**CYCLE III:**
**PHYSIOLOGY OF THE CARDIOVASCULAR SYSTEM.**

<table>
<thead>
<tr>
<th>Unit</th>
<th>Topic</th>
<th>Upper halves of groups</th>
<th>Lower halves of groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Heart I: Cardiac muscle. Physical examination of the chest. Hemodynamics of the cardiac action.</td>
<td>20/02/2017 &amp; 22/01/2017</td>
<td>27/02/2017 &amp; 01/03/2017</td>
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<tr>
<td>2</td>
<td>Heart II: Electrocardiography (part I).</td>
<td>27/02/2017 &amp; 01/03/2017</td>
<td>20/02/2017 &amp; 22/02/2017</td>
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<tr>
<td>3</td>
<td>Heart III: Electrocardiography (part II). Adaptation of the heart to the physical exercise. Cardiac output.</td>
<td>06/03/2017 &amp; 08/03/2017</td>
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<td>4</td>
<td>Arterial circulation – basics of hemodynamics. Arterial pulse. Arterial pressure – measurement and regulation.</td>
<td>13/03/2017 &amp; 15/03/2017</td>
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<tr>
<td>5</td>
<td>Microcirculation. Venous system. Regulation of the cardiovascular system – part I. Neuroregulation. Baroreceptors. Orthostatic reaction.</td>
<td>20/03/2017 &amp; 22/03/2017</td>
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<td>6</td>
<td>Regulation of the cardiovascular system – part II. Chemoreceptors. Local regulation. Exercise adaptation of the cardiovascular system. Coronary circulation.</td>
<td>27/03/2017 &amp; 29/03/2017</td>
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**Retake of the cycle II**

<table>
<thead>
<tr>
<th>Date</th>
<th>Activity</th>
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<td>21/02/2017</td>
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**Repetition of failed and/or absent activities in cycle III.**

<table>
<thead>
<tr>
<th>Date</th>
<th>Activity</th>
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<tr>
<td>27/03/2017 &amp; 29/03/2017</td>
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**Seminar**

<table>
<thead>
<tr>
<th>Seminar</th>
<th>Topic (location)</th>
<th>Date/Group/Time</th>
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<tbody>
<tr>
<td>Sem. XI</td>
<td>Electrocardiography ( Room A – Rybacka St.)</td>
<td>27/01/2017 N2 (12:00) N3 (13:30)</td>
<td>27/01/2017 N1 (12:00) N4 (13:30)</td>
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<tr>
<td>Sem. XI</td>
<td>Electrocardiography (Dept. Physiol.)</td>
<td>22/02/2017 N5 (11:30)</td>
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<tr>
<td>Sem. XII</td>
<td>Mechanical cardiac cycle (Dept. Physiol.)</td>
<td>24/02/2017 N1 (11:15-12:45) N2 (12:45-14:15) N5 (15:00-16:30)</td>
<td>03/03/2017 N3 (11:15) N4 (12:45)</td>
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<tr>
<td>Sem. XIII</td>
<td>Regulation of the cardiac output (Room A – Rybacka St.)</td>
<td>24/02/2017 N3 (12:00) N4 (13:30)</td>
<td>03/03/2017 N1 (12:00) N2 (13:30) N5 (15:15)</td>
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<tr>
<td>Sem. XIV</td>
<td>Reflex regulation of the arterial pressure (Dept. Physiol.)</td>
<td>17/03/2017 N1 (11:15-12:45) N2 (12:45-14:15) N5 (15:00-16:30)</td>
<td>10/03/2017 N3 (11:15) N4 (12:45)</td>
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<tr>
<td>Sem. XV</td>
<td>Factors affecting peripheral resist... ( Room A – Rybacka St.)</td>
<td>17/03/2017 N3 (12:00) N4 (13:30)</td>
<td>10/03/2017 N1 (12:00) N2 (13:30) N5 (15:15)</td>
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**Credit of the cycle III (Rybacka).**

<table>
<thead>
<tr>
<th>Date</th>
<th>Activity</th>
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<tr>
<td>31/03/2017</td>
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</table>
Unit 1. Cardiac muscle. Physical examination of the chest. Hemodynamics (mechanics) of the cardiac action.
1. Specificity of the excitation-contraction coupling in heart. Cardiac action potential.
2. Examination of the heart:
   - Observation of the chest and the precordium.
   - Palpation of the chest. Examination of the apical impulse (apex beat).
   - Percussion of the chest. Assessment of the borders of the cardiac dullness.
   - Auscultation of the heart.
3. Computer programs/simulations - Influence of various chemical substances on heart.

Obligatory terms and problems:
- Types of cardiomyocytes. Ionic channels of the cellular membrane of cardiomyocytes. Relation between the action of particular channels and generation of the action potential in atrial and ventricular cardiomyocytes and P-cells of the cardiac conductive system. Phases of the action potential in cardiomyocytes. Cardiac automatism – function of the P-cell (prepotential and heart rate).
- Cardiac conductive system. Electromechanical coupling in cardiomyocytes. Chronotropism, inotropism, dromotropism, batmotropism, tonotropism.

Unit 2. Heart II: Electrocardiography (part I).
1. Cardiac conduction system.
2. Recording of the electrical activity of the heart with bipolar and unipolar, precordial and limb leads.
3. Introduction to analysis of the normal electrocardiogram.

Obligatory terms and problems:
- Cardiac muscle – functional features. Cardiac conduction system. Spread of the cardiac excitation.
- Electrocardiography:
  2. Electrical waves, complexes, intervals and segments.
  3. Assessment of the rhythmicity and the origin of the heart rhythm, heart rate.
  4. Assessment of waves and complexes, segments and intervals (their duration and shape).
  5. Assessment of the cardiac vectors (the electrical axis of the heart).
  6. Location of the heart in the chest.

Unit 3. Heart III: Electrocardiography (part II). Measuring of the cardiac work. Regulation of cardiac performance.
1. Assessment of the normal electrocardiogram – UNIT TEST IN ECG.
2. Adaptation of the heart to the physical exercise - discussion.
3. Assessment of the physical efficiency based on the chronotropic reaction of the heart – test PWC170.
4. Factors affecting the cardiac output - discussion.

Obligatory terms and problems:
- ECG – See unit 2.
- Factors affecting inotropic state of the cardiac musculature. Preload and afterload: heterometric and homeometric regulation of the heart. Contractility of the heart. Influence of the autonomic nervous system and circulating catecholamines on heart.
- Functional reserve of the heart. Adaptation of SV, HR and cardiac output to the exercise. Energy sources and metabolism of the cardiac muscle. Oxygen consumption. Arterio-venous difference in the oxygen concentration.

1. Arterial pulse.
   - Definition of the arterial pulse.
   - Examination of the arterial pulse characteristics (frequency, rhythm, amplitude, compressibility, rise).
1. Examination of the arterial pulse in various regions.
2. Analysis of the arterial pulse curves. The origin of the dicrotic notch.
3. Determination of the heart rate in ECG during various exercises:
   - after compression of the common carotid artery,
   - during respiration (deep and shallow respiration, hyperventilation, after breath stopping in the peak of inspiration and expiration).
5. Hinness test.
6. Factors affecting the arterial pressure – discussion.

**Obligatory terms and problems:**
- The functional division of the blood vessels. The vascular wall - the morphology. Function of the various parts of the cardiovascular system.
- Sphygmography. Features of the arterial pulse.
- The arterial pressure: primary, secondary, tertiary waves, systolic pressure, diastolic pressure, mean arterial pressure, factors which determine the systolic-diastolic amplitude, effect of gravity.
- The peripheral resistance: essence, location and value. Precapillary sphincters – the function. The local regulation of the blood flow, active (arterial) and passive (venous) hyperemia. Factors influencing the vessel diameter.
- Vasomotor innervation of the circulation system. The myogenic/neurogenic tension.

**Unit 5. Venous system. Microcirculation. Regulation of the cardiovascular system – part I.**
2. Methods and medical significance of measurement of the central venous pressure (CVP) and peripheral venous pressure.
4. Effect of gravity onto cardiovascular system.
   - Schelong test.
   - Orthostatic test.
5. Neuroregulation of the cardiovascular system.

**Obligatory terms and problems:**
- Central and peripheral venous pressure – definition and values. Jugular venous pulse (phlebography) – waveforms of the jugular venous pressure.
- Capillary filtration coefficient. Active and reactive hyperemia. Mechanism of the venous return. Blood reservoirs active and compensatory areas.
- The blood flow – velocity, intensity, and the time of circulation – definitions and values.
- Effect of the gravity force onto circulation – orthostatic reaction.
- Organization of the cardiovascular centre. Organization of the medullar neurons of the cardiovascular system: NTS, nuclei of the vagus nerve, areas – RVLM and CVLM.
Unit 6. Regulation of the cardiovascular system – part II.
1. Adaptation of the cardiovascular system to the exercise – Martinette test
2. Cardiovascular reflexes from arterial chemoreceptors.
3. Local and humoral regulation of the blood flow - discussion.
4. Repetition of failed and/or absent activities in cycle 3.

Obligatory terms and problems:
- Chemoreceptors – location, stimulation, mechanisms of action. Action of precapillary sphincters.
- Local regulation of circulation. Active and passive hyperemia. Humoral factors affecting diameter of vessels.
- Effects of static and dynamic exercises onto cardiovascular system – adaptation, physiological mechanisms exercise reaction. Distribution of blood during exercise.

Seminar XI: Electrocardiography.
1. Heart as a volume conductor.
2. Action potential of the cardiomyocyte and electrocardiogram.
3. Origin and features of the P wave.
4. Function of the cardiac conduction system – PQ interval.
5. Electrical vector of the ventricular depolarization – QRS complex.
6. Location of the heart in the chest.
7. Repolarization of ventricles.
8. ECG leads.

Seminar XII: Mechanical cardiac cycle.
1. Ventricular relaxation (diastole).
   - Protodiastole,
   - Isovolumetric relaxation,
   - Rapid filling,
   - Diastasis,
   - Atrial systole.
2. Ventricular systole.
   - Isovolumetric ventricular contraction,
   - Ejection (rapid; reduced).
3. Heart sounds.
4. Changes of volume and pressure during cardiac cycle. Work of the heart.

Seminar XIII: Regulation of cardiac output.
1. Cardiac output – definition, equation.
2. Regulation of heart rate – influence of the autonomic nervous system.
3. Intrinsic regulations of cardiac output.
   - Heterometric regulation.
   - Homeometric regulation.
4. Heterometric regulation / Starling’s law of heart:
   - End diastolic volume – index of preload.
   - EDV – regulation (venous return, phases of cardiac cycle).
5. Homeometric regulation:
6. Afterload.
7. Law of augmentation, law of restitution.
8. Extrinsic regulation of contractility.
Seminar XIV. Reflex regulation of the arterial pressure.
1. Vasomotor center.
4. Atrial mechanoreceptors (type A, type B) – Bainbridge reflex.
5. Mechanoreceptors of the pulmonary region.
6. Chemoreceptors.
7. Chemodetectors.

Seminar XV. Factors affecting peripheral resistance. Endocrines and the cardiovascular system.
1. The concept of the vascular resistance. Resistant vessels.
2. Passive (elastic) tension.
3. Active tension:
   - Myogenic = basic,
   - Neurogenic.
4. Vasomotor nerve fibers.
5. Factors synthesized in the vascular endothelium
7. Non-eicosanoids (endothelin, EDRF =NO).
8. Effects of hormones on cardiovascular system:
   - Catecholamines.
   - Renin-angiotensin-aldosteron system.
   - Vasopressin.
   - Natriuretic peptides.
   - Thyroid gland hormones.

Credit of the cycle 3. Topic discussed on seminars XI-XV and units 1-6.
Definition of the arterial pulse – cyclic pulsation of arteries related to phases of the cardiac cycle. It is caused by changes of the blood pressure and flow. According to the parameter: volume, pressure and flux pulse can be analyzed.

1. Examination of the arterial pulse characteristics.
To perform the examination, place 3 middle fingers of your hand over the radial artery at the wrist of the subject. Determine following characteristics of the radial artery pulse:

**Frequency:**
- pulsus frequens, tachycardia
- pulsus rarus, bradycardia

**Rhythmicity:**
- (pulsus regularis),
- (pulsus irregularis – arrhythmic).

**Amplitude:**
- high pulse (pulsus altus sue magnus),
- low pulse (pulsus parvus).

**Compressibility** (to estimate the intravascular pressure and condition of the arterial wall press artery with your middle finger, using the force which stops the pulsation of the peripheral part of the radial artery:
- hard pulse (pulsus durus),
- soft pulse (pulsus mollis).

**Rise** of the pulse wave:
- rapid pulse (pulsus celer),
- slow pulse (pulsus tardus).

2. Examination of the arterial pulse in various regions.
Examination can be easily performed over the common carotid artery, temporal artery, subclavian artery, femoral artery, popliteal artery, tibial posterior artery, dorsal artery of the foot, etc.

**Arterial pressure** – results from the extension of the elastic walls of the arterial vessels by the blood present in their bed. This blood volume depends on the output of the left ventricle of the heart and the possibility of outflow through resistance vessels.

**Jugular venous pulse** – phlebogram.
Physiological phlebogram of the jugular venous pulse reflects phasic changes of the pressure in the right atrium, which spreads, retrogressively to the central venous system (velocity of the movement – 1.5 m/s). The phlebogram consists of three positive waves (a, c, v) and two negative waves (x and y).

- **Wave a** – venous distension produced by atrial contraction (the highest wave of the jugular venous pulse).
- **Wave c** – produced by the bulging of the right atrioventricular (tricuspid) valve into the right atrium during isovolumetric contraction of the right ventricle.
- **Wave x** – venous pressure decrease produced by diastolic atrial relaxation and the downward movement of the tricuspid valve (and all the base of the heart) during systolic ejection. Heart works as suction pump only in this phase.
- **Wave v** – produced by the increasing volume of the blood in veins and the right atrium during ventricular diastole (tricuspid valve is closed).
- **Wave y** – produced by the rapid inflow of the blood into the right ventricle from the atrium. Phlebogram finishes with the increase of pressure both in atrium and ventricle in diastasis.