

(VIII.) blood pressure in man

(IX.) Non-invasive methods of blood pressure measurement

Physiology - practicals

# Arterial blood pressure curve

**Blood pressure (BP):** pressure on vascular wall (continual variable)

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

- area under MAP = area above MAP
- approximation:  $MAP \approx DBP + 1/3 PP$  ( $PP = SBP - DBP$ )

## 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

**SBP**

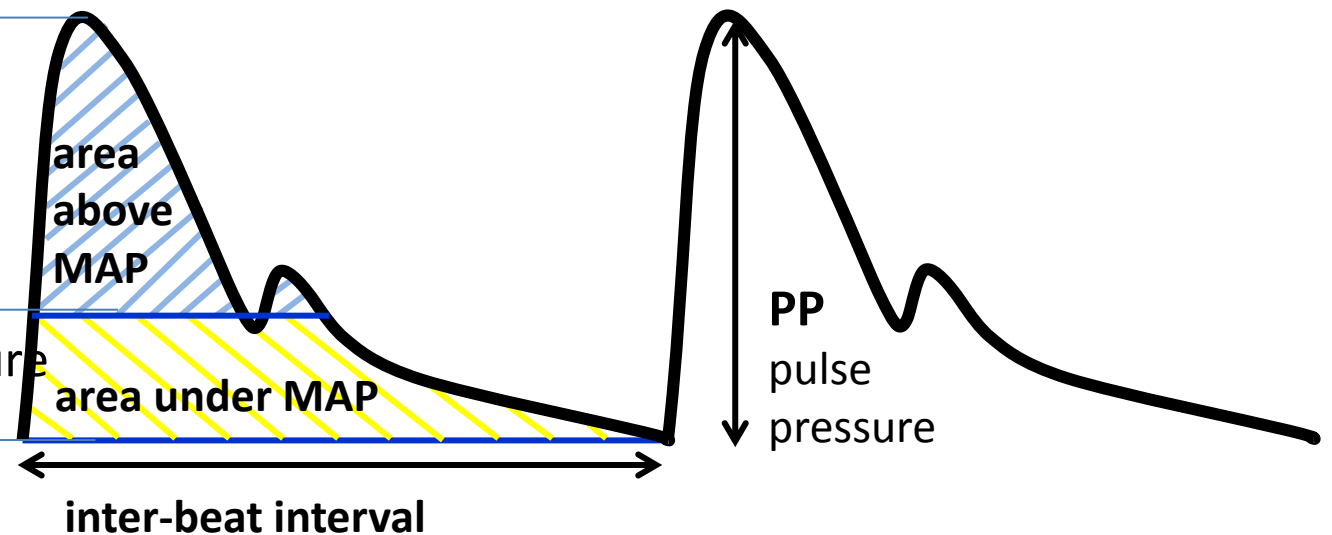
Systolic blood pressure

**MAP**

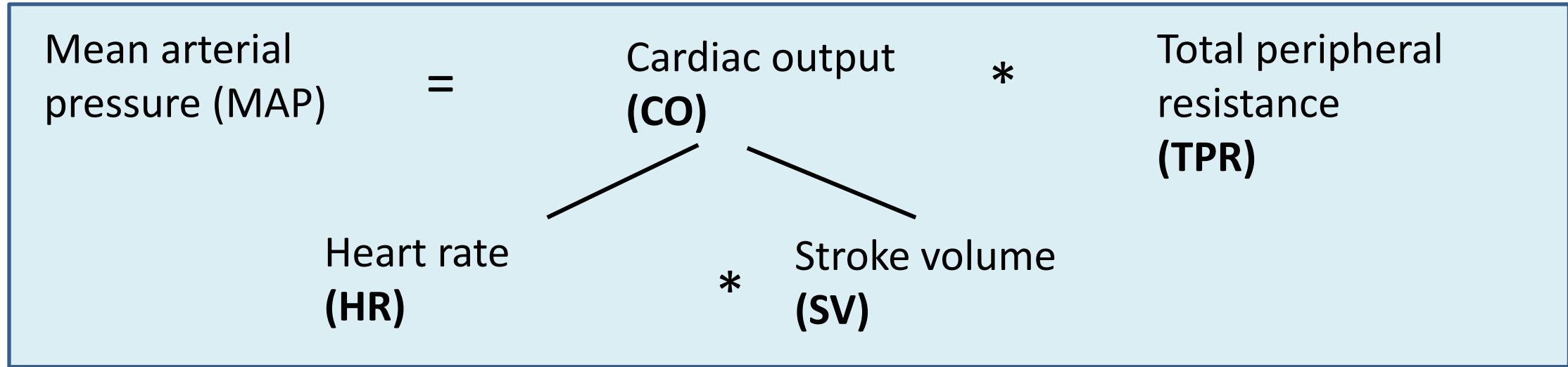
Mean arterial pressure

**DBP**

Diastolic blood pressure



MAP is a function of cardiac output and total peripheral resistance



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

# Blood pressure regulation

- **Short-term** – neural control, mainly baroreflex
- **Medium-term** – hormonal regulation, renin-angiotensin-aldosterone system (RAAS)
- **Long-term** – hormonal regulation of blood volume

# Short-term BP control: Baroreflex

Autonomic nervous system:

*sympathetic nerves* ( $\uparrow$  BP, HR, SV a TPR) X *parasympathetic nerves* ( $\downarrow$ BP, HR, SV a TPR)

**Baroreflex: regulation of BP via changes of HR and TPR**

baroreceptors – sinus caroticus + aorticus  
*afferentation*: n. vagus, n. glosopharingeus

- **Cardiac branch of baroreflex:**

*efferentation*: n. vagus - SA node

*sympathetic efferentation*: change of HR and cardiac contractility

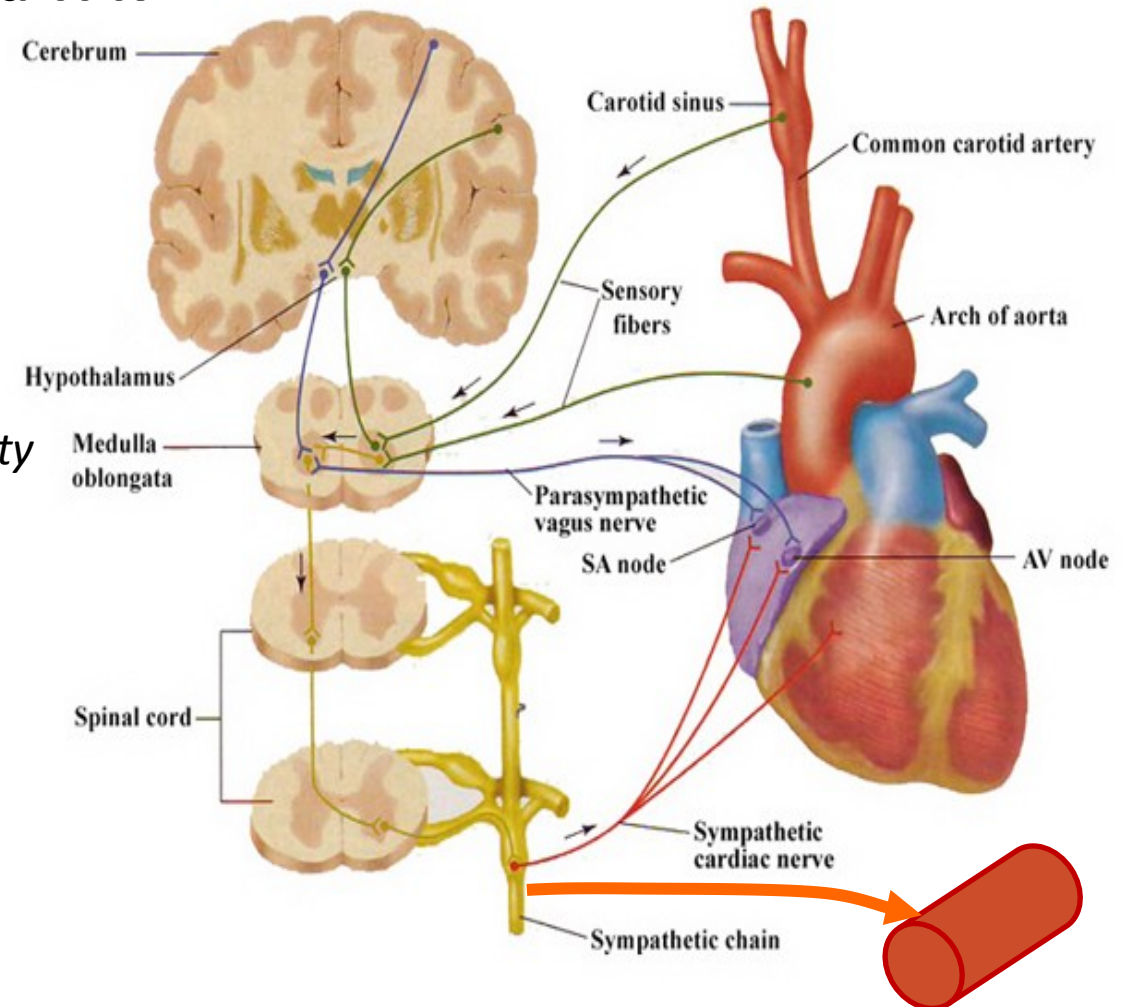
$\uparrow$ BP  $\rightarrow$   $\downarrow$ HR and vice versa

- **Peripheral branch of baroreflex:**

*efferentation*: sympathetic vascular innervation

$\uparrow$ BP  $\rightarrow$   $\downarrow$ TPR and vice versa

(vasoconstriction, venoconstriction)



# Blood pressure changes

## Short-term influences

- blood volume - influence to SV (bleeding, dehydration)
- external pressure to the vessels - intrathoracic and intraabdominal pressure (cough, defecation, childbirth, artificial ventilation)
- position – orthostasis: higher DBP ( $\uparrow$ TPR) and lower SV ( $\downarrow$ venous return  $\rightarrow$   $\downarrow$ heart filling  $\rightarrow$  Starling principle  $\rightarrow$   $\downarrow$ cardiac contraction  $\rightarrow$   $\downarrow$ SV)
- CNS – emotions, mental stress,...
- physical load – BP changes depend on intensity, duration and type of exercise
- heat ( $\downarrow$  TPR), cold ( $\uparrow$  TPR)
- alcohol, medicaments,...

## Long-term influences

- age (the fastest changes during childhood and adolescence)
- sex (men: higher BP)

# Methods of the arterial blood pressure measurement

In practicals:

Palpatory  
(sphygmomanometer)



Auscultatory  
(sphygmomanometer,  
stethoscope)



Oscillometric



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Another approaches:

24-hour blood pressure monitoring



Photoplethysmographic (volume-clamp method, Peñáz)



# Laminar / turbulent flow, Korotkoff sounds

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

laminar flow  $Re < 2000$

turbulent flow  $Re > 3000$

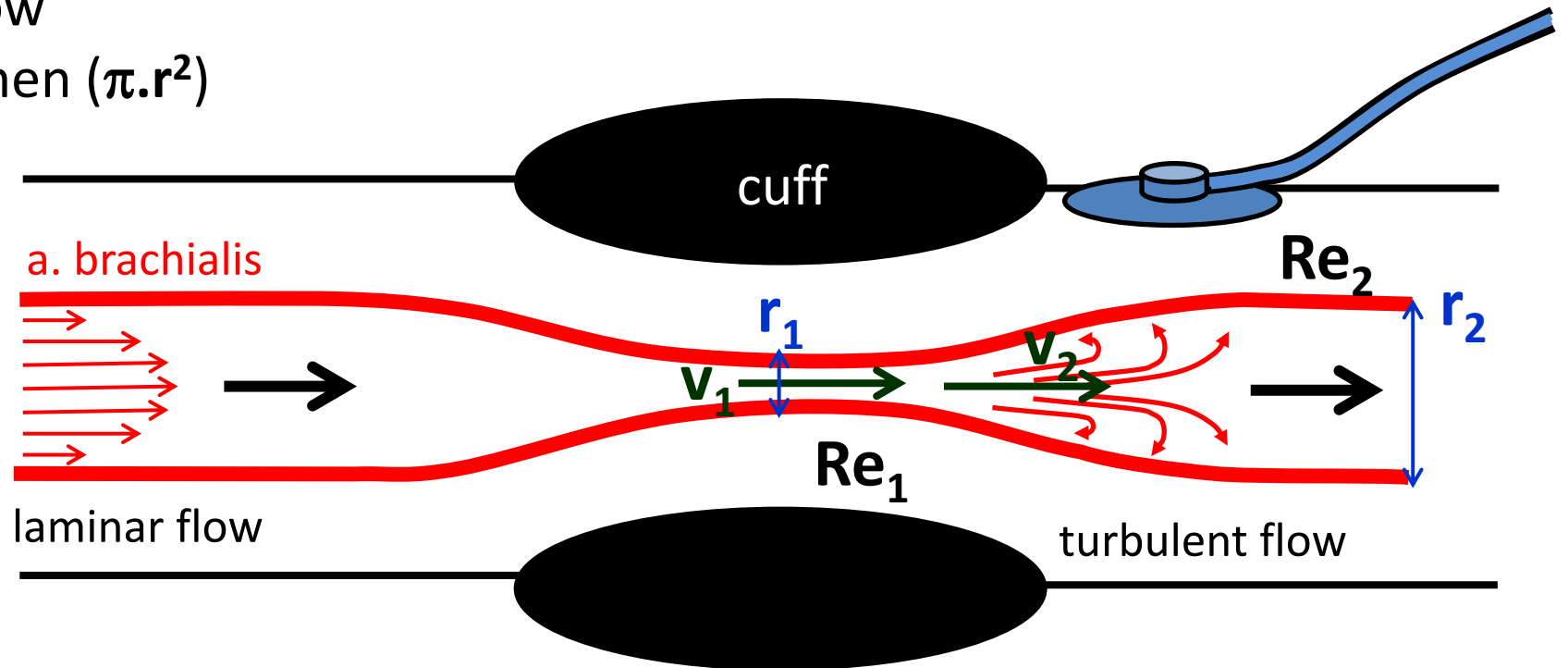
**Reynolds number Re:** predicts the transition from laminar to turbulent of flow

**v:** velocity of blood flow

**S:** area of vascular lumen ( $\pi \cdot r^2$ )

**$\rho$ :** density of blood

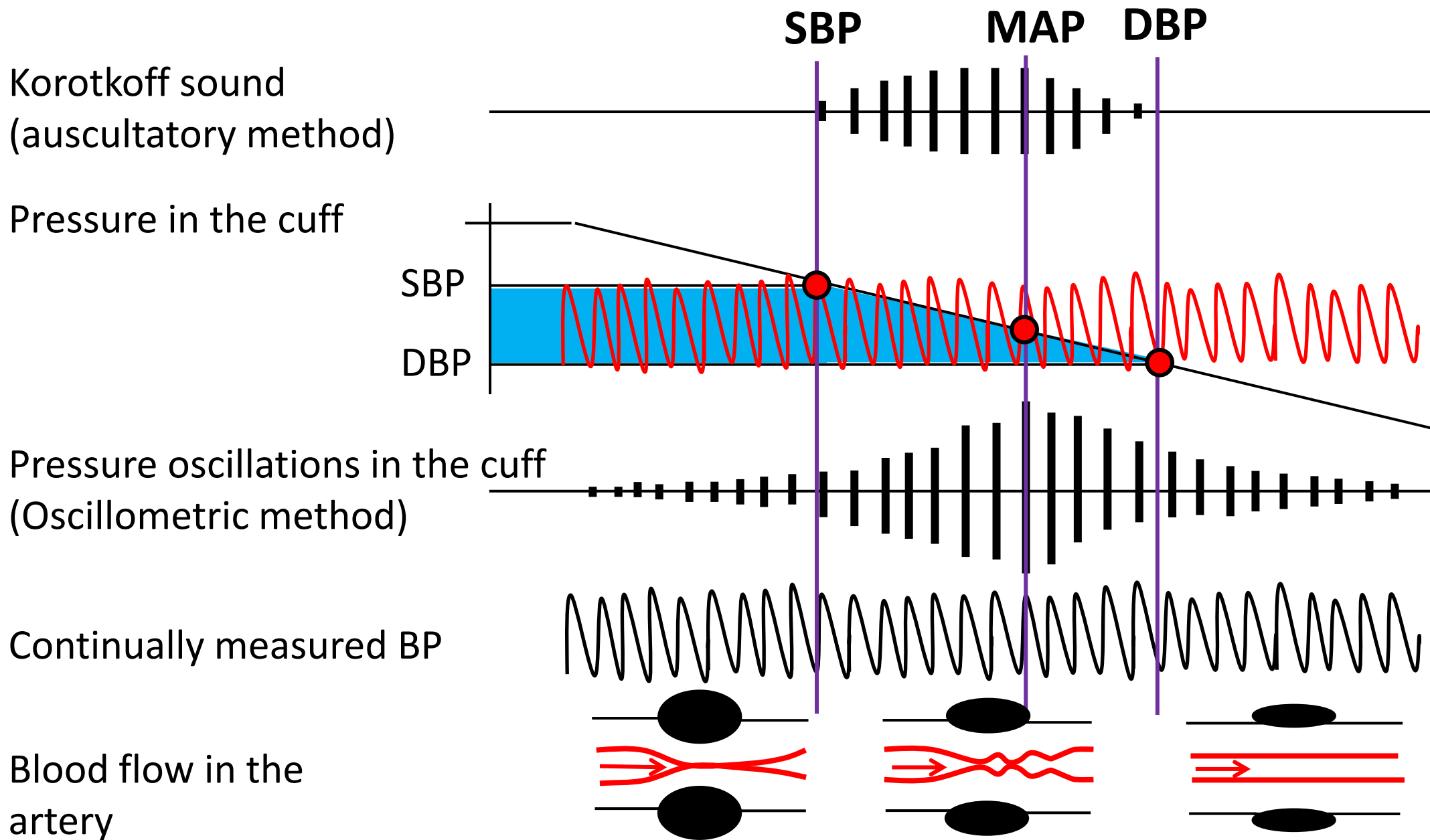
**$\eta$ :** viscosity of blood  
(higher in aneemia)



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

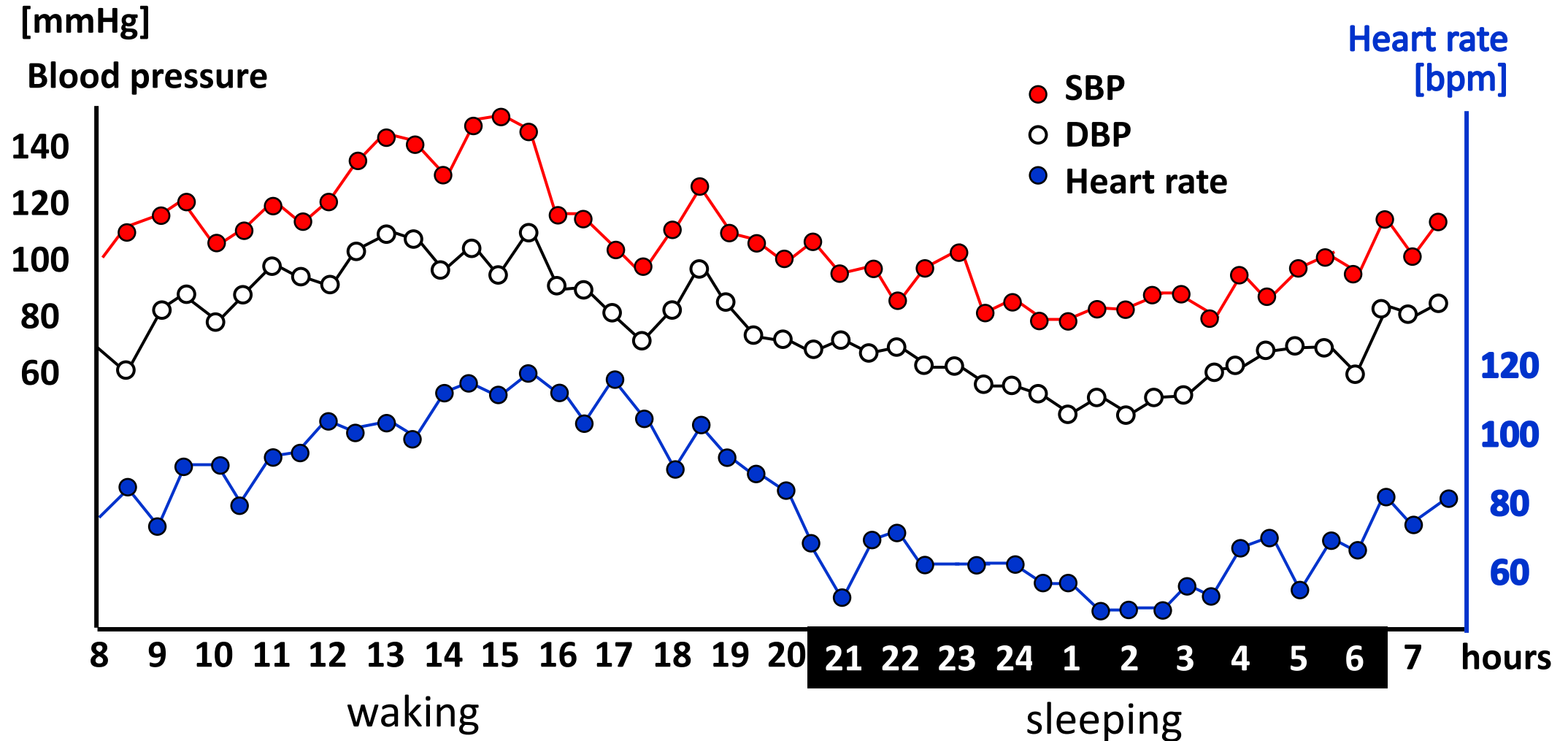


# Principles of blood pressure measurement



# 24-hour blood pressure monitoring

BP decrease during night: 10 - 15%



# During BP measurement following rules must be observed

- Patient is sitting for a few minutes before the measurement.
- Only validated apparatus must be used.
- Perform at least two measurements in the course of 1–2 minutes.
- Use cuff of standard size (12–13 cm width and 35 cm length); however smaller and bigger cuffs must be available for patients with smaller or bigger size of arm, respectively.
- Cuff must be always at the level of heart of examined person.
- Pressure in the cuff must be decreased slowly: 2mmHg/s.

methods	advantages	disadvantages	measured value
auscultatory	<ul style="list-style-type: none"> <li>• exact estimation of SBP/DBP</li> <li>• easy, it doesn't require electricity</li> </ul>	<ul style="list-style-type: none"> <li>• subjective, experience is necessary</li> <li>• SBP/DBP from different IBI</li> </ul>	STK a DTK
oscillometric	<ul style="list-style-type: none"> <li>• exact estimation of MAP</li> <li>• automatic, fast</li> <li>• BP can be measured by layman, cheap (home measurement)</li> </ul>	<ul style="list-style-type: none"> <li>• DBP/SBP is calculated (dependence on model, influence on shape of pulse wave)</li> <li>• SBP/DBP from different IBI</li> <li>• false values during arrhythmia</li> </ul>	MAP, sometimes SBP (it depends on device)
24 – hour BP monitoring	<ul style="list-style-type: none"> <li>• BP record from whole day</li> <li>• diagnosis of white-coat hypertension</li> </ul>	<ul style="list-style-type: none"> <li>• disruptive influence of measuring (during sleeping)</li> <li>• SBP/DBP from different IBI</li> </ul>	BP is measured each 15 – 60 min
photoplethysmographic (Peňáz)	<ul style="list-style-type: none"> <li>• continual BP record</li> <li>• possibility of beat-to-beat SBP/DBP calculation (BP variability analysis)</li> </ul>	<ul style="list-style-type: none"> <li>• measuring on the finger, brachial BP recalculating</li> <li>• expensive device</li> </ul>	continual BP record

# Diagnosis of hypertension

	blood pressure	SBP [mmHg]	DBP [mmHg]	possible complications
normal	optimal	<120	<80	
	normal	120 – 129	80 – 84	
	high normal	130 – 139	85 – 90	
hyper-tension	1. stage	140 – 159	90 – 99	without organ changes
	2. stage	160 – 179	100 – 109	hypertrophy of L ventricle, proteinuria, angiopathy, ...
	3. stage	> 180	> 110	morphological and functional changes of some organs, retinopathy, heart and renal insufficiency, ischemia of CNS, bleeding in CNS

- **isolated systolic hypertension:** SBP > 140 and DBP < 90
- high normal BP – annual monitoring recommended
- home measurement to exclude white coat hypertension
- **hypertension is diagnosed when:**
- average BP from 4 – 5 examinations is > 140/90
- BP during a home measurement repeatedly > 135/80
- mean BP from 24-hour monitoring is > 130/80

# Changes of blood pressure during exercise

- increase of BP depends on the type, intensity and duration of the load
- sympathetic activation: changes in the cardiovascular system serve to satisfy metabolic needs of working muscle
- impact of exercise on blood pressure
  - increased cardiac output →  $\uparrow$ STK
  - Redistribution of blood in the body - metabolic vasodilation in muscle (muscle increases blood flow), vasoconstriction in the GIT, skin and kidneys → maintaining or slight change in DBP (depending on the extent of the TPR decrease)
- vasoconstriction in the skin is temporary, since thermoregulatory mechanisms dominate
- DBP increases during isometric muscle work (eg. weightlifting)
- after exercise: decrease of BP on the initial or a slightly lower value, the blood flow in the muscle remains elevated until recovery
- Recovery interval is determined by the parasympathetic tone (can be increased training)