

Master's degree in molecular biology of cancer

Course syllabus – molecular biology of cancer

Basic course information

Course:	Molecular Biology of Cancer		
Type:	Compulsory		
ECTS credits:	6		
Semester:	1º		
Involved departments:	Biochemistry and Molecular Biology		
Course coordinator:	María Salazar Roa, PhD	Biochemistry and Molecular Biology, Faculty of Biological Sciences, UCM	masala08@ucm.es +34 91394668
Lecturers:	<p>Dr. Guillermo Velasco Díez. Biochemistry and Molecular Biology, F. Chemical Sciences, UCM. gvelasco@ucm.es</p> <p>Dra. Almudena Porras Gallo. Biochemistry and Molecular Biology, F. Pharmacy, UCM. maporras@ucm.es</p> <p>Dra. Arancha Sánchez Muñoz. Biochemistry and Molecular Biology, F. Pharmacy, UCM. munozas@ucm.es</p> <p>Dra. Mónica Yunta González. Biochemistry and Molecular Biology, F. Medicine, UCM. moyunta@ucm.es</p> <p>Dr. Eduardo Pérez. Biochemistry and Molecular Biology, F. Chemical Sciences, UCM. eduperez@ucm.es</p> <p>Dra. Sonia Castillo Lluva. Biochemistry and Molecular Biology, F. Chemical Sciences, UCM. sonica01@ucm.es</p> <p>Dra. Paloma Bragado Domínguez. Biochemistry and Molecular Biology, F. Pharmacy, UCM. pbragado@ucm.es</p> <p>Dra. Olga Antón Hurtado, Biochemistry and Molecular Biology, F. Chemical Sciences, UCM. olganton@ucm.es</p>		

Specific course information

Course description:	<p>In this course, the contents related to the molecular mechanisms involved in cancer development and its molecular characteristics will be covered. Specifically, the following topics will be studied:</p> <ul style="list-style-type: none"> • Molecular mechanisms involved in the origin of cancer and the characteristics of tumors (“the hallmarks of cancer”). • Genes regulating tumorigenic processes: oncogenes, tumor suppressor genes, epigenetic regulation, telomerase activity, etc. • Alterations in cell proliferation and cell death (apoptosis, autophagy, etc). • Molecular mechanisms regulating invasion and metastasis processes (adhesion molecules, tumor microenvironment, angiogenesis). • Tumor dormancy: regulatory mechanisms and biological significance.
Requirements:	None
Recommendations:	None

Learning outcomes

Knowledge and content	<ul style="list-style-type: none"> • Understand the basic molecular and cellular mechanisms whose deregulation leads to cancer development, with special emphasis on oncogenic and tumor-suppressive mechanisms. • Understand the molecular and cellular mechanisms involved in the reciprocal interactions between the tumor and the tumor microenvironment, and how this affect tumor progression.
Skills and abilities	<ul style="list-style-type: none"> • Ability to understand and apply concepts, tools, and methodologies in cancer research, enabling the development of an integrative perspective on scientific advances in this field. • Ability to analyze and comprehend a scientific work, from the initial hypothesis and objectives to the preliminary approach and final conclusions. • Ability to present the results of scientific research in the field of molecular cancer biology clearly and unambiguously in a scientific report or paper written in English. • Ability to communicate the conclusions of scientific work to both specialized and non-specialized audiences clearly and unambiguously: to express, understand, and convey scientific knowledge, results, and strategies in English.

Competencies

- Understand the molecular, cellular, and pathophysiological bases of cancer, enabling autonomous or self-directed study in the field of molecular cancer biology.
- Design experimental approaches to analyze the molecular, cellular, or pathophysiological mechanisms involved in cancer development and progression, as well as to evaluate the efficacy of new diagnostic methods or therapeutic approaches.
- Assess the social and ethical responsibilities, as well as environmental risks, associated with professional practice.
- Prepare foundational documents in the appropriate format to support patent applications and clinical trials in the field of oncology.
- Apply the principles of the scientific method, understanding its value and limitations, while incorporating the ethical principles governing professional practice.
- Develop effective communication and dissemination skills for professional activity, both among specialists and for the general public.
- Be capable of evaluating and selecting appropriate scientific information based on acquired knowledge in molecular cancer biology, in order to make judgments and interpretations from limited information.

Objectives

General objective:

Provide students with a deep understanding of the molecular and cellular mechanisms involved in the initiation, development, and progression of cancer, with special emphasis on oncogenic signaling pathways, tumor suppressor networks, the hallmarks of cancer, and emerging concepts in tumor biology.

Specific objectives:

By the end of the course, students will be able to:

1. Understand the historical and conceptual foundations of cancer biology, including key milestones in oncology research.
2. Explain the general principles of cellular signaling and how their deregulation contributes to malignant transformation.
3. Identify and describe the main signaling pathways involved in oncogenesis (e.g., Ras/MAPK, PI3K/AKT/mTOR, TGF β -SMAD, Notch, Wnt/ β -catenin, Hedgehog, GPCRs).
4. Differentiate between oncogenes and tumor suppressor genes, and analyze their roles in genomic instability, cell cycle deregulation, and tumor progression.
5. Analyze the molecular mechanisms underlying key hallmarks of cancer, such as:
 - Evasion of apoptosis
 - Reprogramming of cellular metabolism
 - Senescence and autophagy
 - Cellular plasticity and cancer stem cells
 - Epigenetic regulation and non-coding RNAs
 - Invasion and metastasis
 - Interaction with the tumor microenvironment
 - Inflammation and immune evasion
6. Critically evaluate current and emerging concepts in cancer biology from evolutionary, ecological, and systems biology perspectives.
7. Interpret and discuss primary scientific literature in oncology, integrating knowledge acquired in workshops and seminars through hypothesis formulation and experimental design.
8. Apply acquired molecular knowledge from a translational perspective, understanding its relevance for the development of new therapeutic strategies and research lines.

Methodology

Description:

The course will follow a **merged teaching methodology**, based on active learning, problem-solving, collaborative work, and autonomous learning. Face-to-face sessions will be combined with individual and group work, supported by digital resources and participatory activities aimed at developing not only theoretical knowledge but also analytical, critical, and communication skills relevant to a research environment.

Lectures (face-to-face theoretical classes)

Lectures will enable students to acquire the fundamental knowledge of the course through a structured presentation of key concepts and relevant experimental data. These classes may be delivered by the course faculty and guest specialists who provide applied or innovative perspectives in specific areas. Each thematic block will begin with an overview of the objectives

and conclude with open-ended questions or proposals that encourage content integration and critical thinking. Teaching materials (slides, readings, videos, links, simulations, etc.) will be made available to students through the Virtual Campus.

Seminars and workshops (active classes)

Critical analysis and discussion of current scientific articles, case studies, and real-world problems in molecular cancer biology will be promoted. Students will actively participate in presenting and defending work, guided debates, and interactive sessions that enhance their data interpretation, scientific reasoning, and oral communication skills.

Tutorials

Tutorial sessions will be established to delve into specific topics, guide, and facilitate learning. These 5 hours of tutorials are integrated into the seminar/workshop schedule as part of the time dedicated to active learning activities.

Autonomous work

Independent student work is fundamental in this course. It includes personal study of theoretical content, critical reading of scientific literature, completion of practical or written exercises, preparation of presentations, reports, and debates, and active participation in forums or collaborative tasks.

Continuous and formative assessment

Although formal evaluation will be conducted through a final exam, continuous assessment mechanisms will also be included. Results from seminars, workshops, and presentations will be considered in the final grade, aiming to reinforce progressive learning.

	Hours	% in-person attendance	
Distribution of teaching activities	Theoretical classes:	30	100
	Presentations and/or seminars:	11	100
	Tutorials:	5	100
	Assessment:	2	100
	In-person work:	48	100
	Independent work:	102	0
	Total:	150	

Assessment

Applicable criteria:

The assessment of this course will be based on a **mixed system**, combining a final exam with continuous and formative assessment, in alignment with the principles of active learning, the development of research competencies, and monitoring individual student progress.

1. **Final Exam (40%):** This will consist of a written test evaluating the integrated understanding of theoretical and applied content covered throughout the course. The exam may include essay questions, case analysis, interpretation of experimental data, and problem-solving tasks.
2. **Continuous Assessment (30%):** Continuous assessment will involve monitoring students' work throughout the course, including active participation in seminars, workshops, practical sessions, collaborative activities, quizzes, and other formative tasks. These elements will allow evaluation of both individual progress and engagement with autonomous and collaborative learning.
3. **Presentation and Discussion of Research Projects (30%):** A significant part of the assessment will focus on the presentation, defense, and critical discussion of research projects, whether individually or in groups. These activities will evaluate students' ability to interpret scientific literature, communicate ideas clearly, and argue rigorously, promoting essential skills in the research field.

Students must actively and responsibly participate in **at least 70% of face-to-face formative activities**. All grades will be expressed on a **0–10 scale**, according to the system established by Royal Decree 1125/2003. To pass the course, a **minimum overall grade of 5** is required.

Continuous assessment and project presentations are **not compensatory** with respect to the final exam but are an essential part of the learning and evaluation process. Continuous feedback will be

provided, aimed at progressive improvement and the development of scientific, critical, and communication competencies.

Semester organization

This course will be offered **during the first semester** (24 classes).

Syllabus

Theoretical Curriculum:

Block 1- Introduction

- **C1 and C2: General Introduction to the subject.** Origin and classification of tumors. Cancer epidemiology. History of cancer research.
- **C1. Foundations of cell signaling:** *How signaling pathways regulate cellular processes and how these are altered in cancer.* Signal transduction cascades (phosphorylation, second messengers, protein complexes...). Types of signaling (autocrine, paracrine, endocrine). Concepts of signal amplification, feedback regulation and modulation. Crosstalk and redundancy in signaling, integration of multiple pathways, cellular adaptation.
- **C2. Key Signaling Pathways in cancer I:** RTKs, Ras-MAPK.
- **C1 and C2. Key Signaling Pathways in cancer II:** PI3K-AKT-mTOR, phosphatases, nuclear receptors.
- **C1. Key Signaling Pathways in cancer III:** TGF β -SMAD.
- **C2. GPCRs.**
- **C1 and C2. Key Signaling Pathways in cancer IV:** Notch, Wnt/ β -catenin, Hedgehog.

Workshop / seminars: The foundations of cell signaling in cancer.

Block 2- The Hallmarks of Cancer

- **C1. Oncogenes.**
- **C2. Growth factors** and their cellular receptors.
- **C1. Tumor suppressor** genes and **genomic instability** in cancer.
- **C2. Cell cycle** deregulation in cancer.

Workshop / seminars: oncogenes *versus* tumor suppressors.

- **C1. Senescence and quiescence** in cancer.
- **C2. Apoptosis** and cancer.
- **C1. Autophagy** and cancer.
- **C2. Deregulation of cellular metabolism.**

Workshop / seminars: metabolic reprogramming in cancer, senescence and autophagy.

- **C1. Unlocking cellular plasticity: cancer stem cells.**
- **C2. Epigenetic** modifications and **miRNAs** in cancer.

Workshop on cancer stem cells and tumor plasticity.

- **C1. Stages involved in tumor progression:** adhesion molecules, metalloproteinases.
- **C2. Mechanisms of metastasis.**

Seminar on EMT and metastatic tumors.

- **C1 and C2. Tumor microenvironment I:** Bidirectional interactions between tumor cells and tumor stroma in the development and progression of cancer.

- **C1 and C2. Tumor microenvironment II:** Bidirectional interactions between tumor cells and tumor stroma in the development and progression of cancer.

Workshop on tumor cell dormancy *in the context of the tumor microenvironment*.

- **C1 and C2.** Tumor-promoting **inflammation** and cancer **immunology I**.
- **C1 and C2.** Tumor-promoting **inflammation** and cancer **immunology II**.

Workshop / seminars: tumor immunology *in the context of the tumor microenvironment*.

Block 3- Transversal perspectives of cancer biology

- **C1:** Milestones and **frontiers in cancer biology**. New challenges and visions
- **C2: Workshop / practical session:** Cancer through the lens of ecology and evolution. Cancer as a biological emergent system.

Practical sessions:

As indicated in the syllabus breakdown, each thematic block will include **practical sessions**, which may take the form of debates, seminars led by external experts, workshops, etc. All seminars will involve the course instructor and, when applicable, the invited expert on the specific topic. Workshop activities will be varied, adapted to each concept, and always guided by the instructors in the classroom. Workshops will involve individual or small-group work, and in all cases, ideas and conclusions will be presented and discussed in class.

- **Workshop / seminars:** The foundations of cell signaling in cancer.
- **Workshop / seminars:** oncogenes *versus* tumor suppressors.
- **Workshop / seminars:** metabolic reprogramming in cancer, senescence and autophagy.
- **Workshop** on cancer stem cells and tumor plasticity.
- **Seminar** on EMT and metastatic tumors.
- **Workshop** on tumor cell dormancy.
- **Workshop / seminars:** tumor immunology.
- **Workshop / practical session:** Cancer through the lens of ecology and evolution. Cancer as a biological emergent system.

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*In lectures and practical sessions, **specific bibliography** will be recommended for each topic to be covered.*