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Blood pressure

Physiology II – practice
Spring, weeks 7th-9th

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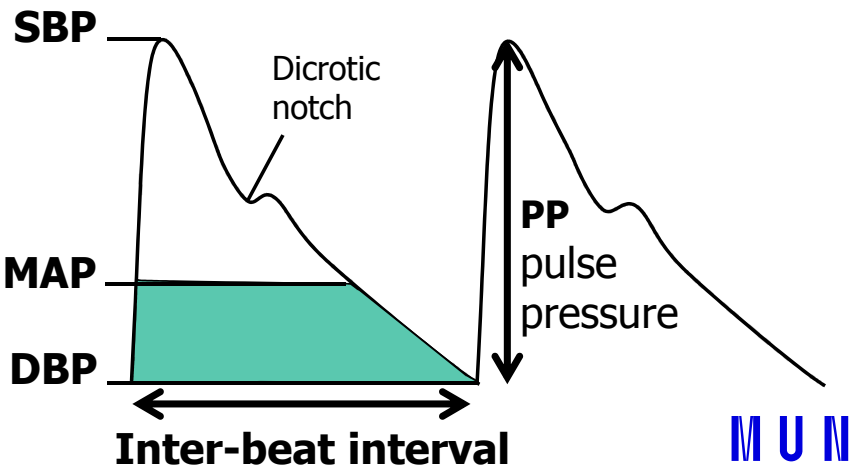
Arterial blood pressure curve

- **Blood pressure (BP): pressure of blood on the vessel wall**
  (arterial BP – part of the energy of systole converted into lateral pressure on the vascular wall)
- **Mean arterial pressure (MAP):** mean value of blood pressure in the inter-beat interval (IBI) – integral of the BP curve; **area above MAP = area below MAP**
  (MAP is an additional quantity, it is not the arithmetic mean of the systolic (SBP) and diastolic (DBP) pressure values, because the duration of systole and diastole during the cardiac cycle is different)
  aproximation: MAP = DBP + 1/3 PP (PP = SBP – DBP)
- **Definition:**
  - **SBP (systolic BP)**
    maximal of BP in the inter-beat interval
  - **DBP (diastolic BP)**
    minimal BP in the inter-beat interval
  - Attention: Values of SBP and DBP vary in different parts of the cardiovascular system



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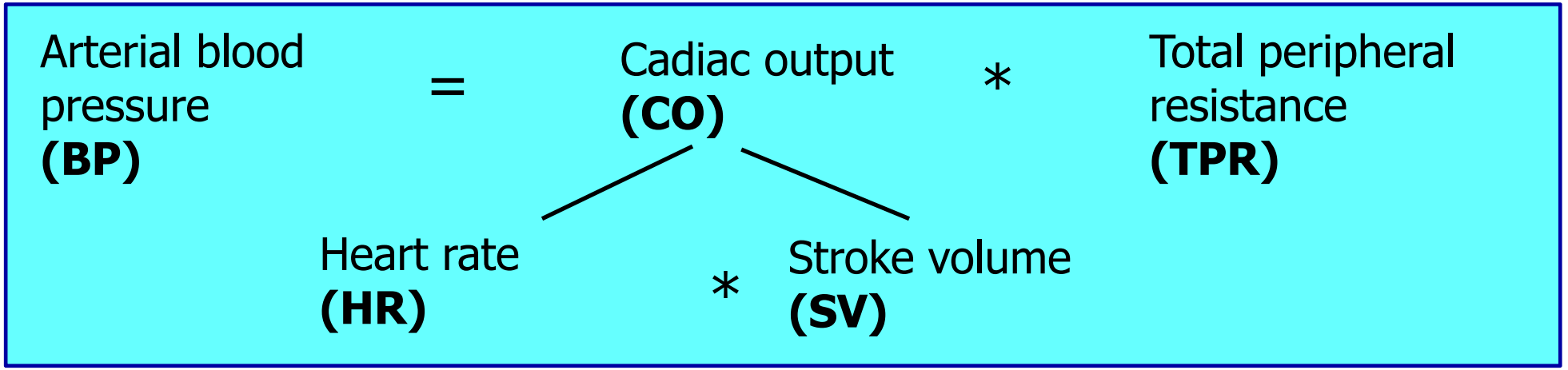
Blood pressure

MAP is a function of cardiac output (CO) and total peripheral resistance

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



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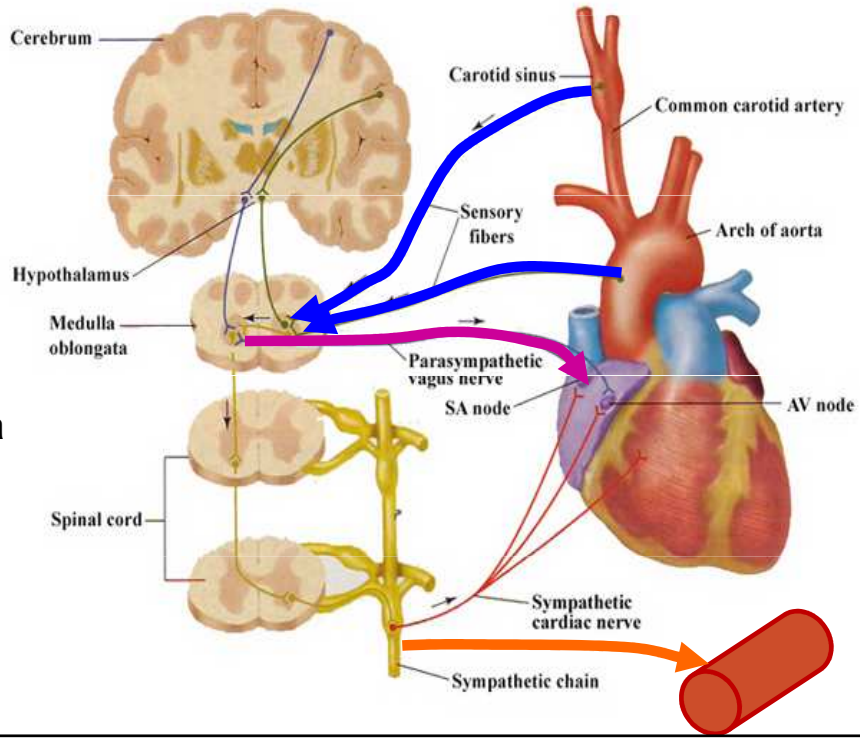
Blood pressure regulation

- Short-term – neural control, mainly baroreflex
- Middle-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 (↑ BP, HR, SV, TPR) X parasympathetic nerves (↓ BP, HR, SV, TPR)
- Function: rapid regulation of BP via changes in HR and TPR
  - baroreceptors – sinus caroticus + sinus aorticus; afferentation: n. vagus, n. glossopharyngeus
- Cardiac branch of baroreflex:
  - Parasympathetic efferentation: rami cardiaci n. vagus to SA node - ↓ HR and cardiac contractility
  - Sympathetic efferentation: n.cardiaci to SA node - ↑ HR and cardiac contractility
- Peripheral branch of baroreflex:
  - Only sympathetic efferentation: sympathetic vascular innervation (mainly of arterioles)
    ↑ BP → ↓ TPR due to vasodilation in peripheral circulation and vice versa (↑TPR due to vasoconstriction)

(notice: vasoconstriction of small arteries and arterioles, venoconstriction – blood redistribution)



Blood pressure changes

- Short-term influences
  - blood volume – influence on cardiac output (bleeding, dehydration)
  - external pressure to the vessels – intrathoracic and intraabdominal pressure (cough, defecation, childbirth, artificial ventilation)
  - position – orthostasis/clinostasis: redistribution of blood due to gravity
  - CNS – emotions, mental stress, …
  - physical exercise – BP changes depend on intensity, duration and type of exercise
  - heat (↓ TPR), cold (↑ TPR)
  - alcohol, medicaments,…
- Long-term influences
  - age (the fastest changes during childhood and adolescence, in adults slow increase in SBP)
  - sex (men have higher BP)
  - genetics

Methods of the arterial BP measurement

In practicals

Palpatory
(sphygmomanometer)

Oscillometric

Auscultatory
(sphygmomanometer,
stethoscope)

Another methods:

24-hour blood pressure monitoring

Photoplethysmografic (volume-clamp method, Peňáz)

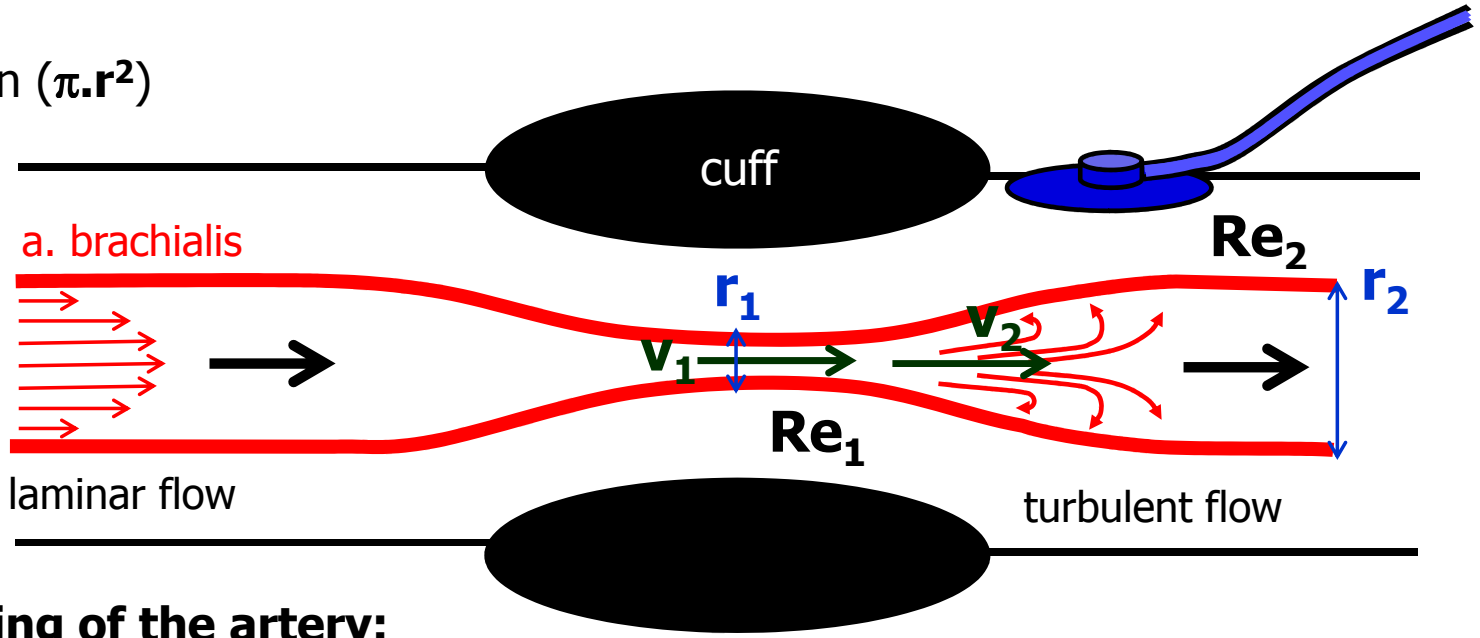
Basic principle: Laminar / turbulent flow

(Korotkoff sounds in auscultatory method; oscillation in oscilometric method).

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

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 ($\pi.r^2$)
ρ: density of blood
η: viscosity of blood
(lower in anemia)



closely behind narrowing of the artery:

$S_1 < S_2$ a $v_1 \approx v_2 \rightarrow Re_1 < Re_2 \rightarrow$ turbulent flow

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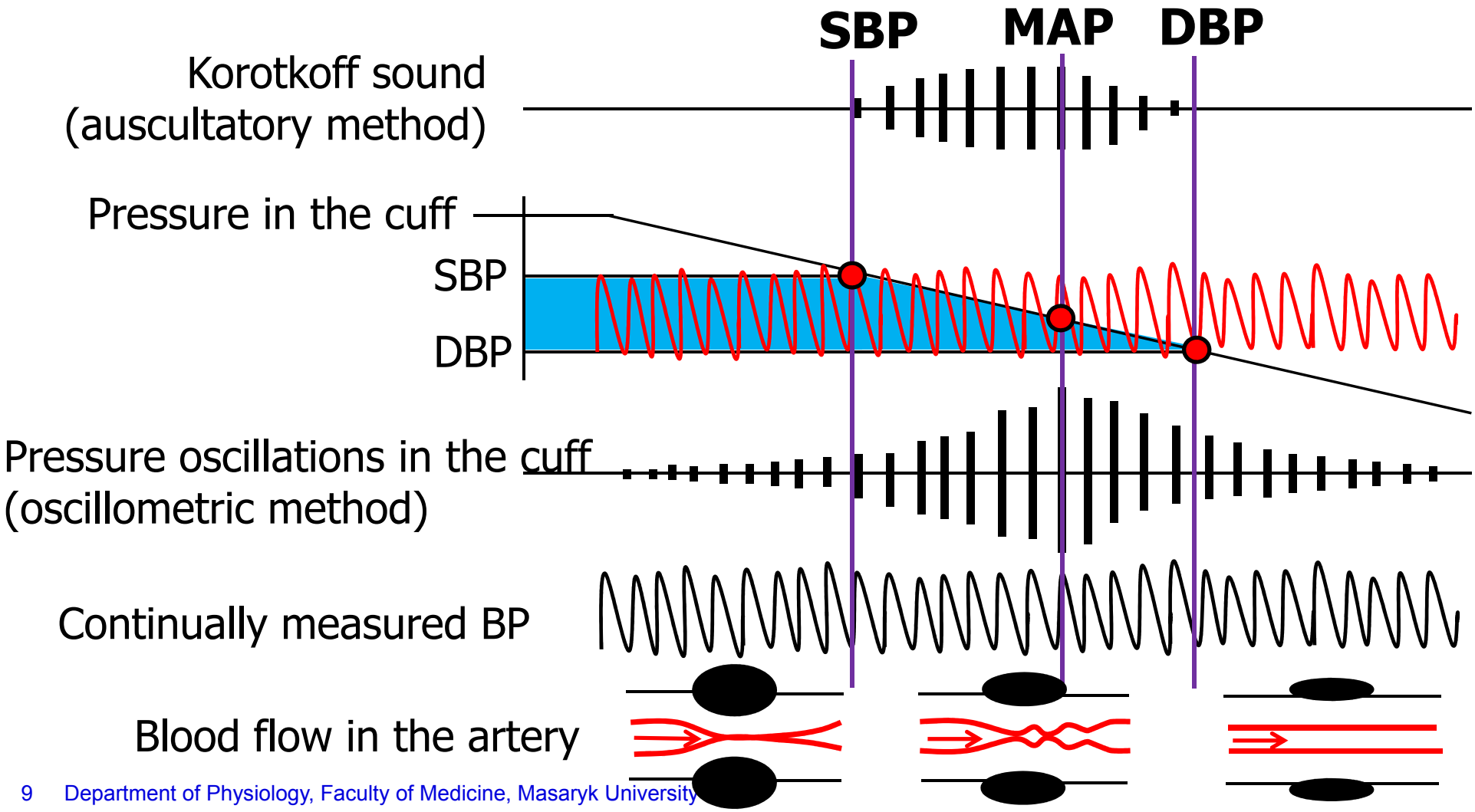
Principles of BP measurement



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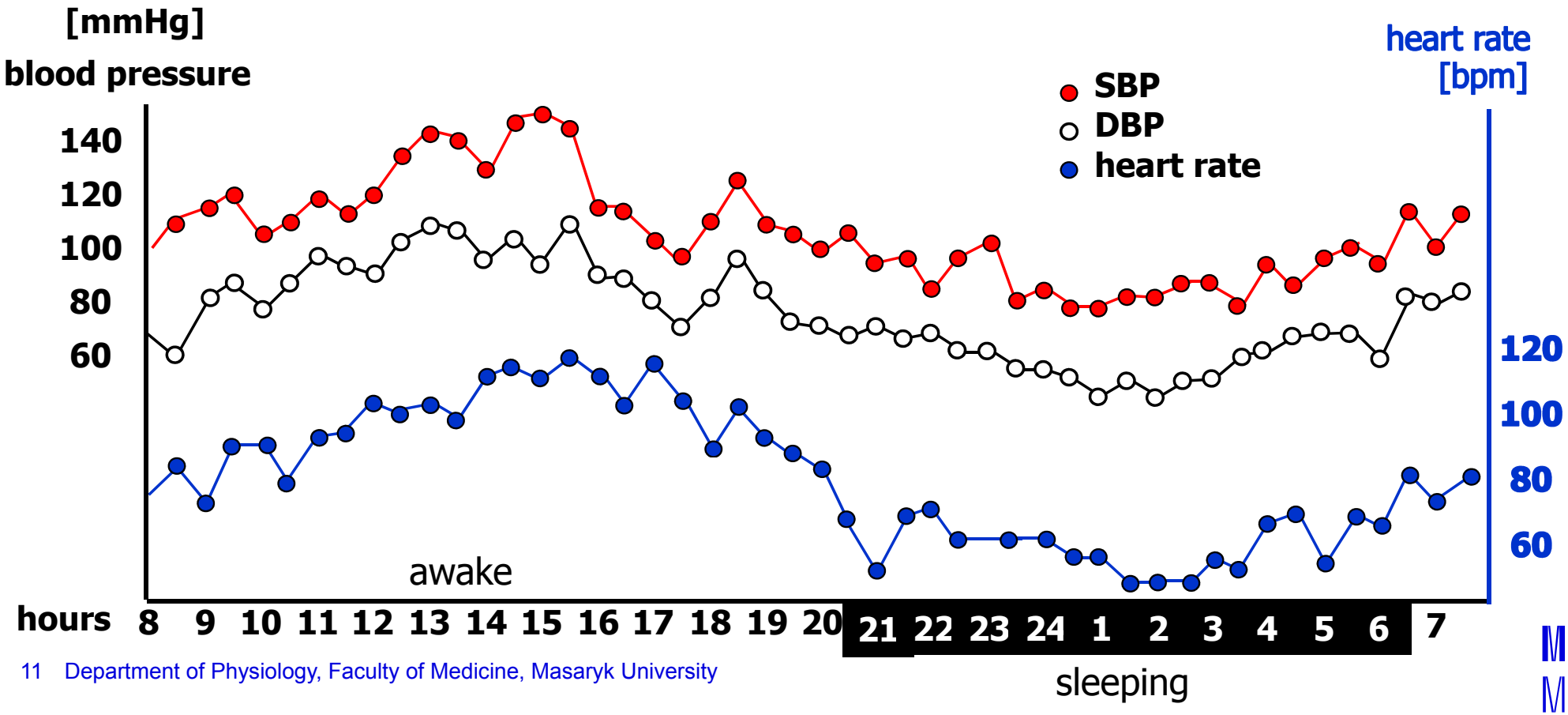
Rules for BP measurement

- Environment: pleasant room temperature, quiet surroundings
- Position: the patient sits with his back leaning backwards, both legs are on the floor, forearm rests on a surface
- Reasonable cuff size, correct positioning at heart level
- The measurement happens at rest and starts after 5 – 10 minutes of sitting down
- Measurement by auscultatory method
  - Inflate the cuff to a pressure 30 mmHg higher than the pressure at which the radial pulse disappeared
  - The pressure reduction rate in the cuff is 2 – 3 mmHg/s
  - The pressure value is determined with 2 mmHg accuracy
- The BP should be measured 3 times at least five minutes apart and the final BP value is a mean value of the last two measurements

24-hour blood pressure monitoring

BP decrease during night: 10-15%



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method	advantages	disadvantages	measured value
auscultatory	• exact estimation of SBP/DBP • easy, it doesn´t require electricity	• subjective, experience is necessary • SBP/DBP from different IBI	SBP and DBP
oscillometry	• exact estimation of MAP • automatic, fast • BP can be measured by layman, cheap (home measurement)	• DBP/SBP is calculated (dependence on model, influenced by a shape of pulse wave) • SBP/DBP from different IBI • false values during arrhythmia	MAP, sometimes SBP (it depends on a device)
24-hour BP monitoring	• BP record from whole day • diagnosis of white-coat hypertension	• disruptive influence of measuring (during sleeping) • SBP/DBP from different IBI	BP is measured each 15–60 min
photople-thysmography (Peňáz)	• continual BP record • possibility of beat-to beat SBP/DBP calculation (BP variability analysis)	• measurement on a finger, brachial BP is calculated • expensive device	continual BP record

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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	
hypertension	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 mmHg
- 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 mmHg
  - BP during a home measurement repeatedly > 135/80 mmHg
  - mean BP from 24-hour monitoring is > 130/80 mmHg

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Changes in blood pressure during exercise

- Increase in BP depends on the type, intensity and duration of the exercise
- Sympathetic activation: changes in the cardiovascular system serve to satisfy the metabolic needs of working muscle
- Impact of exercise on blood pressure:
  - Increased cardiac output → ↑ SBP
  - Redistribution of blood in the body – metabolic vasodilation in muscle (increased blood flow in the muscle), 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, till thermoregulatory mechanisms dominate
- DBP increases during isometric muscle work (e.g. weightlifting)
- After exercise: decrease in BP to resting values or slightly lower values, the blood flow in the muscle remains elevated until recovery
- Recovery interval is determined by the parasympathetic tone (can be increased by training)

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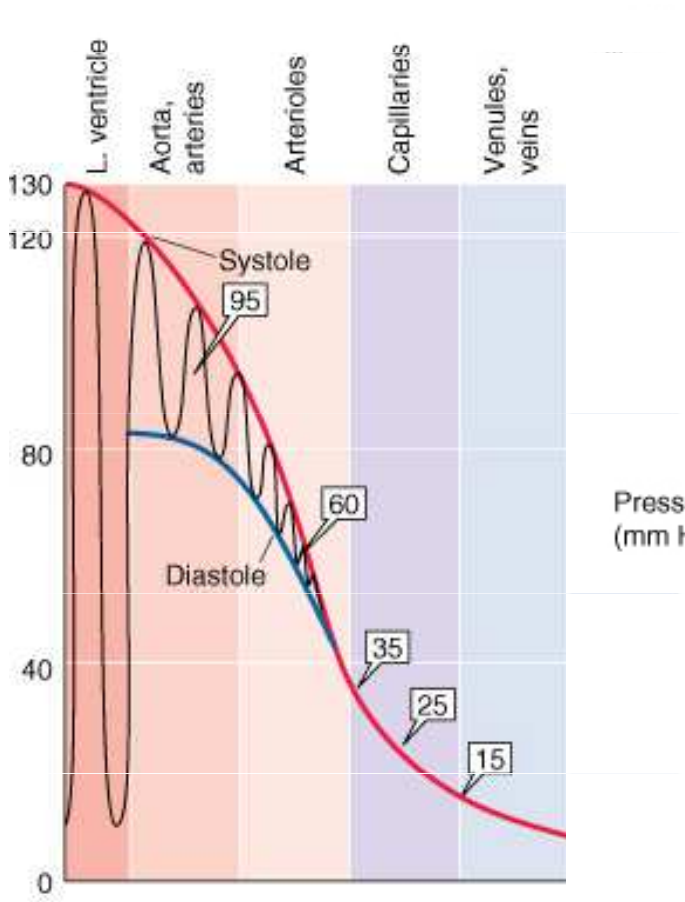
In addition

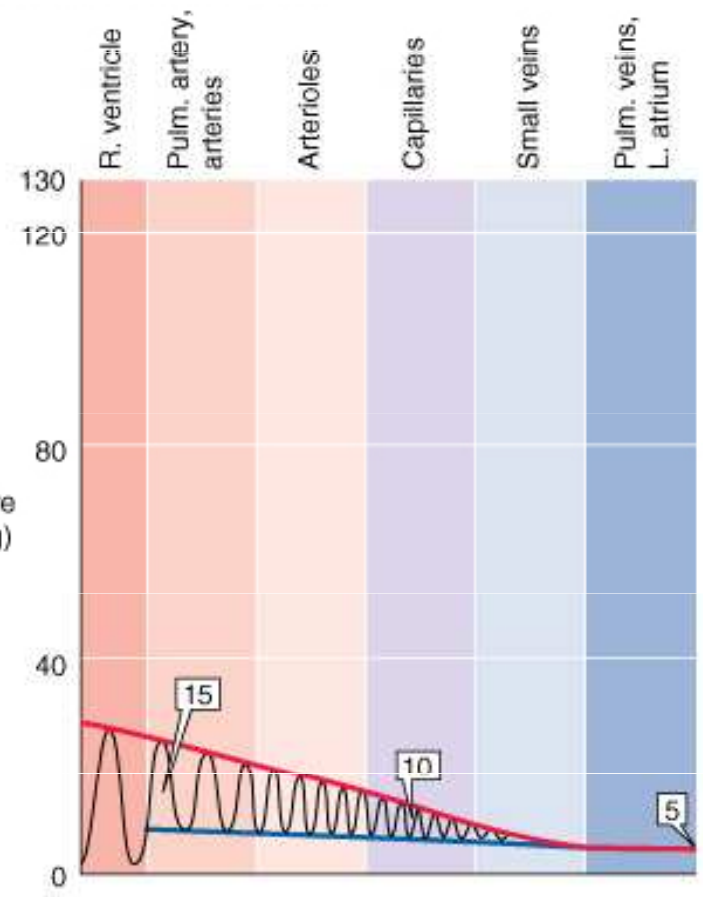
Blood pressure

Large circle



Pressure (mm Hg)

Small circle



Boron and Boulpaep, Medical physiology

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Arteries – „garden" analogy

Baroreflex

- A decrease in arterial pressure leads to sympathetic activation → an increase in heart rate (and cardiac output) and peripheral resistance
- An increase in arterial pressure leads to activation of the parasympathetic nervous system → a decrease in heart rate (and cardiac output) and, indirectly, in peripheral resistance

Heart
cardiac output

Carotids
perfusion pressure in the brain

Arteries,
arterial BP

The primary purpose of BP neural regulation is to maintain constant perfusion pressure in the brain.

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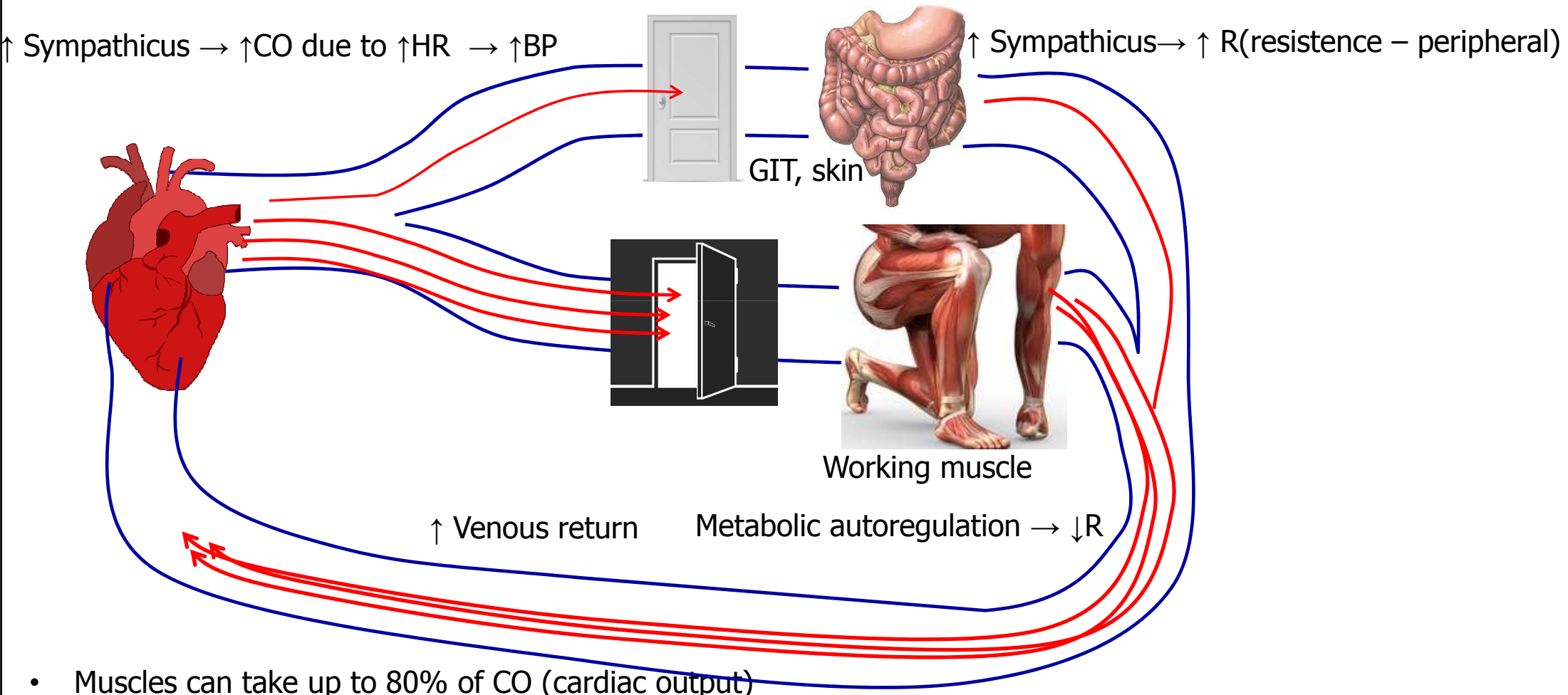
Changes in cardiovascular system during exercise



- Muscles can take up to 80% of CO (cardiac output)
- After the sudden termination of heavy exercise without slowing down – "bleeding out into the muscle" – the heart has already decreased CO, but the vessels of the muscle are still dilated – blood redistribution to the muscle – strong drop in BP – fainting

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