

Physiological demonstration

Continual blood pressure
measurement
Baroreflex sensitivity
(spring semester 2024)



Blood pressure

blood pressure is in the **entire** cardiovascular system

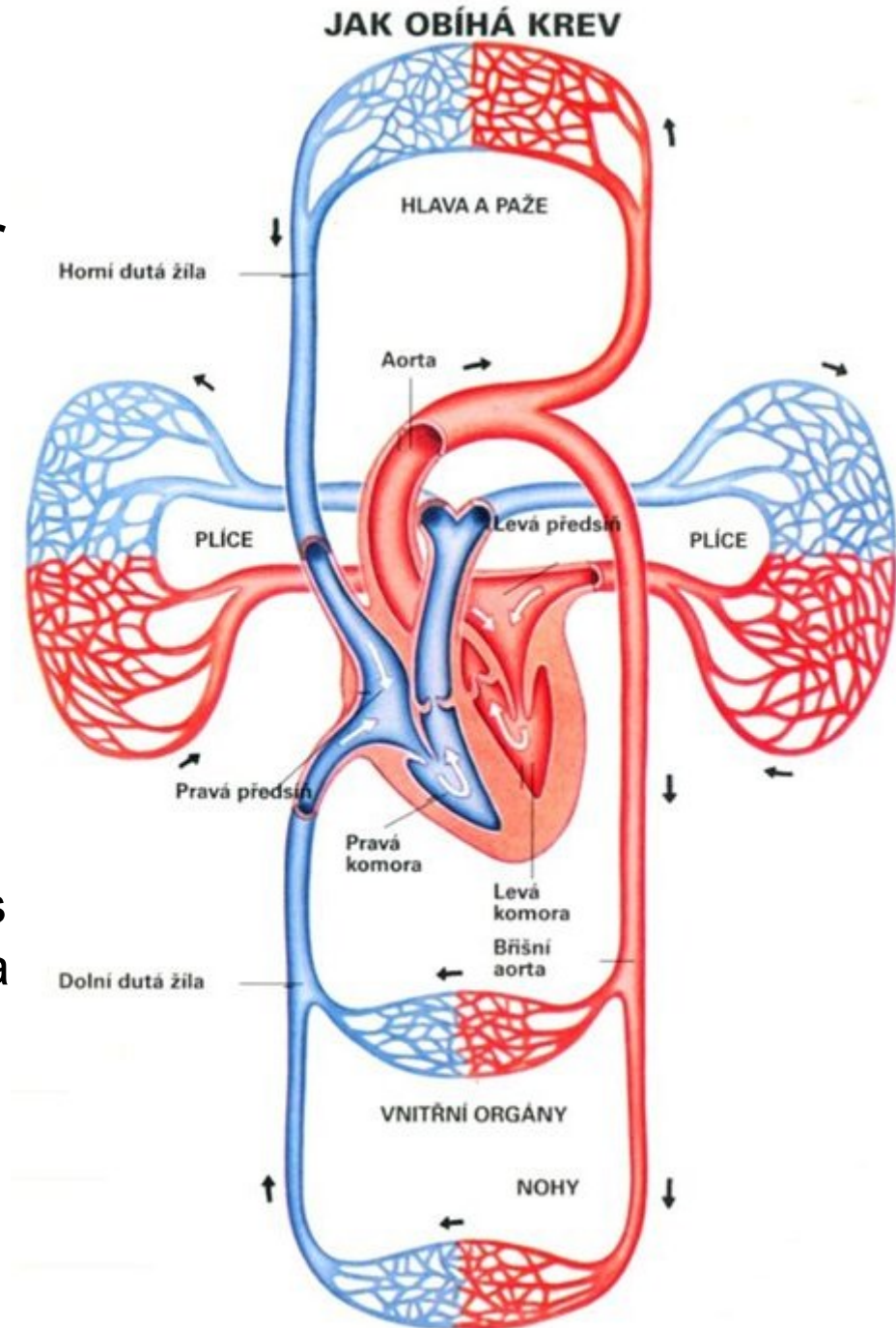
- **Arterial pressure** – the driving force for blood flow through blood vessels

(mainly through brain – cerebral perfusion pressure
 $CPP = MAP - ICP$)

- **basic vital function variable**

other pressures and their significance

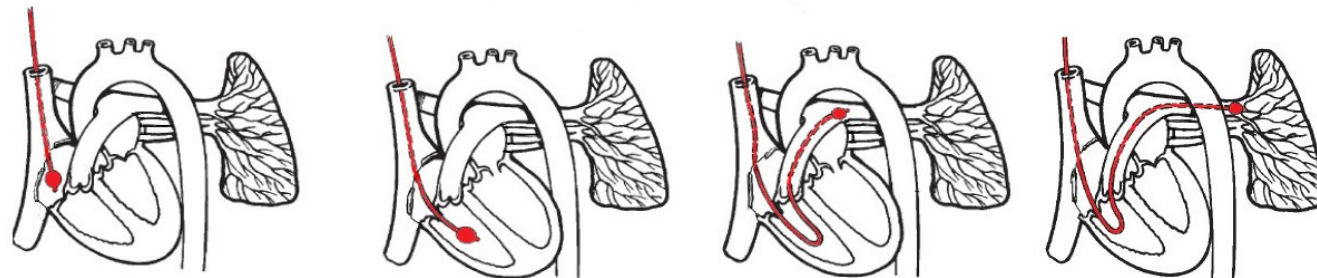
- Atrial and ventricular pressures – cardiac function variables
- Pulmonary pressure (<20 mmHg) – increased pressure is a sign of pulmonary hypertension
(primary – of endothelial origin, secondary – a consequence of lung diseases or left heart failure)
- Central venous pressure (0-8 mmHg)
monitoring of right heart function and intravascular filling (venous return, hydration)
- Capillary pressure (15 – 30 mmHg) –
assessment of tissue blood supply, risk of edema



Blood pressure measurement in the heart



- Right access – catheter with pressure sensor through v. subclavia/jugularis/femoralis
 - Vena cava → right atrium → right ventricle → a. pulmonaris → Pulmonary Capillary Wedge Pressure (equal to pressure in left atrium)
- Left access – catheter through a. radialis/brachialis/femoralis
 - Aorta → left ventricle



https://www.wikiskripta.eu/w/Pravostrann%C3%A1_srdce%C4%8Dn%C3%AD_katetrizace

Arterial blood pressure

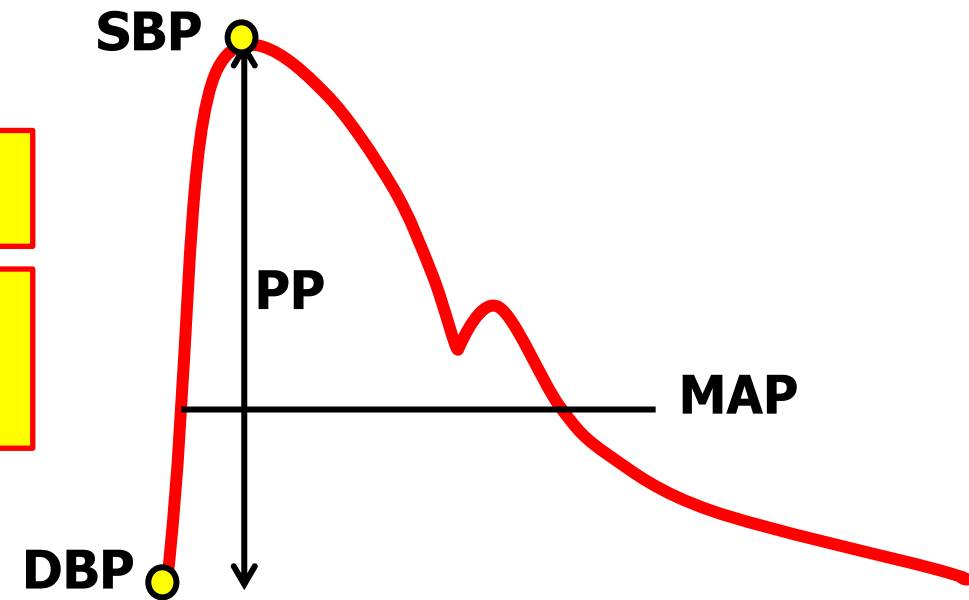
is a continual variable

Constant component $MAP = CO \cdot R = SV \cdot HR \cdot R$

Pulsation component $PP = \frac{SV}{C}$

Variables determining arterial pressure:

- CO – cardiac output
- SV – stroke volume
- HR – heart rate
- R – resistance
- C – compliance



– **Methods** of continual blood pressure measurement

- Invasive – arterial catheter
- Non-invasive – photoplethysmography (Peñáz's method)

Invazivní metoda měření arteriálního tlaku

– In patients with critical threat to vital functions (ICU)

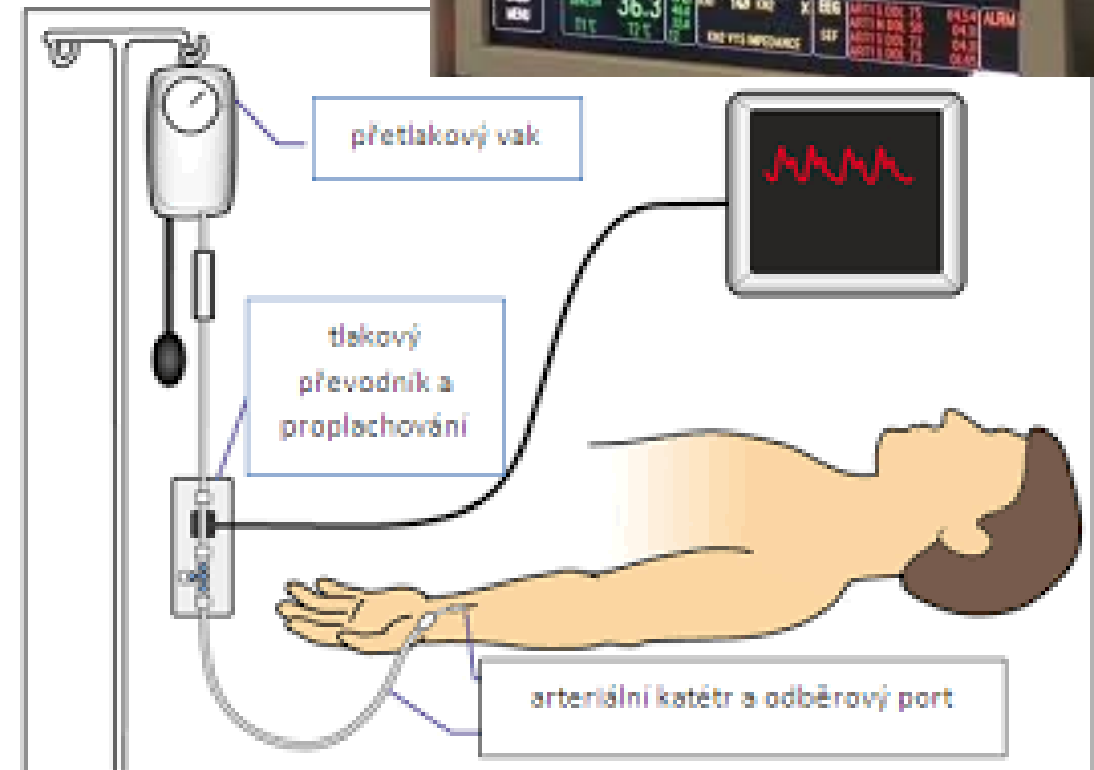
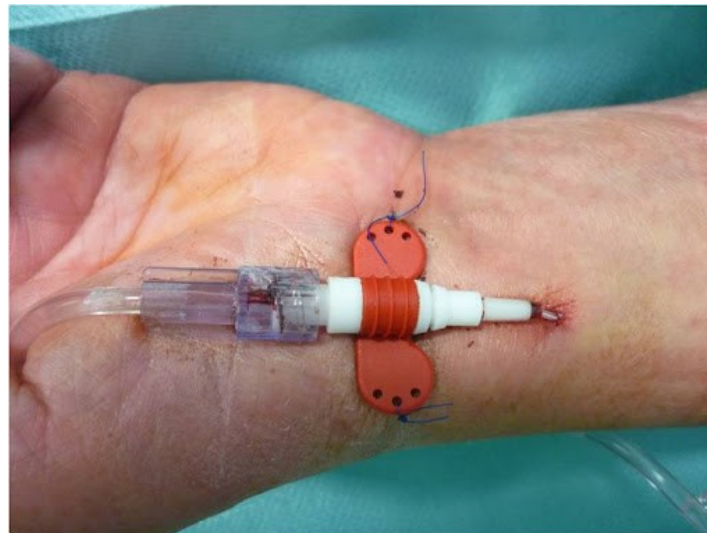
- critical hypotension, vasopressor administration
- Brain perfusion monitoring (CPP = MAP-ICP)

– Advantages

- accurate
- Collection of arterial blood for analysis of ABR, iont balance, etc. (needle-less acces)

– disadvantages

- infection
- bleeding



Principle of non-invasive continual blood pressure measurement

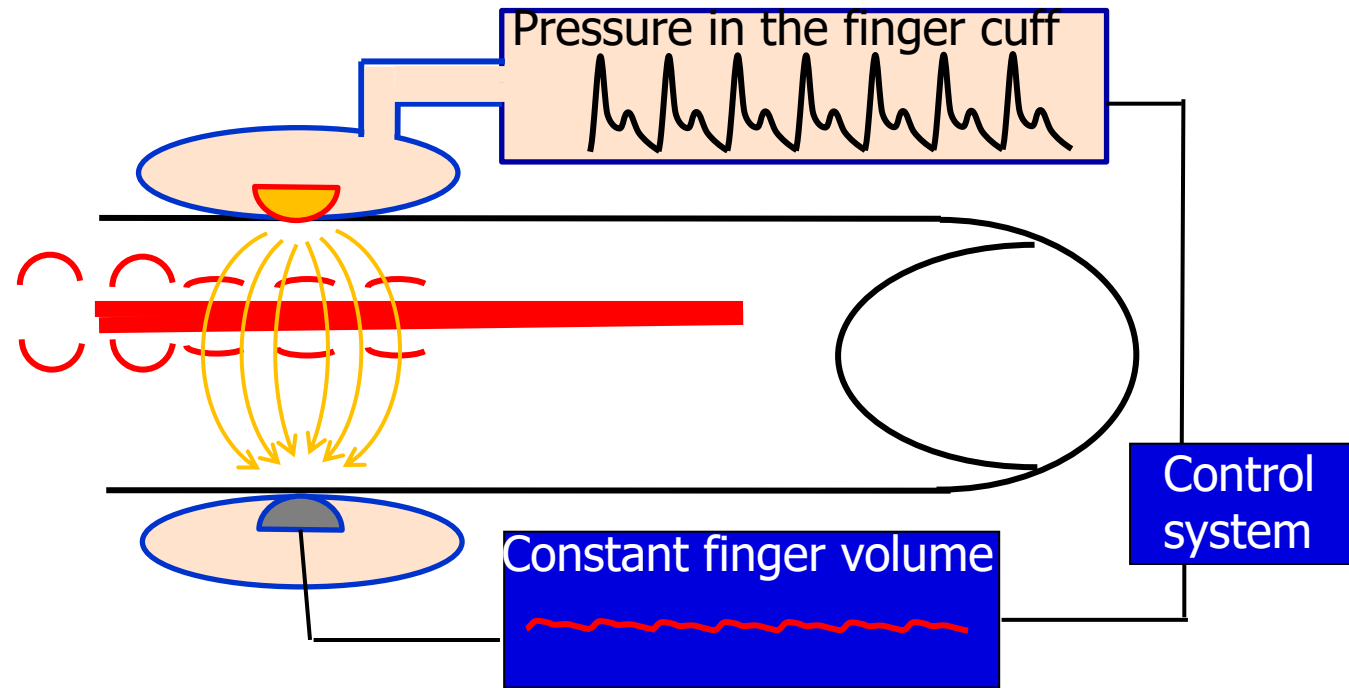
– Photoplethysmographic/Peñáz/volume-clamp method

Control system:

Correction of the pressure in the finger cuff according to the arterial lumen changes.

Aim: maintaining of constant arterial lumen through pressure changes in the cuff.

Tlak v manžetě pak kopíruje arteriální tlak



Arterial lumen
(finger volume)

application of control system

Pressure
in the cuff

Before application of
control system



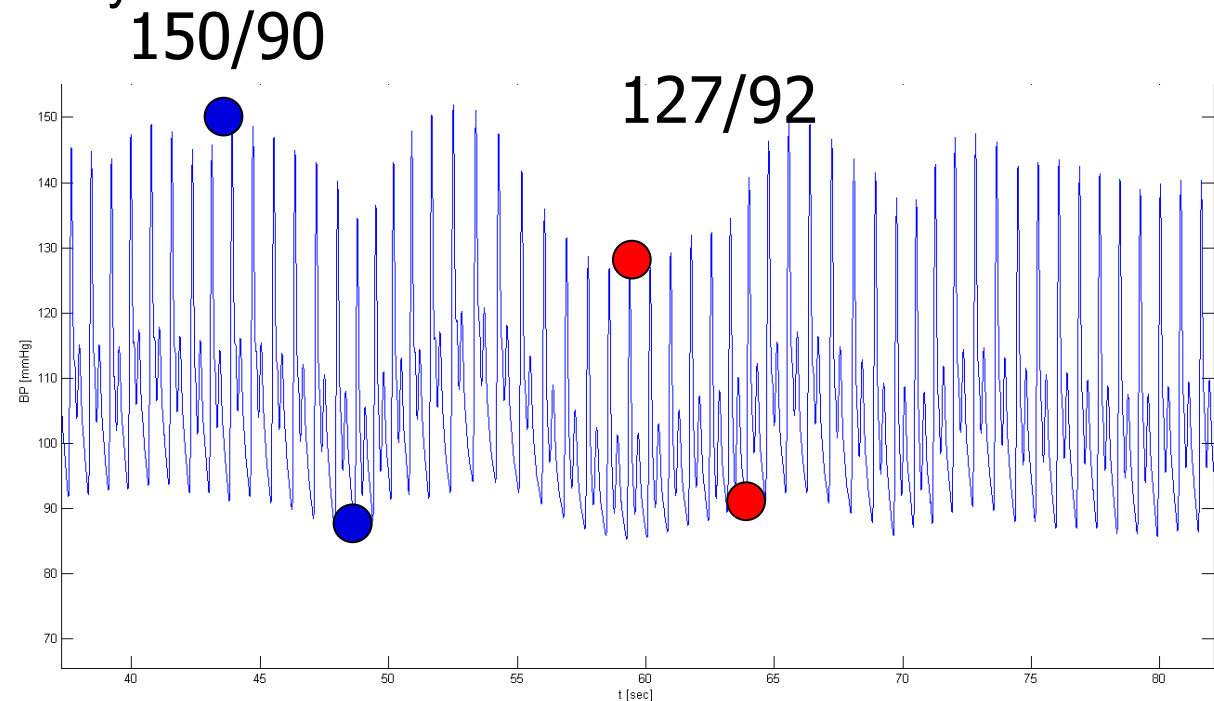
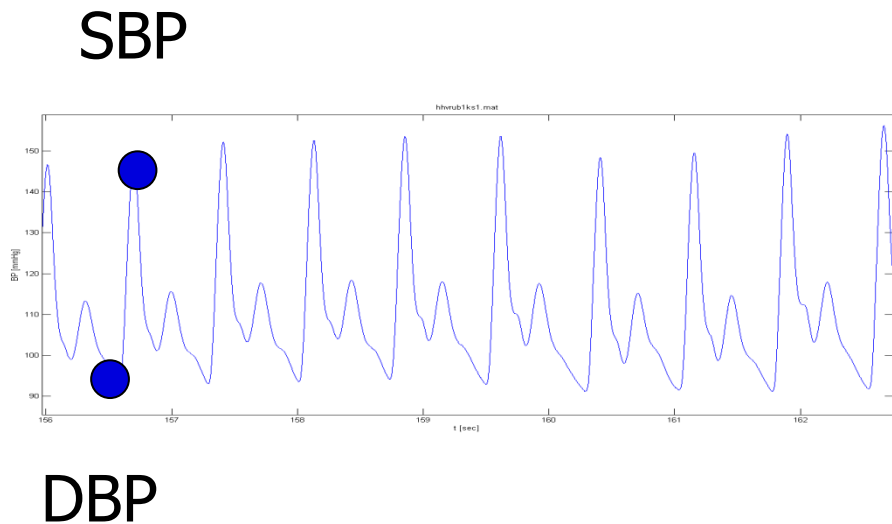
Neinvazivní kontinuální měření krevního tlaku

– advantages

- non-invasive (safer, painless), continuous recording (evaluation of short-term variability, detection of beat-to-beat values, research, monitoring)

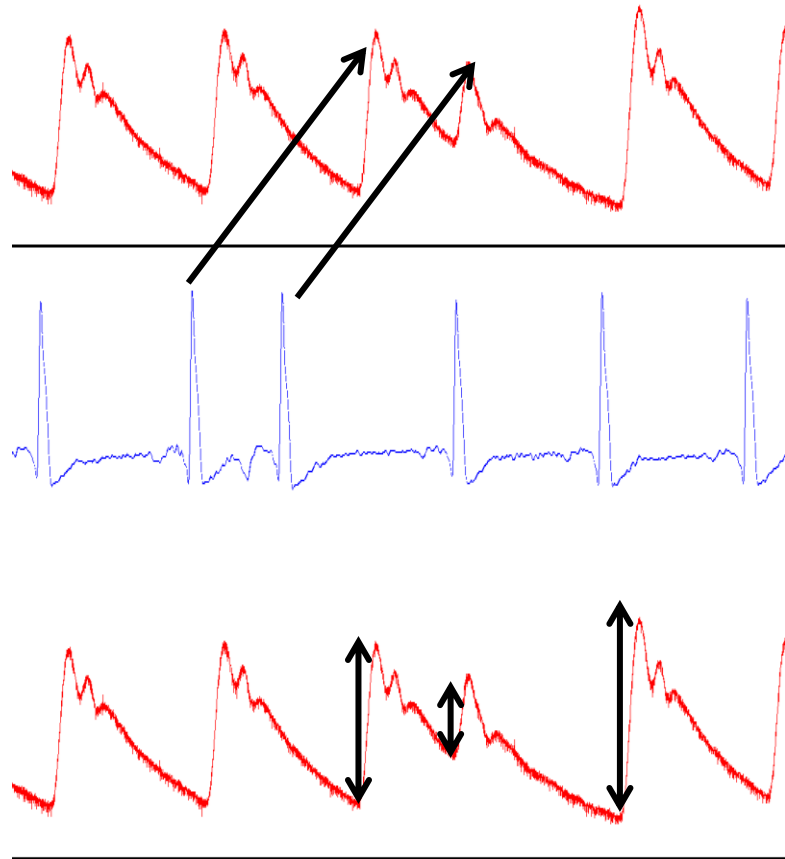
– disadvantages

- Long-term pressure of the finger with the cuff affects the results, it is not accurate for part of the population, calibration with the arm cuff is necessary

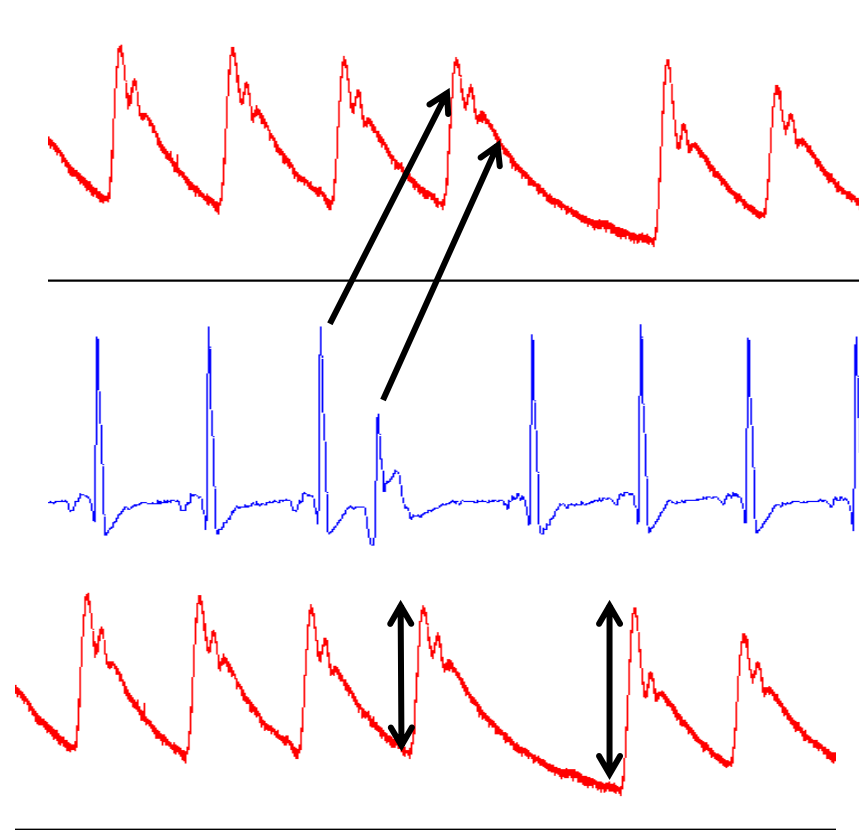


Extrasystoles

supraventricular



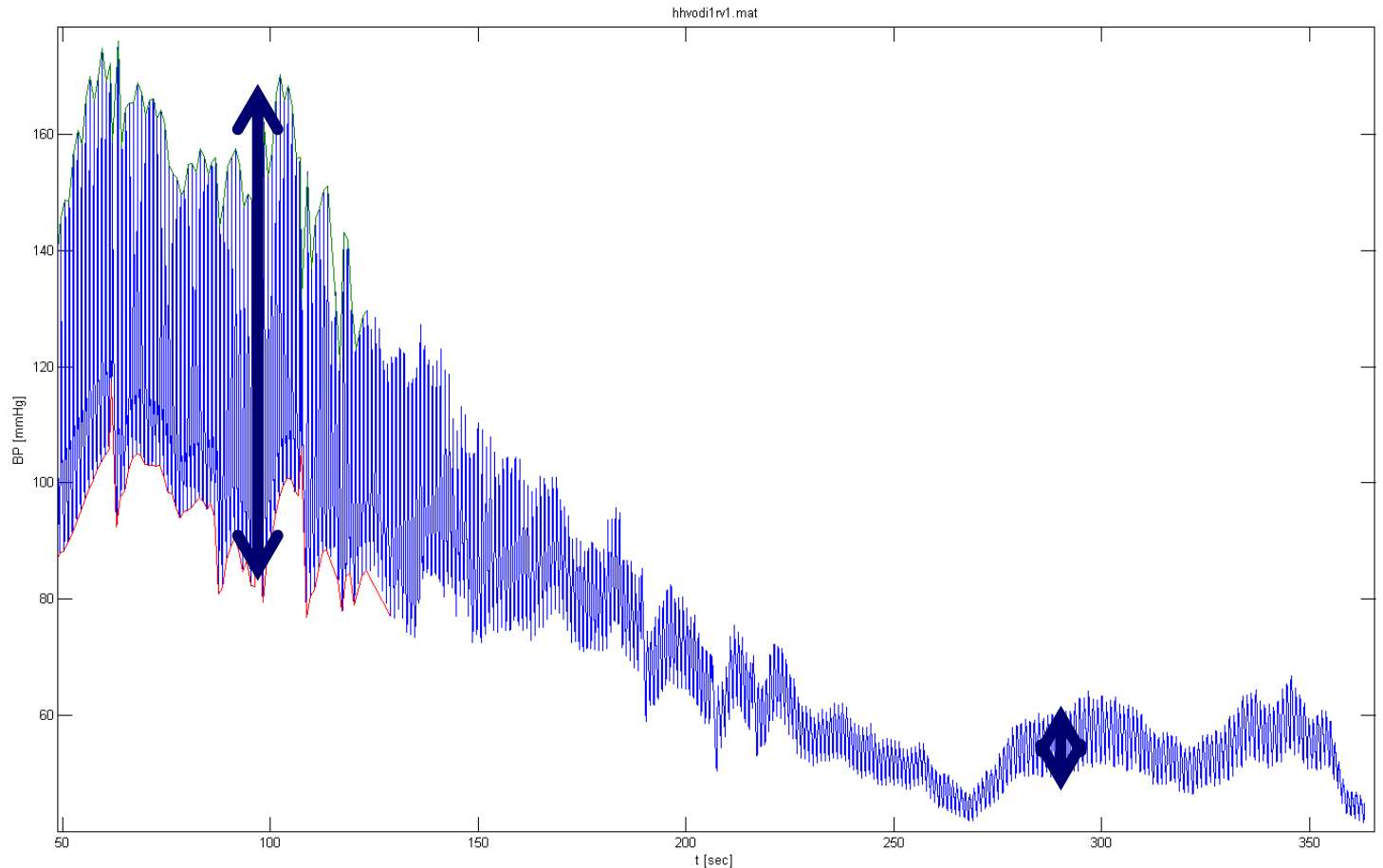
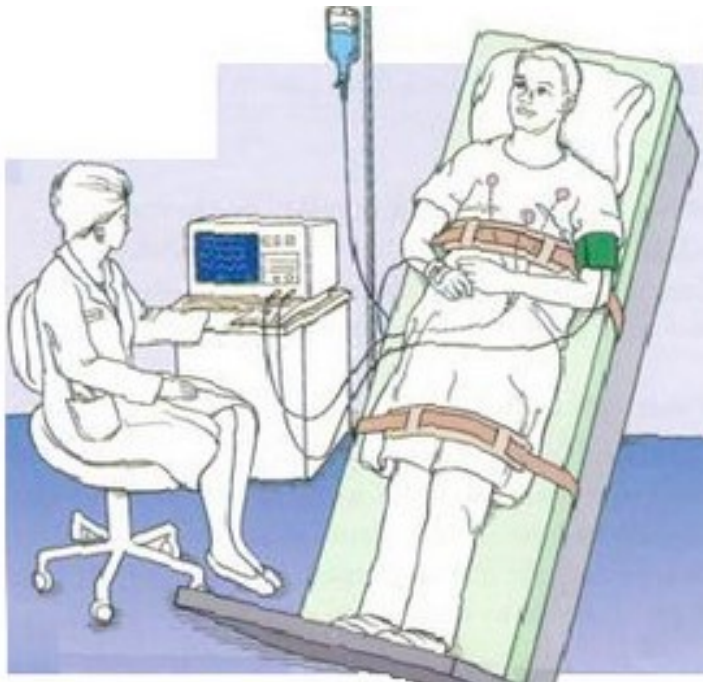
ventricular



Orthostatic hypotension diagnosis

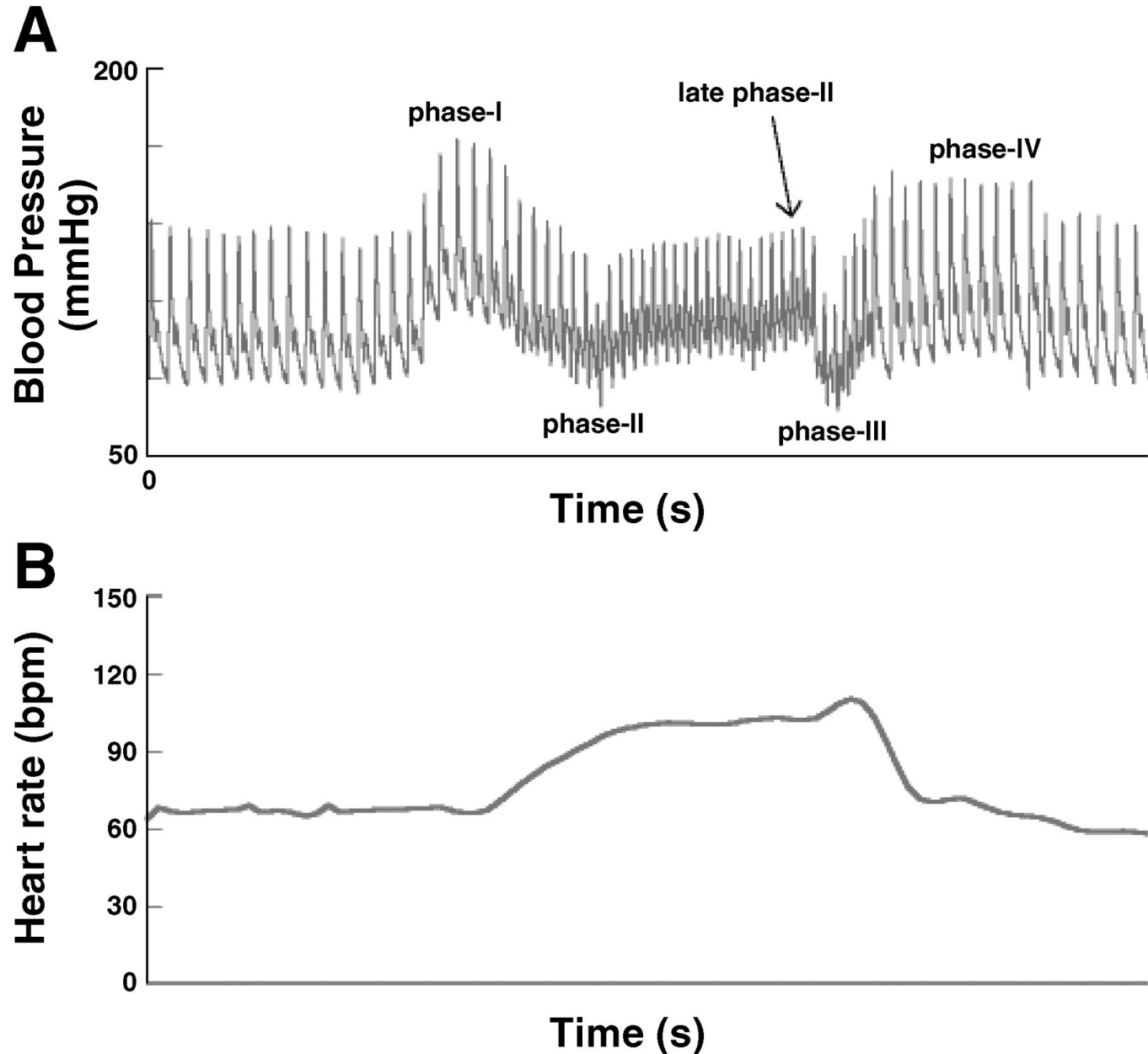
– Tilt-table test

If there is such a significant drop in blood pressure when patient is tilting that syncope occurs, the test is positive



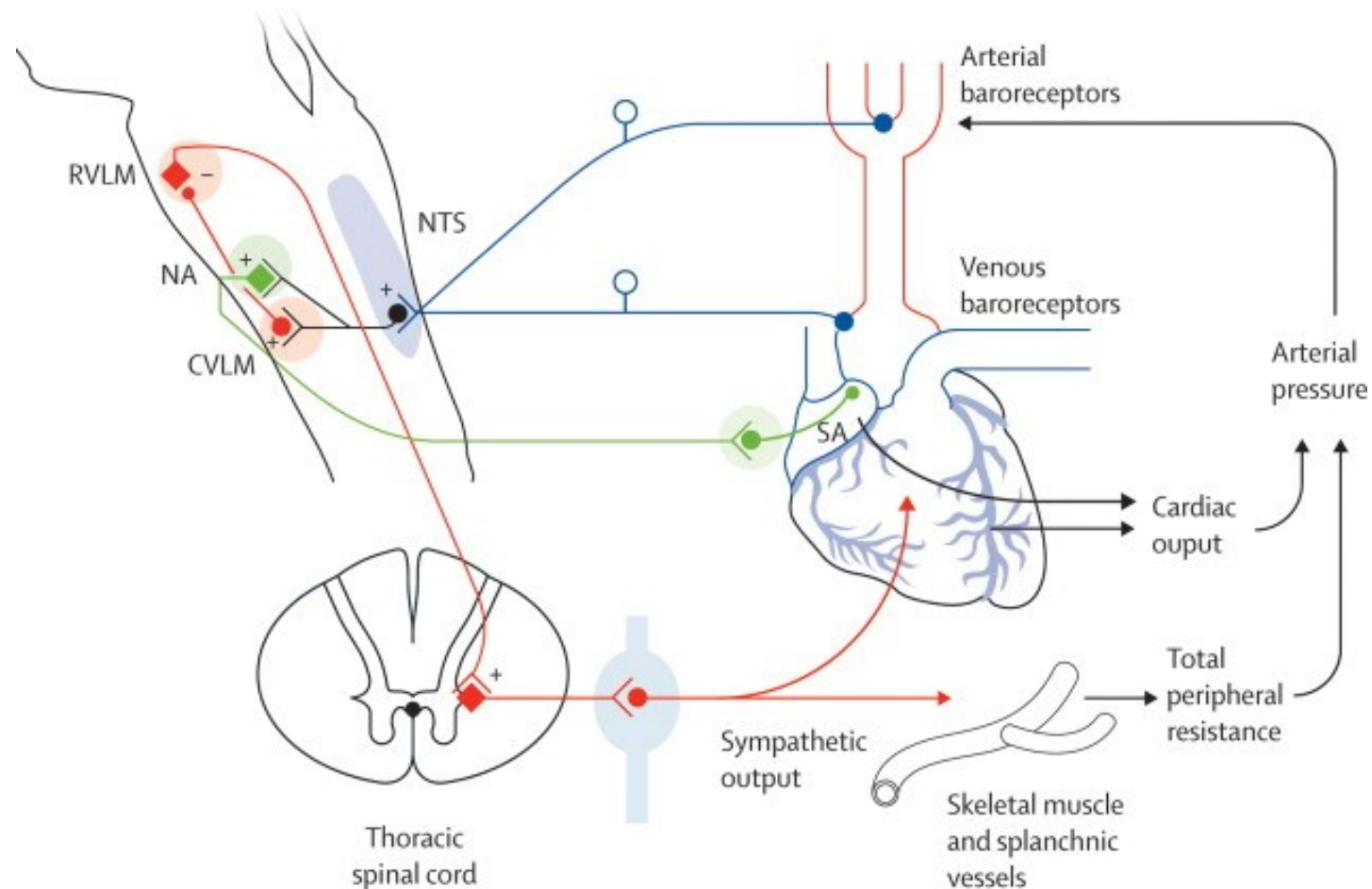
Valsalva maneuver

- **Phase I:** exhalation against a closed glottis. Transiently, the intrathoracic pressure rises and so does the pressure on the arteries in the chest. There will be a transient increase in pressure.
- **Phase II.** Exhalation continues against the closed glottis. High intrathoracic pressure compresses the vena cava. Venous return decreases and thus cardiac filling, cardiac output, and blood pressure decreases. The baroreflex responds to this by accelerating the heart rate.
- **Phase III.** Release of intrathoracic pressure and free breathing. Blood pressure drops temporarily because the pressure in the chest on the thoracic arteries decreases.
- **Phase IV.** A drop in intrathoracic pressure will restore venous return. Increased cardiac filling and systolic volumes will increase blood pressure and pulse amplitude. The baroreflex responds to an increase in blood pressure and reduces the heart rate. This phase is used to assess baroreflex sensitivity.
- Note The Valsalva maneuver with its bradycardic part is used as the first method to stop supraventricular tachycardia.



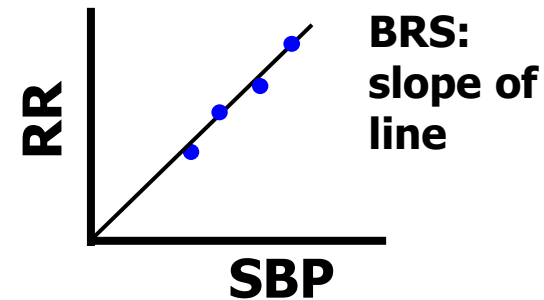
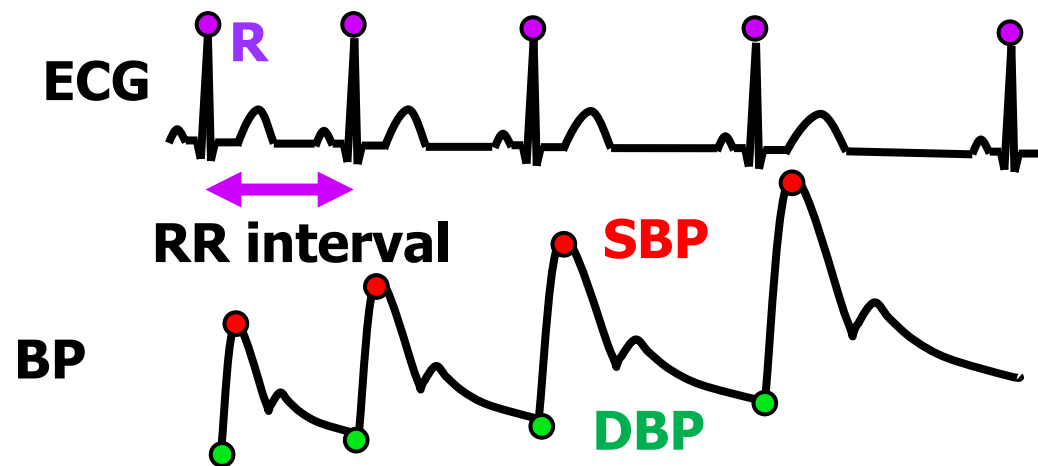
Baroreflex

- Fast regulation of arterial blood pressure by changes of heart rate and peripheral vascular resistance



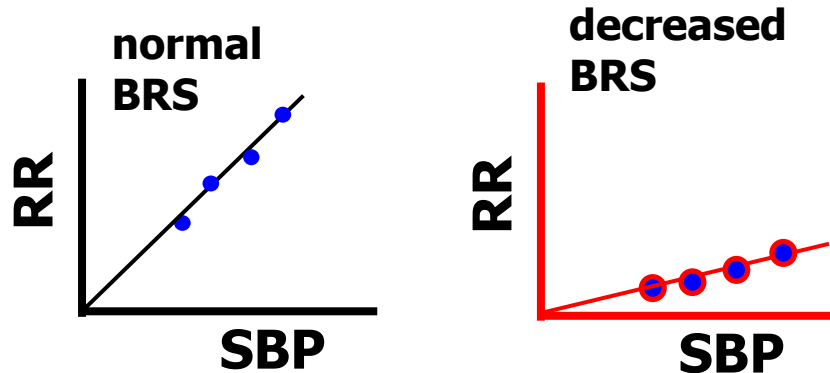
Baroreflex sensitivity (BRS)

- Evaluation of cardiac baroreflex function through SBP and heart rate (cardiac cycle) changes
- BRS: change of cardiac cycle caused by SBP change by 1 mmHg [ms/mmHg]

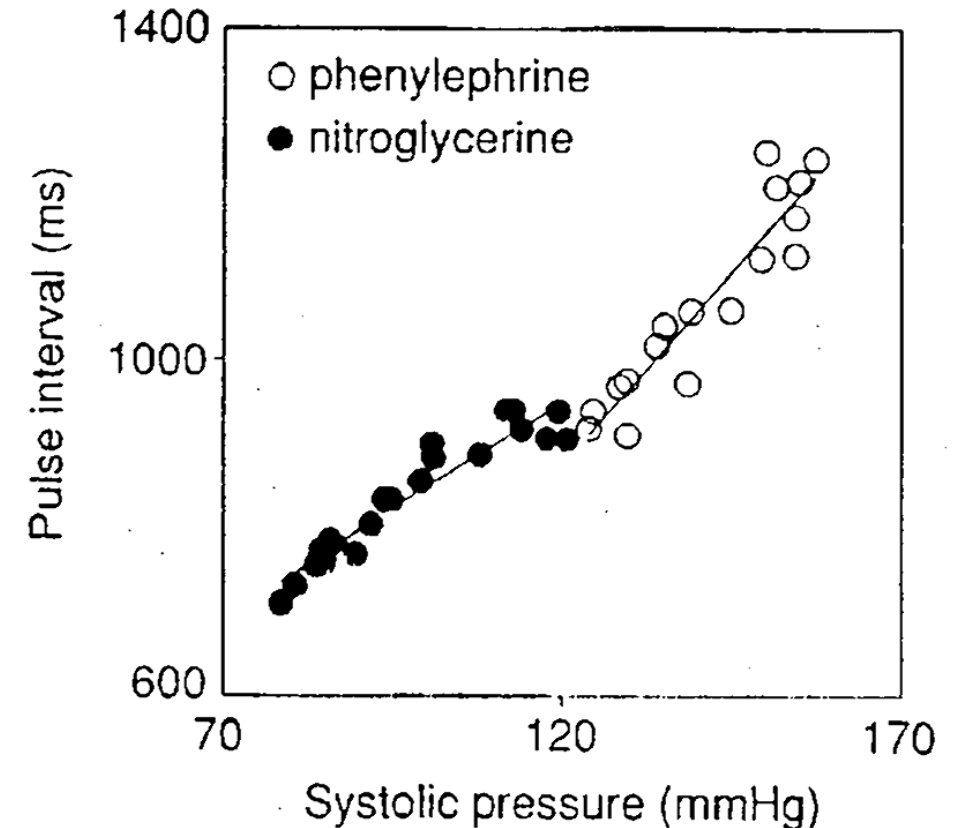


Standard (oxford) method of BRS evaluation

- Application of phenylephrine (vasoconstrictor) – increase of SBP
- RR prolongation is measured



Bolus injections of vasoactive drugs



Decreased BRS

– Physiologically

- psychic stress – increased sympathetic activity
- Physical exercise – increased sympathetic activity
- In old age

– Pathologically

- hypertension – decreased baroreceptor sensitivity (atherosclerosis, increased arterial stiffness)
- diabetes – neuropathy of autonomic nervous system
- Chronic depression (neurogenic)
- Heart insufficiency/failure – heart do not response
- Transplanted heart - denervation
- Myocardial infarction – heart do not response



Cardiovascular signal variability

– Cardiovascular signals

– Easy to measure

EGG: RR intervals, heart rate - HR ($1/RR$)

Blood pressure: systolic (SBP), diastolic (DBP), mean (MAP), pulse pressure (PP)

– Difficult to measure directly (bioimpedance method), can be evaluated indirectly from blood pressure wave (Windkessel model)

Stroke volume (SV), cardiac output (CO), total peripheral resistance (TPR)

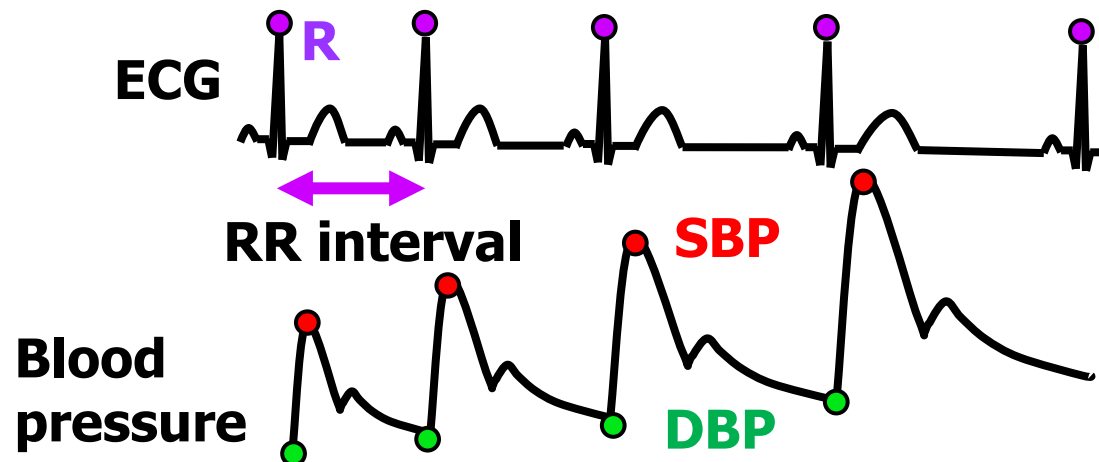
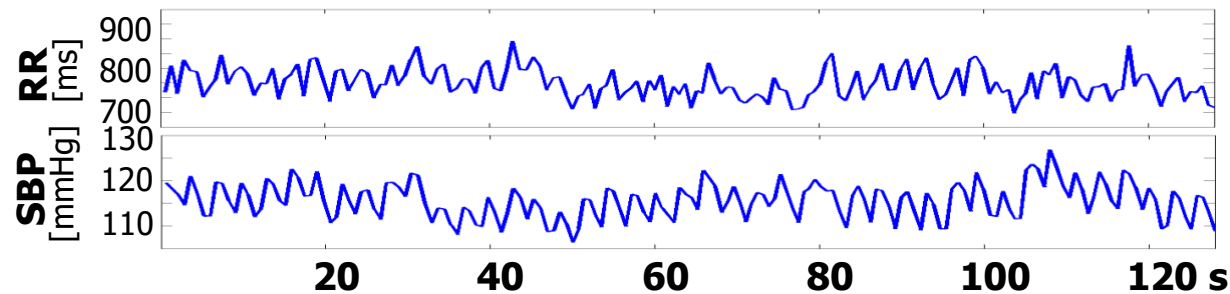
– Very difficult to measure directly (invasive measurement)

Blood flow and pressure in various places of vessels



Signal: time series

- Beat to beat (for example 5 minutes)
- RR interval: 805, 820, 815, 817, 822, 816,..... ms
- Hear rate: 70, 73, 68, 65, 67, 71,..... bpm
- Systolic blood pressure: 115, 117, 120, 116, 121, 119,..... mmHg



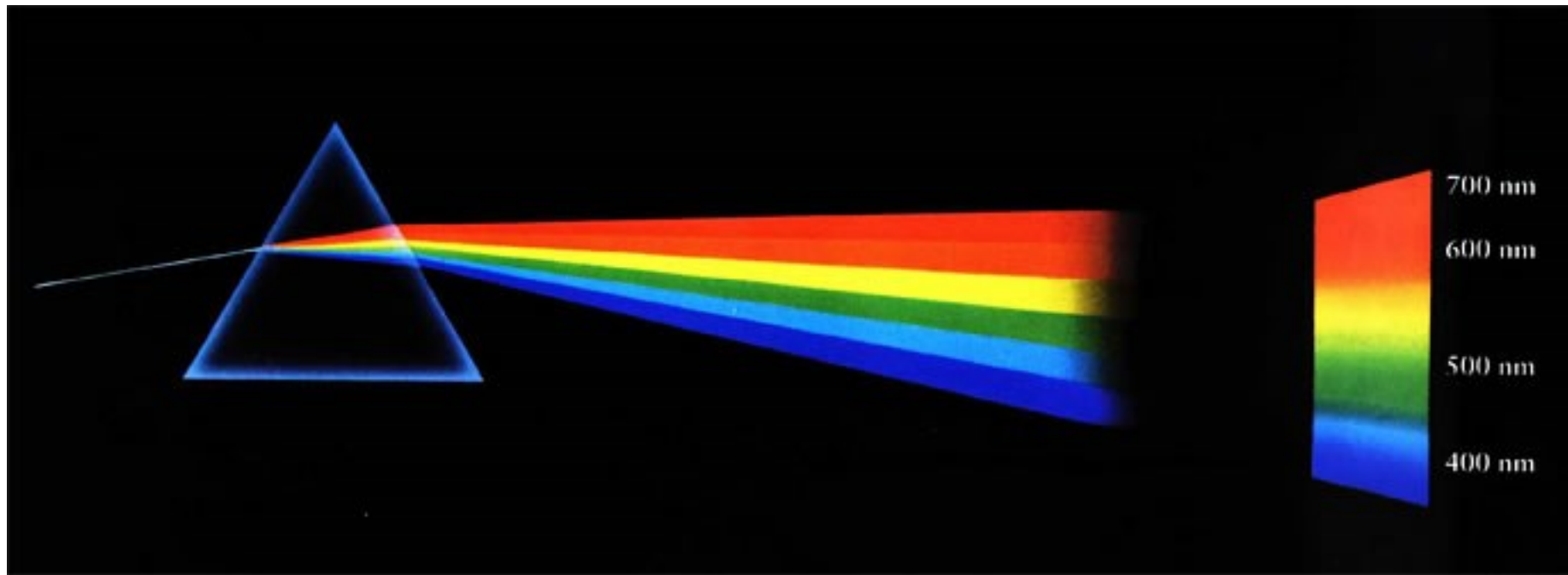
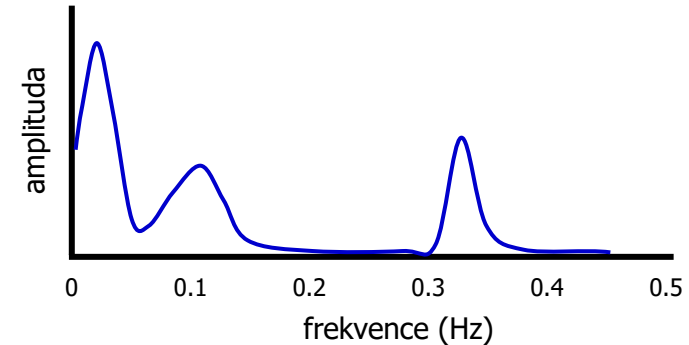
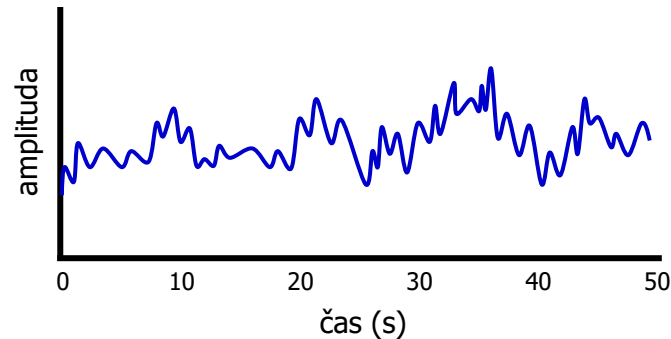
Metody frekvenční domény - spektrální analýza

Time series
Signal in time domain



Spectrum
Signal in frequency domain

Signal is decomposed in individual frequencies



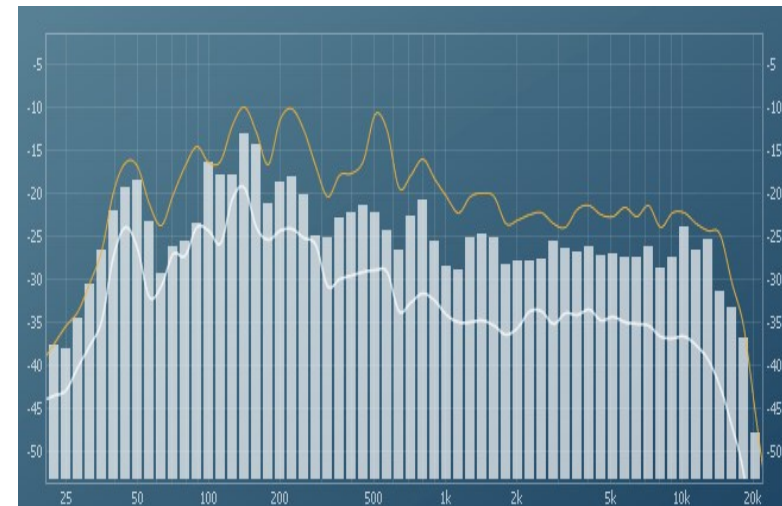
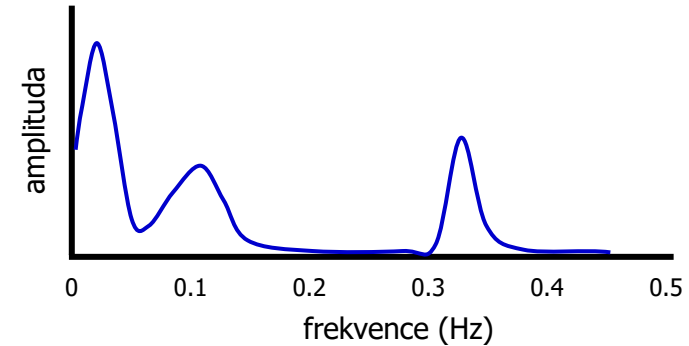
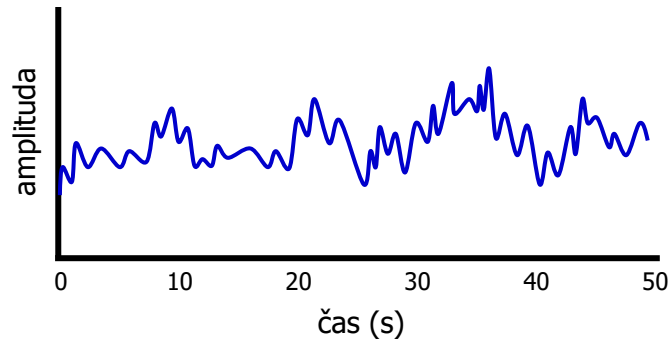
Metody frekvenční domény - spektrální analýza

Time series
Signal in time domain



Spectrum
Signal in frequency domain

Signal is decomposed in individual frequencies



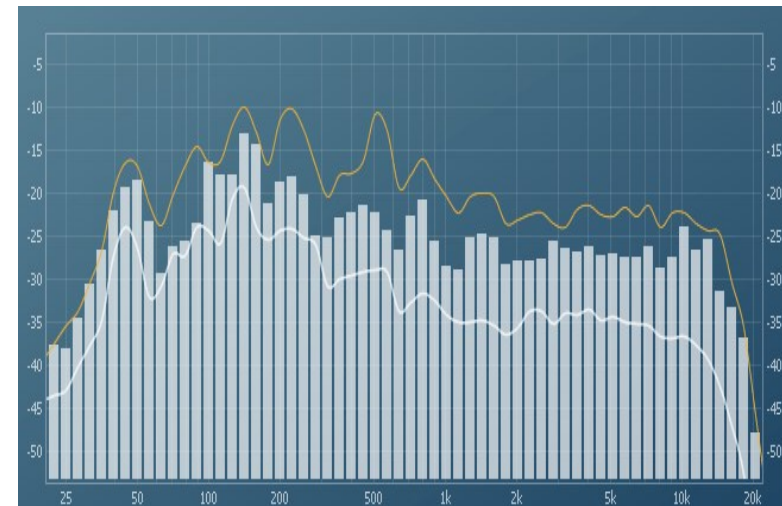
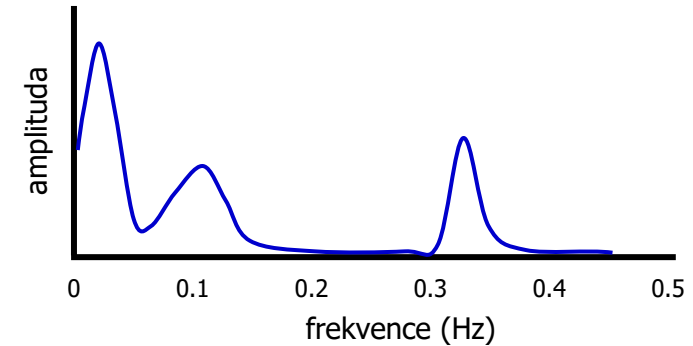
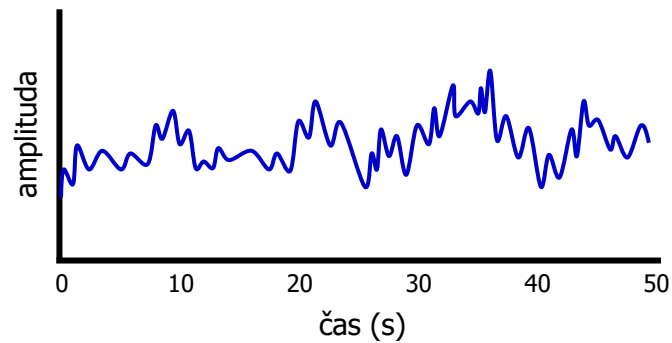
Metody frekvenční domény - spektrální analýza

Časová řada
Signál v časové doméně

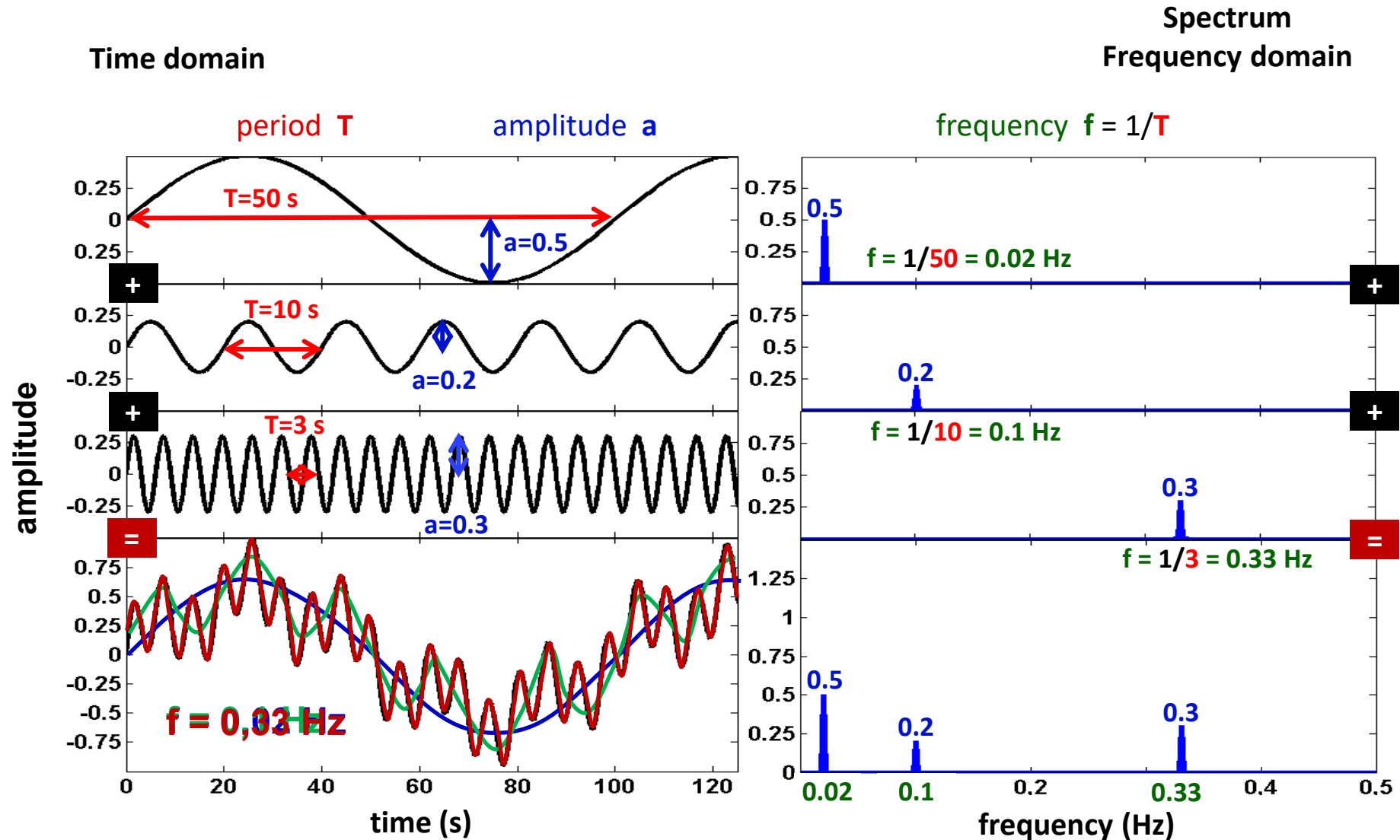


Spektrum
Signál ve frekvenční doméně

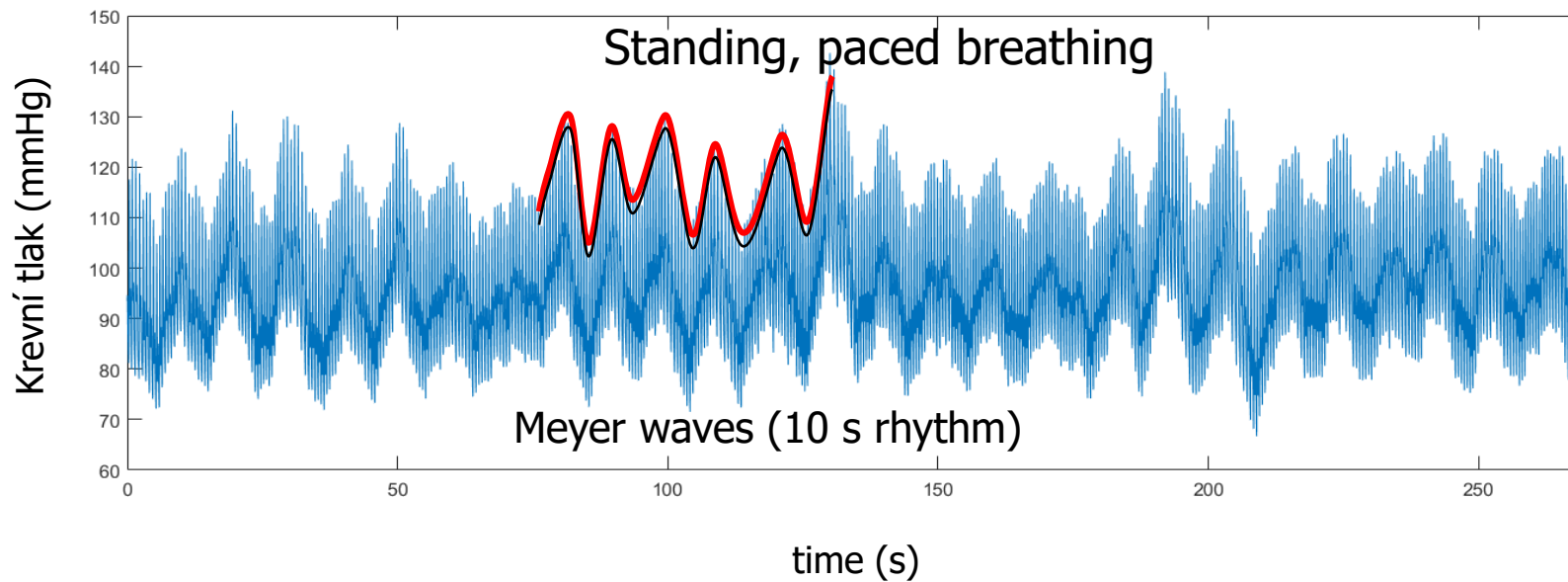
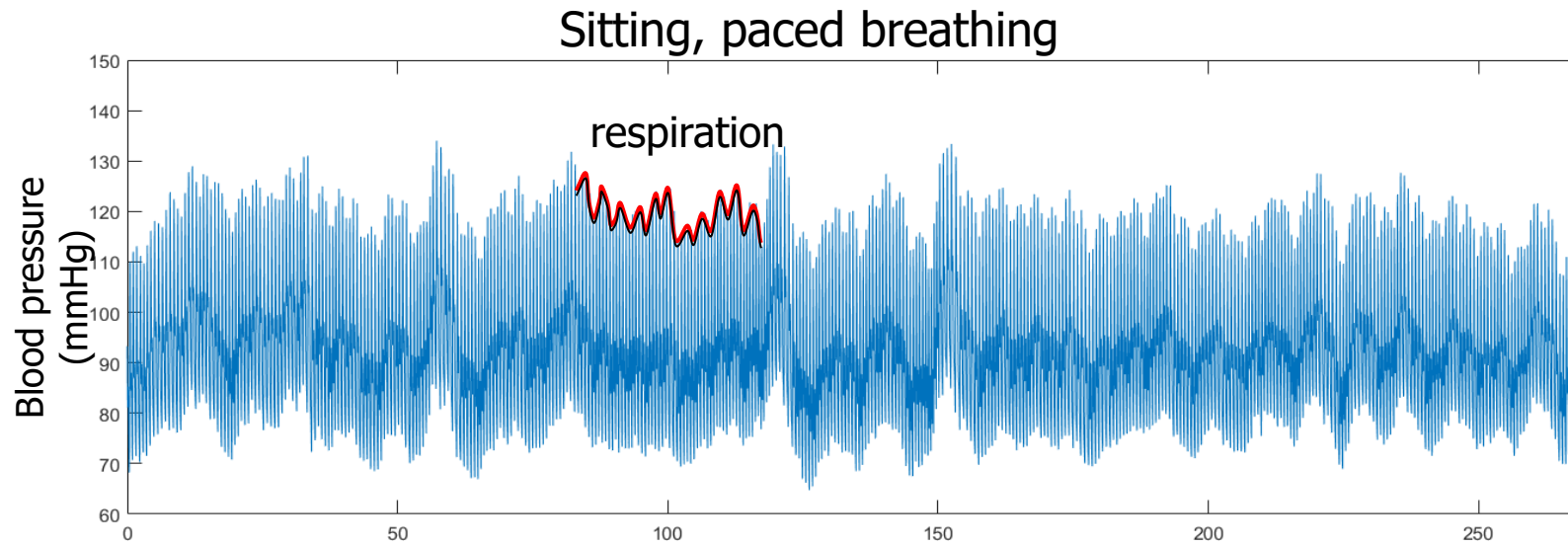
Rozložení signálu na jednotlivé frekvence



How the spectrum is formed?

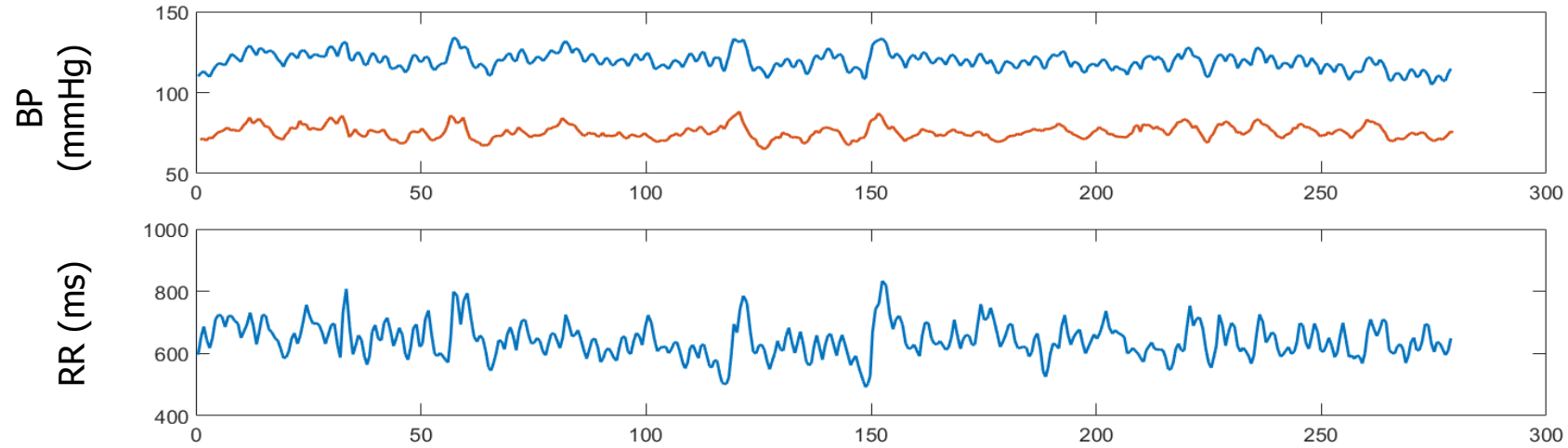


Blood pressure signal (270 s)

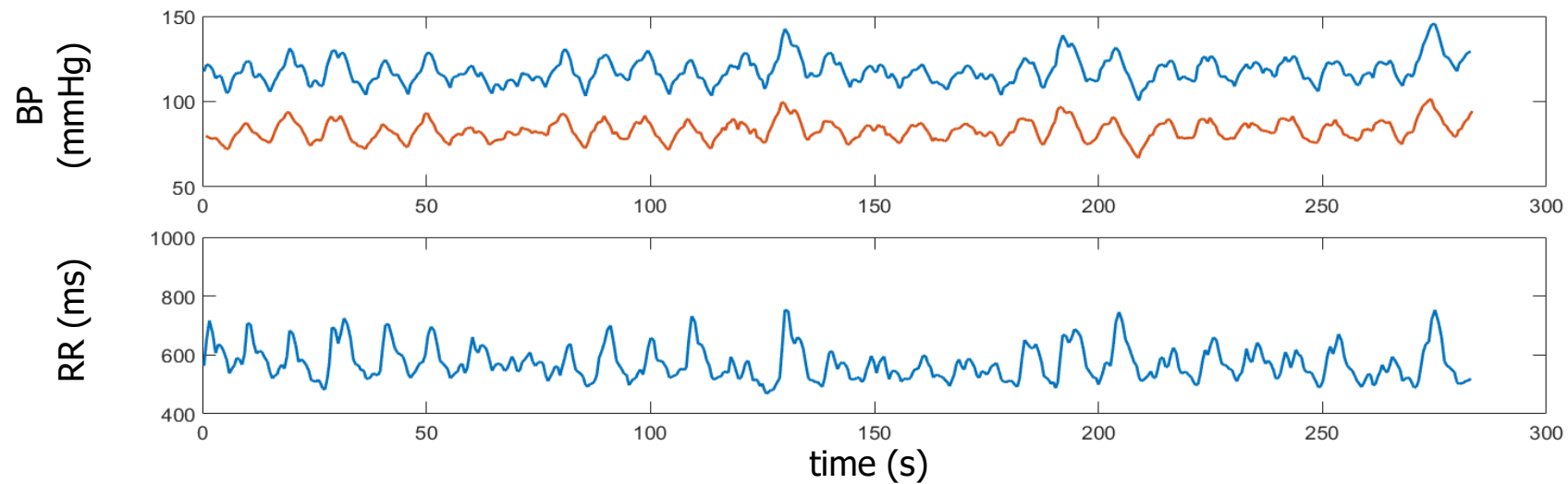


sequentions of SBP, DBP and RR intervals

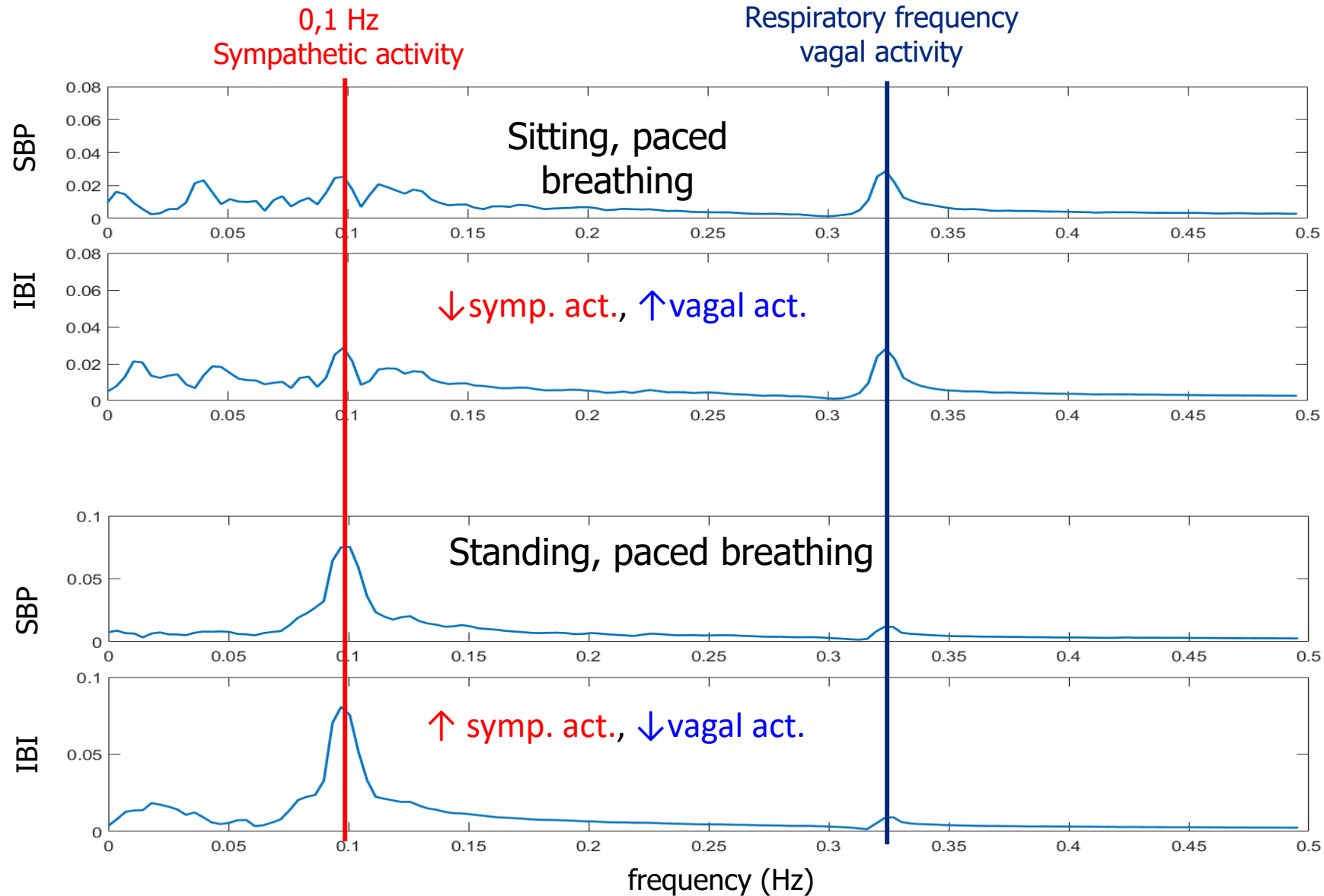
Sitting, paced breathing



Standing, paced breathing

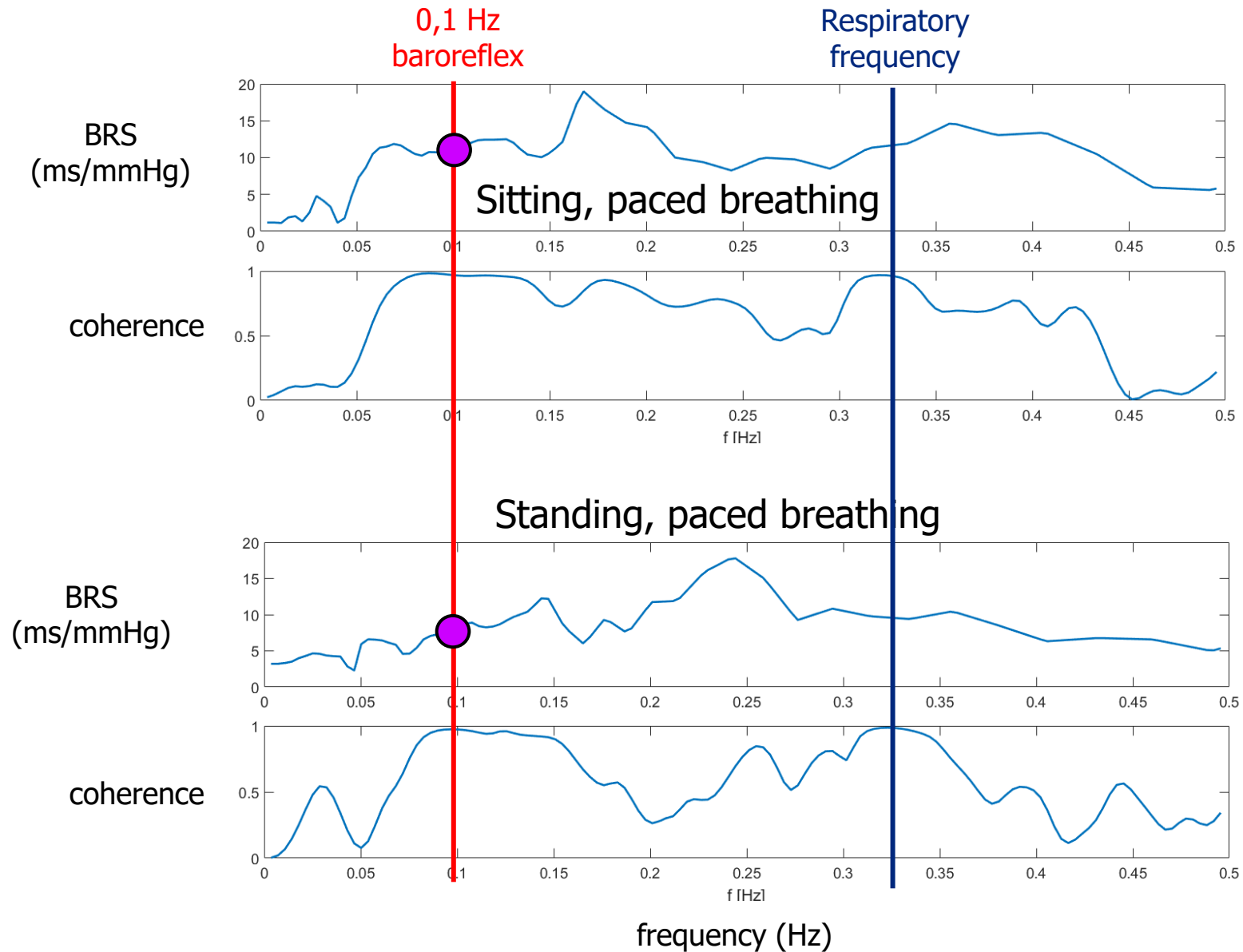


Spectra of SBP and IBI

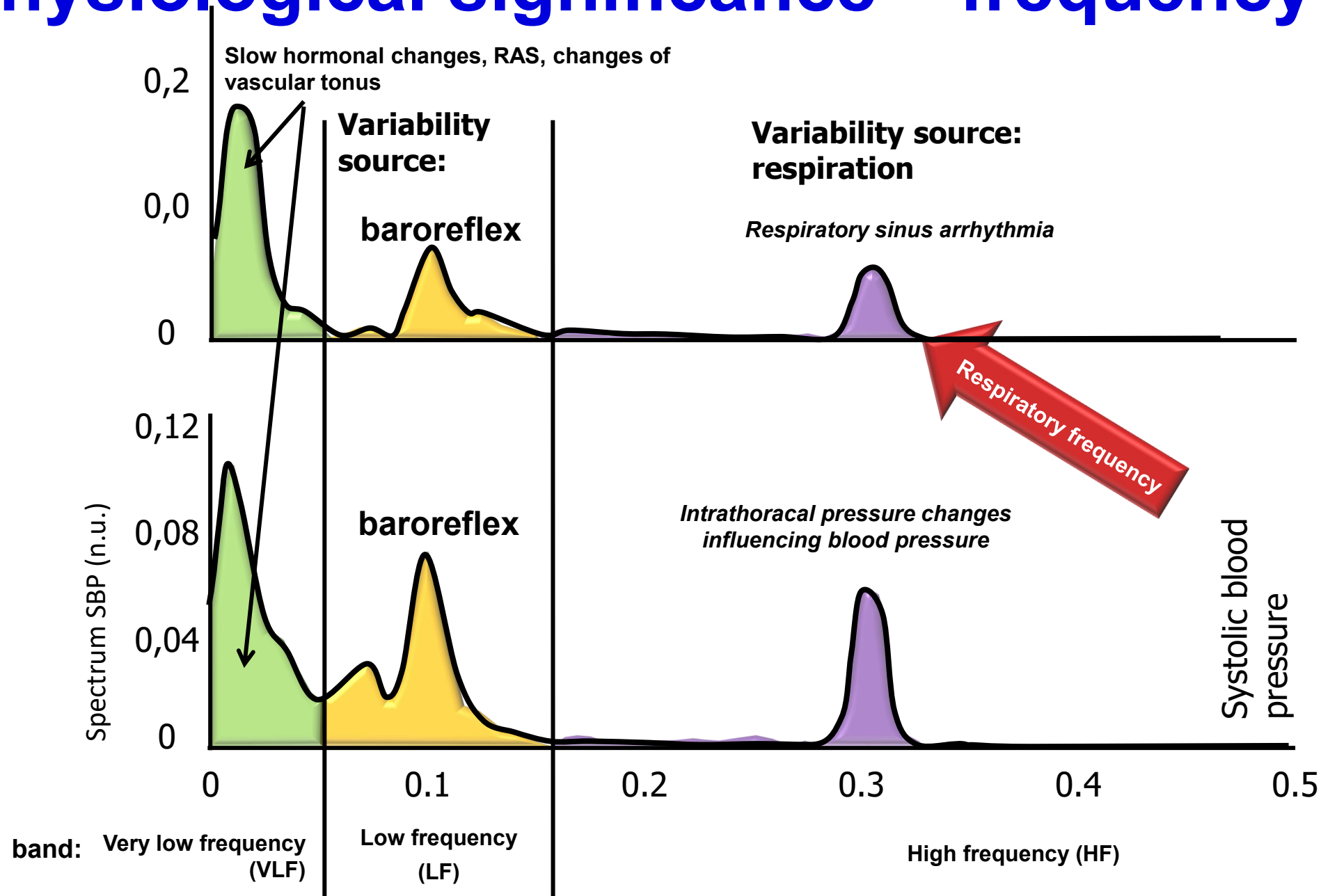


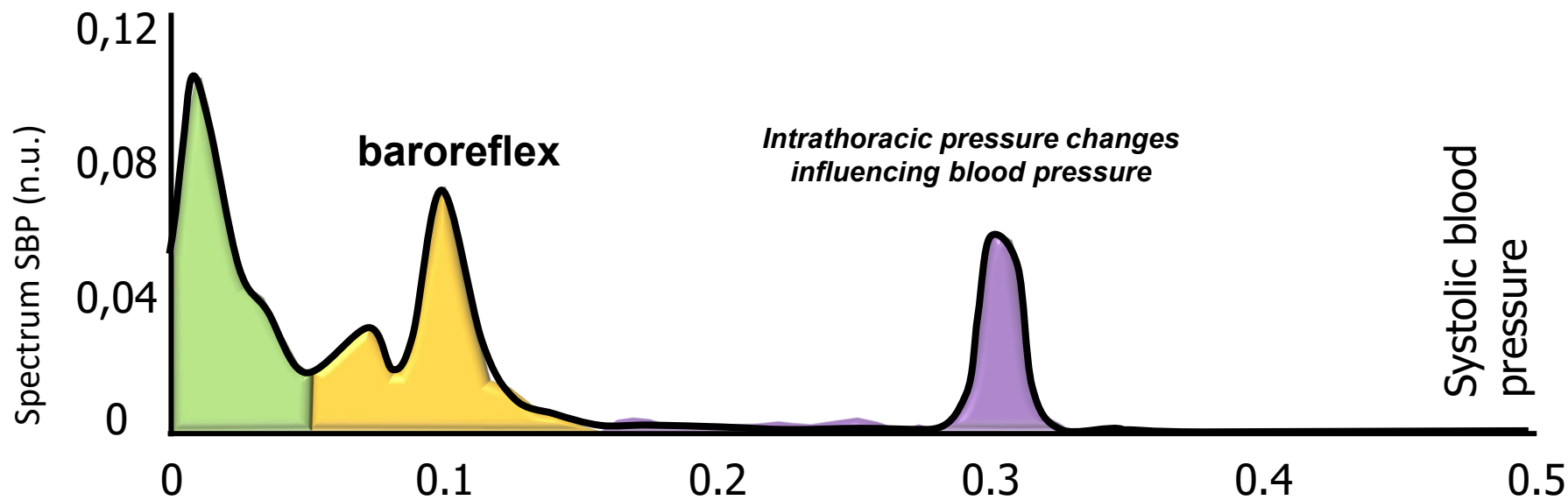
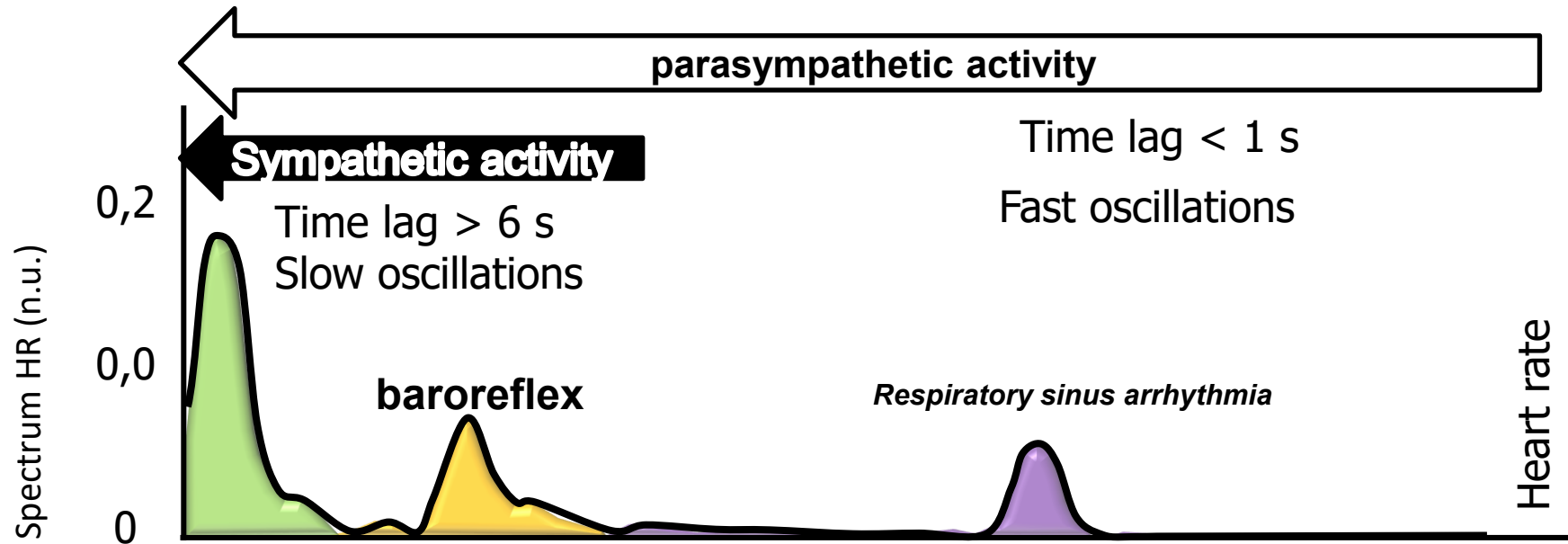
Coherence a BRS

coherence: synchronization between signals (correlation on particular frequency)

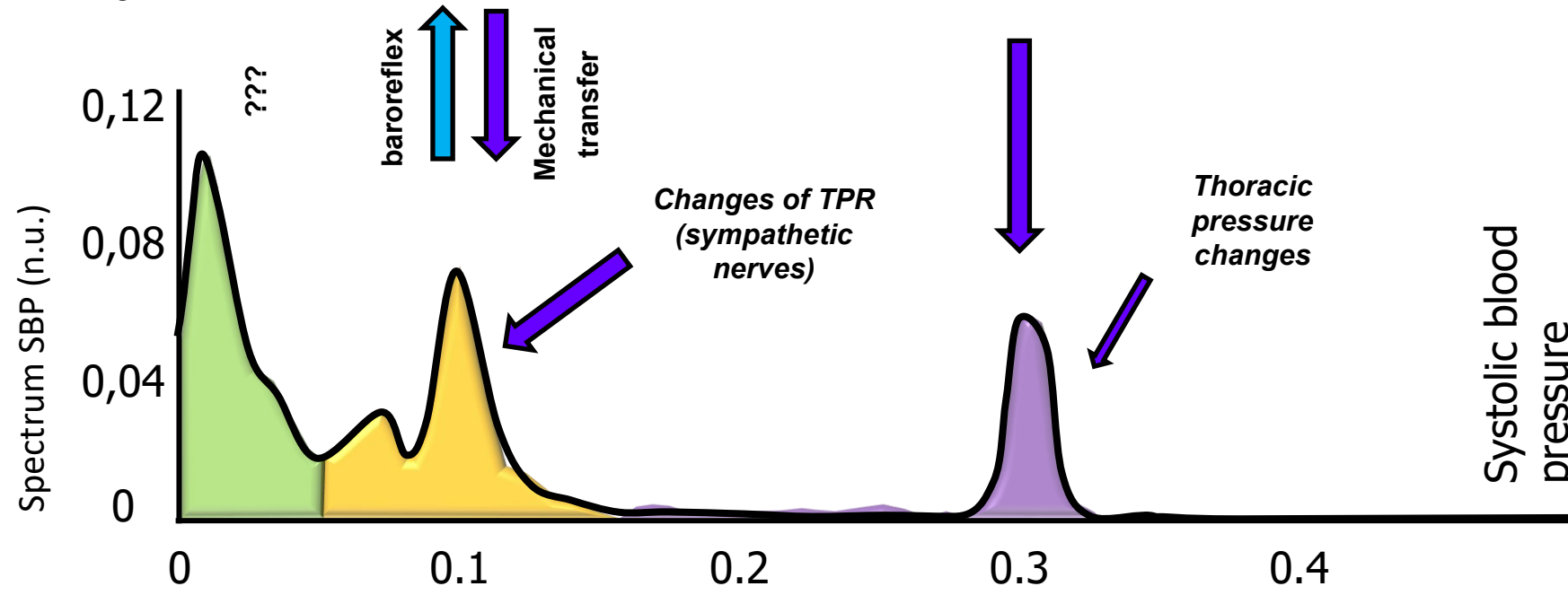
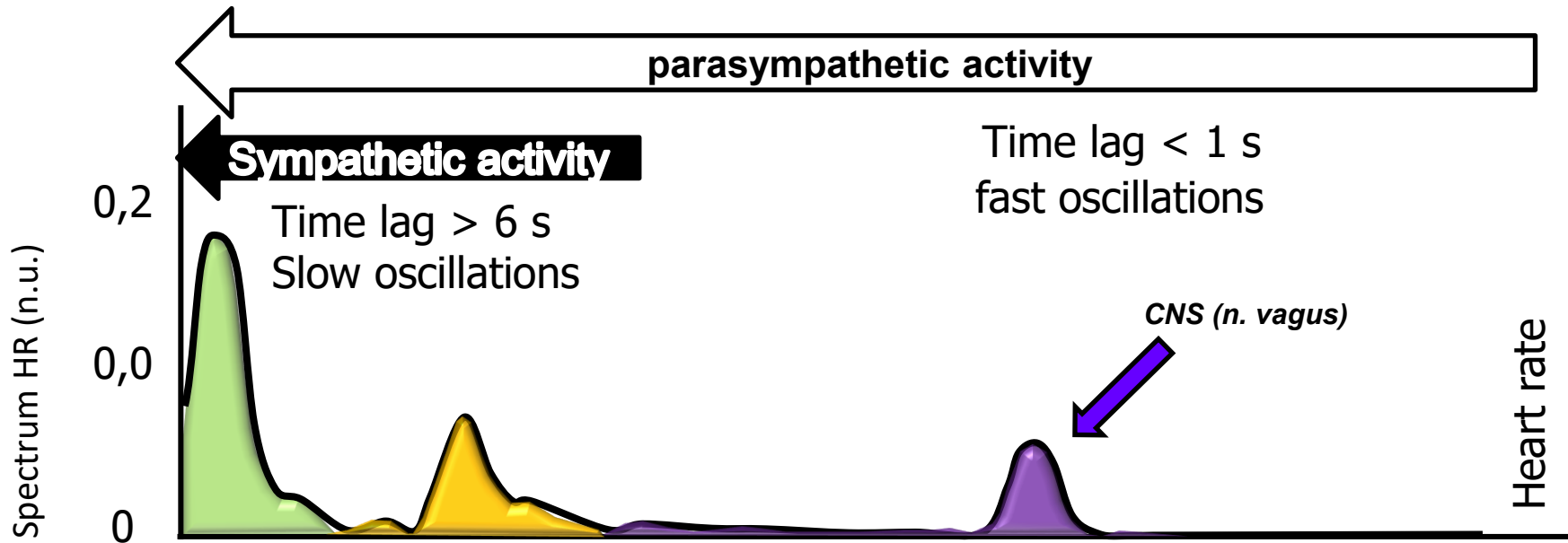


Physiological significance – frequency bands





band: Very low frequency (VLF) Low frequency (LF) High frequency (HF)



band: Very low frequency (VLF) Low frequency (LF) High frequency (HF)

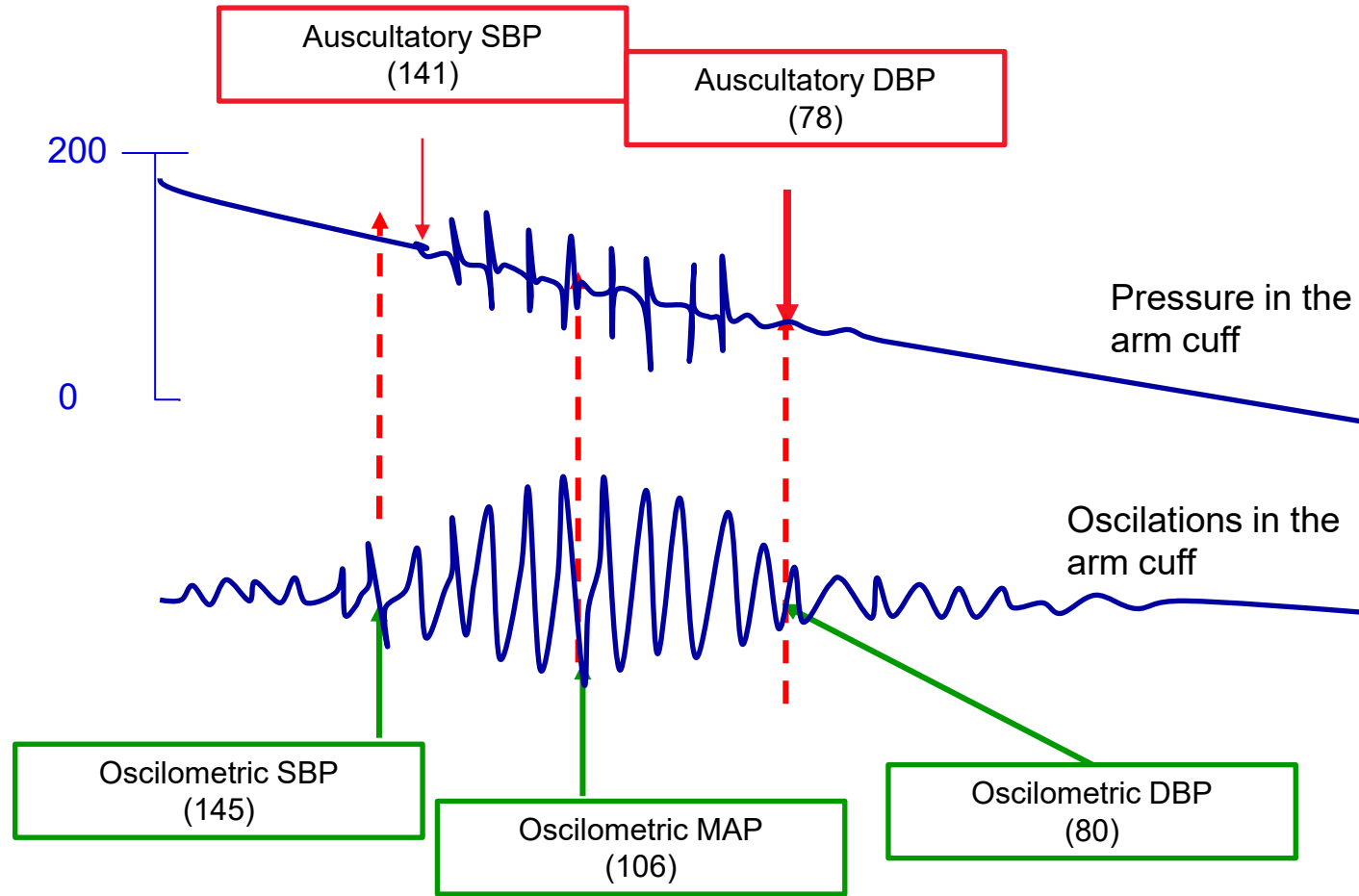
Variability – for exam

- The variability of cardiovascular rhythms provides information about the regulation of the cardiovascular system
- Evaluated parameters (time series):
 - beat-to-beat heart rate (or RR intervals) - easy to measure (ECG)
 - systolic pressure sequence (slightly more difficult measurement, Peňáz method)
- The main methods of evaluating the variability of a single signal
 - Variations to standard deviations (sometimes used in the clinic and some devices have them implemented)
 - Spectral analysis
- The main methods of evaluating the relationship between two signals
 - Baroreflex sensitivity (definition: change in RR induced by a 1 mmHg change in SBP)

Variability – for exam

- Heart rate variability – autonomic nervous system activity analysis
 - high – good regulation of heart
 - low – increased cardiovascular risk
- Baroreflex sensitivity (BRS)
 - sufficient (> 4 mmHg) – baroreflex activity probably OK
 - low (< 3 mmHg) – increased cardiovascular risk
in hypertension, heart failure, diabetes, in stress
- Predictors of sudden cardiac death: near-zero HRV and BRS values
- Spectra HR and SBP
 - Frequency bands (VLF, LF a HF)
 - HF (0.15-0,5Hz): parasympathetic activity, respiration
(in HR – respiratory sinus arrhythmia)
 - LF (around 0,1 Hz): sympathetic/parasymp. activity, baroreflex
 - VLF ($< 0,03$): low changes in vascular system (hormones, TPR, RAS,...)













Non-invasive blood pressure measurement



Non-invasive blood pressure measurement

- advantages/disadvantages, measurement errors

Factors Affecting Blood Pressure Readings

Variance ↓ (mmHg)	Cause of Variance	Variance ↑ (mmHg)
	Cuff is too small	 10-40
10-40 	Cuff over clothing	 10-40
	Back/feet unsupported	 5-15
	Legs crossed	 5-8
	Not resting 3-5 minutes	 10-20
	Patient talking	 10-15
	Labored breathing	 5-8
	Full bladder	 10-15
	Pain	 10-30
	Arm below heart level	 1.8/inch
1.8/inch 	Arm above heart level	

Source: American Diagnostic Corporation

Good luck in exam



if you focus too much on the
problem,
you may miss the solution