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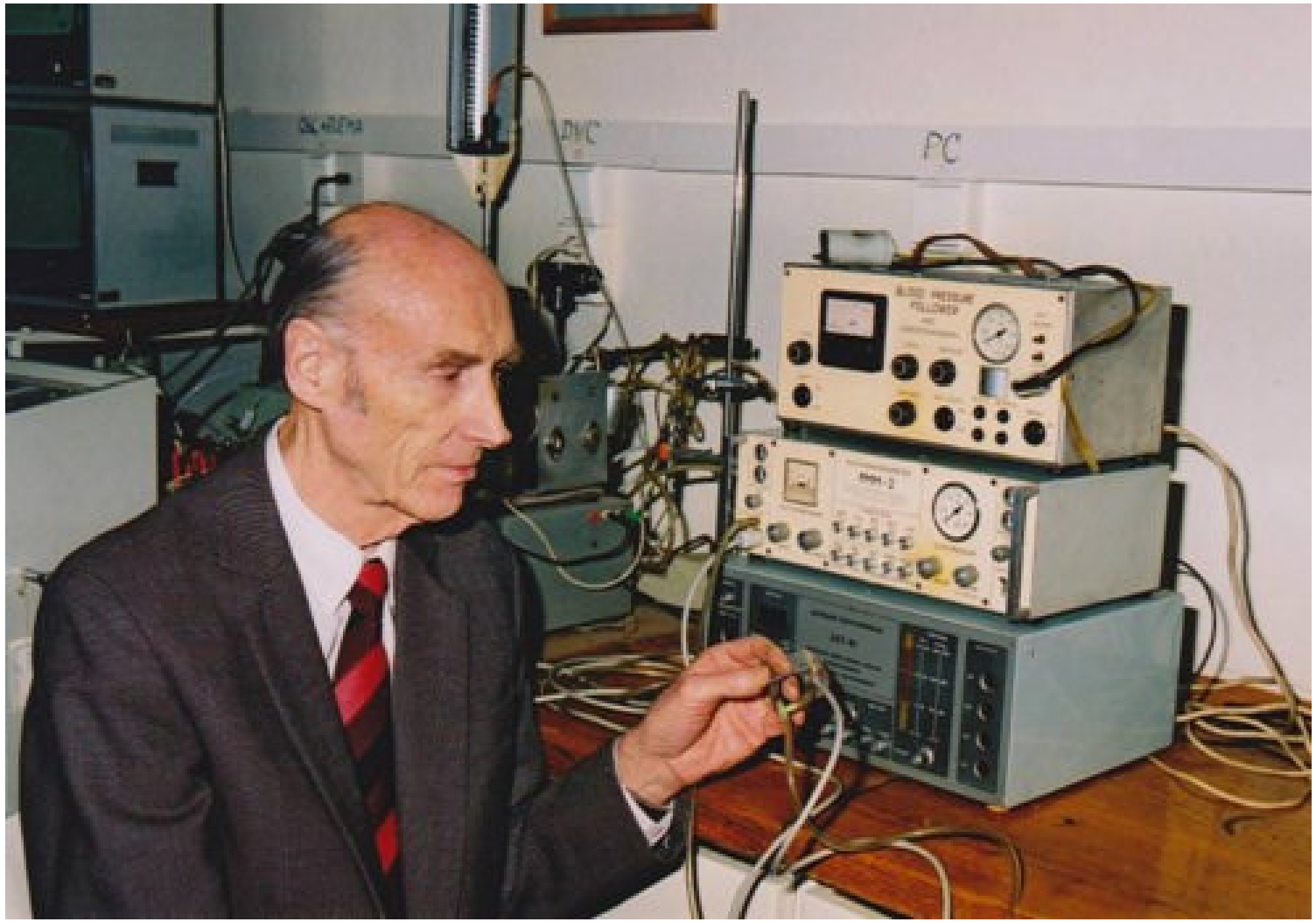
Physiological demonstration

Continual blood pressure measurement
Baroreflex sensitivity
(spring semester 2025)



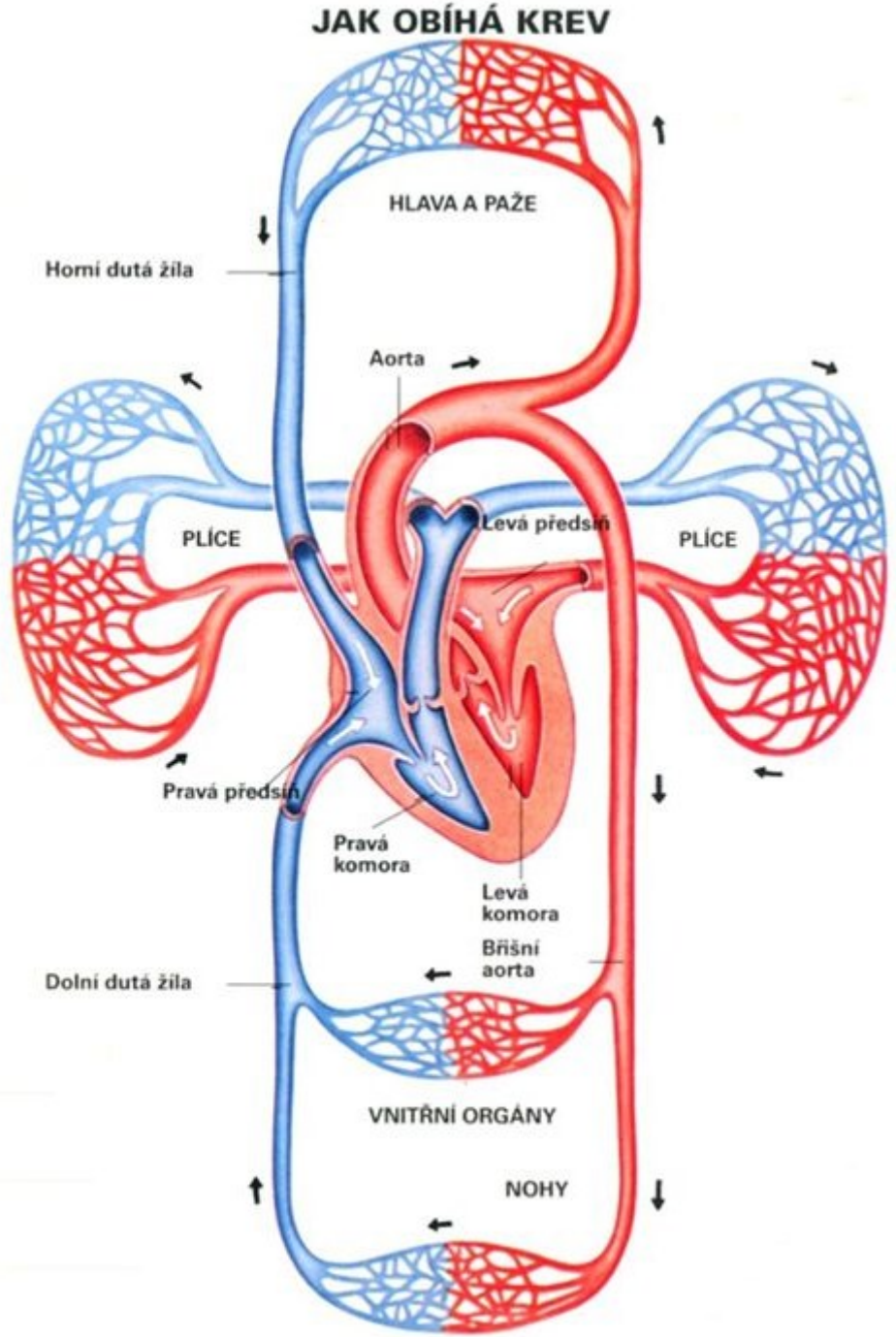
Blood pressure

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

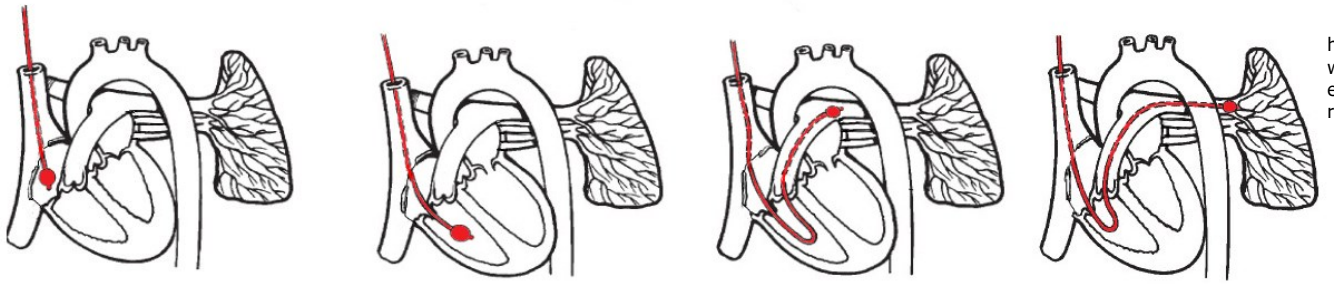
other pressures and their significance

- 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)
- Capilary pressure (15 – 30 mmHg) –
  assessment of tissue blood supply, risk of edema



Blood pressure measurement in the heart

- Right access – catether 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 – catether through
  a. radialis/brachialis/femoralis
  - Aorta → left ventricle



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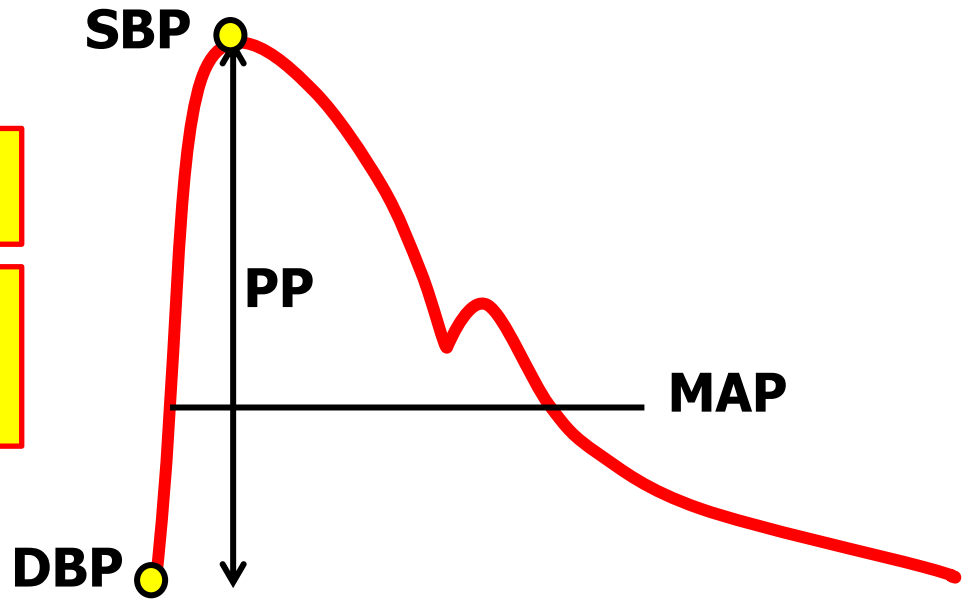
Arterial blood pressure

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 catether
  – Non-invasive – photoplethysmography (Peňáz´s method)

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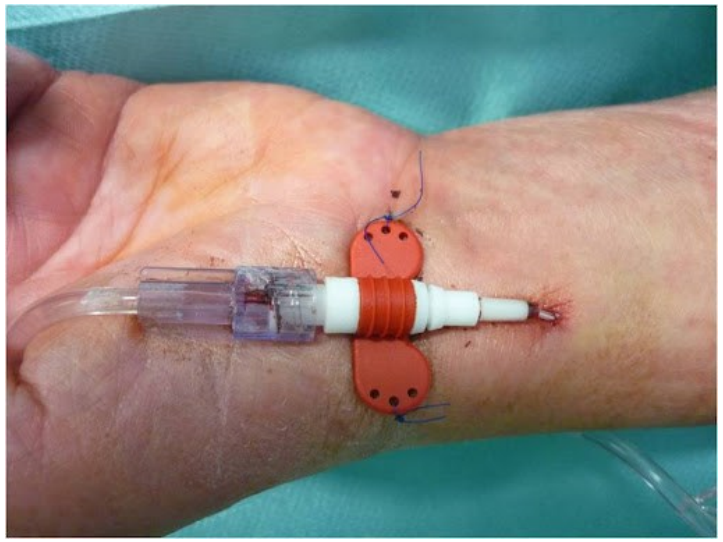
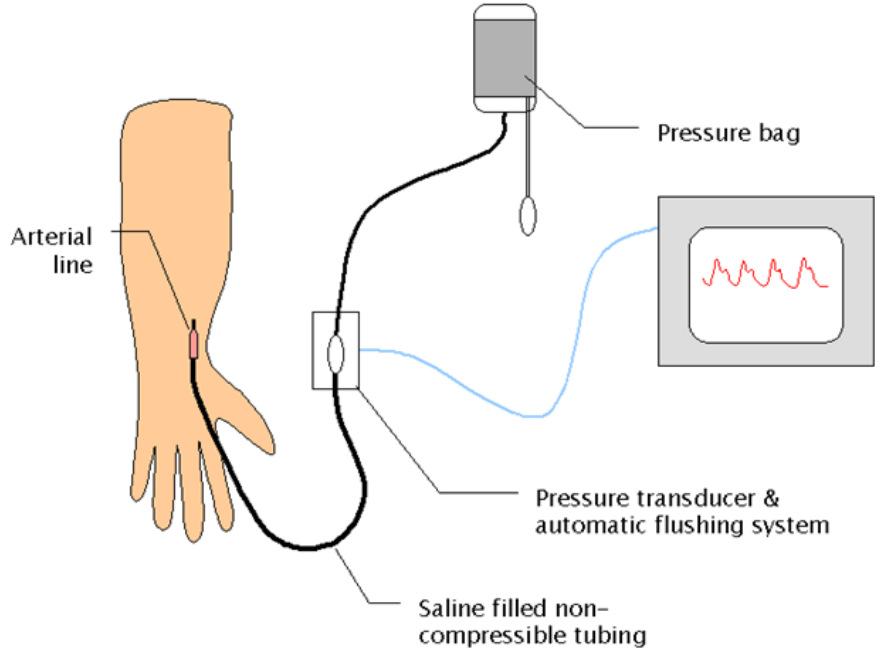
Invasive method of arterial BP measurement

- 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



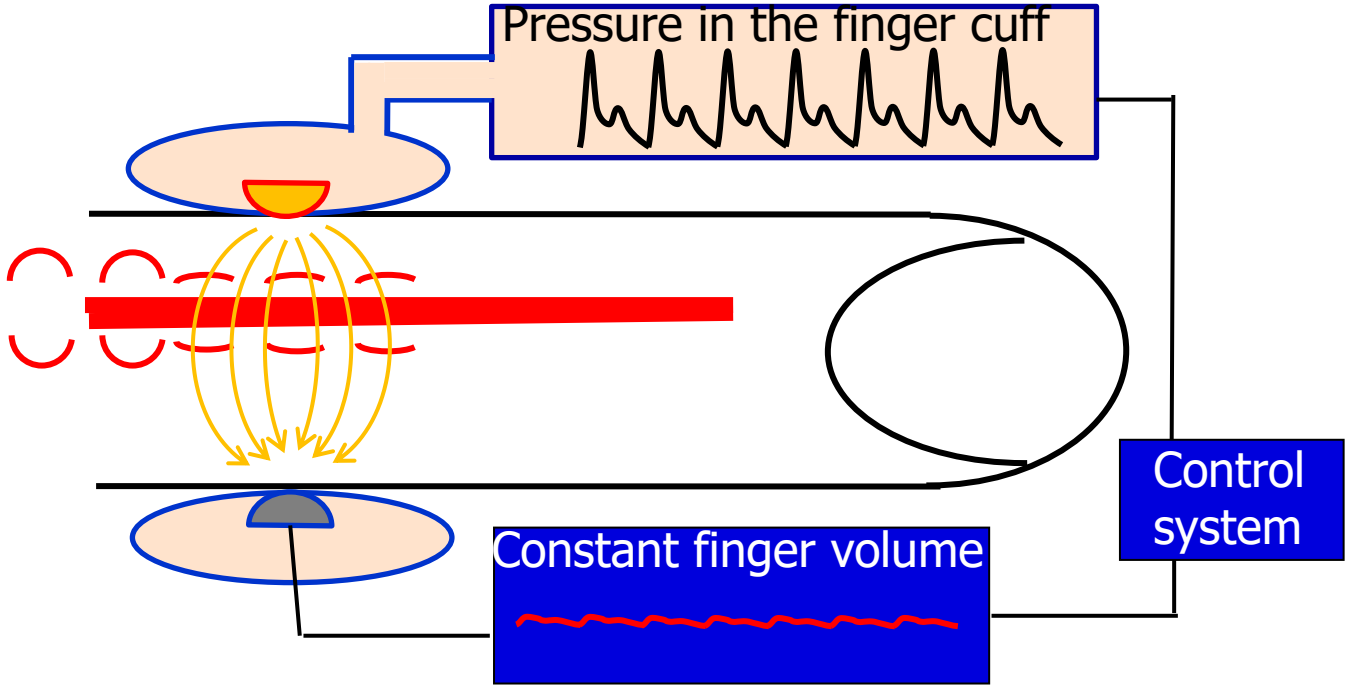


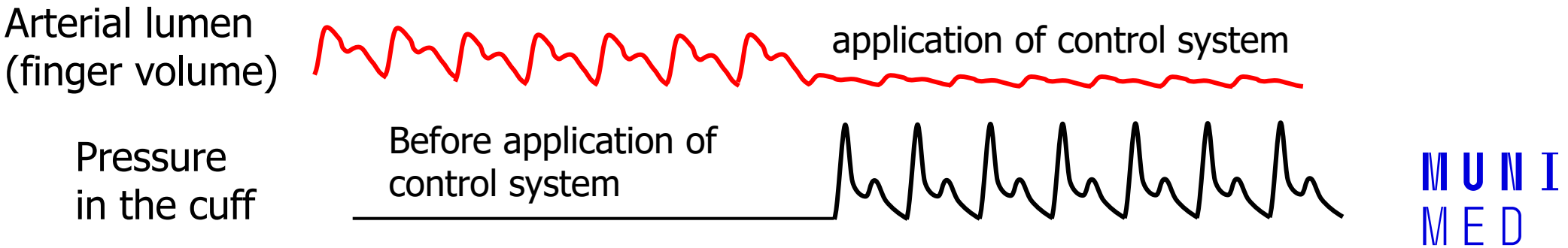
Principle of non-invasive continual blood pressure measurement

– Photoplethysmographic/Peňáz/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





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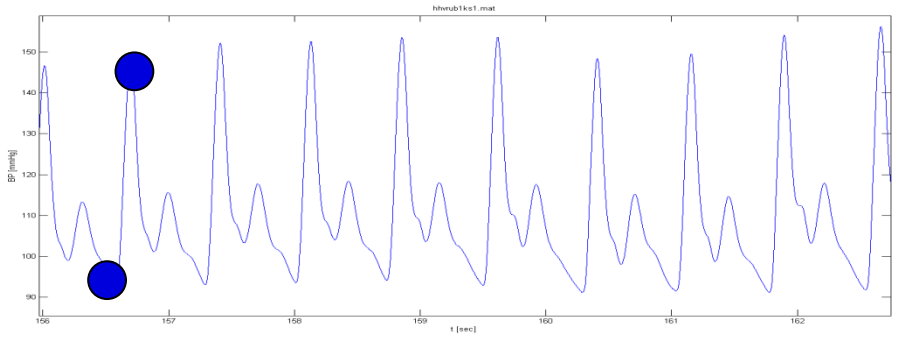
Neinvazivní kontinuální měření krevního tlaku

- 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

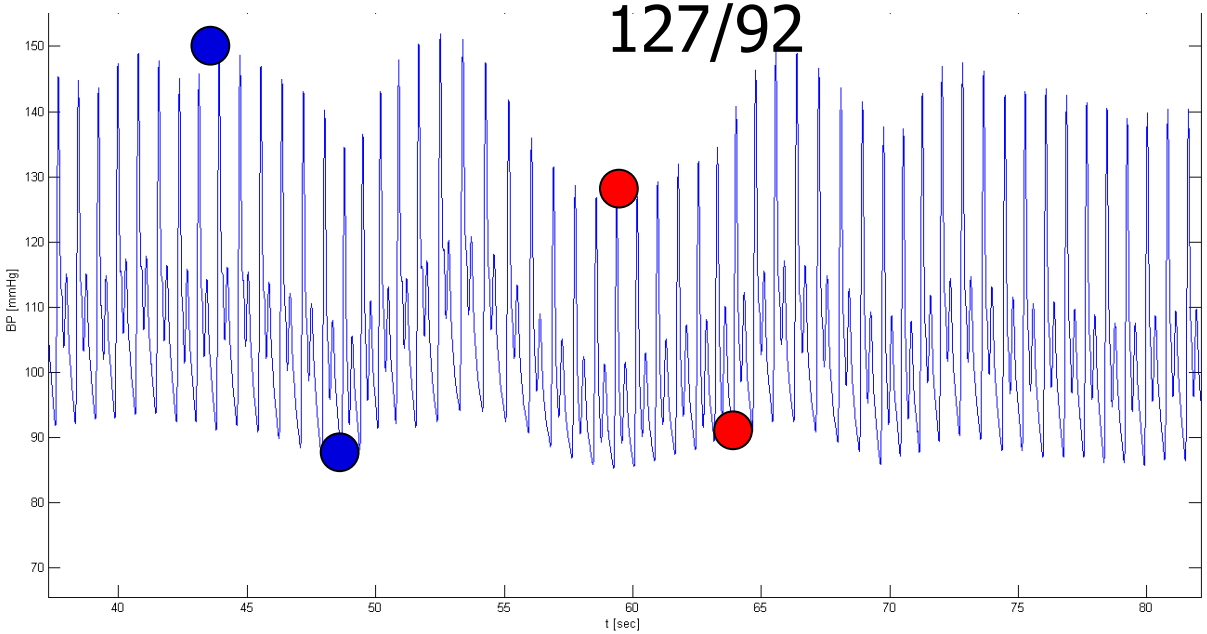
SBP



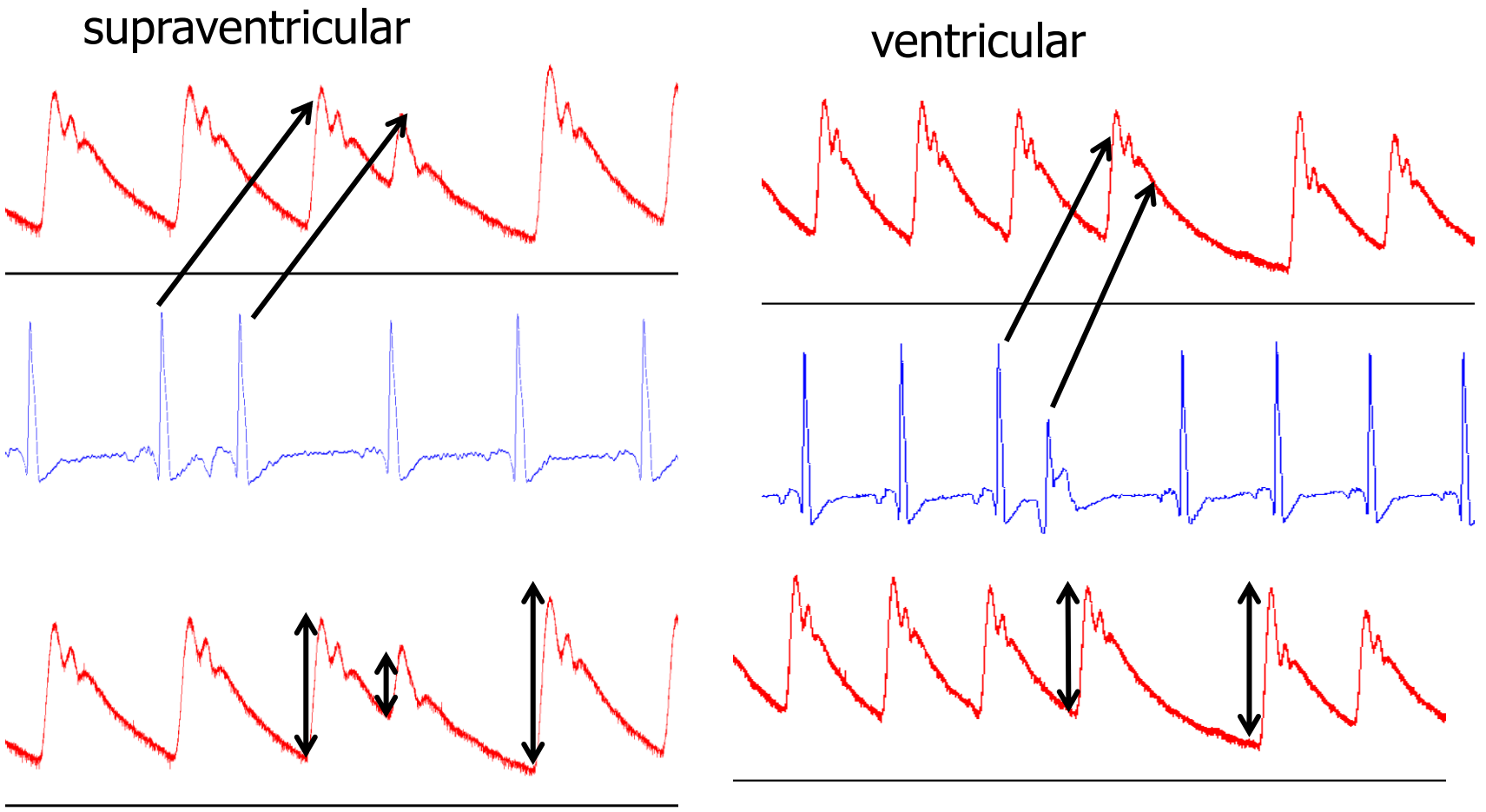
DBP

150/90

127/92



Example: extrasystoles



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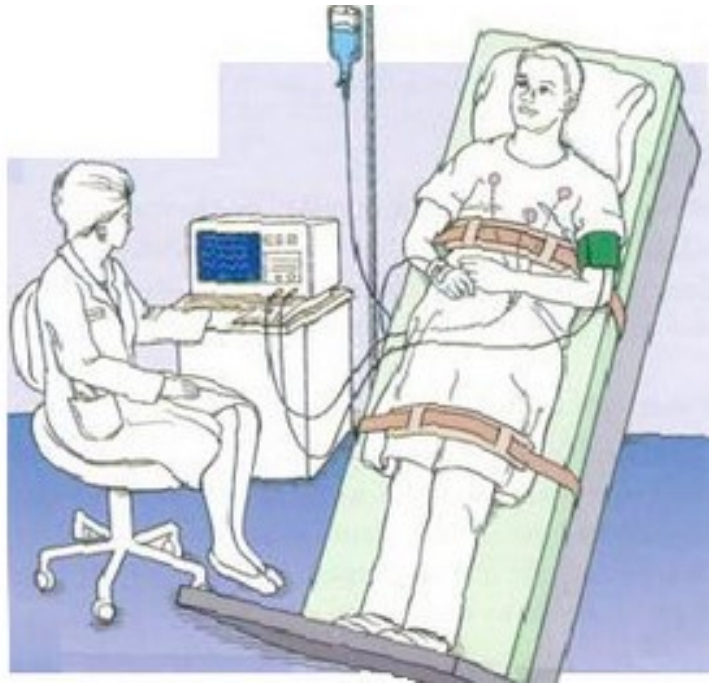
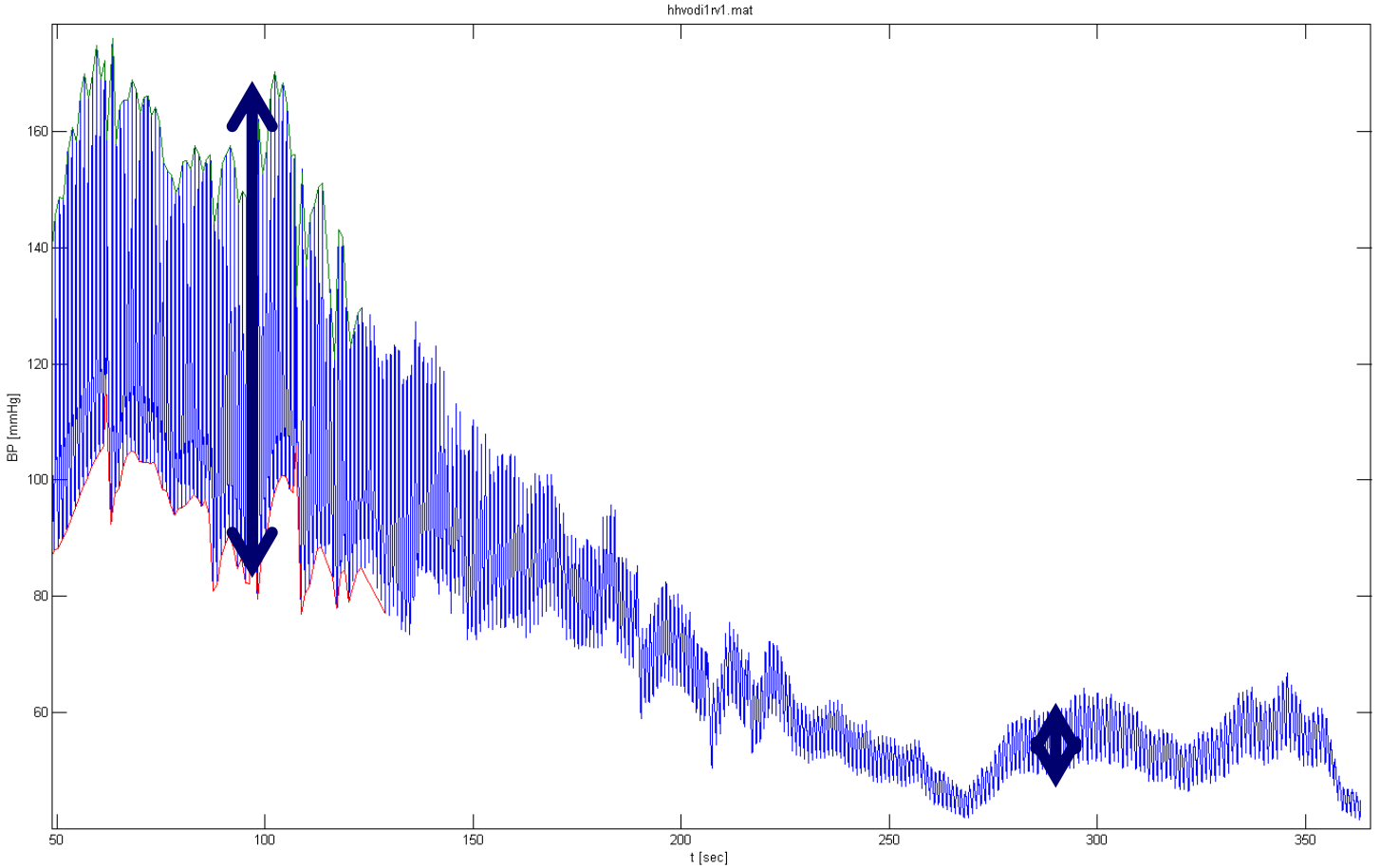
Orthostatic hypotension diagnosis

- Tilt-table test

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

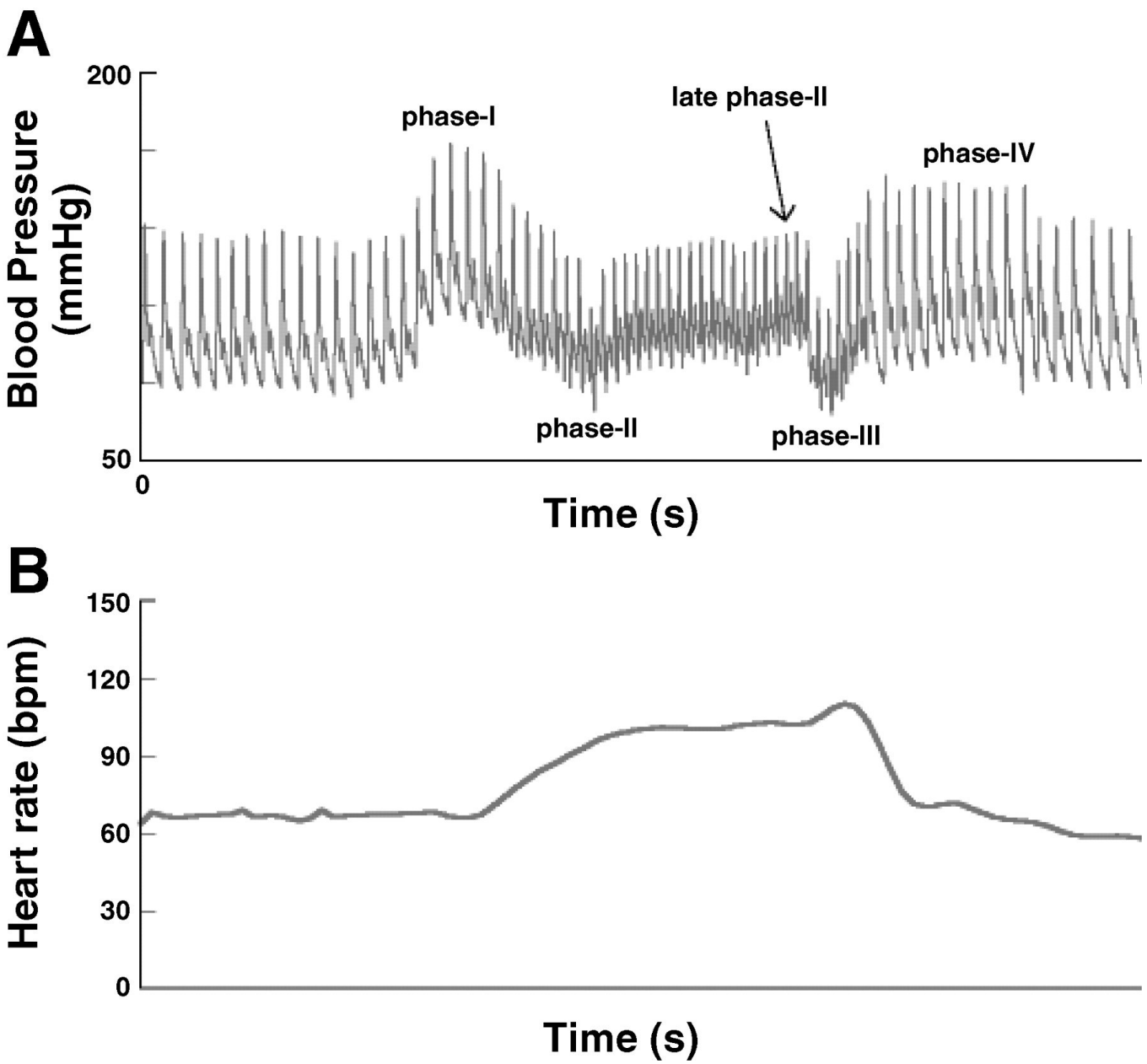




Valsalva manuever

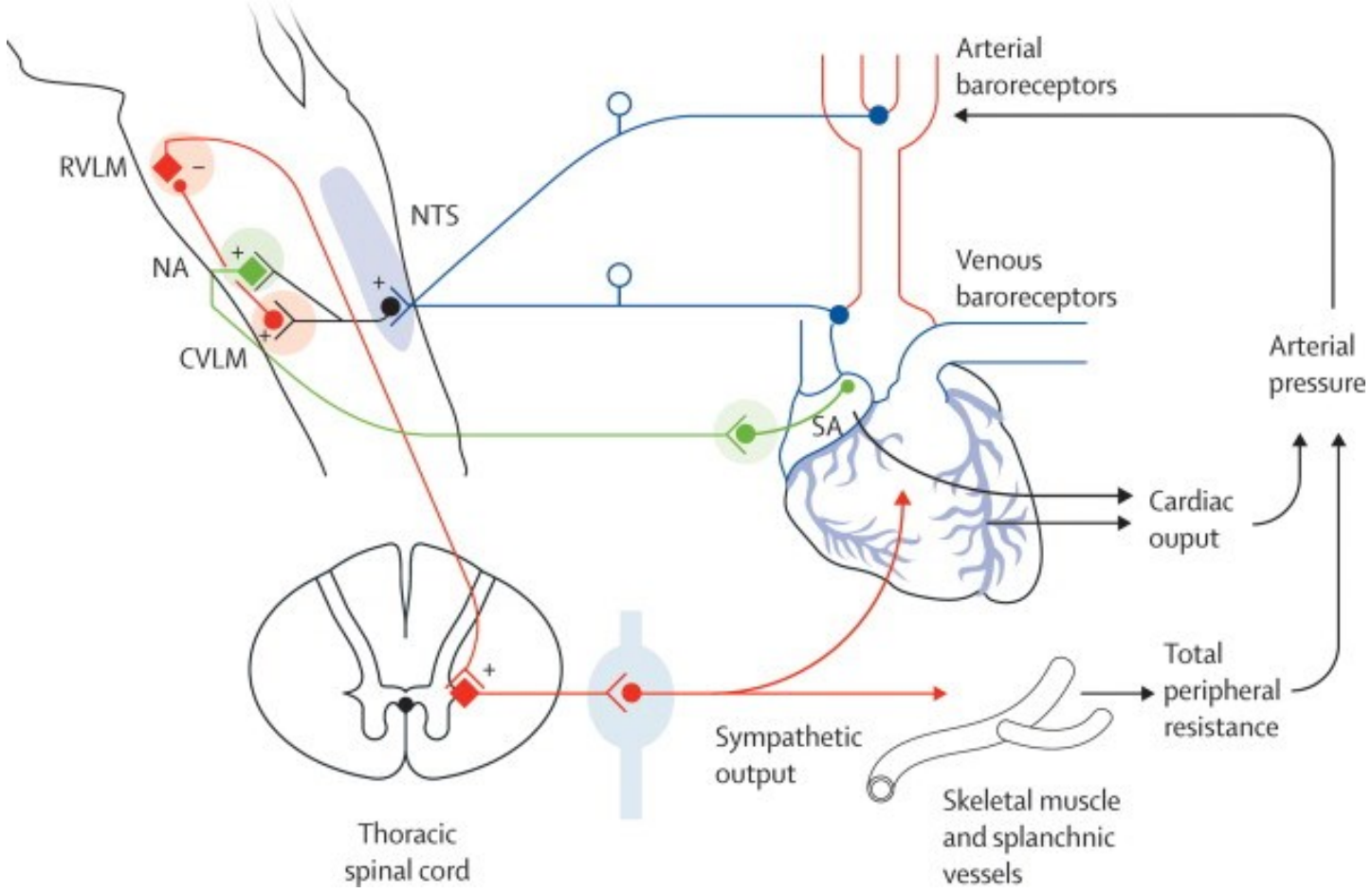
- **Phase I:** exhalation against a closed glottis. Transiently, the intrathoracic pressure rises and so does the pressure on the arteries in the chest. There will be a transient increase in pressure.
- **Phase II.** Exhalation continues against the closed glottis. High intrathoracic pressure compresses 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.



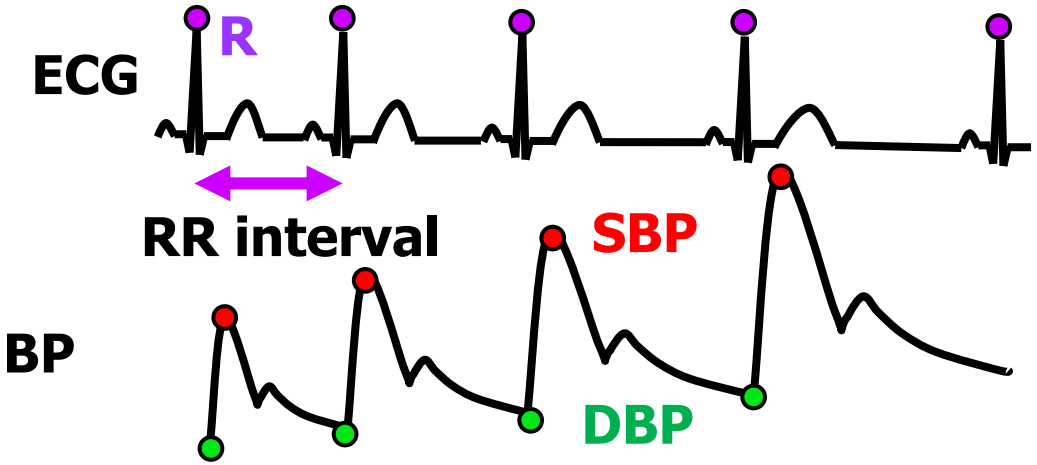
Baroreflex

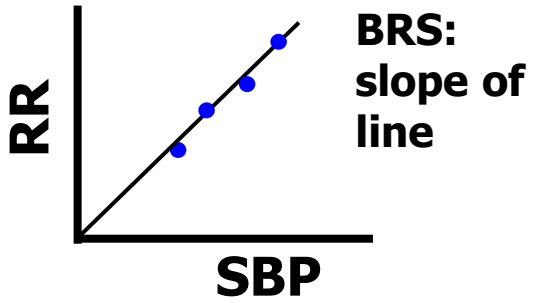
- Fast regulation of arterial blood pressure by changes of heart rate and peripheral vascular resistance



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]





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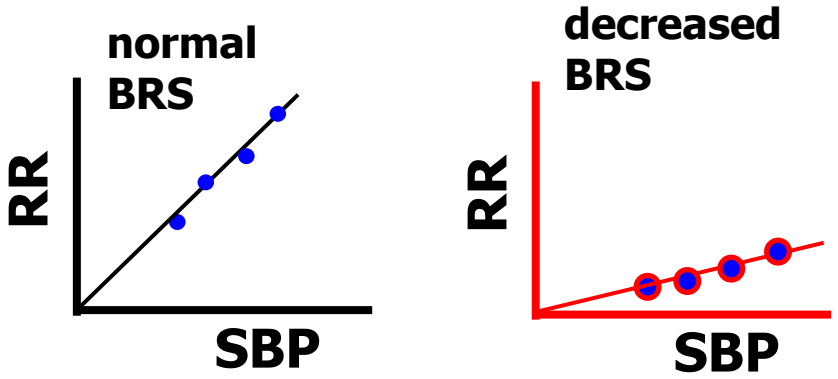
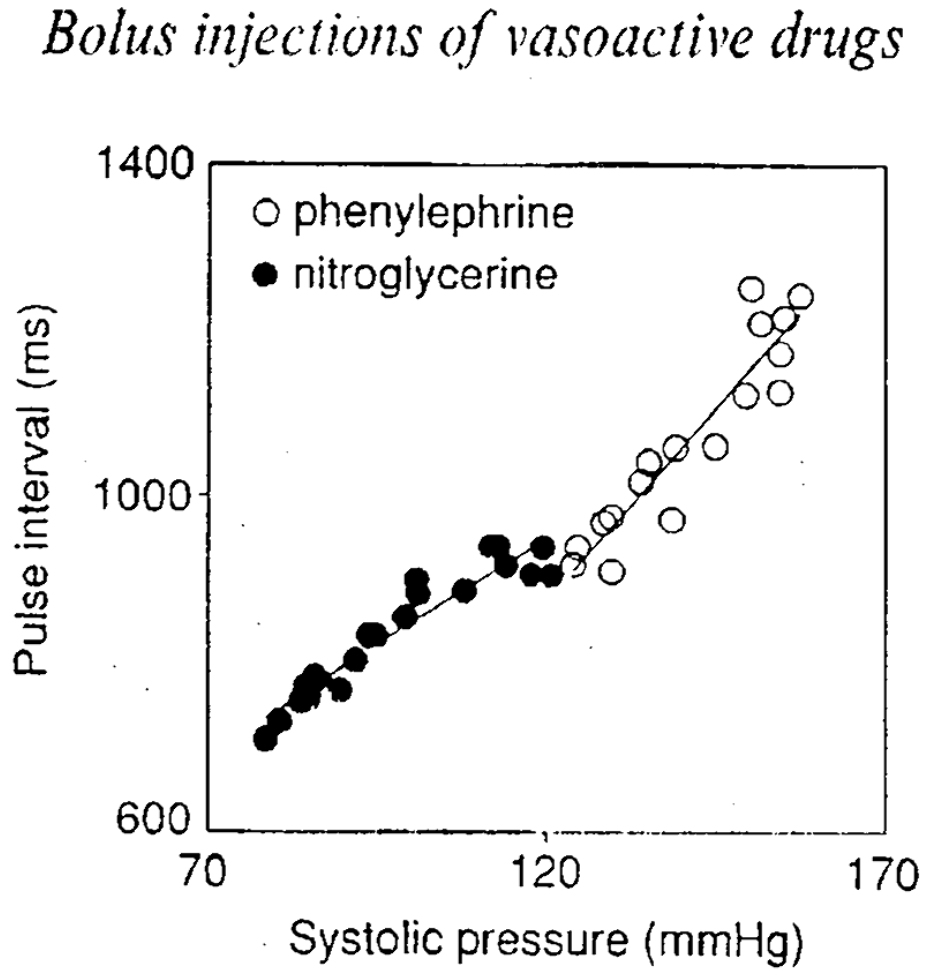
Standard (oxford) method of BRS evaluation

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





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

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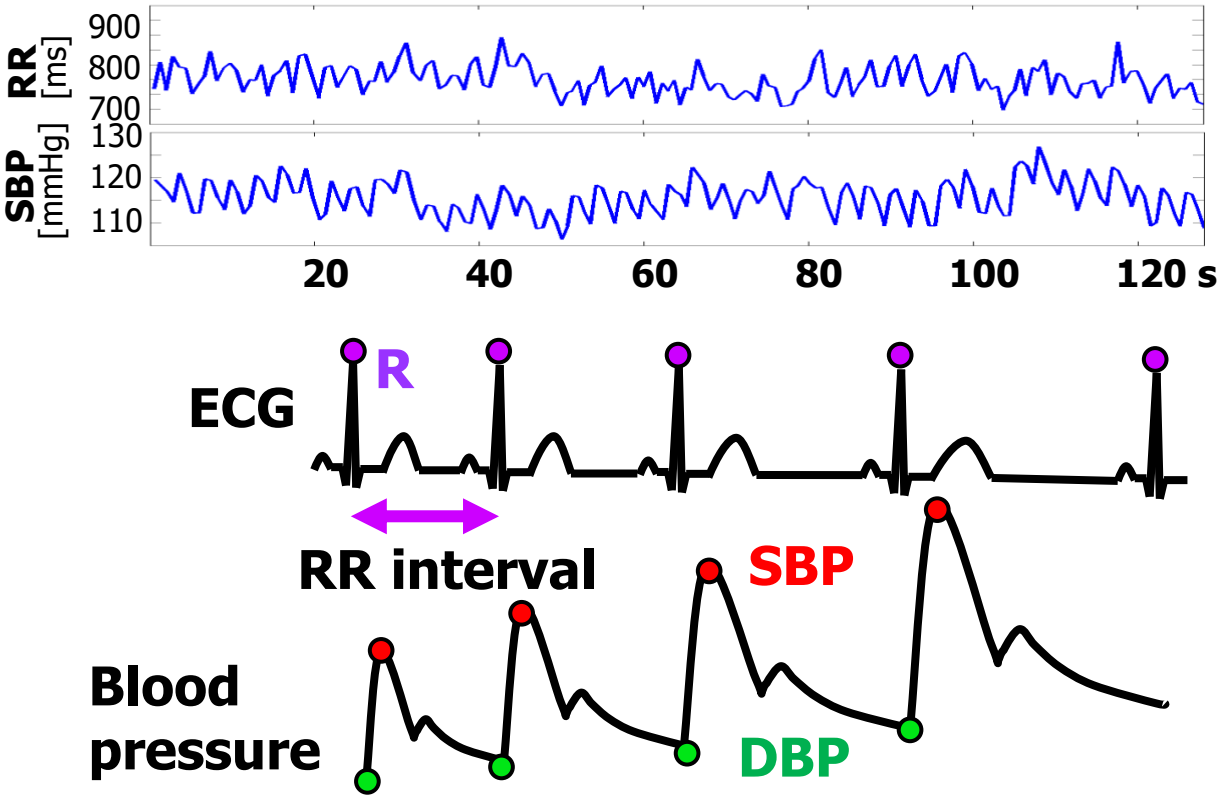
Signal: time series

- 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



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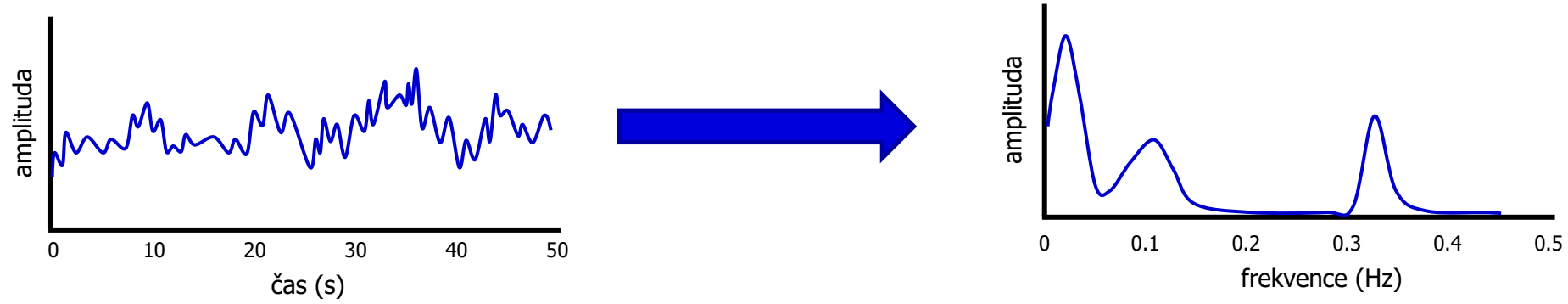
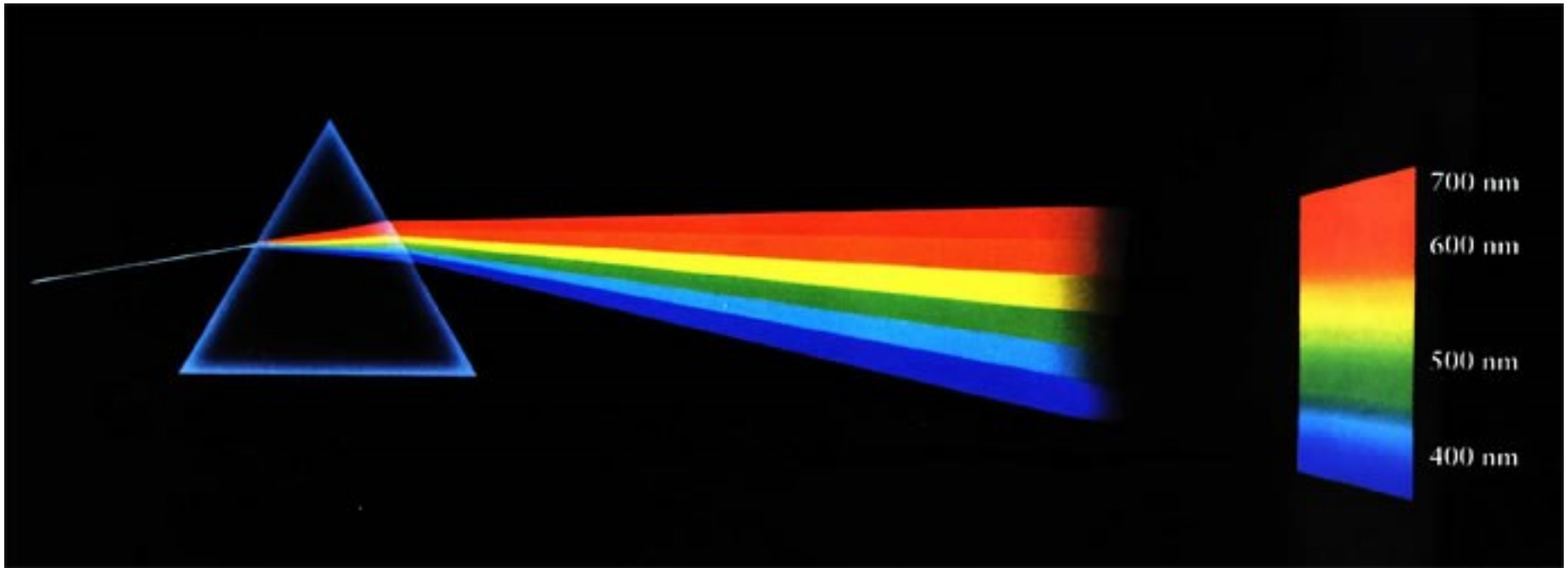
Metody frekvenční domény - spektrální analýza

Time series
Signal in time domain

Spectrum
Signal in frequency domain

Signal is decomposed in individual frequencies





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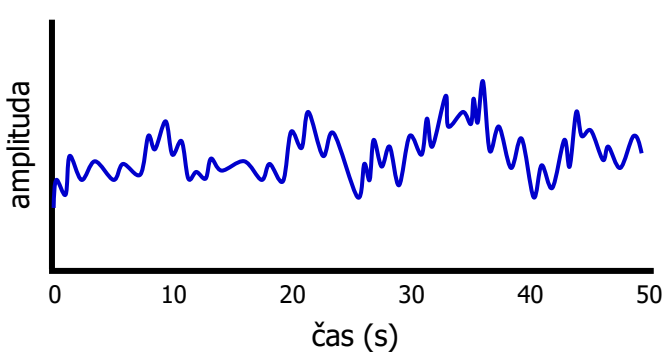
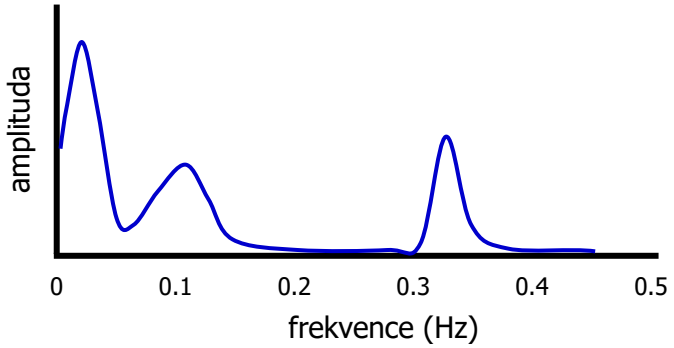
Spectral analysis of time series

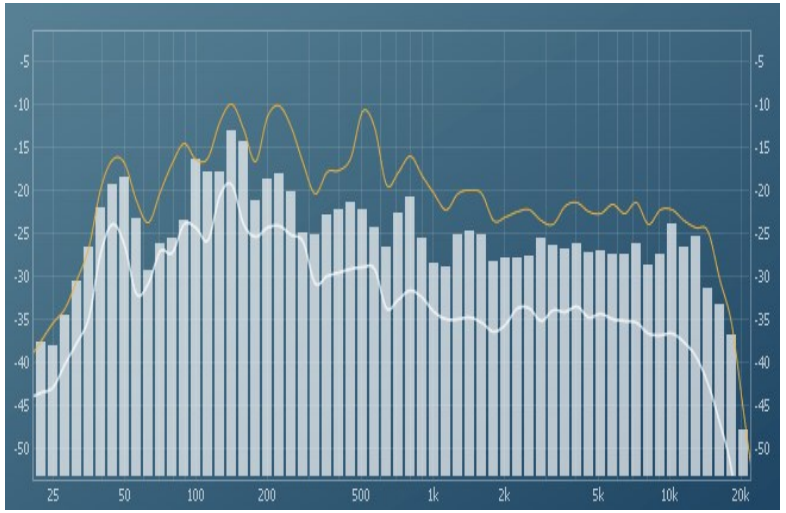
Time series
Signal in time domain

Spectrum
Signal in frequency domain

Signal is decomposed in individual frequencies







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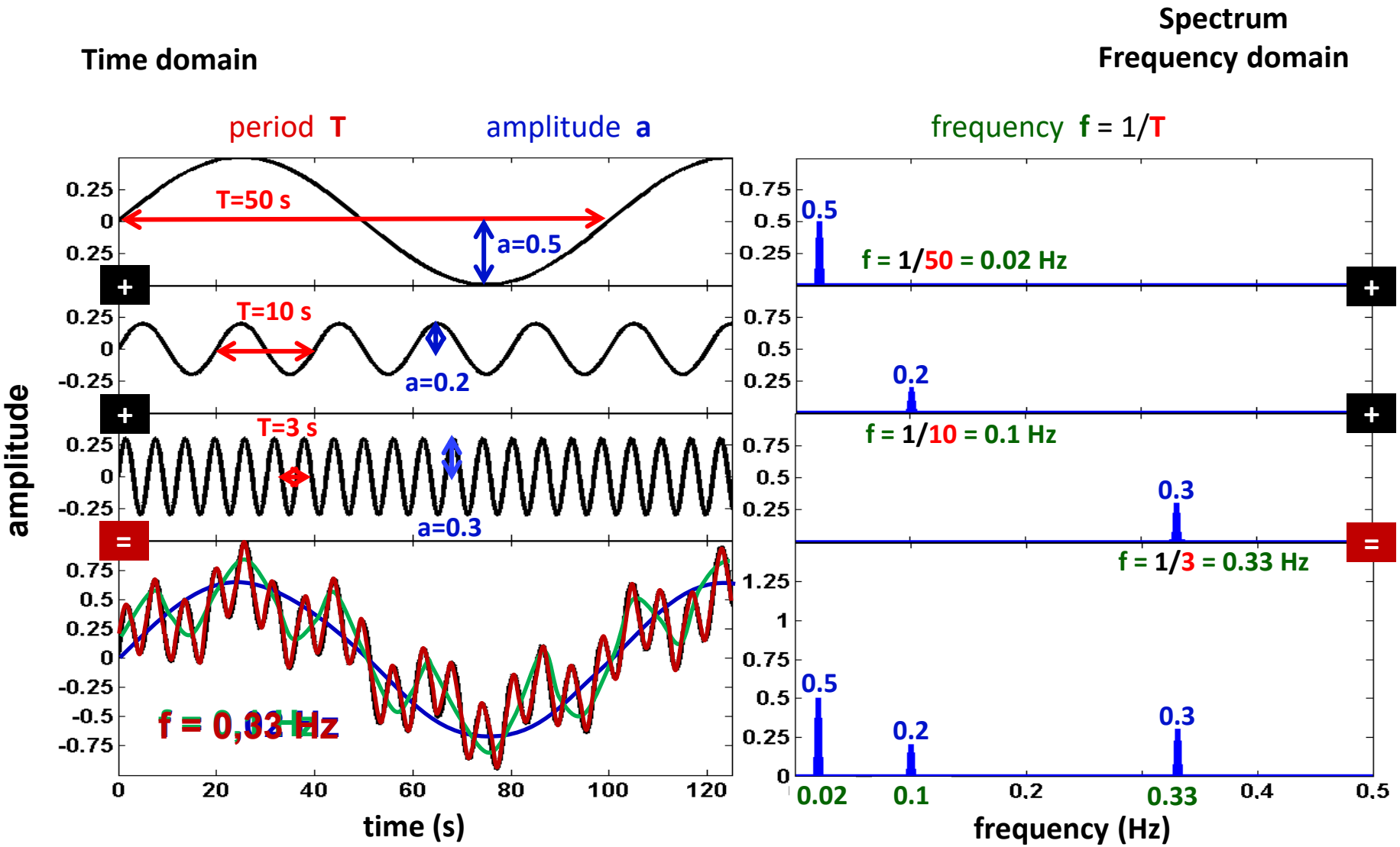
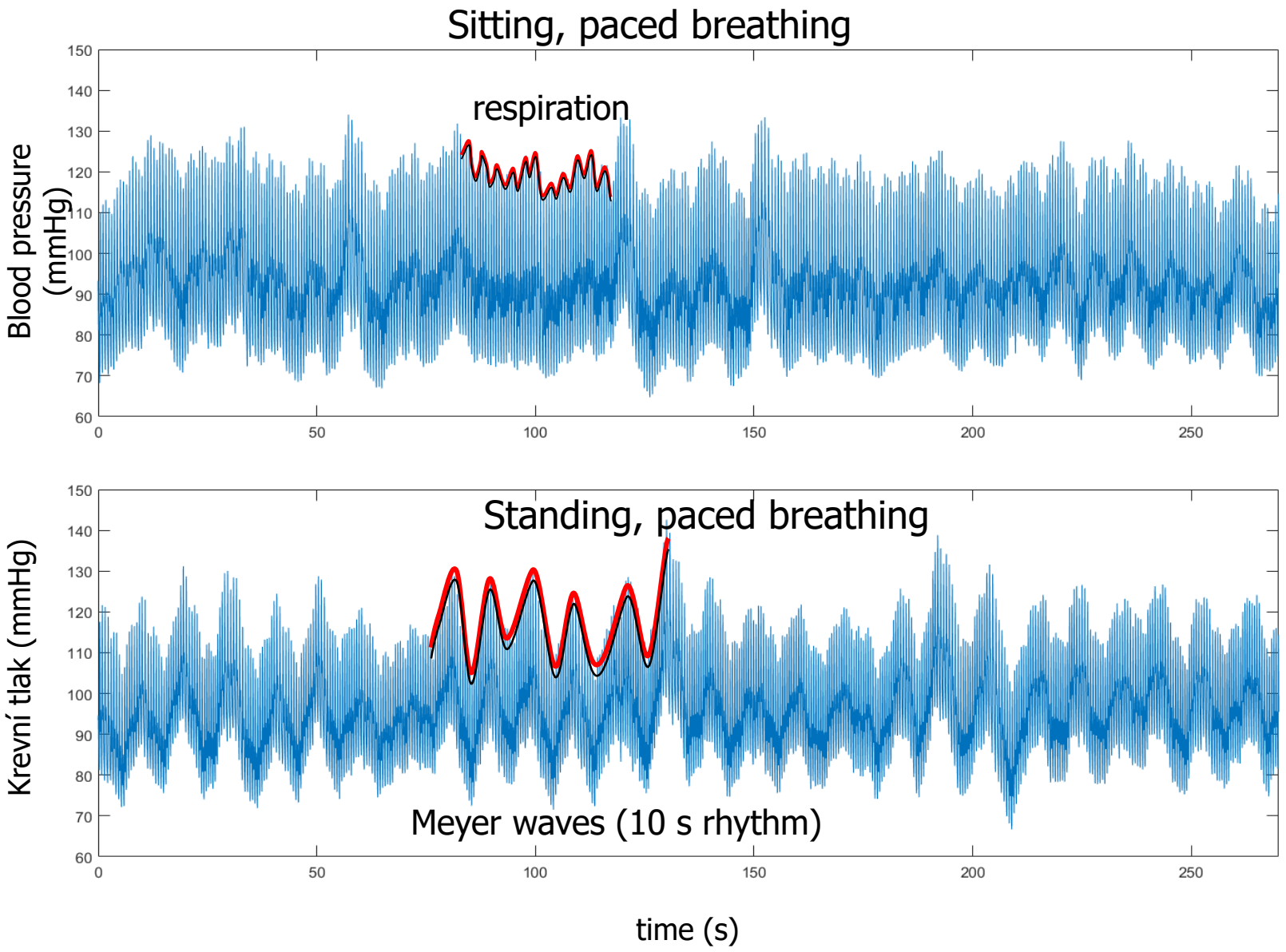
How the spectrum is formed?



Blood pressure signal (270 s)



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sequentions of SBP, DBP and RR intervals

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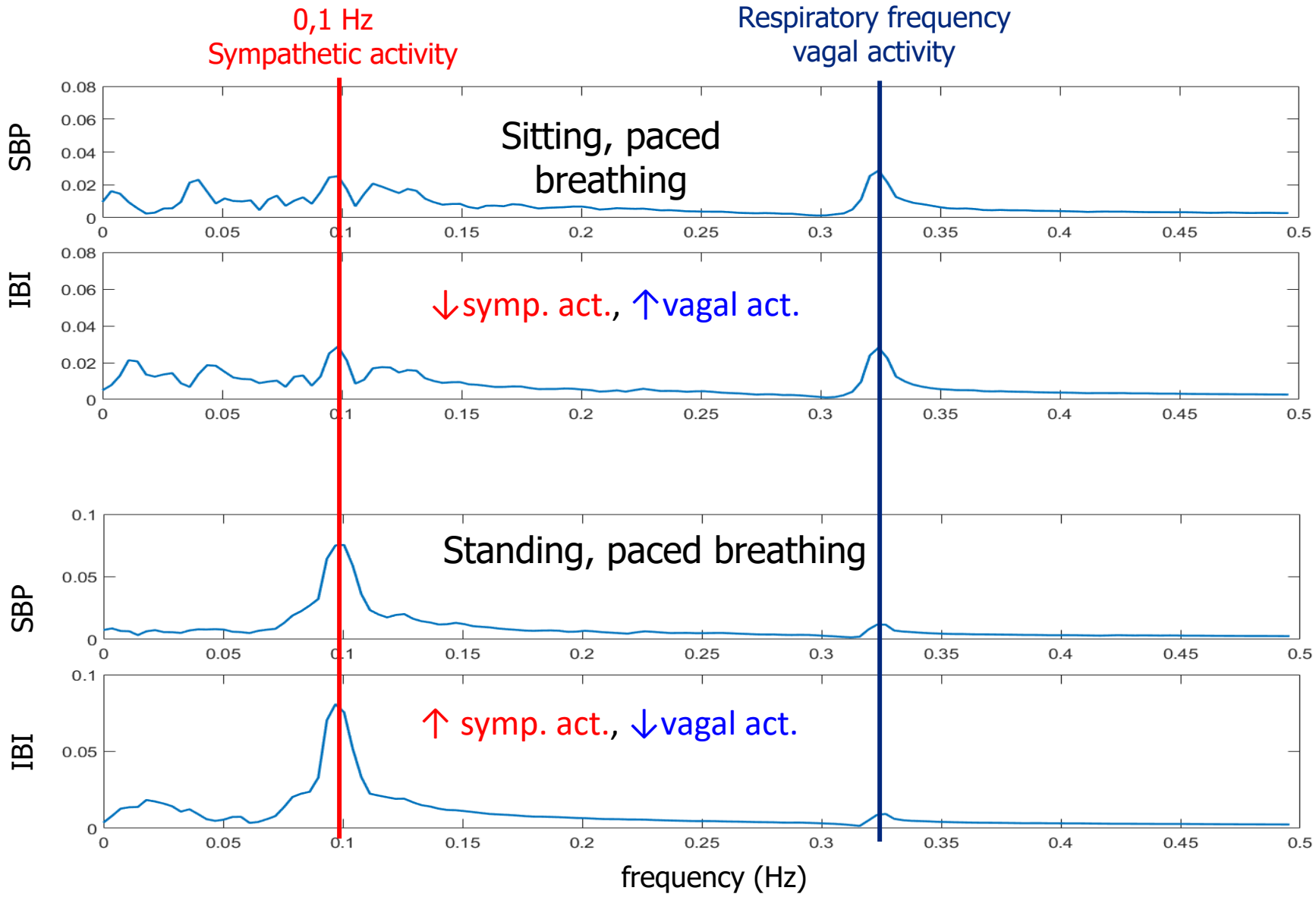
Spectra of SBP and IBI



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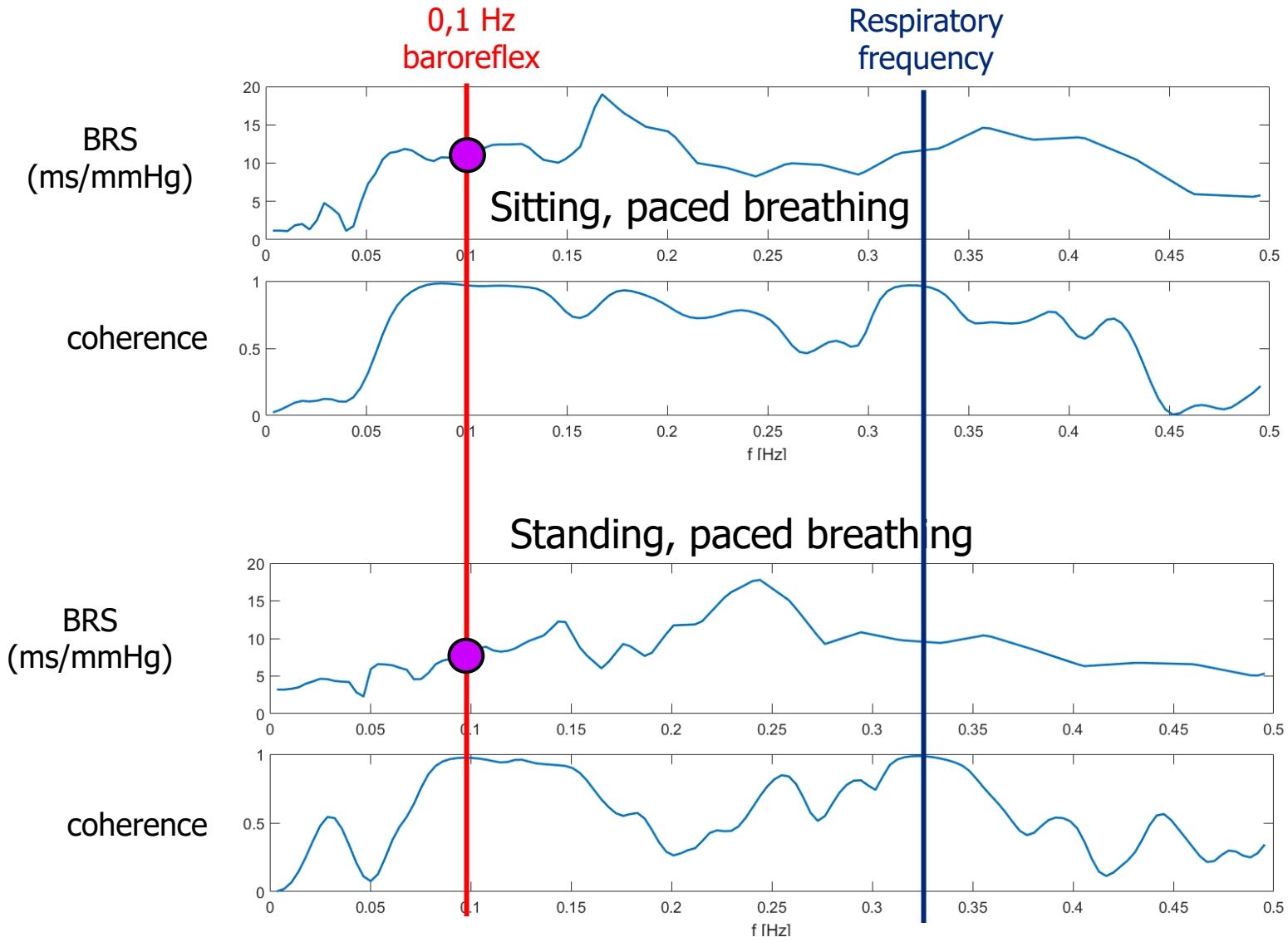
Coherence a BRS

coherence: synchronization between signals (correlation on particular frequency)



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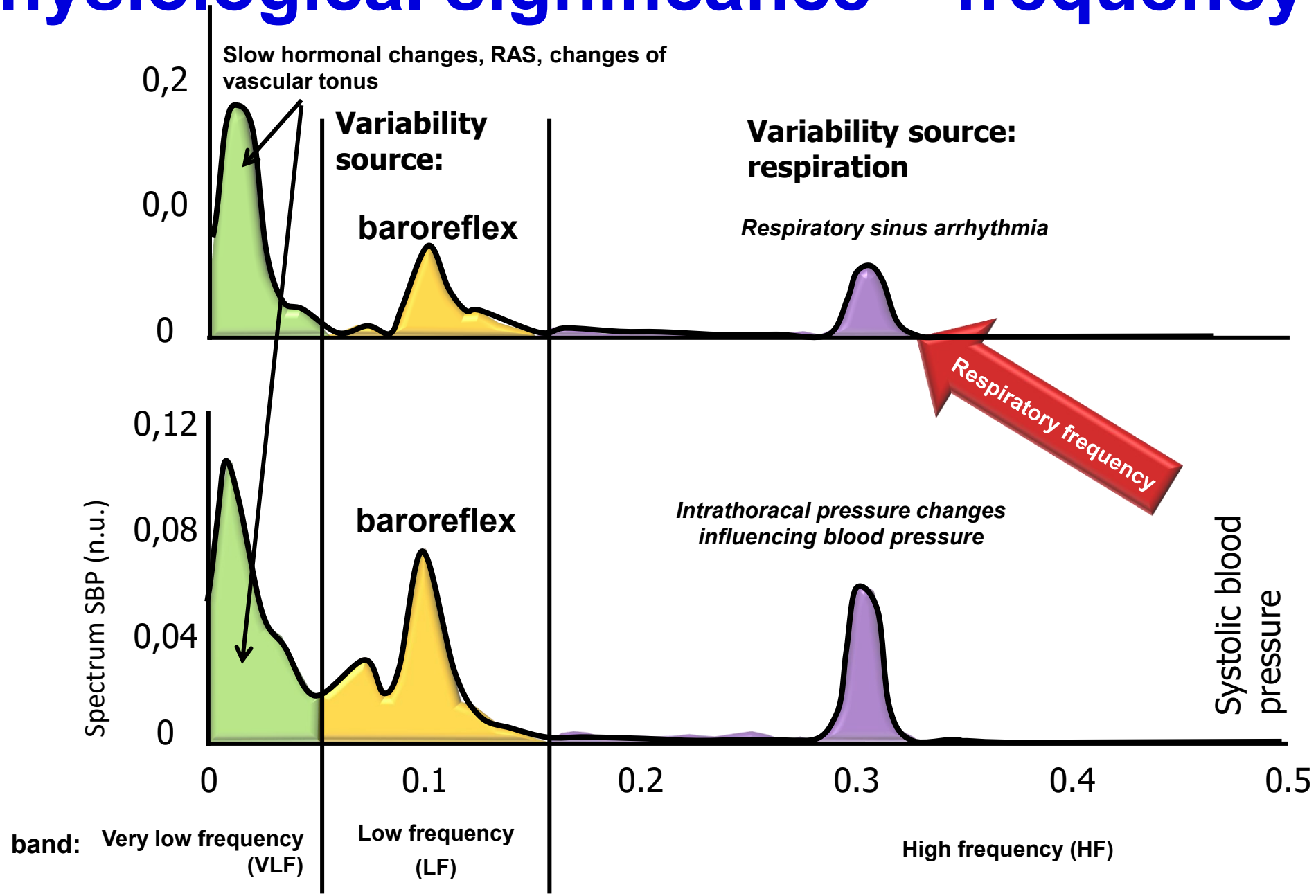
Physiological significance – frequency bands



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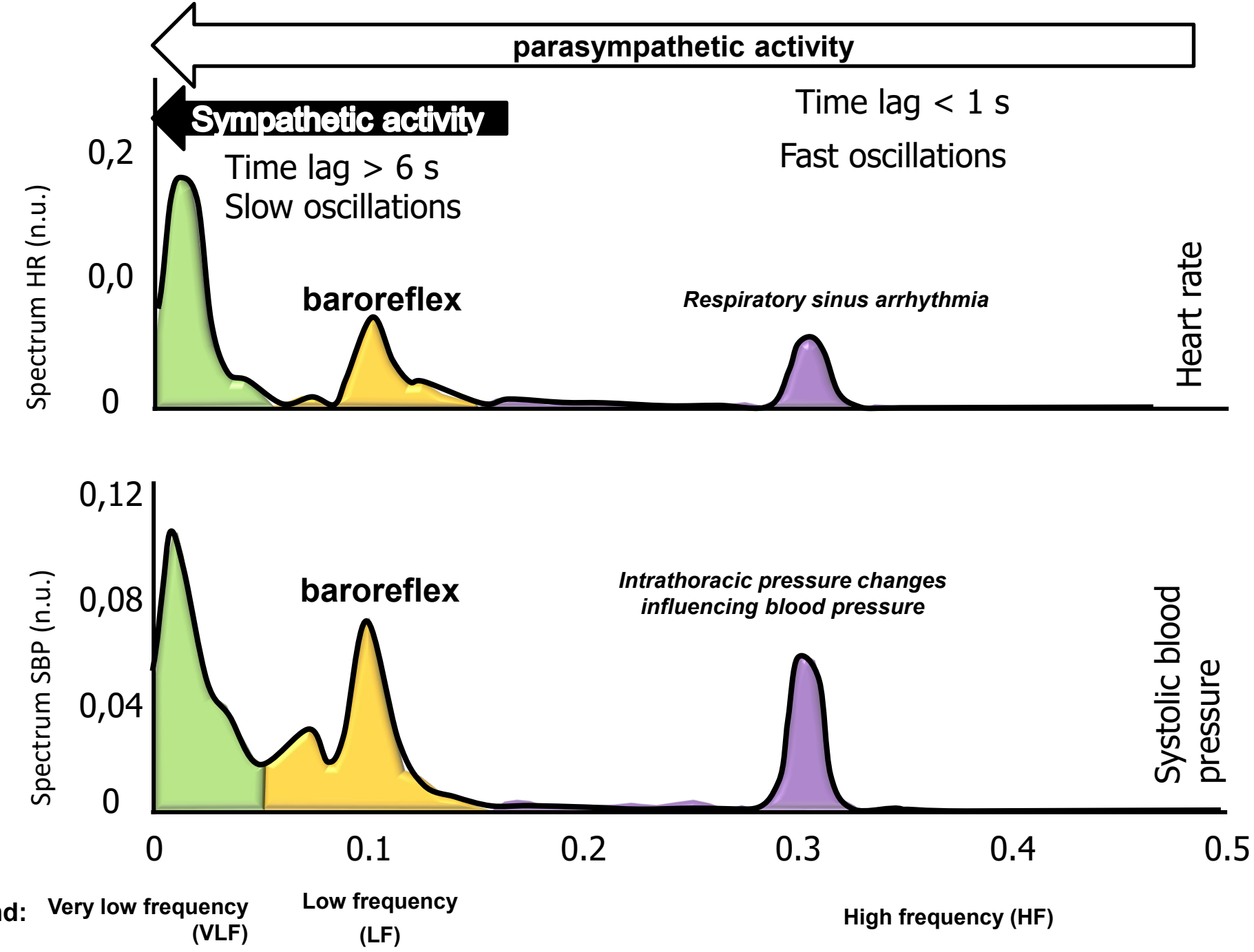
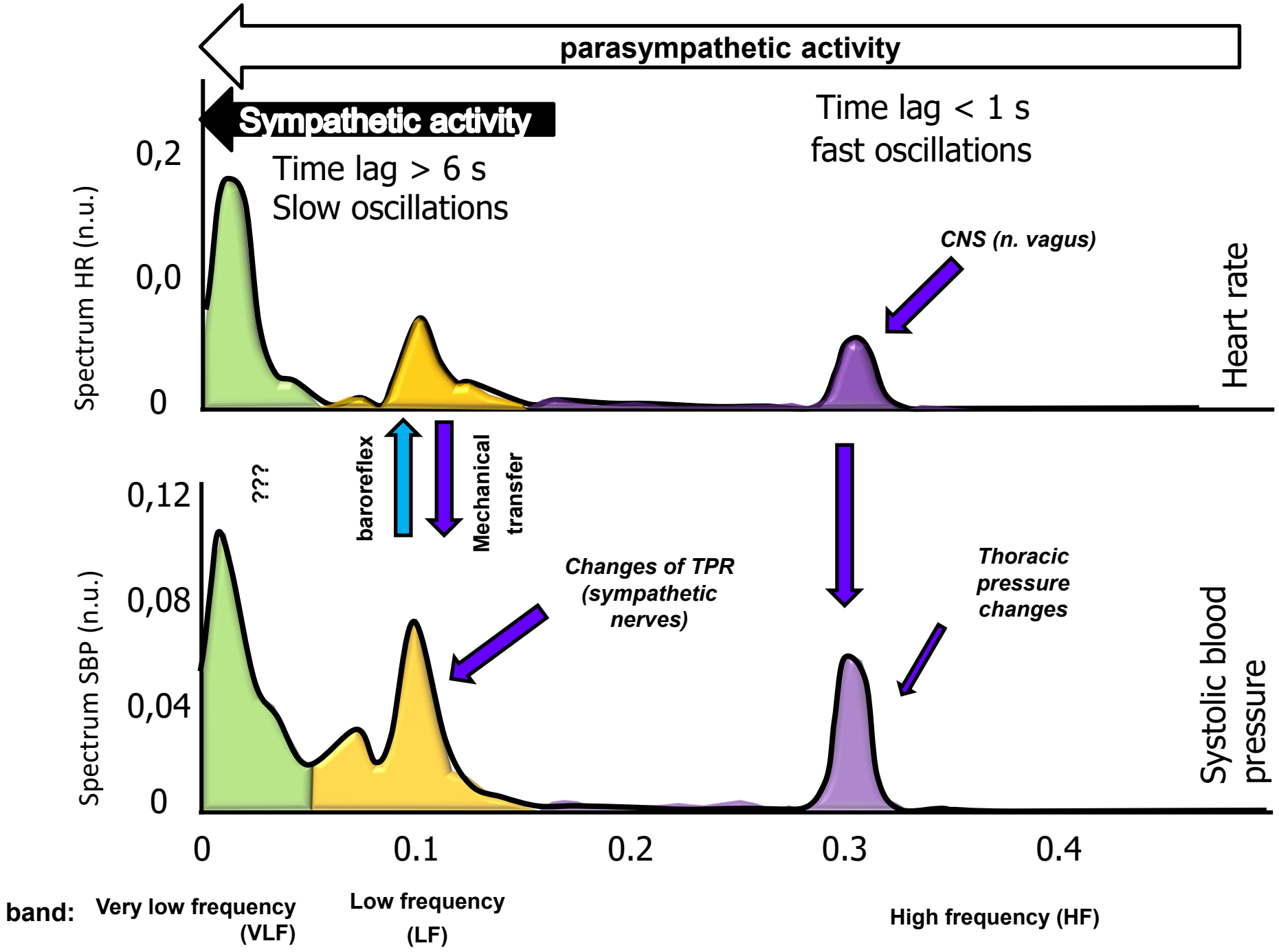

parasympathetic activity
Sympathetic activity
Time lag < 1 s
Fast oscillations
Time lag > 6 s
Slow oscillations
0,2
0,0
0
Spectrum HR (n.u.)
baroreflex
Respiratory sinus arrhythmia
Heart rate
0,12
0,08
0,04
0
Spectrum SBP (n.u.)
baroreflex
Intrathoracic pressure changes
influencing blood pressure
Systolic blood
pressure
0
0.1
0.2
0.3
0.4
0.5
band:
Very low frequency
(VLF)
Low frequency
(LF)
High frequency (HF)


parasympathetic activity
Sympathetic activity
Time lag > 6 s
Slow oscillations
Time lag < 1 s
fast oscillations
CNS (n. vagus)
Heart rate
Spectrum HR (n.u.)
0,2
0,0
0
baroreflex
Mechanical transfer
???
Changes of TPR (sympathetic nerves)
Thoracic pressure changes
Systolic blood pressure
Spectrum SBP (n.u.)
0,12
0,08
0,04
0
0
0.1
0.2
0.3
0.4
band:
Very low frequency (VLF)
Low frequency (LF)
High frequency (HF)

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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)

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Variability – for exam

- Heart rate variability – autonomic nervous system activity analysis
  - high – good regulation of heart
  - low – increased cardiovascular risk
- Baroreflex sensitivity (BRS)
  - sufitient (> 4 mmHg) – baroreflex aktivity 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 arhytmia)

    LF (around 0,1 Hz): sympathetic/parasym. activity, baroreflex

    VLF (< 0,03): low changes in vascular system (hormones, TPR, RAS,…)

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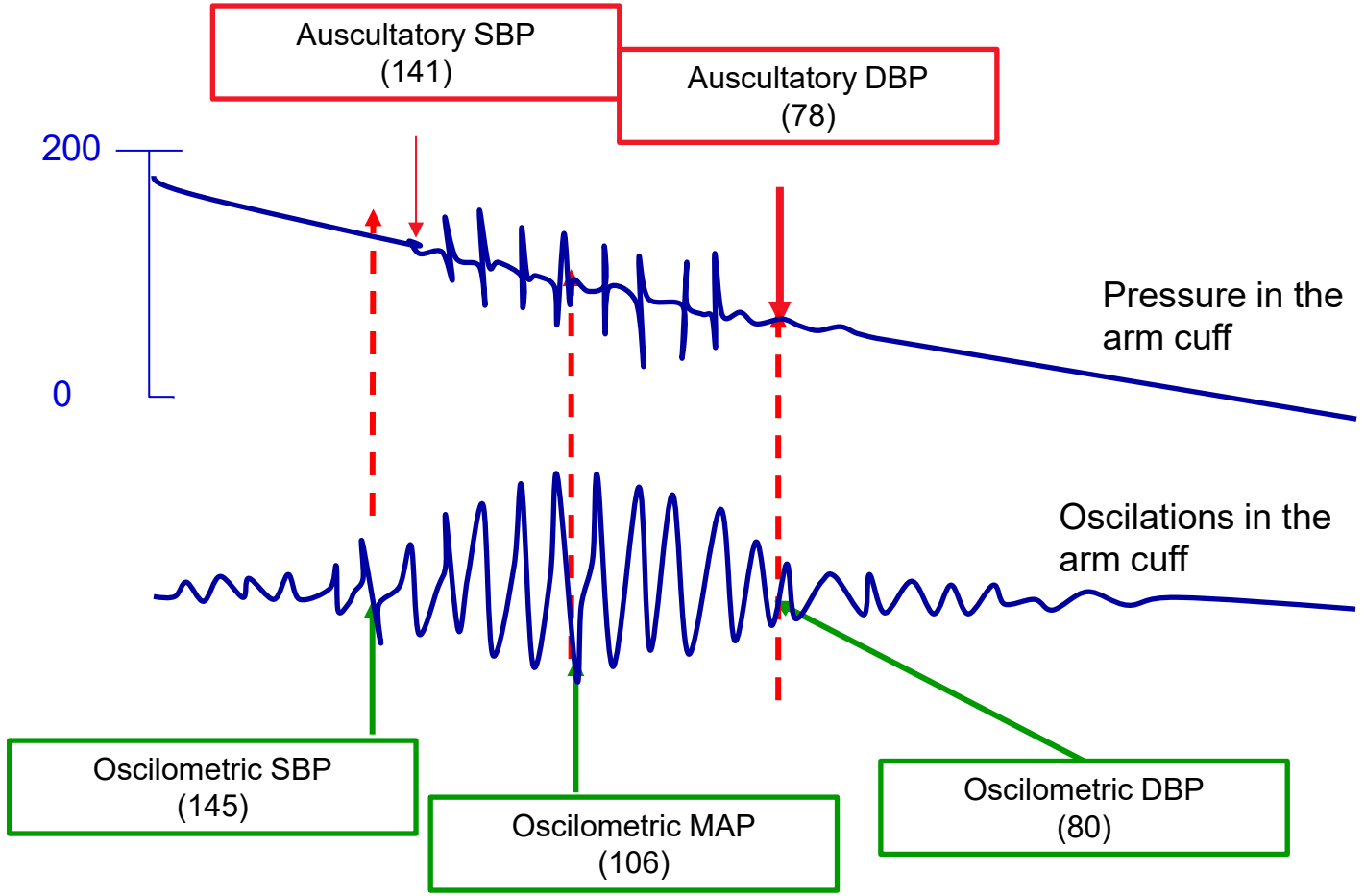
Non-invasive blood pressure measurement

Auscultatory and oscilometric method



Only discrete values of SBP and DBP are obtained
(in compare to whole continual blood pressure signal)

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Oscilometric blood pressure measurement

- advantages/disadvantages, measurement errors

Factors Afecting 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

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Good luck in exam

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