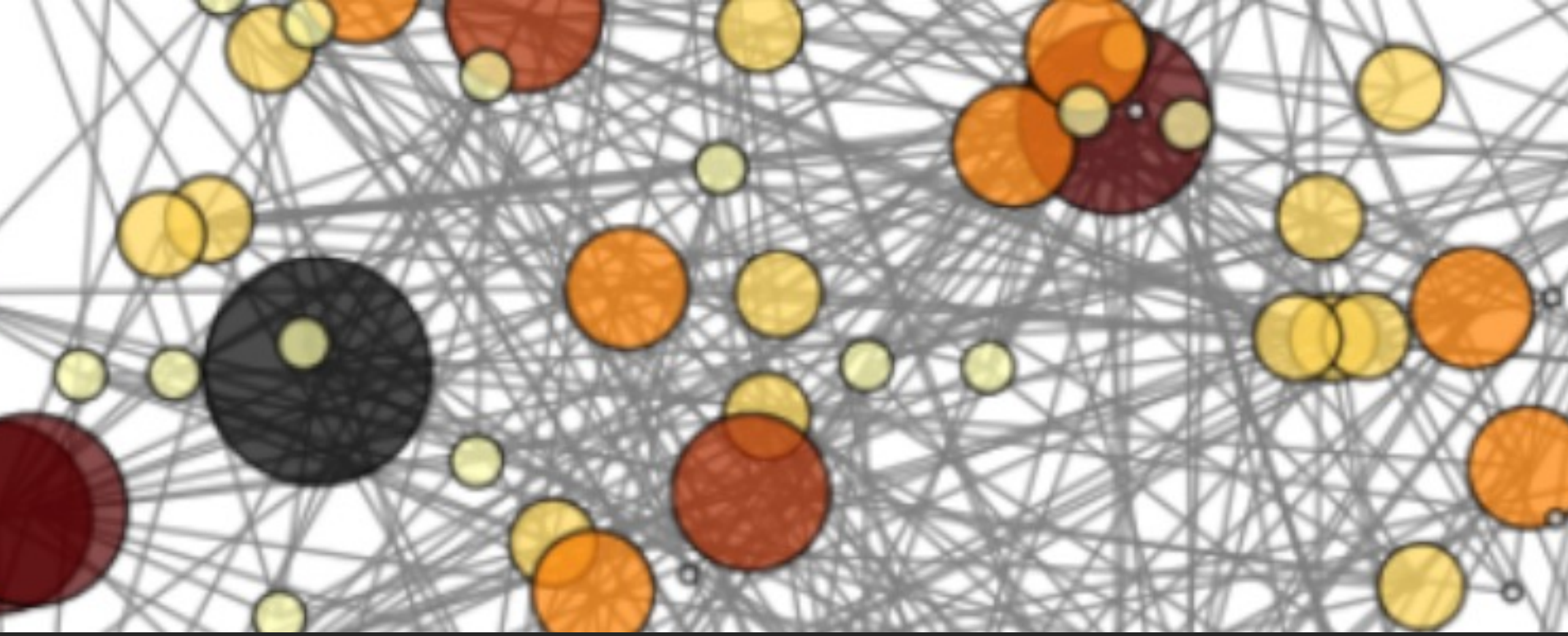

Master's Degree in Physics of Complex Systems and Biophysics

UNIVERSITAT DE BARCELONA

Master’s Degree in Physics of Complex Systems and Biophysics: Curriculum

LEARNING OBJECTIVES

The main objective of the master's degree in Physics of Complex Systems and Biophysics is to provide students with the theoretical knowledge and analytical and computational tools needed to understand and model the emerging properties, collective behavior and physical aspects of complex and biological systems upon the rules that govern the individual behavior of the parts that form them, and of the complex interactions between these parts.

SUBJECTS — 60 ECTS

Compulsory Subjects — 39 ECTS

Own Optional Subjects — 27 ECTS

Optional Subjects from an Affine Master’s Degree — 18 ECTS

Free-Choice Subjects from other Master’s Degree — 12 ECTS (Maximum)

Two Non-Exclusive Academic Itineraries, ‘Complex Systems’ and ‘Biophysics’

Fall Semester

First half		Second half	
Complex Systems	Biophysics	Complex Systems	Biophysics
Statistical Physics in Complex and Biological Systems			
Non-Equilibrium Statistical Physics			
Probability and Statistics		Analysis and Visualization of Massive Data	
Dynamical Systems		Introduction to Machine Learning	
	Molecular Biophysics	Pattern Formation	
Molecular Modelling			

Spring Semester

First half		Second half	
Complex Systems	**Biophysics**	**Complex Systems**	**Biophysics**
Advanced Statistical Physics	Experimental Techniques	Complex Networks	Soft Matter
Disordered Systems	Neuroscience	Master's Thesis	
Physics of Economic and Social Systems	Cellular Biophysics		
Advanced Methods of Molecular Simulation	Computational Systems Biology		

Fundamentals of Statistical Physics and Biophysics

STATISTICAL PHYSICS IN COMPLEX AND BIOLOGICAL SYSTEMS — 6 ECTS

1. **Summary of statistical physics**
2. **Statistical models of interfaces and membranes**
3. **Statistical physics of information**
4. **Criticality: critical phenomena, percolation and self-organized criticality**
5. **Phase transition dynamics**
6. **Active matter**

NON-EQUILIBRIUM STATISTICAL PHYSICS — 6 ECTS

1. **Non-equilibrium thermodynamics**
2. **Fluctuations and Brownian motion**
3. **Stochastic processes, master equations and Fokker-Planck equation**
4. **Applications: Activated, reaction-diffusion and directed processes, ratchets**
5. **Phase transitions and critical out-of-equilibrium phenomena**

Statistics and Data Processing

PROBABILITY AND STATISTICS — 3 ECTS

1. **Summary of probability theory**
2. **Convergence of random variables**
3. **Entropy and information**
4. **Long queues and rare events**
5. **Extreme-value statistics**
6. **Statistical inference**
7. **Hypothesis validation**
8. **Estimators**

ANALYSIS AND VISUALIZATION OF MASSIVE DATA — 3 ECTS

1. **Introduction and conceptual framework**
   - **Storytelling — Open Science — Visualization**
2. **Creating and editing graphics**
   - **Presentations — Infographics — Interactive graphics — Maps — Dashboards**
3. **Scientific communication, open science and public participation in research**
   - **Article writing — Scientific outreach**

Dynamical Systems

DYNAMICAL SYSTEMS — 3 ECTS

1. **Introduction to dynamical systems**
2. **Models with discrete time and continuous time**
3. **Local bifurcations**
4. **Introduction to Chaos**
5. **Population dynamics**
6. **Synchronization**

Introduction to Machine Learning

INTRODUCTION TO MACHINE LEARNING — 3 ECTS

1. **General introduction to machine learning**
2. **Unsupervised learning**
3. **Supervised learning**
4. **Deep neural networks**

Advanced Statistical Physics

PATTERN FORMATION — 3 ECTS

1. **Introduction to spatially extended dynamical systems**
2. **Reaction-diffusion patterns**
3. **Hydrodynamic and interfacial instabilities**
4. **Weakly nonlinear analysis**

ADVANCED STATISTICAL PHYSICS — 3 ECTS

1. **Statistical field theory**
   - **Interfaces — Quantum transitions — Complex fluids**
2. **The Renormalization Group**
3. **Advanced subjects in out-of-equilibrium physics**
   - **Fluctuations**

DISORDERED SYSTEMS — 3 ECTS

1. **Introduction to disordered systems**
2. **Applications in physics**
   - **The Ising model**
   - **Spin glasses**
3. **Applications to other disciplines**
   - **Biophysics**

Molecular and Cellular Biophysics

MOLECULAR BIOPHYSICS— 3 ECTS

1. **Fundamentals**
2. **Biological molecules**
3. **Structure and biophysics of DNA and RNA**
4. **Structure and biophysics of proteins**
5. **Kinetics, reactions and biomolecular interactions**
6. **Molecular motors**

CELL BIOPHYSICS— 3 ECTS

1. **Physics of biological membranes**
   - **Properties — Fluctuations — Morphology**
2. **Power generation and traffic**
   - **Cytoskeleton — Cell division**
3. **Mobility**
   - **Hydrodynamics**
4. **Active materials**

Molecular Modeling and Simulation

MOLECULAR MODELING — 6 ECTS

1. **Description of atomic and molecular systems at different scales**
2. **Quantum models**
3. **Classic models**
4. **Molecular dynamics**
5. **Monte Carlo method**
6. **Molecular modeling practices**

ADVANCED METHODS OF MOLECULAR SIMULATION — 3 ECTS

1. **Advanced Monte Carlo methods**
2. **Quantum Monte Carlo**
3. **Advanced molecular dynamics**
4. **Quantum methods in molecular dynamics**
5. **Basic state search optimization algorithms**

Systems Biology and Neuroscience

NEUROSCIENCE — 3 ECTS

1. **Basic neurophysics of the neuron**
2. **The neuron as an excitable system**
3. **Coupling between neurons: Neural networks**
4. **Experimental techniques**
5. **Simulation of neural networks.**
6. **Collective phenomena in neural networks**

COMPUTATIONAL SYSTEMS BIOLOGY — 3 ECTS

1. **Introduction and contextualization of computational systems biology**
2. **Computational systems biology for the study of genetic regulation**
3. **Computational systems biology for the study of cell signaling processes**
4. **Computational systems biology for the study of metabolism**

Interdisciplinary Applications of Physics and Complex Systems

PHYSICS OF ECONOMIC AND SOCIAL SYSTEMS — 3 ECTS

1. **Introduction to social and economic systems from the perspective of complex systems**
2. **Complexity in financial markets**
   - **Market behavior — Efficient market hypothesis — Options — Agent-based models**
3. **Complexity in social systems**
   - **Social dilemmas - Mobility**

Interdisciplinary Applications of Physics and Complex Systems

COMPLEX NETWORKS — 3 ECTS

1. **Dynamic systems and scale laws**
2. **Spatial-temporal structures**
3. **Complex networks**

SOFT MATTER — 3 ECTS

1. **Introduction to soft matter**
2. **Phase interactions and transitions**
3. **Macromolecules**
4. **Colloids**
5. **Supramolecular self-coupling**
6. **Interfacial phenomena**
7. **Deformation and flow**

Experimental techniques

EXPERIMENTAL TECHNIQUES— 3 ECTS

1. **Rheology**
2. **Optical and electron microscopy**
3. **X-ray, neutron and light scattering**
4. **Force spectroscopy: Optical and magnetic tweeters. Atomic forces**
5. **Laboratory practices**

Master’s Thesis

MASTER’S THESIS — 18 ECTS