

„mercury sfygmomanometr“
The cuff on the arm
Stethoscope at the elbow



Oscilometric method

Based on **the same principle** as auscultation: **changes of laminar to turbulent flow**

During instrument testing it has been repeatedly shown that **the point of maximum oscillations corresponds to the mean arterial pressure measured invasively.**

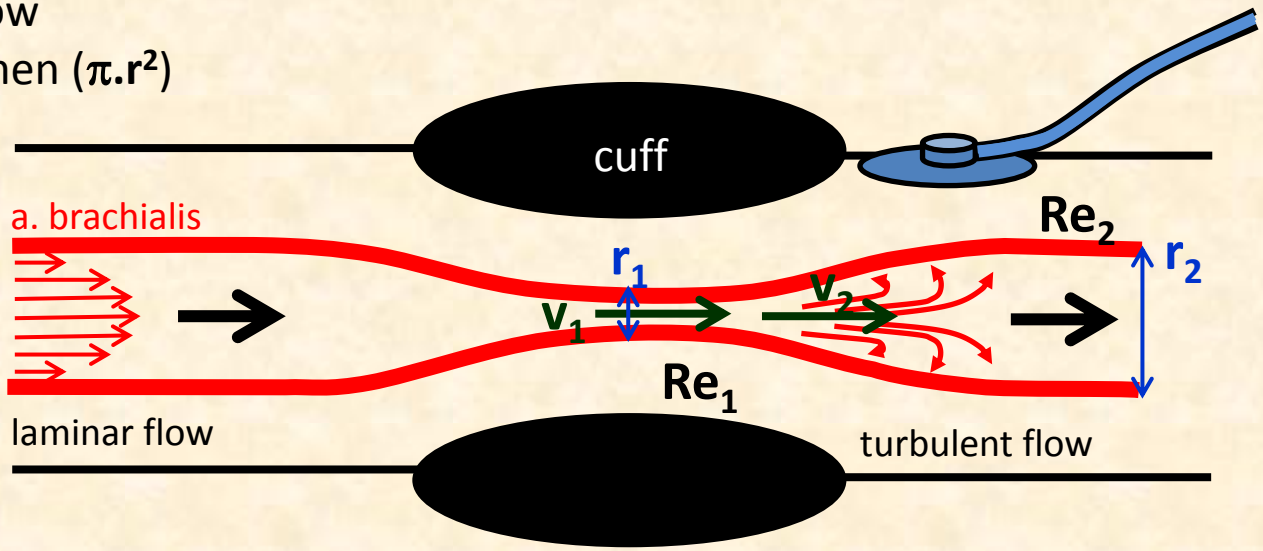
Oscillations begin around systolic pressure values and continue after cuff release = both **systolic and diastolic pressure are estimated only indirectly based on empirical derived algorithms**

Laminar / turbulent flow, Korotkoff sounds

$$Re = \frac{v \cdot S \cdot \rho}{\eta}$$

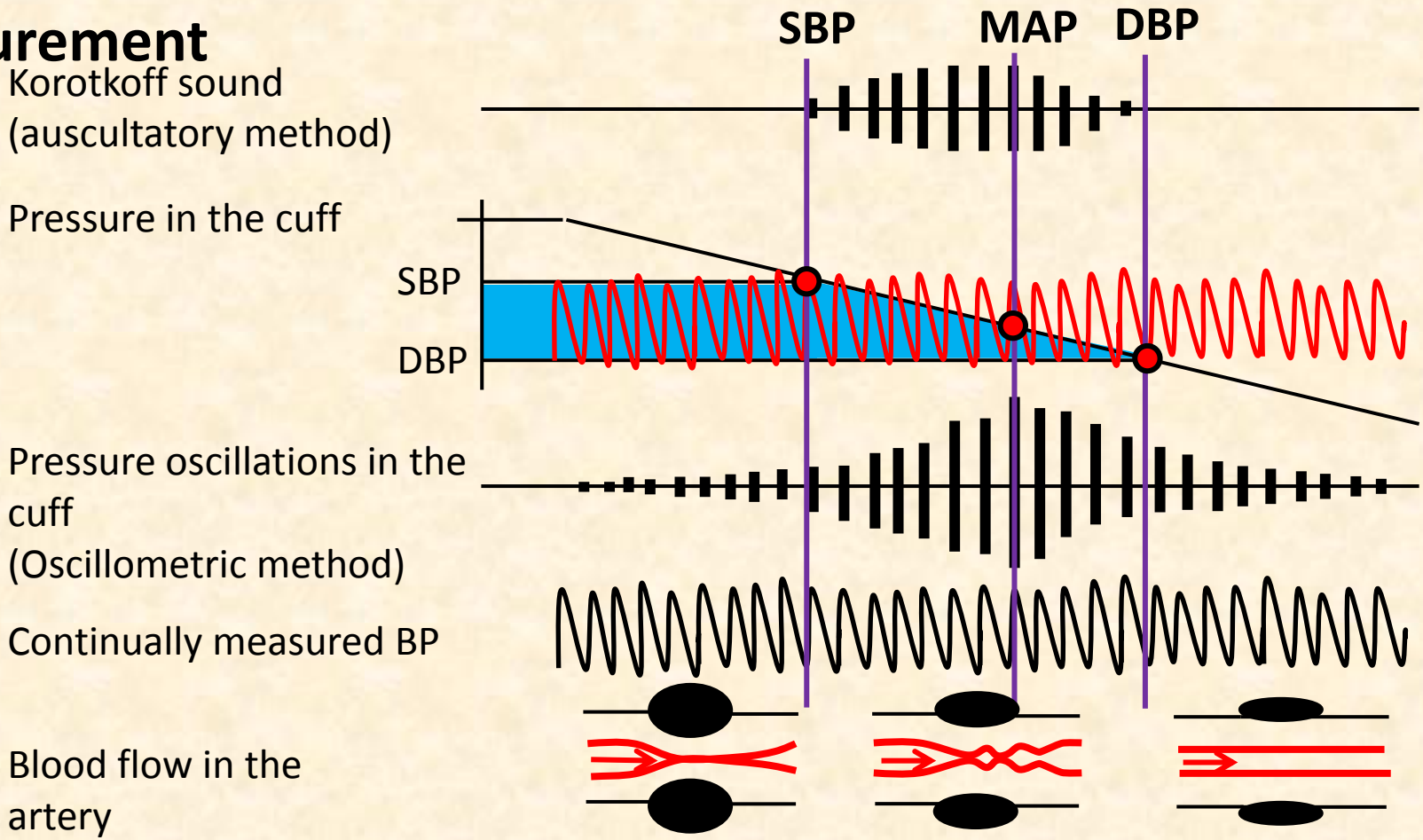
laminar flow Re < 2000
turbulent flow Re > 3000

Reynolds number Re: predicts the transition from laminar to turbulent flow
v: velocity of blood flow
S: area of vascular lumen ($\pi.r^2$)
ρ: density of blood
η: viscosity of blood



closely behind narrowing of the artery: $S_1 < S_2$ a $v_1 \approx v_2 \rightarrow Re_1 < Re_2 \rightarrow$ turbulent flow

Principles of blood pressure measurement



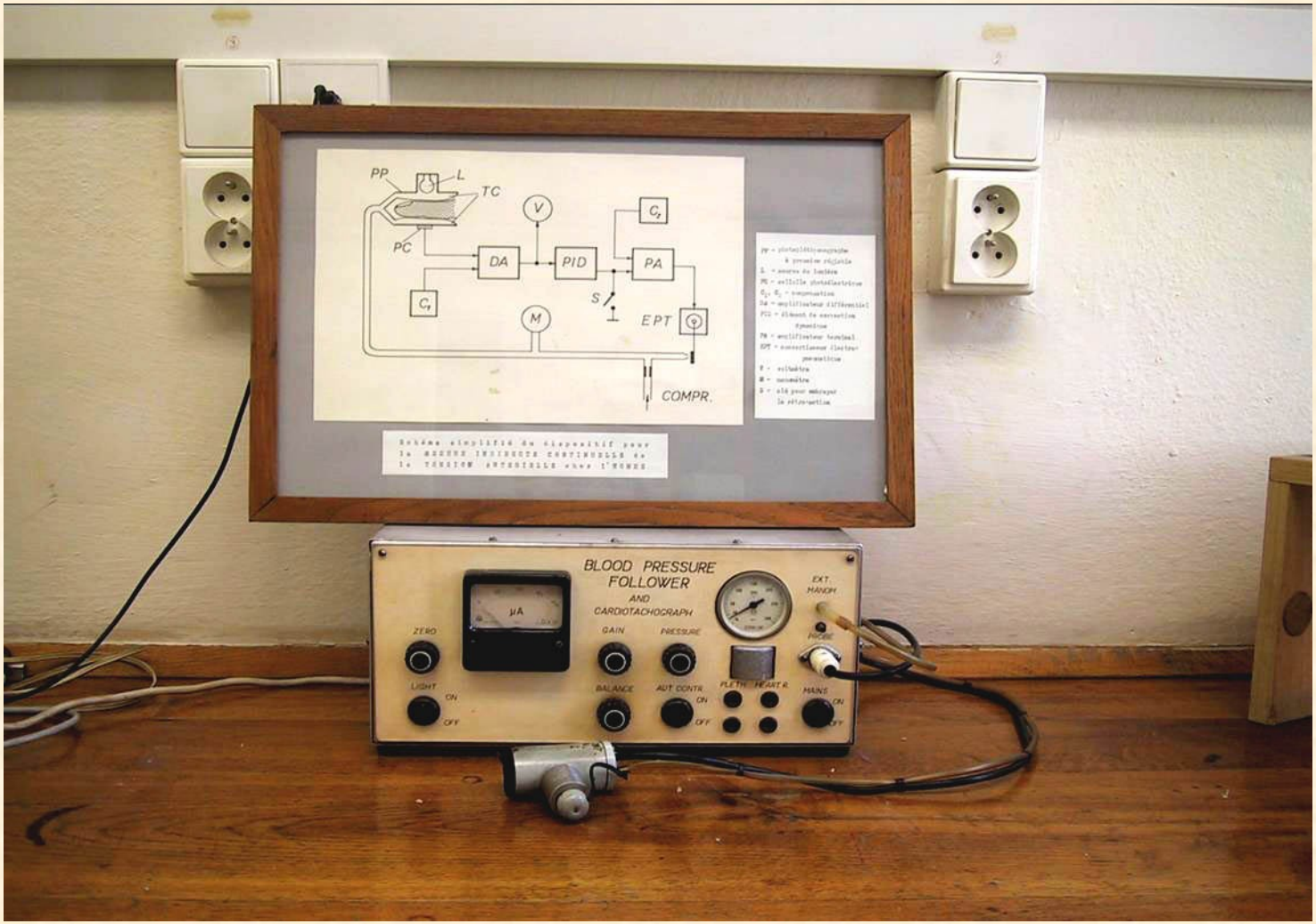
The size of the cuff in adults

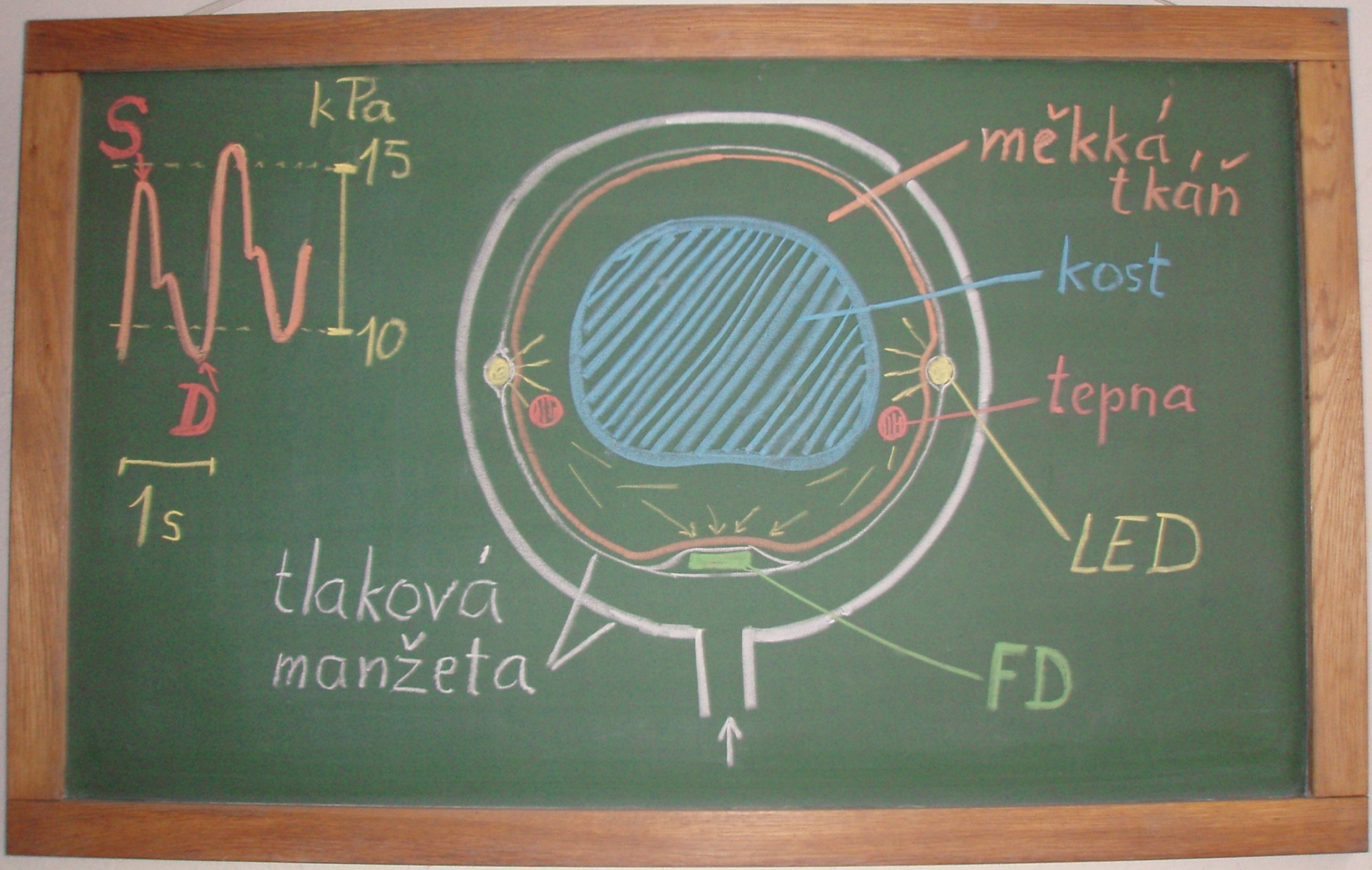
Cathegories	Circumference of arm (cm)	Cuff width x length (cm)
Small adult cuff	22 - 26	10 x 24
Adult cuff	27 - 34	13 x 30
Large adult cuff	35 - 44	16 x 38
Tight adult cuff	45 - 52	20 x 42

Noninvasive continuously beat-to-beat measurement of finger arterial pressure

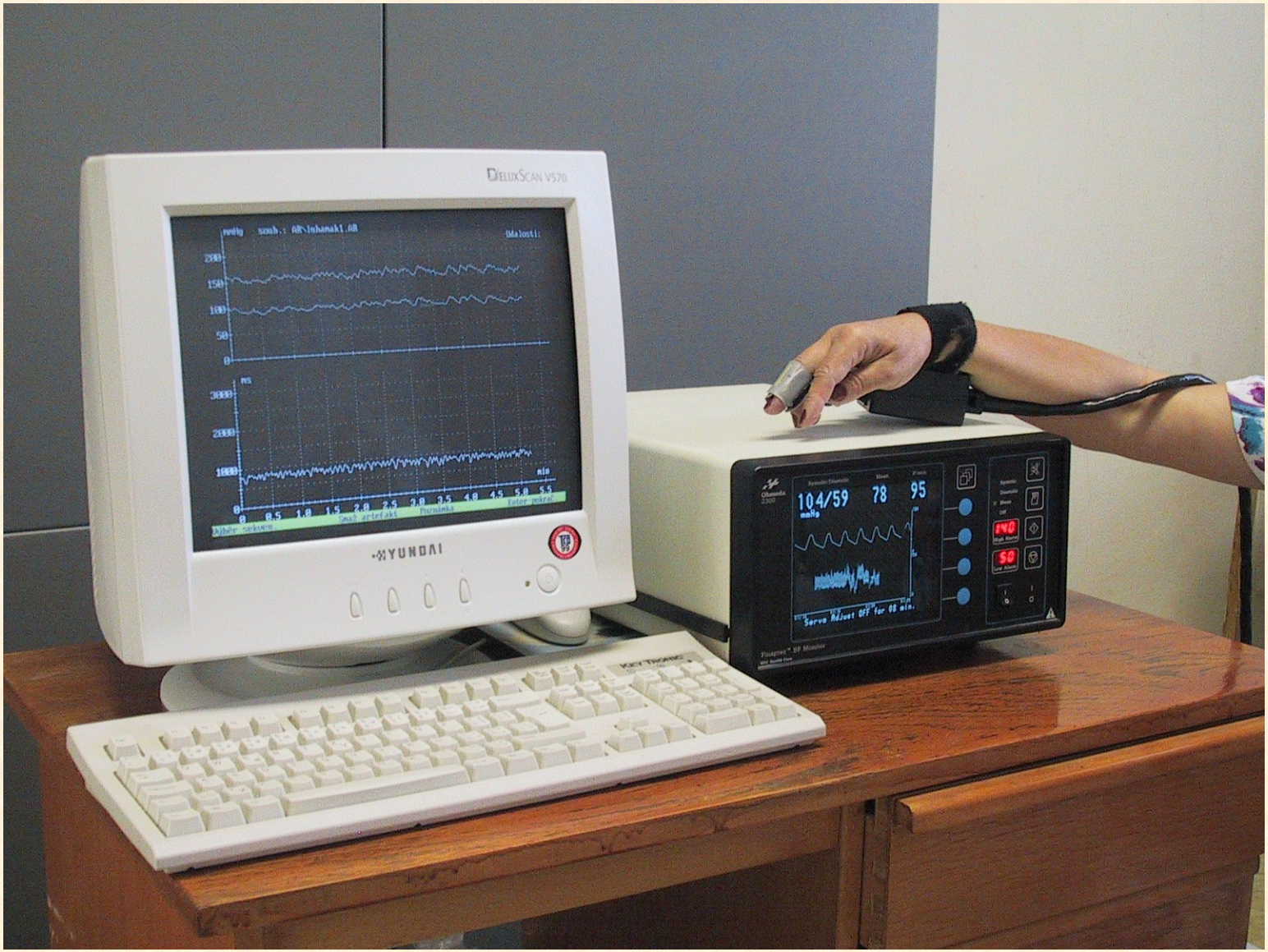
- Prof. Jan Peňáz, MD, PhD
- Teacher and researcher on the Department of Physiology, Masaryk university, Brno
- Patent 1969

Non-invasive continuously blood pressure measurement beat-to-beat by Peňáz




S
kPa
15
10
D
1s
měkká tkáň
kost
tepna
LED
FD
tlaková manžeta

Finapres (Ohmeda, USA)




Finometr (FMS, Nizozemí)
start / stop
FMS Finometer

- **Peňáz method**
- **photopletysmography** (Recorded photoelectric plethysmogram)
- (volume-clamp method – method of „lightway artery system“)

- It is based on clamping the volume of finger arteries by fast changes of **pressure** in a special cuff equipped with a photoelectric plethysmograph to measure the vascular volume.

- based on the fact- - we need than **pressure in the cuff corresponds to the pressure in the digital artery**

*The new term: **Transmural pressure** – Pt (the pressure across the wall of the artery)*

So, we know following parameters:

BP=Blod pressure inside of digital artery, Pc = pressure in cuff, Pt =transmural pressure

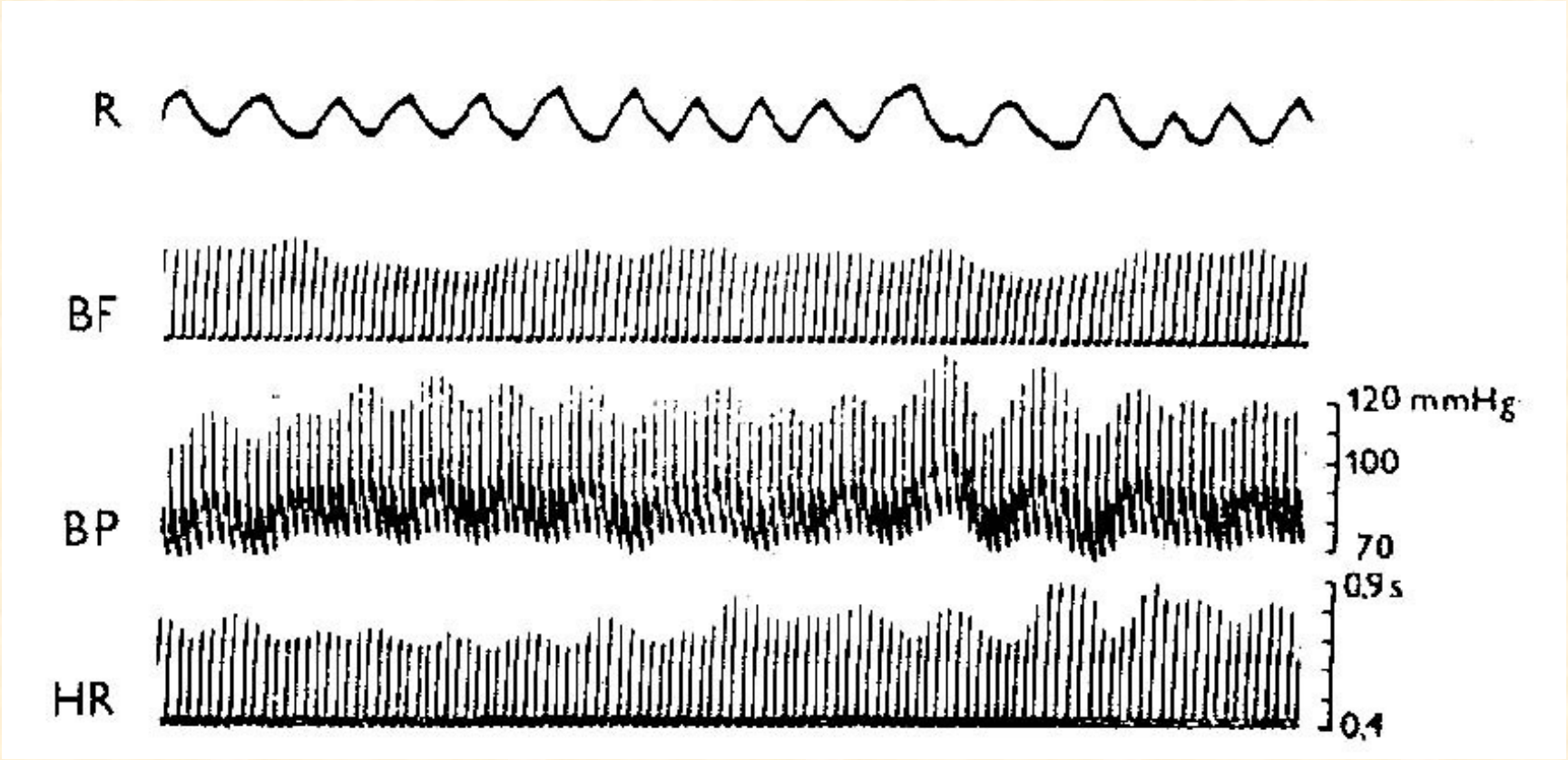
We estimated: **BP = Pc it is mean, that Pt = 0 …** photoplethysmogram registered the highest amplitude of oscilation --- we measure the **MAP**

This situation comming at the beginning of measurement, when the cuff is inflated step by step (5 mmHg) and Pc increase. In the moment of the highest amplitude is registered – **feed-back loop** started for obtained the constant volume of the finger. This feed-back control is based on record amount of the light from photocells

Peňáz patent (1969)

- He used a photocell signal to control the outer cuff pressure so that the finger volume did not change

Records of circulatory parameters



24-hour ambulatory blood pressure monitoring (ABPM)

- **Circadial rhythm** – fluctuation of blood pressure during 24 h (physiological)
- The highest values - the morning, 6 –10h a.m.
  - the afternoon, 4 – 6h p.m.
- The lowest values – 3 – 4h a.m.

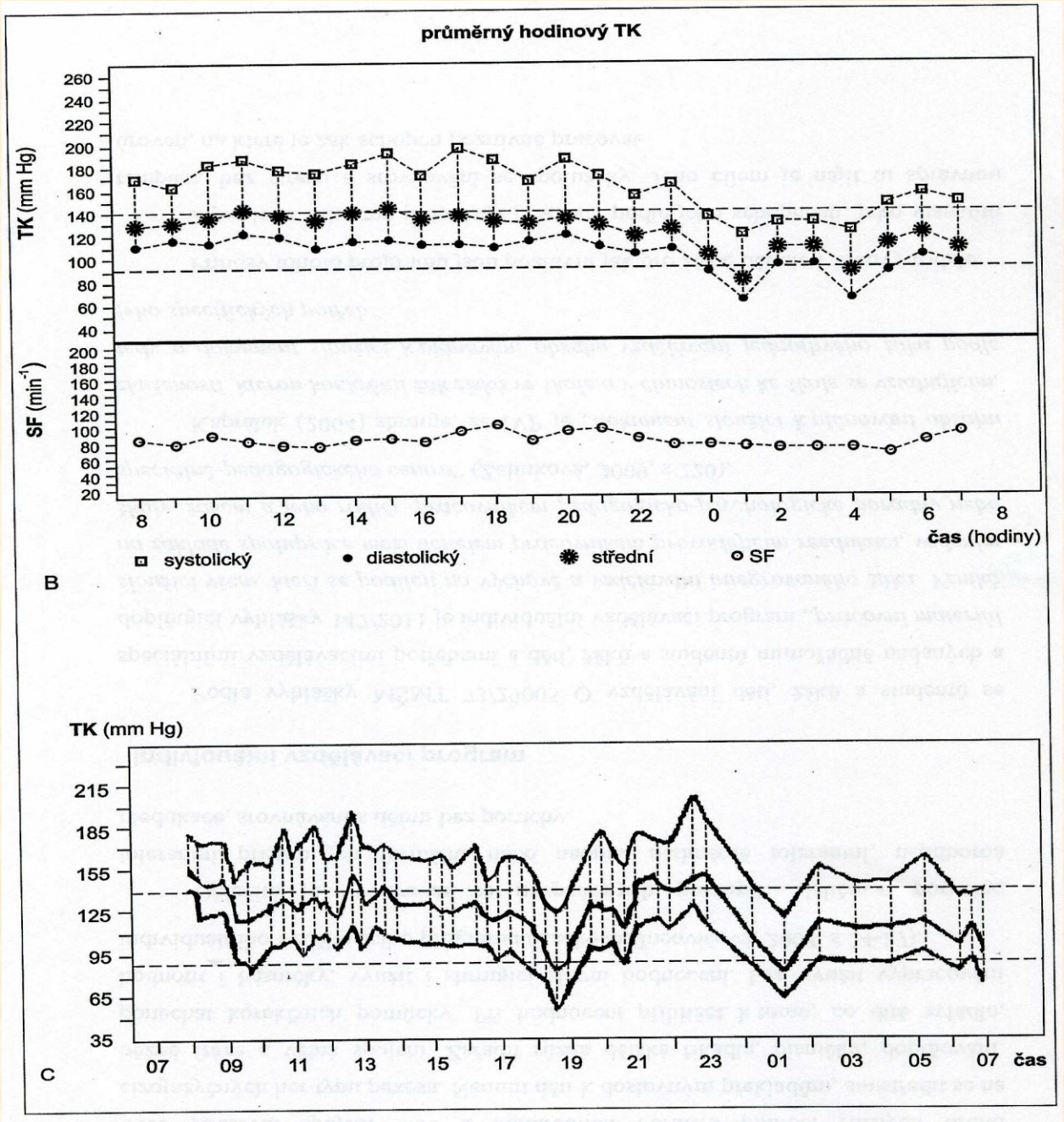
- **Diurnal rhythm** – differences between day – night - physiological

Dippers (at night comes physiological decreasing of BP)
Nondippers (there is no reduction of BP at night - pathological)

- ABPM - record of BP during 24 h (or 48h or 7 days is now also possible)

- Dif.dg. : **white coat** hypertension **or**
  masked hypertension
  + Control of treatment of hypertension

- **Evaluation: Physiological values**
- Mean values during 24 h: less than 125/80mmHg
- Mean values during day period:less than 135/85mmHg
- Mean values during night period:less than 120/70mmHg
- **Hypertension:**
  - **More than 40% values above 140/90 at day, 120/80 at night**


průměrný hodinový TK
TK (mm Hg)
260
240
220
200
180
160
140
120
100
80
60
40
SF (min-1)
200
180
160
140
120
100
80
60
40
20
8
10
12
14
16
18
20
22
0
2
4
6
8
čas (hodiny)
systolický
diastolický
střední
SF
B
TK (mm Hg)
215
185
155
125
95
65
35
07
09
11
13
15
17
19
21
23
01
03
05
07
čas
C

[redacted]

numeric display of day / night phase

	overall time 08:15 - 08:00		day phase 06:00 - 22:00		night phase 22:00 - 06:00		Day -> Night
	mean	max	mean	max	mean	max	
Ps [mmHg]	127	160	129	160	118	152	-8 %
Pd [mmHg]	74	120	76	120	63	81	-17 %
Pm [mmHg]	91	133	93	133	81	104	
BP-Ampl.	53	95	52	95	55	76	
Pulse [1/min]	71	103	74	103	62	79	-16 %
measurement count	95		76		19		
repeat measurements	13		10		3		
error + ignored meas.	14		11		3		
	count	%	count	%	count	%	
Ps > 140 mmHg:	14	17	12	18	2	13	
Pd > 90 mmHg:	9	11	9	14			
Pulse > 100 / min:	2	2	2	3			