



**Università degli Studi di Verona**  
**Corso di Laurea in Scienze delle attività motorie e sportive**  
**A.A. 2019-2020**

<p><i>Integrated Course</i> <i>Physiology</i> <i>12CFU</i></p>	<p><i>Professor</i> <i>Carlo Capelli (coordinator)</i> <i>Enrico Tam</i></p>
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**Receiving hours: Carlo Capelli, on Tuesday 14:00- 15:00; Enrico Tam, on Tuesday 14:00- 15:00**

**Targets of the Course**

- Learning the basic functions of the human body intended as a set of organs and systems by integrating and complementing the existing knowledge of physics, chemistry, biochemistry, anatomy and biology.
- Learning how to apply the scientific method to the analysis of physiological responses to stresses such as physical exercise.
- Identifying the functional purpose of the physiological systems understanding their role in the maintenance of homeostasis of human organism.
- Acquire the fundamental physiological basis of motor control in humans.

**Course Topics**

**Preliminary general knowledge**

In order to understand the course of Physiology, you must have first assimilated the basics of Chemistry, Physics, Biochemistry and Mathematics, in particular:

- **Chemistry:** the concept of pH, molarity, colligative properties of solutions, osmolality and osmotic pressure, diffusion.
- **Biochemistry:** concepts of enthalpy, entropy, free energy, biological macromolecules, their classification and function, the main metabolic pathways, enzyme kinetics and mitochondrial enzymes.
- **Physics:** physics of gases, electro physics, surface tension, Laplace's law, the basics of mechanics, statics and dynamics of fluids, laws of thermodynamics.
- **Biology:** biophysical characteristics of the cell membrane; structure of the cell and cellular organelles; the genetic code; transcription and translation; protein synthesis; membrane receptors; the intracellular signals and the second messengers (Protein G, AMP cyclic, Calcium, etc.); transport mechanisms through the membrane; mechanisms of cell regeneration.
- **Mathematics:** the concept of the logarithm, the concept of function and axes, functions, linear, power, exponential; methods of manipulation of logarithms, the concepts of derivative and integral; units of the international system

## **Topics**

1. Principles of general physiology and biophysics of the cell
2. Physiology and biomechanics of striated muscle
3. Motor control (spinal and supraspinal mechanisms)
4. The autonomic nervous system
5. Physico-chemical characteristics of the blood; coagulation and hemostasis
6. Cardiovascular physiology: heart and circulation Regulation of acid-base
7. Respiration
8. Renal Physiology: filtration, reabsorption, secretion and excretion
9. Acid-base regulation
10. Fluid and electrolyte balance
11. Metabolism and thermoregulation
12. Physiology of the endocrine system
13. Physiology of muscular exercise

### **1. Principles of general physiology and biophysics of the cell**

Preliminary knowledge: principles of electro-physics: concept of electric charge, potential, electric field, electric resistance, capacitor, potential, potential difference and electric current. The student should learn:

- 1.1 The definition of cellular homeostasis; identify the main mechanisms that ensure its maintenance, the composition and the biophysical characteristics of the plasma membrane, the importance of passive and active transcellular transport mechanisms for molecules in solution, for ionized substances and water, with explicit reference to **osmosis** and to the osmotic phenomena.
- 1.2 Understand the importance of ionic equilibria in order to learn the principles of excitability, conduction, synaptic transmission and muscle contraction; achieve a thorough understanding of the cellular resting potential and of action potential, of the morpho-functional model of synaptic transmission (electrical and chemical **synapses**, excitatory and inhibitory), as the basis for the functional integration of the nervous system, neuronal integration (spatial and time summation).

### **2. Physiology and biomechanics of striated muscle.**

Preliminary knowledge: anatomy and histology of the striated muscle-skeletal

- 1.1 Structure of the functional unit of muscle: the sarcomere; thin and thick filaments: structure and organization in the sarcomere; structure and function of the sarcoplasmic reticulum; electro-mechanical coupling; concept of a single twitch, clone and tetanus; mechanical model of muscle: contractile elements, elastic elements in series and parallel; determinants of muscle performance or power: strength and speed; types of contraction (isometric, isotonic, isokinetic, concentric, eccentric); biomechanics of muscle: force-length curves and curve speed strength; work and muscle power, the concept and definition of motor units; types of motor units and muscle fibers; in vivo regulation of muscle strength.

### **3. Motor control**

Preliminary knowledge: detailed knowledge of the anatomy of the spinal cord and CNS anatomy and physiology and biomechanics of striated skeletal muscle.

- 1.2 Organization of motoneurons and spinal interneurons; spinal motor activity: reflexes and central pattern generator of locomotion.
- 1.3 Muscle sensory systems: receptors of tension and elongation; the neuromuscular spindles; stretch receptors that detect muscle length and velocity of contraction; gamma MN; Golgi tendon organs (OTG): tension receptors.
- 1.4 Spinal reflexes (stretch reflex, inverse stretch reflex, flexor reflex of avoidance); functions of the brainstem in the control of posture.
- 1.5 Neural pathways of the brainstem; localization, somatotopic organization, cellular topography of the motor cortex; descending corticospinal pathways.

- 1.6 Organization and function of sensory feedback to the motor cortex; the supplementary motor areas and the programming of the movement; the posterior parietal cortex and sensory integration during intentional movements.
- 1.7 Anatomical and functional aspects of cerebellum: cerebellar lobes, topography of cerebellar function; deep nuclei of the cerebellum; afferent and efferent pathways of the nuclei; general functioning of the cerebellar circuits; cerebellar cortex, purkinje cells, climbing and mossy fibers;
- 1.8 The basal ganglia.

#### **4. *The autonomic nervous system.***

Preliminary knowledge: Detailed anatomical knowledge of the schema of the autonomic nervous system.

- 4.1 Functional anatomy of the SNA; chemical mediators and preganglionic and postganglionic receptors; overview of the functions of SNA; pharmacology of the SNA; the adrenal medulla; the negative feedback control mechanism: examples of autonomic reflexes: the baroreflex.

#### **5. *Physical and chemical characteristics of the blood; coagulation and hemostasis.***

Preliminary knowledge: concept of osmotic pressure, osmolarity and osmolality, colligative properties of solutions, hydrostatic pressure and osmotic concentration of a solution (Molar and Molal), the concept of equivalent.

- 5.1 Characteristics of red blood cells: regulation of erythropoiesis, life span,; white series; platelets.
- 5.2 Physical properties of the blood, density and viscosity, plasma composition (concentration and types of plasma protein, osmotic pressure, oncotic pressure).
- 5.3 Coagulation and haemostasis.

#### **6. *Cardiovascular Physiology: Heart and circulation.***

Preliminary knowledge: functional anatomy of the heart and of circulation; elements of the physics of fluids (static and fluid dynamics, the Hagen-Poiseuille law, Bernoulli's theorem, laws of Stevino and Leonardo, laminar and turbulent flow, viscosity and density of the fluid), the anatomical organization of the brain stem and of the system autonomic nervous.

- 6.1 General: identifying the functional role of the system and of its elements; understand the simplified model of the circulatory system and the division of the vessels by category: wall morphology and function. Describe the fall in blood pressure in the vascular and the velocity of flow in the different sections; understand the concept of circulatory average pressure and of the distribution of the blood volume in function of the capacitance.
- 6.2 The Heart - cardiac electrophysiology: knowledge of the details that distinguish cardiac electrical phenomena from those of other excitable cells: divide the myocardial in common, conduction tissue and myocardium of work; understand the basis for the cardiac automatism and conduction of excitation in the heart of the state.
- 6.3 The Heart - electrocardiography: the essential elements of electrocardiography: definition and explanation of phenomenology; Einthoven's triangle; standard electrocardiographic leads, and precordial amplified; description of the waves of an ECG standard, with analysis of their origin. Practical use of the ECG in the field of motor at rest and under stress; what the EGC says and what it does not say. Sinus rhythm and main rhythm disturbances.
- 6.4 The Heart – The heart pump: describe analytically, also with graphical representation, the mechanical events of the cardiac cycle: splitting in systole and diastole; further subdivision in different periods, with reference to the development of pressure, to volume changes, the behaviour of the valves. Changes in pump function under stress. Understanding the functioning of the heart as a mechanical pump: the heart-lung preparation of Starling and law, phenomenology and mechanisms; concept of contractility and its regulation; regulation of cardiac output and frequency; effect of stimulation of the vagus and sympathetic; humoral control. The work of the heart at rest and during different types of exercise (isometric and dynamic); cardiac efficiency (cardiac work, determined in energy consumption of the heart; efficiency of the heart); pathophysiology of heart failure and heart size.

- 6.5 The circle - principles of haemodynamics: the fundamental laws of fluid dynamics. Poiseuille's law and the determining role of viscosity and radius of the vessels; resistors in series and in parallel; laminar and turbulent flow; blood velocity in the different sections of the circulatory system. Compliance and capacitance. Filling volume and the volume in excess.
- 6.6 The circle - blood pressure: determinants of blood pressure; systolic, mean and diastolic; role of the elasticity of the arteries in the maintenance of pressure in diastole; arterial compliance; pulse wave: definition, origin and propagation; monitor performance; short-and long-term blood pressure control (baroreflex, chemoreflex); response to postural changes; blood pressure normal and diseases.
- 6.7 The circle - the microcirculation: identifying the functional function of capillaries of the circulatory system, through an analysis of the structural elements that allow the exchange and the forces that govern them; concept of capillary permeability and application of the laws of diffusion; Starling equilibrium for the exchange of liquids: the four pressures that come into play; pore pressure; notes on the formation, composition and lymph circulation.
- 6.8 The circle - the peripheral circulation and its control: vascular smooth muscle as effector control mechanisms of resistance and capacitance vessels; auto-regulation of the blood vessels; metabolic regulation; nervous regulation: vasoconstriction and vasodilation; bulbar vasomotor activity.
- 6.9 The circle – other vascular districts: acquire general concepts on the elements that characterize the regulation of the flow to each organ, studying in detail:
- skin circulation, with reference also to the temperature control function;
  - circulation of skeletal muscle, with reference to adaptation during muscular work and the effects of training;
  - the coronary circulation, with reference to the work and the return rate;
  - cerebral circulation;
  - the renal circulation;
  - the pulmonary circulation (pulmonary haemodynamics: a low-resistance circuit; distribution of the output of the right ventricle; recruitment and distension of the capillaries; model of the three zones of West; regulation of pulmonary circulation: role of innervation, localized or general response to hypoxia , pulmonary circulation in the fetus and changes in structural and functional at birth).

## **7. Respiration**

Preliminary knowledge: functional anatomy of the respiratory system, physical - chemical properties of the blood (haematocrit, haemoglobin concentration, coefficient of oxygen binding to haemoglobin), the structure of haemoglobin, the basic concepts of physics and mechanics of fluid physics, the lung circulation, concept of pH, buffer substances, anatomical organization of the brainstem and of autonomic nervous system.

- 7.1 General: concepts of the physics of gas (Avogadro's law, Henry's law, equation of state, Dalton's law, correction of gas volumes (ATPS; STPD; BTPS), Fick's law applied to gas), air composition environment.
- 7.2 Ventilation: lung volumes and methods of determination, total pulmonary ventilation, alveolar ventilation, dead space (anatomical, physiological and alveolar) and its determination (method of Fowler and Bohr equation).
- 7.3 Pulmonary mechanics: inspiratory and expiratory muscle and their mechanism of action; static pulmonary pressure - volume curve of the thoraco-pulmonary system, of the lung, of the chest wall (pleural or esophageal, transpulmonary, transthoracic, alveolar pressures); lung compliance and respiratory system; role and function of alveolar surfactant; determinants of lung compliance; regional distribution of ventilation. Dynamics; resistance to airflow; volume of closure; analysis of alveolar, transpulmonary and intrapleural pressures in the spontaneous respiratory cycle; work of breathing.
- 7.4 Alveolar - capillary transfer: Fick equation applied to the diffusion of gases, diffusing capacity for carbon monoxide and oxygen; alveolar - capillary transfer limitation by diffusion and perfusion;

alveolar - capillary transfer of oxygen in normal conditions, during exercise in hypoxia and pulmonary capillary transit time.

- 7.5 Transport of oxygen and carbon dioxide: the oxyhaemoglobin dissociation curve, the total transport capacity of the blood for oxygen, physiological factors that affect the allosteric affinity for oxygen; CO poisoning. Transport of carbon dioxide in the blood, blood dissociation curve of total CO<sub>2</sub>, Haldane effect.
- 7.6 Gas exchanges: alveolar air equation (simplified); the cascade of oxygen; composition of the alveolar air and of the blood (oxygen cascade); causes of hypoxemia: hypoventilation, veno-arterial shunt anatomical and physiological hypo-diffusion, alveolar-capillary ratio and its distribution curve (normal and in diseases). Arterio-venous differences of oxygen and carbon dioxide; oxygen consumption, carbon dioxide production, and respiratory quotient; determination of cardiac output by the Fick principle.
- 7.7 Neural and chemical control of ventilation. Nervous control: respiratory centers, generation of the respiratory rhythm. Chemical control: central and peripheral chemoreceptors; functional responses to hypoxia, acidosis and hypercapnia.
- 7.8 Responses ventilatory exercise: hyperventilation, ventilatory equivalent for oxygen and carbon dioxide during exercise; reduction of vascular resistance and recruitment of alveolar-capillary units; optimization of the ventilation / perfusion ratio; relative reduction of the velocity of blood in the capillaries.

## **8. Renal Physiology**

Preliminary knowledge: functional anatomy of the kidney and urinary tract, the concepts of osmotic pressure, osmolarity and osmolality, concept definition of pH, buffer substances.

- 8.1 Filtration: definition, functional organization of the nephron; vascularization, innervation. Structure and function of the glomerulus; ultrafiltration; filtration pressure; GFR: inulin clearance, filtration fraction.
- 8.2 Tubular function in the proximal tubule; distal tubular reabsorption and secretion; clearance of PAH; reabsorption of AA, glucose, sodium, potassium and water; secretion of hydrogen ions, bicarbonate reabsorption.
- 8.3 Obligatory and optional Reabsorption of water: loop of Henle and counter current multiplication mechanism, function of vasa recta and of collecting ducts; role of urea, antidiuretic hormone: mechanism of action, function and regulation of the release.
- 8.4 Adjustment of renal function: self-regulation of flow and of filtration rate; functions of the juxtaglomerular apparatus; sympathetic nervous control.

## **9. Fluid and electrolyte balance**

Preliminary knowledge: Concepts of osmotic pressure, osmolarity and osmolality.

- 9.1 Water compartments; application of the method of dilution for the determination of the volume of water compartments; role of ion pumps and membrane permeability in the control of the composition of liquids; principle of isotonicity and passive movement of water; control of extracellular fluid volume and sodium excretion.

## **10. Regulation of acid-base**

Preliminary knowledge: concept and definition of pH, buffer substances.

- 10.1 Henderson-Hasselbalch equation, buffering capacity and buffers of the body, bicarbonate-CO<sub>2</sub> system.
- 10.2 Diagram of Davenport; normal values, respiratory acidosis and alkalosis, metabolic acidosis and alkalosis.
- 10.3 Integrated control of pH by the kidney and respiratory system.

## **11. Metabolism and Thermoregulation**

Preliminary knowledge: strong knowledge of the main metabolic pathways for the resynthesis of ATP; concepts of heat, energy, work, power and related measurement units.

- 11.1 Warm-blooded animals and poikilotherms, normal body temperature, factors that determine the body temperature: i) heat production (metabolism); ii) physical and physiological mechanisms of heat exchange between organism and environment (evaporation, convection, radiation, conduction); iii) transport of heat within the body (circulatory convection and conduction).
- 11.2 Neural regulation of maintain homeothermy (hypothalamic centers, temperature set point, thermoceptors for the hot and cold); defense against the cold; protection from heat; circulation of the skin, fever, hyperthermia and heat stroke; hypothermia, muscle exercise, body size and temperature.
- 11.3 Metabolism: the concept of internal energy of the food; gross, net and delta efficiency of muscular performance; measure of the available energy of food (bomb calorimeter, energy equivalent of oxygen for individual substrates), resting metabolic rate.
- 11.4 Measurement of energy expenditure in vivo: direct methods (human calorimeter) and indirect (gas exchange, energy equivalent in vivo of oxygen).
- 11.5 Dailiy energy intake, hunger and thirst.

## **12. Physiology of the endocrine system**

Preliminary knowledge: strong knowledge of anatomical and functional organization of the endocrine system, knowledge of the metabolic pathways.

- 12.1 General principles of endocrine physiology, mechanisms of intercellular communication, the endocrine system and the nervous system, the main endocrine glands: types of hormones, synthesis and action of peptide hormones, synthesis and action of the steroid hormones, mechanisms of regulation of hormones.
- 12.2 Adeno pituitary: functional unit of the hypothalamic - pituitary portal system, metabolic and neuroendocrine actions of the pituitary cells their structure, hypothalamic-pituitary axis, regulation of function of adenohypophysis, rhythmicity and pulsatility of secretion, tropinse, specific tropines, growth hormone, GH and exercise muscle action of GH, GH and growth, acromegaly, prolactin, posterior pituitary.
- 12.3 Adrenal gland: secretion in the various zones of the adrenal gland, the synthesis of adrenal hormones, aldosterone-mineralocorticoid, aldosterone and renin-angiotensin system, aldosterone action and physiological effects of aldosterone, androgens, glucocorticoids – cortisol, regulation of the synthesis of cortisol, cortisol and stress, cortisol secretion and light-dark cycle, the permissive action of cortisol, catabolic action of cortisol, cortisol and hepatic gluconeogenesis, the adrenal medulla, adrenal medulla and SNA, hyperglycaemic effect, action of catecholamines, integration of the response to stress.
- 12.4 Thyroid: thyroid and thyroid follicles, biosynthesis, cellular mechanisms, iodine thyroid, transport of T3 and T4 in plasma, control of the synthesis and secretion, mechanism of action, actions of thyroid hormones, pathophysiology (hyperthyroidism and hypothyroidism).
- 12.5 Endocrine pancreas: physiological anatomy of the islands of Langerhans, human insulin molecules, control the secretion of the endocrine pancreas, synthesis and secretion of insulin receptors for insulin, hypoglycemic effect; insulin: muscle and anabolic effect, insulin and lipid metabolism, biological effect of insulin, pathophysiology of insulin, diabetic keto-acidosis, hypersecretion of insulin, glucose tolerance curve; glucagon ratio insulin-glucagon, pancreatic hormones and metabolism of carbohydrates, pancreatic hormones and intermediary metabolism, pancreatic hormones and exercise, somatostatin.
- 12.6 Metabolism of calcium and phosphorus and vitamin D; calcium body distribution and plasma calcium and phosphorus concentrations, physiological actions of calcium and phosphorus, daily balance of calcium, bone tissue and calcium and phosphate homeostasis, bone formation and remodeling , bone mass and age, calcium metabolism - parathyroid hormone synthesis and secretion of PTH,

calcium metabolism and PTH, vitamin D, D3 and Ca<sup>++</sup> concentration regulations, calcitonin, calcium and phosphorus metabolism, bone metabolism and the endocrine system.

### **13. Physiology of muscular exercise.**

Preliminary knowledge: strong knowledge of the main metabolic pathways, mitochondrial respiration, metabolic pathways for the resynthesis of ATP, the concepts of power and mechanical work, physiology of respiration and circulation.

13.1 Model of muscle energetics, definitions of work and power, energy bases of muscle contraction, power and capacity of the mechanisms of energy production.

13.2 The aerobic metabolism, maximal oxygen consumption, factors limiting maximal oxygen consumption, V'O<sub>2</sub> kinetics, principles and methods of measurement of maximal oxygen uptake: direct and indirect methods.

13.3 Cardiovascular and respiratory responses during dynamic and isometric exercise.

### **Practical activities**

In addition to the *ex-cathedra* lessons, theoretical and numerical exercises will be organized bi-weekly in the classroom with computer aids. These exercises will focus on the main topics covered during the lessons and will involve the students called to answer questions.

### **Examination methods**

The exam consists of a multiple-choice test (80 questions in 150 minutes). The examination procedures are identical for attending and non-attending students.

The minimum score for the written examination is 48/80. During the course will be available on the University e-Learning (Moodle) space in teacher / teaching page, examples of multiple choice questions on the various topics covered in class.

The correspondence between votes and the number of correct answers is calculated according to the ECTS conversion table (A-F) as follows

- 30 cum laude:> 70 correct answers (A)
- 30: 68 correct answers (B)
- 29: 66 correct answers (B)
- 28: 64 correct answers (C)
- 27: 62 correct answers (C)
- 26: 60 correct answers (D)
- 25: 58 correct answers (D)
- 24: 56 correct answers (D)
- 23: 54 correct answers (E)
- 22: 52 correct answers (E)
- 21: 51 correct answers (E)
- 20: 50 correct answers (E)
- 19: 49 correct answers (E)
- 18: 48 correct answers (E)
- Test not passed (F): below the 48 correct answers.

The outcome of the Exam is communicated on the same day online, on the alert page of the Department of Neuroscience, Biomedicine and Movement: <http://www.dsnm.univr.it/?ent=avviso&dest=200>

Candidates must notify the vote within a maximum time of 7 days. In the absence of communication, the corresponding evaluation in thirtieths will be automatically recorded.

**Teaching materials**

All course materials covered in class will be made available on the student teacher's page / course. and will appear on the University's e-Learning (Moodle) space.

**Recommended reading**

- Human Physiology, e.g. Prampero and A. Veicsteinas, Edi-Ermes Milan 2002
- General and Human Physiology II edition on American IV, Rhoades - Pflanzer, Piccin, Italy
- Vander-Fisiologia, II edition on XIV English edition, Zanichelli, Bologna, 2018

**Other Reference Books**

- Fisiologia medica, Hall J. E., Guyton A. C., traduzione della XIII<sup>ed</sup>, -Edra Editore, 2017
- Fisiologia Medica 1 e 2, a cura di F. Conti, Edi.Ermes, Milano, 2010
- La locomozione umana su terra, in acqua, in aria. Fatti e teorie, PE di Prampero, Edi.Ermes, Milano 2015