

ANIMAL PHYSIOLOGY COURSE SYLLABUS

ACADEMIC YEAR: 2014-2015

"All organisms are professional problem solvers: before life, problems did not exist. Problems and life entered the world together, and with them problem solving".

Sir Karl Raimund Popper
(Austrian and British philosopher)

Welcome to Animal Physiology

Please, remember that it is very important to read and understand the syllabus. It is the best source of information about the subject and it contains all the information you need to follow the course over the term.

Remember that it's your responsibility to read and understand all the material on the syllabus. If you find that the syllabus is missing some information, please make sure you ask me to provide it.

1. SUBJECT DESCRIPTION

Degree:	Biotechnology
Course:	Animal Physiology
Module:	Fundamentals of Biology, Microbiology and Genetics
Department:	Physiology, Anatomy and Cellular Biology
Academic Year:	2014-15
Term:	First Semester
Total Credits:	6
Year:	Year Three
Type of Course:	Compulsory Subject
Course Language:	English

Teaching Model	A2
a. Lectures (General Background):	70%
b. Labs and experimental procedures:	15%
c. Guided Academic Activities:	15%

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2. SUBJECT COORDINATOR

Name:	Antonio Prado Moreno
School:	Experimental Sciences
Department:	Physiology, Anatomy and Cellular Biology
Academic Area:	Physiology
Category:	T.U.
Tutorials:	Friday: 10:00 to 14:00 Thursday: 12:00 to 14:00 On line: 24/7 (through the virtual classroom)
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3. CONTEXT

3.1. Course Description and Objectives

This course is an introduction to concepts and basic issues in Animal Physiology, Students will master the basic principles of physiology and use these to understand and interpret the operation of the physiological systems, as well as the structural design that allows this operation. At the end of the semester, the student:

- Meet the nomenclature and the basics in animal physiology and processes that allow the operation of physiological systems, particularly, their regulation and interaction.
- Understands and can efficiently handle texts and manuals of Animal Physiology.
- Able to develop experiments animal physiology laboratory under supervision.
- Can solve problems based on the diversity of the physiological processes of different animal groups.

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3.2. Contributions to the training plan

Among the main contributions of the subject "Animal Physiology" to the Graduate Training Plan in Biotechnology, knowledge and understanding of the physiological mechanisms underlying animal life, has to be noted. The subject uses a comparative and multidisciplinary approach and devotes special attention to the regulatory mechanisms.

- Throughout the course, students become familiar with the basic terminology in Physiology.
- Students will acquire the right knowledge about the basic principles of the discipline.
- The course should provide students an integrated view of the functioning of biological systems animals.
- Upon completion of the course students must know the functions of the organs and systems and their control, and have a clear idea about the physiological mechanisms developed by different groups of animals to survive in their habitat.
- While exploring the content mentioned, students will strengthen several transferable skills and they should be able to apply the fundamental concepts of physics and chemistry in their understanding of physiological phenomena.
- Students will improve their ability to verbally articulate themselves to a group during guided academic activities.

3.3. Recommended or required prior knowledge

- General knowledge of biology.
- Understanding and familiarity of the essential concepts of physics and chemistry
- Good English (spoken and written)
- Managing the WebCT platform is of great interest to follow the course.

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4. SKILLS

4.1 Degree skills developed in the course

General skills and cross-cutting

- Based on the expertise of a level secondary education, to know and to understand completely the basic facts, concepts, principles and theories related with the study of living organisms and their interplay with human activities.
- Being able to transmit information to other professionals both their work area or related areas, such as to a lay audience, and make judgments that include reflection on relevant social, scientific or ethical.
- Develop methods of acquisition, interpretation and analysis of information with a critical understanding of the appropriate contexts for use, to apply their knowledge in a professional manner and demonstrate their skills by developing and sustaining arguments and solving problems within their field of study.
- Develop learning skills adequate to undertake, with a high level of autonomy, later studies.
- Knowledge and understanding of general biological processes from a molecular standpoint, cellular, physiological and, where appropriate, of communities, of living beings.
- Know and understand the information obtained from biological processes and their adjustment to the theoretical framework of each of the subjects taught.
- Use rigorous terminology, nomenclature and classification systems in each of the subjects taught.
- To acquire basic experimental skills appropriate to each of the issues taught by the description, quantification, analysis and critical evaluation of the experimental results obtained independently.
- Use the leading scientific and technical literature, acquiring the ability to perceive clearly the current developments and possible future developments.
- Assimilate, from multidisciplinary source, relevant knowledge and deliver insights and judgments based on the integration of that knowledge.
- Be able to demonstrate the ability of responsible initiative in the workplace.
- Be aware of the importance of teamwork and empowerment of critical discussion of common goals.
- Develop creativity and innovation that results in the identification of analogies between situations that allow the application of known solutions to new problems.
- Be able to engage in the on-going development of biotechnology and its applications, as well as philosophical and ethical issues involved.
- Knowledge of methodologies and technologies appropriate for the proper presentation and communication of the different aspects that affect biotechnology (data analysis, biostatistics, etc.).
- Ability to analyse, synthesize and use critical thinking in science.

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- Understand the scientific method.
- To work properly in a biological, chemical or biochemical laboratory, knowing and applying the rules and techniques related to health and safety, handling of laboratory animals and waste management.
- Understand and apply the tools, techniques and experimental protocols in the laboratory.
- Acquire, develop and apply the main techniques of preparation, staining and observation of biological samples.
- Acquire the skills of observation and interpretation of the results.

Specific skills

- Know the common characteristics of physicochemical transport processes: diffusion, osmosis, electrophoresis, etc.
- Identify and describe the different animal and plant tissues in histological preparations and distinguish the various structures and functions of animal tissues and organs and vegetables.
- Know how to design and run a laboratory experimental methodology in order to solve real problems using for this genetic model organisms and techniques and materials typical of a basic experimental level.
- Have a good understanding of the concept of measurement in science, including the correct use of units and systems of meaning and management involved in any measurement errors.
- Correctly calculate the relevant parameters of a process or experiment by manual representation of experimental data and mathematical functions on graph paper, semilog and double log.
- Be familiar with some trials of physiological activities (transport, chemotaxis), and be able to understand and interpret experimental results aimed at elucidating the functioning of various microbial physiological processes, and propose biotechnological applications of some of these processes.

4.2. Module Competencies developed in the course

- Distinguish the different structures and functions of animal tissues and organs and vegetables.
- Being able to find good quality and specialized scientific literature in databases using different criteria. Start reading and understand scientific articles.

4.3. Specific skills of the subject

- Know and understand the physiological mechanisms that underlie animal life and understand the fundamental physiological differences between the different animal groups.
- Understand the principles and mechanisms of regulation in animal physiology, and the relationship between structure and function in physiology.
- Be able to integrate and explain the concepts acquired during the study of physiology, in particular the interactions between the different systems and feedback mechanisms.

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5. COURSE CONTENT (COURSE TOPICS)

The emphasis will be on comparative physiology but there will be some coverage of other physiology approaching. The laboratory component of the course is designed to reinforce some of the topics discussed in lecture, as well as to familiarize students with some of the laboratory techniques and equipment used in the acquisition of physiological data.

The course is divided into the following eight blocks (each including several topics of about one hour "EB" session). Most of the topics will be presented in the classes and the students will be asked to present the others as a summary in their portfolio.

I. INTRODUCTION. PRINCIPLES OF PHYSIOLOGY

We can define physiology as *"the study of how living systems function"*. We study living systems from the subcellular level all the way to the level of the whole organism and how organisms adapt to enormously different environmental conditions such as hot, cold, dry, humid, or high altitude. Even in the face of constantly changing external environmental conditions, the physiological parameters in the animal body are persistently maintained within very narrow limits.



Topic 1. Introduction to Animal Physiology.

Concept of Physiology. Basic characteristics of living organisms. Fundamentals of issues of Physiology. Contents of the course. Discussion and literature program.

Topic 2. Central principle of physiology. Concept medium

Central principle of physiology. Organizational levels. The external environment as determinant of physiological processes. The internal environment and constancy. Homeostasis and regulation. Integration of biological functions. Levels of adaptation.

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II. NEURONAL FUNCTION

Neurons are the central components of the nervous system.

In this unit we will try to give answer to questions like “What makes neurons different from all other cells” or “When, during the course of evolution, did neurons first appear”

Once we can understand the basic principles governing the neuron function, we will focus on how the neurons can process and transmit information through electrical and chemical signals.



Topic 3. General organization of the nervous system

General Organization of the Nervous System. General principles from an evolutionary perspective. Invertebrate nervous system. Sensory neurons. Motoneurons. Centralization and cephalization. Segmentation. Basic elements of the vertebrate nervous system.

Topic 4. Central Nervous System and Peripheral Nervous System

Central Nervous System. Elements of the Brain. Peripheral Nervous System. Overview of the Nervous System. Autonomic Nervous System. Sympathetic and parasympathetic divisions. Spinal and cranial nerves. Coordination of sympathetic and parasympathetic systems.

Topic 5. General physiology of excitable cells

Concept of excitability. The neuron as excitable cell model. Cell types in the nervous system. Nerve cells. Glia. Electrical properties of excitable cells. Ion Channels. Concept of local potential. Action potential. Action potential propagation.

Topic 6. Signalling in the nervous system

Concept of synapses. Synaptic transmission. Cholinergic synapses. Synaptic regulatory mechanisms. Chemical nature of neurotransmitters. Functional classification. Molecular classification. Neuromodulators. Integration at synapses.

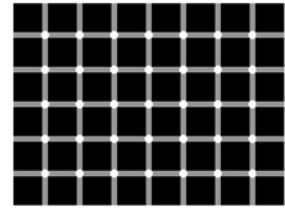
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III. SENSORY RECEPTION

Aristotle's description of our senses has influenced our culture in such a way that many people still think that we only have five senses.

But today, physiology study receptors in the muscles, tendons and joints, in the vestibular organs, within the circulatory system or in the digestive tract. Even some brain cells have been found to be sensitive to changes in blood chemistry or to changes in temperature within the brain itself.



Topic 7. Sensory mechanisms. General physiology of sensory receptors

General properties of sensory reception. Concept of sensory receptor. Sensory transduction. Interpretation of sensory information.

Topic 8. Vision

The vision. Electromagnetic radiation. Structure and components of the vertebrate eye. Retina. Photoreceptors. Visual pigments and phototransduction. Basic mechanisms of vision. Visual perception. Vision in invertebrates. Detection of polarized light.

Topic 9. Mechanoreception.

Mechanoreceptors. Organization of sensory pathways. Touch receptors. Proprioceptors. Baroreceptors.

Topic 10. Hearing.

Basics of sound and hearing. Hair cells. Lateral line in fish and amphibians. Body balance. Ear.

Topic 11. Chemoreception. Thermoreception. Nociception.

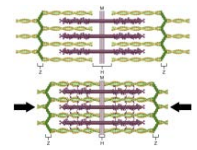
Chemoreception: taste and smell. Mechanisms of taste reception. Gustatory chemoreception. Olfaction. Thermoreceptors. Nociceptors.

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IV. EFFECTOR SYSTEMS

An effector is any part of the body that produces a response. A muscle, gland, or organ capable of responding to a stimulus is considered an effector. We will concentrate here on the essential structural aspects of muscle and the biomechanical processes for the understanding of muscle contraction.



Topic 12. Concept and types of effectors. Muscular fibre structure

Effector systems. Muscle tissue. Skeletal muscle. Structural basis of muscular contraction. Sliding filament theory. Regulation of muscle contraction.

Topic 13. Excitation-contraction coupling

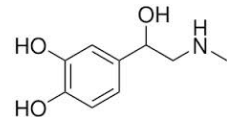
Excitation contraction coupling. The relaxation contraction cycle. Metabolism. Skeletal fiber types. Heart muscle. Smooth muscle.

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V. ENDOCRINE SYSTEMS

The endocrine system refers to the set of animal glands which produce substances that act as messengers and, released into the blood, carry out their function in different parts of the body.



Ultimately it is a signal system, which analogously to the nervous system, but typically slower and in a lasting way, allows the intercommunication between organs and, therefore, the maintenance of homeostasis organism.

Topic 14. Introduction to the study of endocrine systems

The concept of homeostasis. The endocrine system and the nervous system work together. Anatomy of the endocrine system. General types of chemical messengers. Mechanisms of hormone action.

Topic 15. The hypothalamic-pituitary axis.

The hypothalamus. The hypophysis or pituitary gland. Types of cells secreting pituitary. Classification of pituitary hormones. Hypophysiotropic hypothalamic hormones. Preproopiomelanocortin derived hormones. Growth hormone or somatotropin. Prolactin. Oxytocin. Vasopressin.

Topic 16. Pineal gland. Intermediate pituitary.

Pineal gland and melatonin. Functions of melatonin. The intermediate pituitary. MSH physiological roles. Functions of colour in animals. Stimuli that induce colour changes. Effector pigment cells. Neural and hormonal regulation of the color changes. Hormonal action mechanisms in physiological color changes. Hormonal actions in morphological changes colour. Control MSH secretion.

Topic 17. The thyroid and thyroid hormones. Parathyroid hormone.

The thyroid gland. Thyroid hormone biosynthesis and secretion of hormones. Mechanisms of action of thyroid hormones. Regulating the secretion of thyroid hormones. Physiological actions. Parathyroid hormone. Functional importance and calcium homeostasis. Bone tissue. Types of bone. Osteogenesis and bone remodelling. Hormonal regulation of bone cell activity

Topic 18. Adrenal glands

Adrenal glands. Hormones of the adrenal cortex. Mechanisms of action of intracellular receptors. Mineralocorticoids. Glucocorticoids. Adrenal medulla. The adrenal sympathetic system. Neurotransmitters of the sympathetic-adrenal. Catecholamines. Adrenergic receptors and mechanisms of action. Physiological effects of hormones on the bone.



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Topic 19. Endocrine pancreas

Functional anatomy of the endocrine pancreas. Physiological importance of glucose homeostasis. Insulin. Mechanisms of insulin secretion. Regulation of glucose transport by insulin, the insulin receptor. Actions of insulin. Glucagon. Somatostatin. Pancreatic polypeptide.

Topic 20. Sex and Placental Hormones

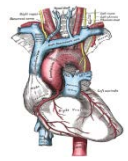
Sex hormones. Male reproductive system. Testicular function. Secretion, metabolism and action of androgens. The female reproductive system. Ovarian function. Ovarian follicle development. Hormonal patterns during the menstrual cycle hormonal regulation of oogenesis. Functioning of the corpus luteum. Hormonal regulation of reproductive tract function. Mechanisms of action and metabolism of ovarian steroids. Female puberty and menopause. Placental Hormones.

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VI. CIRCULATORY SYSTEMS AND GAS EXCHANGE.

Here we study the circulatory (or cardiovascular) system, responsible for blood circulation and transport of nutrients, gases, hormones, and blood cells. In these topics we will focus mainly on the heart functioning and the transport of the oxygen by the blood.



Topic 21. Overview circulatory systems.

Concept of circulation. General organization of the circulatory systems. Open and closed circulatory systems. The heart. Electrical properties of the heart. Mechanical properties of the heart. The vertebrate heart.

Topic 22. Gas transfers in animals.

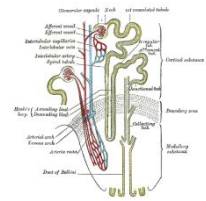
Introduction. Physical gases. Respiratory pigments. Oxygen transport by the blood. Breath. Respiratory systems. Gases in water and in air. Features of breathing in the air environment. Respiration in aquatic environments. Control mechanisms.

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VII. ION BALANCE AND OSMOTIC. EXCRETORY SYSTEM

Homeostasis (referred to the water content in the body) is performed by osmoregulation. The processes involved in osmoregulation are very different depending on the environment of the animal. During the lessons in this block, we will pay attention, particularly, to the mechanisms of urine formation and the major problems that different types of animals have to solve based on their environments.



Topic 23. Fluid compartments of organisms. Osmoregulation.

The importance of water. Compartmentalization of living beings. Cell membrane permeability. Osmosis. Functions excretion. Factors contributing to the compulsory exchange of ions and water. Osmoregulatory organs of invertebrates. Osmoregulatory organs of mammals. The kidney of mammals.

Topic 24. Urine formation

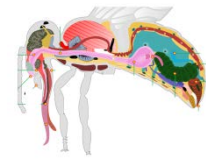
Urine formation. Urine concentration mechanism. Kidneys of non-mammalian vertebrates. Excretion of nitrogenous waste.

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VIII. NUTRITION AND DIGESTION

Nutrition refers to the activities by which living organisms obtain the materials that cells metabolize and from which they synthesize structural components, enzymes, energy-rich compounds, etc. Rarely the organic molecules come in forms that are readily useful. Digestion is the processing of the food into forms that can be absorbed.



Topic 25. Nutrition and digestion.

Nutritional concepts digestion and metabolism. Biological significance of nutrition. Types of nutrition. Obtaining food. Feeding strategies. Nutritional requirements. Nutrient molecules. Digestion. Digestive hydrolysis. Energy metabolism and metabolic rate.

Topic 26. The digestive system

The digestive system. Gut motility. Gastrointestinal secretions. Exocrine glands. Gastrointestinal secretions. Bile and digestive enzymes. Control of digestive secretions. Absorption of nutrients.

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6. METHODOLOGY AND RESOURCES

The course described in this guide, "Animal Physiology" (6 credits, 150 hours), follows a course type A2

The tandem "student-professor" through the "coincident work" (EB + EPD + AD) represent the 30% of the total time scheduled for this subject. This 30% (45 hours) is distributed as follows: **Basic Teachings (70%), Teaching and Development Practices (15%) and Guided Activities (15%)**.

It is expected that the 60% (90 hours) of the time dedicated to an A2 subject is **student autonomous work**. The last 10% (15 hours) is dedicated to **evaluation** tasks.

The course includes 31 hours of "EB" classes (on site) where we will develop the basics of the subject

For the development of the basic teachings assigned classrooms will be used, with up to 60 people and equipped with computer for video projection, allowing presentations with images and animations for the presentation of concepts. In addition, all classrooms have slate for the detailed explanation of those concepts requiring additional explanations or detail.

Throughout the course, part of theoretical knowledge will be developed in 5 ("EPD") lab sessions

Hands-on lab sessions are conducted primarily in the student's laboratory of Physiology, equipped with the necessary instrumental to perform different practices. Laboratories also have audio visual, simulation tools and consumables necessary for practice. When necessary the sessions will take place in a computer room for the complete development of practices that require it.

The Guided Activities will take place in small groups

For the "AD" sessions (4) lab groups splits into two. Students will have the opportunity to discuss videos related to the subject, scientific articles and their own approaches on issues of interest within the scope of the program.

Personal work

Taking in consideration that the subject's activities extend throughout 14 week, the 90 hours of autonomous work represent about 6 hours of independent student work per week. The campus has the necessary resources (library fully equipped with library material in paper and on-line subscriptions), sufficient study rooms with flexible schedules, computer rooms open access, etc. This will allow the students, to develop work related to the subject without any lack.



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Virtual Classroom

As well, at all times the student can use the virtual classroom course, which interactively with the teacher and their classmates. The student should visit this website regularly for further information, outlines, hand-outs, and links to other sites of interest.

All together, the student is expected to spend 150 hours to pass the course, which would be broken down as follows for the present subject:

- **Basic Teachings: 31 hours**
- **Hands-on labs sessions and guided activities: 14 hours**
- **Student work (including tutorials): 90 hours**
- **Evaluation: 15 hours**

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7. ASSESMENT

The time dedicated to the evaluation of the course is 15 hours. Please, do not forget that we follow a **continuous assessment system**. EPD and AD will be evaluated by the submission of the correspondent reports. The presentation of essays and reviews about the basic teachings will be evaluated. Finally, a written exam will assess the basic teachings of the course. **Only the exam will be mandatory to pass the course.**

Continuous assessment

Since the attendance and participation are very important for the qualifications of this subject, the possibility of knowing who is who from the beginning is necessary for the normal development of the course.

For that reason and in order to make possible the continuous assessment, the students are kindly requested to provide an ID-photo at the beginning of the semester. You can post your picture directly through the virtual classroom or, if you prefer, you can send it to your professor by any other means.

You have to understand that without this tool it would not be possible to take into consideration your public contributions to the course.

Evaluation

The evaluation will be based on the levels shown in five different sections:

- **Lab sessions (20%).** Is scored separately attendance and participation (5%) and a written report of the work done (15%)
- **Guided activities (10 %).** Attendance and participation (5%), written memories of the activities (5%)
- **Literature review (20%).** Presentation of a topic related to the course chosen by the student.
- **Summaries of specific topics of the basic teachings (10%).**
- **Performing tests (40%).** The exam, to be held at the end of the semester ("first evaluation") consists of two parts (60 multiple choice questions, 20%) and 4 essay questions (20%). As mentioned above, this exam is mandatory and it is needed to get a minimum mark of "5/10" to pass the course.

Those students who do not pass the first exam (the only mandatory exercise for this subject), can (in order to pass the course) perform a second test ("retake or second-chance exam"), to be held in June or July. The student has the option to retain all the other grades acquired during the continuous assessment.

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This second-chance examination exam maintains the same structure than the first one (two parts: 60 multiple choice questions and 4 essay questions). Again you need to obtain a grade of “5/10” to pass the course. For the calculation of the final mark the percentages of the different tasks do not change.

For the completion of any activity (including exams), the use of paper dictionary is allowed. The exam duration is 3 hours and necessary instructions and recommendations are given in situ. As a general rule, for the elaboration of any kind of reports, and particularly for the exams, it is very advisable the use of diagrams and schemes that improve the understanding of the topic.

To pass the subject a minimal mark of 5/10 (taking together all the scores) is necessary.

Evaluation of "single test"

In any case, following the current rules from our University¹, any student can ask for a final exam that permits the assessment of all the knowledge and skills acquired along the course.

In this situation, the student must submit (at least 10 days before the official date for the retake exam) a written renounce to all the obtained previous scores and have to accomplish an exam including:

- a) Written test about all the hands-on and guided activities (30 %)
- b) Written summary about the specific topics selected during the course (10 %)
- c) Literature review of a selected topic related to the course (20%)
- d) Multiple choice test (60 questions) about the topics presented in classes as EB (20%)
- e) Short essay questions test (4) about the topics presented in classes as EB (20%)

Plagiarism

The students have to remember that cheating and plagiarism are violations of University policy and are considered serious offenses and that the “Physiology, Anatomy and Cellular Biology” Department takes all incidences of academic dishonesty seriously and acts accordingly. “Self-plagiarism” (the use of your own previous work in a different subject) is also not allowed in any of the activities of this subject.

¹ <https://upo.gob.es/opencms/AlfrescoFileTransferServlet?action=download&ref=29c3de26-80d5-43c0-a3b8-682187fe36f8>

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Rubrics

a) Rubric for AD y EPD

		0-4	5-8	9-10
20%	Format / Structure	Exercise does not meet the minimum organization and clarity requirements.	Exercise is organized and adequate (but some aspects could be improved).	Exercise noticeably meets the criteria of clarity and structure required.
40%	Content	Content is not appropriate or does not cover satisfactorily the proposed work.	The assigned work meets, reasonably, the criteria requested.	The work highlights the quality of submitted content.
40%	Presentation / Understanding	The presentation of the work presented does not allow the adequate understanding.	Exercise meets the minimum criteria and proper exposure, but complete understanding is not unequivocally showed.	The exposition of work reached a good level and shows the overall understanding of the subject treated.

b) Rubric for course assignments.

		0-4	5-6	7-8	9-10
20%	Format / Structure	Exercise does not meet a minimum of clarity and organization	Exercise is enough and is minimally organized, although it can be improved.	The clarity of presentation and structure are good.	The format presented (oral presentation or exposed) document is impeccable.
40%	Content	Content is not appropriate or sufficient for the proposed work.	The presentation uses knowledge which is generally accurate with only minor inaccuracies.	The presented work is notable for the quality of its content. The treatment of the information used is sufficient.	The content and depth of the work, and used bibliography conform to excellent levels.
40%	Presentation / Understanding	The presentation of the work presented does not allow an adequate understanding.	The assigned work meets some assignment requirements.	Both the exposition of work as understanding of the aspects he collected, maintained a good level.	Overall, exposure and understanding of the presented work fully met all requirements.

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8. LITERATURE

As general references following books are recommended. During the development of the course may suggest additional manuals for tracking specific topics. References marked with an asterisk (*), and some others, are available online.

Basic Literature:

- Richard W. Hill, Gordon A. Wyse, and Margaret Anderson (2012). **Animal Physiology***. 3rd edition. Sinauer Associates, Inc.
* www.coursesmart.com/9780878935598
- Randall, D., Burggren, W. and French, K. (2002). **Eckert Animal Physiology***. 5th Ed. W.H. Freeman.
* <http://www.whfreeman.com/Catalog/product/eckertanimalphysiology-fifthedition-randall>

Additional Bibliography:

- Hall J.E. (2012). **Guyton and Hall Textbook of Medical Physiology**. 12th Edition. Saunders.
- C.D. Moyes and P.M.Schulte (2007). **Principles of Animal Physiology: International Edition (2e)**. Pearson Higher Ed USA
- Eric R. Kandel, James H. Schwartz, Thomas M. Jessell and Steven A. Siegelbaum (2012). **Principles of Neural Science**, Fifth Edition. McGraw-Hill Companies Inc.
- Thomas W. Sadler (2010). **Langman's Medical Embryology** (11th Edition). Lippincott Williams and Wilkins.
- Kim E. Barrett, Susan M. Barman, Scott Boitano and Heddwen Brooks (2012). **Ganong's Review of Medical Physiology**, 24th Edition. McGraw-Hill Companies Inc.
- Hochachka Peter W. and Somero George N. (2002). **Biochemical adaptation: mechanism and process in physiological evolution**. Oxford University Press.

Laboratory Manuals:

- Dee U. Silverthorn, Bruce R. Johnson and Alice C. Mills (2005). **Lab Manual for Physiology**. Benjamin-Cummings Publishing Company.

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Additional Internet Resources:

- The Physiology Place:
(<http://www.pearsonhighered.com/thephysiologyplace/>)
- UTK Mathematical Life Sciences Page for Education
(<http://www.tiem.utk.edu/~gross/bioed/modulelist.html>)
- Pat Brown's Path webpage Interactive Physiology
(<http://faculty.alverno.edu/bowneps/>)
- Quantitative Literacy
(<http://faculty.alverno.edu/bowneps/new%20indexes/quantindex.html>)
- Moyes and Schulte Animal Physiology Textbook
(<http://www.pearsonhighered.com/educator/product/Principles-of-Animal-Physiology-2E/9780321501554.page>)
- Companion Website for Principles of Animal Physiology.
(http://wps.aw.com/bc_moyes_animalphys_2/)
- Eckert Animal Physiology
(<http://www.whfreeman.com/Catalog/product/eckertanimalphysiology-fifthedition-randall>)
- Eckert Animal Physiology. Student resources
(<http://www.whfreeman.com/Catalog/product/eckertanimalphysiology-fifthedition-randall/studentresources>)
- Sherwood Animal Physiology Textbook
(http://www.brookscole.com/cgi-wadsworth/course_products_wp.pl?fid=M20b&flag=student&product_isbn_issn=9780534554040&discipline_number=22)
- Physiology by Numbers Richard F. Burton Chapter 1: Introduction to Physiological Calculation
(<http://assets.cambridge.org/97805217/72006/sample/9780521772006wsc00.pdf>)
- Physioviva Educational Videos
(<http://www.youtube.com/user/llkeelely?feature=mhee>)