Barcelona Institute of
Science and Technology

Universitat
Pompeu Fabra
Barcelona

Master of Multidisciplinary Research in Experimental Sciences

List of Major Research Projects

Course 2017-2018

Major Research Projects

A key feature of the program is in-depth hands-on research training in multiple fields. Students undertake a 6-month long major project (Major Research Project) and a 10-week minor project, in two different research disciplines in leading research institutions. Students are provided with extensive training in professional research skill, and engage directly with and learn from outstanding local and international researchers. Students will choose their top three major projects in the application and will discuss minor projects later with supervisors.

Major Research Project: 6-month long project carried out under the supervision of a PI from one of the participating institutions. Upon completion of the project, the student will write a research paper and publicly defend the work he or she has done.

Minor Research Project: 10-week long research project, complementary to the student's major research project, carried out in a different research laboratory. Upon completion of the project, the student will prepare a poster and publicly defend the work he or she has done.

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The Department of Experimental and Health Sciences (DCEXS-UPF)

DCEXS-RP01. Role of vascular signals in neural stem cells (NSC) activation during brain regeneration in zebrafish

Supervisor. Berta Alsina
Research Group. Morphogenesis and Cell Signaling in Sensory Systems

Project Description. Brain injury (BI) caused by strokes is one of the main deaths and disabilities in our industrialized society. The lack of regeneration in the human brain is the major impediment for recovery. Already 30 years ago, it was discovered that neural stem cells (NSC) were present in few regions of the brain, embedded in particular cellular niches. In particular, vascular signals have been shown to regulate their quiescence and activation when needed. For this reason, intense work has focused on understanding how and when NSC initiate adult neurogenesis with hopes to modulate adult neurogenesis after injury. The zebrafish is a powerful vertebrate model to explore the regeneration of the brain for several reasons. On one hand, the zebrafish transparency and superficial location of NSC allow good life imaging of the brain. Secondly, there is a handful of distinct transgenic lines labelling specific brain cell types, as well as mutants. Thirdly, the zebrafish has a broader regenerative potential than mammals and thus, by unravelling its regenerative mechanisms, one can hope to extend this knowledge to mammals for a better regeneration. Aims:
1) establish a model of brain strokes by laser ablation; 2) elucidate the role of vasculature in telencephalic regeneration; 3) identification of the vascular signals interacting with NSC;
The student will learn sophisticated imaging technologies, transgenesis in the zebrafish, RNA-seq, knowledge in neurobiology and stem cells

Keywords. brain, regeneration, zebrafish, transgenic, vascular system, signalling

Required background. Students should hold a degree in the biomedical field. Motivation for neurosciences or imaging will be a plus.
Minor project. To be determined

DCEXS-RP02. Controlling the cell cycle: elaborating an integrative map of DNA synthesis regulators and tumor progression

Supervisor. Jose Ayté
Research Group. Oxidative Stress and Cell Cycle Group (OSCCG)

Project description. At the OSCCG we are ultimately interested in deciphering the mechanisms that control cell cycle progression. Inactivation of the Retinoblastoma protein (RB) leads to unregulated cell cycle progression promoting cell growth, genomic instability and aneuploidy, hallmarks of tumor progression. RB activity is achieved through binding the E2F family of transcription factors. It is well known that a tumor process is very complex, accumulating secondary mutations that eliminate the brakes to the cell cycle. Even though many regulators of the RB-E2F are known, an integrative view of all the

regulatory events controlling the G1/S transition is required to anticipate putative interventions able to block proliferative processes. The candidate will characterize the regulation of the yeast MBF complex (functional homolog of human RB-E2F). The regulated activity of this complex is also essential for the G1/S transition since cells with hyperactive MBF have genomic instability. The candidate will perform 2 whole-genomic screens searching for global regulators of MBF. We have developed a reporter strain in the laboratory that measures MBF activity in vivo as an YFP/RFP output, either on FACS or on an automated fluorescence microscope platform. This reporter strain will be introduced in a commercial yeast KO deletion library. These screenings will allow the creation of a complete map with all the MBF regulators and, by extrapolation, will establish the nodes that regulate the RB pathway.

Keywords. Cell cycle, G1/S transition, replicative stress, transcription, yeast
Required background. A high motivation towards a scientific career in projects related to basic research, which is the research that is carried out in our group, is a must. Also, a solid background in Genetics, Cell Biology and Molecular Biology is a requirement to carry out this project.
Minor project. As a result of the screenings (by FACS, fluorescence on an automated microscope platform and by sorting cells on a Cell Sorter), the candidate will use bioinformatic tools to analyze the different positive clones. These analyses will allow to overcome the redundancy of regulatory networks and to create an integrated E-map of regulators. It will also help to establish homologous nodes that regulate the RB pathway in metazoans. This part, which is essential to complete the major project, will be done with the supervision of a different PI with a strong background in the bioinformatic field

DCEXS-RP03. Stochasticity and heritable phenotypes

Supervisor. Lucas Carey
Research Group. Single Cell Behavior

Project Description. Single isogenic cells are phenotypically heterogeneous. This is implicit in ideas such as LD50 (the drug concentration that kills 50% of cells): in the absence of variability either 100% would be killed, or none would be. The long-term objective of my research program is to determine how brief stochastic events at the molecular level generate heritable phenotypic variability in single cells and in organisms. Non-genetic heterogeneity allows microbes to survive antibiotics, tumor cells to survive chemotherapy, and results in incomplete penetrance of deleterious mutations. What are the discrete stochastic molecular events that cause individual cells to proliferate at different rates? How are these non-genetic differences in cell-state inherited? What are the phenotypic consequences of heterogeneity in proliferation, such as drug resistance or differentiation trajectory? These questions can be answered by combining experiments, computational analysis of existing data and
mathematical models. The exact project will depend on the candidate's background.

Keywords. stochastic, proliferation, mathematical modeling, systems biology

Required background. Either a programming background (preferably R or Matlab) or an experimental one (bacteria, yeast or cell culture)
Minor project. The minor project will be complementary. For example, if the student has an experimental background, they will do experiments in my lab, and then go to a group with expertise in modeling to build a mathematical model from the data they've generated

DCEXS-RP04. Monitoring Single Cell MAPK dynamics

Supervisor. Francesc Posas, Eulalia de Nadal
Co-supervisor. Manel Joaquin
Research Group. Cell Signaling Research Group

Project Description. Cells possess the extraordinary ability to sense and respond to changing environments. Building up a proper adaptation response is critical for cell fitness and survival. Nonetheless alteration of the cell signalling networks has devastating consequences leading to cancer, diabetes or autoimmunity which arise from inability of cells to properly evaluate information. It has become evident that cell signalling dynamics at a population are different from those observed in cells. Therefore, the use of dynamic single-cell reporters, capable of measuring cells individually with high spatiotemporal resolution, provides a more accurate representation of cell-to-cell variations than averaged measurements. In our laboratory we monitor MAPK signalling dynamics in single cells (Regot et al., 2014) by time lapse epi-fluorescent microscopy. In vivo single cell measurements of the three main MAPKs (ERK, JNK and p38) have shown a complex pattern of cross networking and negative feed-back loops. We are currently employing a broad range of techniques to uncover the signalling relationship between MAPK pathways and their effect on cell adaptation.
The main focus of this proposal is characterizing single cell signalling dynamics of input integration in mammalian
signalling networks. By using state of the art technologies, we will be able to gain knowledge on the basis for the individual behavior and phenotype variation of mammalian cells in response to multiple simultaneous external cues.

Keywords. Single cell, time lapse microscopy, cell signaling, MAPK, cell stress

Required background. A highly motivated student with a strong interest in developing a successful research career in the fields of molecular signalling, molecular biology and mathematical modelling.
Minor project. We propose to perform in depth single cell analysis and we plan to combine this information with mathematical modelling to 1) characterizing signalling heterogeneity and dynamics in mammalian cells and 2) dissecting input integration in mammalian signalling network. Specific molecular mechanisms of the behaviors observed will be tested by mathematical models, involving Boolean networks or ordinary differential equation (ODE) models, depending on the scale of the behavior observed

DCEXS-RP05. Molecular determinants of cell identity and phase transition between cell phenotypes

Supervisor. Eduardo Eyras
Co-supervisor. Juan Valcárcel (CRG)
Research group. Computational RNA Biology

Project Description. Phase transitions describe changes between different states of matter and are specified by measurable macroscopic variables, which are themselves determined by the statistical properties of microscopic variables. In this project we propose to study cell differentiation and cell identity as a phase transition process. Our body contains approximately 200 different cell types, which specify differentiated cell states with specialized physiological functions and properties. We now know many of the molecular mechanisms that trigger or revert differentiation. Expression and splicing differences between cell types, as well as between differentiated and undifferentiated states, indicate that cell properties are completely defined by specific molecular configurations. We plan to study the transcriptomes of single cells at different differentiated and undifferentiated cell states to identify the molecular determinants of cell

identity and study cell differentiation as a phase transition between cell states. The student will learn basic techniques of cell biology to establish cell cultures and induce cell differentiation or pluripotency in cells. The student will also learn basic analytical and numerical techniques to study phase transitions. The student will learn to analyze high-throughput sequencing of transcriptome from single cells to measure gene expression and splicing and to implement these measurements into the analytical and numerical models of phase transition.

Keywords. cell type, differentiation, gene expression, splicing, phase transitions

Required background. This project will require a student with a solid analytical background, experience with mathematical modelling, some knowledge of statistical mechanics and models of phase transitions and some basic knowledge of cell biology or biophysics. Programming skills is advisable.

Minor project. It is known that different RNA binding proteins play a role in differentiation to distinct cell types by inducing expression and splicing changes in relevant genes. We plan to reproduce some of the differentiation pathways described to obtain cells at different differentiation stages. These cells will be selected for single cell sequencing to determine their transcriptomes, which will be analysed during the main project. The student will sample different properties from cultured cells, like proliferation rate, cell-to-cell adhesion and cell motility, as well as differentiation stage. These will conform the macroscopic variables. Differentiated and undifferentiated cells will be sent for single cell transcriptome sequencing.

DCEXS-RP06. Study of ion channels in mechanobiology

Supervisor. José Manuel Fernández Fernández

Research Group. Laboratory of Molecular Physiology

Project Description. Mechanical forces influence cell behavior, from cell shape and movement to cell division, cell communication, and gene transcription through mechanotransduction and mechanoresponsive pathways triggered by cells. Understanding how cells dynamically integrate mechanical signals from the microenvironment is a challenging question in cell biology. So far, force and geometry sensing focuses on cell interaction with extracellular matrix via integrin-based complexes and the closely associated actomyosin cytoskeleton. However, cell behavior under defined 3-dimensional (3D) environments may also show integrin- and actomyosin-independent transducing mechanisms. The novelty of our proposal is to place Mechanosensitive Ion Channels (MIC) (particularly Piezo1-2 and TRPV4 channels) central to both integrin-dependent and -independent processes. We will address several basic questions: How is MIC activity tuned? What role has MIC in short- and long-range cellular responses? Do cells sense confinement via MIC? Does cell proliferation/adhesion/invasion require MIC activity? Do MIC participate to invadosome dynamics? Are MIC functionally related with key elements in neurotransmission? Project development will involve several disciplines, including: 1) electrophysiology and live cell imaging; 2) microfluidics and photolithography; 3) cellular and molecular biology; 4) atomic force microscopy and biophysics. We will provide full training regarding MIC channels study using disciplines 1 and 3.

Keywords. PIEZO and TRPV4, cytoskeleton-matrix, mechanobiology, cancer, neurotransmission

Required background. Bachelor degree in Biological or Biomedical Sciences, or in Physics.
Minor project. The minor project may involve the elaboration of materials/ substrates of different rigidity and microfabricated devices that allow us the measurement of forces developed by cells during proliferation/adhesion/migration under different experimental conditions related to altered function/regulation/ expression of MIC. Invasion capability of different cancer cells expressing or not MIC may also be evaluated during the minor project

DCEXS-RP07. Molecular basis of cellular memory

Supervisor. Jordi Garcia-Ojalvo
Research group. Dynamical Systems Biology lab

Project Description. The goal of this project is to analyze how the structure of cellular regulatory networks determines the ability of cells to store a record of preceding environmental signals, and eventually forecast future conditions. The study will be done on transcriptional, protein-protein and metabolic networks, and will make use of statistical and complex systems methods to examine computationally the structural properties of those networks, and their role in establishing their dynamical behavior.

Keywords. Biological networks, cellular computation, machine learning
Required background. Programming experience in Python and/or C is advisable, but not required. The student should have a BSc degree in any biology, physics, or engineering specialty.
Minor Project. To be determined

DCEXS-RP08. Oxidative stress in the onset of Alzheimer's disease: the amyloidogenic pathway in the cholinergic forebrain

Supervisor. Francisco J. Muñoz
Research Group. Ageing Brain Research Group - Laboratory of Molecular Physiology

Project Description. The main goal of this research project is to explain why cholinergic neurons of the Nucleus Basalis of Meynert (NBM) are the first to degenerate in Alzheimer's disease (AD) and its consequences. We hypothesised that the NBM is more sensitive to oxidative stress, therefore to aging, activating the amyloidogenic machinery and producing a steady increase in beta-amyloid peptide (Aß) production, which will aggregate forming the neurotoxic oligomers and fibrils. Furthermore oxidative stress effect will be increased by the pathological production of peroxynitrite as a result of nitric oxide reaction with superoxide anion. The partial objectives of research project are: 1) To demonstrate that cholinergic neurons are more sensitive to the oxidative damage and aging than other neurons. 2) To demonstrate that oxidative damage and aging activate the amyloidogenic processing pathway of amyloid precursor protein (APP) in cholinergic neurons through the sensor stress kinases.

Keywords. Alzheimer's disease, amyloid, neurons, oxidative stress, nitric oxide
Required background. Bachelor degree in Biological or Biomedical Sciences.
Minor project. The minor project will be focused in the study of the cell viability in cholinergic neurons compared to other kind of neurons such as dopaminergic neurons, looking for a higher cell death in cholinergic cells exposed to low micromolar concentrations of hydrogen peroxide and amyloid peptide forming oligomers

DCEXS-RP09. Controlling hindbrain neurogenesis through in vivo modulation of cell signaling by optogenetics

Supervisor. Cristina Pujades
Research Group. Developmental Neurobiology

Project description. The hindbrain is the most evolutionarily ancient part of the vertebrate brain controlling important physiological processes. It is transitory segmented into rhombomeres that constitute developmental units of gene expression and cell lineage compartments. The segmentation involves the formation of an interface between adjacent segments, with a specialized cell population named rhombomere boundary cell population that serves to distinct functions as development proceeds: boundary cells work as an elastic mesh preventing cell intermingling between adjacent compartments, they behave as a node for signaling pathways instructing the neurogenesis, and only later on, they provide proliferating progenitors and differentiating neurons. Therefore, a fundamental question is how the different functional properties unfold over hindbrain morphogenesis. In this project we will address the role of boundary cells as a source of instructing signals for neurogenesis. Our hypothesis is that Wnt signals from the boundary play a role in allocating neuronal specification to rhombomeric territories. To demonstrate this, we will make use of inhibitors and activators of Wnt signaling pathway that can
be inducible by light, and analyze the functional effects on neurogenesis upon induction. We will employ the zebrafish embryo as a model system because it allows us to combine high-resolution in vivo imaging with genetic tools and optogenetics.

Keywords. Neurogenesis, wnt signaling, optogenetics, imaging, zebrafish

Required background. We are seeking for highly motivated and enthusiastic candidates with Graduate studies related to Biomedicine. Previous work in developmental biology or in imaging will be a plus.
Minor project. To be determined

DCEXS-RP10. Real time monitoring of intracellular analytes with an optical nanosensor

Supervisor. Pilar Rivera Gil
Co-supervisor. Pablo Loza (ICFO)
Research Group. Integrative biomedical materials and nanomedicine lab

Project Description. The remote profiling of cellular ions is emerging as a hot topic as it determines the balance between the physiological and pathophysiological state. For example, dysregulation of the K+ entry might alter Ca2+ homeostasis; thus, leading to neuronal degeneration and all associated diseases like Alzheimer, stroke or ischemia, and epilepsy. So far, there is no technique allowing for a rapid, in situ, non-destructively and parallel detection of ions at very low concentrations inside living cells. One possibility toward this direction is the use of particles as carrier matrix/container for analyte-sensitive molecules. Furthermore, by using an optical (Raman) read out together with plasmonic nanoparticles we can reach ultra-high sensitivity, even down to the single molecule regime, with ultrahigh spatial resolution even within cells. Besides, the existence of a differentiable Raman fingerprint for most chemical compounds, enables label-free analysis. The lack of water interference also allows in situ analysis. In this project, sophisticated plasmonic nanocapsules will be used to sense relevant intracellular analytes with surface-enhanced Raman scattering (SERS). The biosensors will allow multiplexing and noninvasive quantification of several analytes in paralell with subcellular resolution at real time. Imbalances will be correlated to disease (Alzheimer) progression.

The student will learn state of the art methods in: 1) synthesis of nanoparticles; 2)cell culture and manipulation; 3) surface-enhanced Raman scattering; 4)Data analysis with MatLab or similar

Keywords. nanosensors, surface enhanced Raman scattering, living cells, alzheimer, nanomedicine

Required background. This is a highly interdisciplinary project therefore, any applicant from a scientific discipline is welcome. Backgrounds like Bioinformatics, Chemistry (inorganic, physical-chemistry, analytical, etc), Health Sciences (Medicine, Biology, Pharmacy), Nanoscience, Physics, etc will be helpful.

Minor project. Modern diagnostic tools require specific, sensitive, and quantitative analysis for rapid and reliable examination of (patho)physiological parameters. Several well-established and commercially available analytical methods present important limitations. For example, all techniques require extensive sample manipulation prior to analysis, some, are destructive, with low sensitivity or do not permit multiplexing. In the quest for improved analytical tool, SERS spectroscopy has been recently arisen as a candidate technology with a huge potential in a variety of diagnostic fields. SERS takes advantage of the coherent oscillation of the conduction electrons in metal nanoparticles and the excitation of localized surface plasmon resonances at specific wavelengths of incident light. This optical phenomenon induces gigantic electromagnetic field amplification onto the surface of the nanostructure. This enhancement of the Raman signal reach maximal levels at localized hot-spots potentially created by the nanoparticles and permit an ultra-trace level analysis down to zeptomolar regime, which is several orders of magnitude below conventional technologies

DCEXS-RP11. From Biophysics to Immunology: the Zinc issue

Supervisor. Rubén Vicente

Research group. Biophysics of the Immune System

Project description. Zinc is an essential mineral for the human physiology. Deficiency in this metal causes impairment in body growth, neurological disorders and immunosuppression, leading to morbidity and an increased infection rate. It is considered a major public health problem worldwide. Zinc is a common structural component of proteins but free zinc cellular signals have been also described to influence several signaling cascades and cellular transcription programs promoting the idea of zinc as a second messenger. In this scenario, despite the strong impact the zinc has on the immune system, there are no clear mechanisms of how this element enters these cells and exerts its effect. The main goal of the project is exploring the function and regulation of zinc fluxes in immune cells in order to have a better understanding of zinc signals and its consequences. The specific goals are the characterization and the study of the regulation of the important zinc transporters in immune cells and investigating the consequences of zinc fluxes on their activation and differentiation programs.

The student will join a team of biophysicist experts on ion fluxes monitoring by fluorescence microscopy and electrophysiology. During the project the student will learn the basic biophysical language and will be taught in different techniques to monitor ion fluxes in living cells. Besides, the project will require molecular biology techniques, flow cytometry and confocal microscopy.

Keywords. Biophysics, Immunology, Zinc

Required background. Students with a degree in Biology, Chemistry, Physics and related degrees are suitable for developing the project. **Minor project.** The minor project will be decided during the interview process depending on the background and interest of the student.

Center for Genomic Regulation (CRG)

CRG-RP12. Wnt-mediated mechanisms regulating somatic cell reprogramming and pluripotency

Supervisor. Maria Pia Cosma
Research group. Reprogramming and Regenration

Project Description. 1. Dissecting out how Wnt signalling controls somatic cell reprogramming. 2. Identifying and studying the function of early reprogramming factors and stem-cell-associated factors through gene network analysis. 3. Decoding chromatin and DNA structure in cells undergoing reprogramming and differentiation, using superresolution microscopy.
The student will learn methods in the area of stem cell biology and somatic cell reprogramming as well as he/she can learn super resolution microscopy approaches. The student will be exposed to a number of concepts and disciplines since he/she will be part of a highly interdisciplinary laboratory working in the area of cell biology,tissue regeneration, biophysics and modeling.

Keywords. stem cells, Wnt, somatic cell reprogramming, STORM, gene network

Required background. Students should hold a degree in the biomedical or biophysic field. Previous lab experience in cell biology or imaging will be positively evaluated.
Minor Project. The minor project will be decided based on the student's background.

CRG-RP13. Understanding the mechanism of unconventional protein secretion

Supervisor. Amy Curwin
Co-supervisor. Vivek Malhotra
Research group. Malhotra Lab - Intracellular Compartmentation

Project Description. Protein secretion is a fundamental process that controls cell compartmentation, permits cells to signal to one another and tissues to both form and function. Important examples include hormones and collagens. Such proteins contain a signal sequence to target them to the ER-Golgi pathway for their secretion. However, a much lesser studied class of secretory proteins exists that does not contain a signal sequence. The first example of such a protein is the cytokine interleukin 1-beta, which is secreted in response to inflammation. In the lab we use the model organism S.cerevisiae to study this process of "unconventional protein secretion" (UPS) and we focus on a pathway that is dependent on the Golgi protein GRASP, or Grh1 in yeast. GRASP is conserved in eukaryotes and regulates the unconventional secretion of another conserved protein, Acb1. We have shown that Grh1 labels a novel organelle we called CUPS (compartment for unconventional protein secretion) that we believe is a sorting station for UPS cargoes. The major part of the project will be to perform a genome-wide co-localization screen to localize Grh1 with every other protein in the cell to learn more about CUPS. Minor side-projects will depend on the status of the UPS project, but to allow diversity for the student

will include mammalian tissue culture to identify and analyze the presence of CUPS in mammals. Basic molecular biology and biochemical techniques will be learned, and advanced microscopy and data analysis.

Keywords. Unconventional protein secretion, GRASP, CUPS, yeast

Required background. Bachelor's degree or equivalent in Cell Biology and/or Biochemistry. Any lab experience would be an asset. The student should be highly motivated, enthusiastic, able to work independently, but also as part of a larger team.

Minor project. The minor project will be carried at ICFO under the supervision of Felix Campelo in the lab of Maria Garcia-Parajo. In trying to tie the major and minor projects, and making use of the imaging expertise of ICFO, one major goal of the minor project will be to develop a program to analyze the data of the genome-wide colocalization screen. Such control images will be acquired in small scale in the first weeks before beginning the minor project. Imaging and analysis of GRASP in mammalian cells will most likely be performed as well, perhaps using a mouse knock-out model currently being set-up in the lab or other human tissue-culture system to identify and analyze CUPS in mammals.

CRG-RP14. Role of RNAs in targeting Polycomb to chromatin in embryonic stem cells

Supervisor. Luciano Di Croce
Co-supervisor. Valerio Di Carlo
Research Group. Epigenetic events in Cancer

Project Description. Our laboratory is studying the role of protein complexes involved in epigenetic regulation of chromatin dynamics. Among the several complexes implicated in chromatin regulation, Polycomb group of proteins (PcG) are particularly fascinating, having a major role in controlling epigenetic memory, repressing gene expression, and contribute to cancer. How Polycomb is recruited to specific loci is still not completely understood. Some accessory proteins can guide the complexes, by binding specific histone marks or genomic elements; however, more recently, RNAs have emerged as key players in guiding/antagonizing the recruitment of Polycomb to chromatin. In particularly, the project will focus on de novo recruitment mediated by RNAs occurring in the transition from mouse pluripotent embryonic stem cells to differentiated cells, where a large chromatin-rearrangement take place, leading to great transcriptional changes.
The candidate will employ cutting edge techniques of molecular biology and cell biology. This will include using CRISPR/Cas9-mediated endogenous protein tagging to create cell lines expressing several tagged proteins for the two Polycomb complexes.Then, he/she will utilize iCLIP and fRIP techniques to identify the RNAs associated to the specific tagged proteins/complexes. Finally, he/she will identify changes in RNA binding of the complexes in the absence of specific factors, which will be depleted using shRNAs or CRISPR/Cas9.

Keywords. ncRNA, embryonic stem cell, CRISPR

Required background. Students should hold a degree in the biomedical field. Previous lab experience in molecular biology will be positively evaluated.

Minor Project. The minor project will be decided based on the student's background.

CRG-RP15. Intracellular localization and regulation of the protein UNR/CSDE1

Supervisor. Fátima Gebauer
Research Group. Regulation of Protein Synthesis in Eukaryotes

Project Description. UNR/CSDE1 is a highly conserved protein that regulates mRNA translation and stability. We have recently

shown that CSDE1 functions as an oncogenic driver and promotes metastasis in melanoma by coordinating RNA regulons which ultimately lead to cytoskeletal reorganization, migration and invasion (Wurth et al., Cancer Cell 2016). Very little is known about this protein in mammals. For example, how CSDE1 might be regulated, or
whether it associates with specific cellular structures is unknown. As a first line of research, we propose to investigate whether CSDE1 associates to cellular structures (ER, mitochondria, the cytoskeleton at adhesion foci, etc) to promote oncogenic traits. The project will include using microscopy techniques learnt during the minor project (confocal, but possibly also super-resolution) to study the detailed location of endogenous CSDE1 in human cell lines. The study will be combined with mutational analysis to understand the determinants of CSDE1 localization, and will be correlated with IHC studies we are currently performing on patient samples. A second line of research (to be decided with the student) is the study of post-translational modifications of CSDE1. We propose to draw a map of CSDE1 modifications by using mass spectrometry on UNR purified from cancerous and non-cancerous cells. We will then focus on specific modifications for further functional analysis.

Keywords. CSDE1, localisation, phosphorylation, metastasis, cytoskeleton

Required background. The student should have a degree in Molecular Biology or Biochemistry, and have knowledge of Cellular Biology. Basic training on protein and RNA manipulation, or on microscopy techniques will be positively evaluated.
Minor project. Potential minor projects (to be negotiated with the student and the potential minor project supervisor): 1) Melike Lakadamyali (ICFO)- The student will learn advanced and super-resolution fluorescence microscopy techniques, which can be later used during the major project at CRG. 2) Raúl Méndez (IRB)- The student will learn basic principles of RBP phosphorylation, and techniques to identify phosphorylated proteins/domains, including phosphorylation/de-phosphorylation assays, labeling and chromatography. 3) Jens Lüders (IRB)- The student will learn basic concepts and technologies to study the organization of the cytoskeleton in invasive migratory behavior.

CRG-RP16.Development of a quantitative high-throughput method for mapping protein domain-domain interactions

Supervisor. Sebastian Maurer
Co-supervisor. Lucas Carey
Research Group. Cytoskeleton dependent mRNA localisation mechanisms

Project Description. In neurons, delivery of mRNAs to remote dendritic and axonal locations is essential for differentiation, axon guidance and synaptic plasticity. Defects in components of the RNA transport machinery lead to severe neurodegenerative disorders. With this project we want to obtain a systematic understanding of direct interactions between the mRNA interactome and molecular motors which are required for neuronal mRNA transport. We want to reveal which specific domains of RNA binding proteins and motor proteins interact directly. Using a matrix screening technology developed in our labs, the master student will develop a technique to identify direct interactions between protein domains with a novel high-throughput approach.
Research Objectives: 1) Adaptation of our newly developed matrix-screening method for HT-domain-domain interaction screening; 2) Generation of a protein-domain library; 3) Screen and bioinformatic analysis of the domain library.
We expect this project to generate two important outcomes: on one hand we will establish and new method allowing high-throughput matrix-screening of domain-domain interaction, an endeavour which was traditionally laborious and low-throughput. On

the other hand we will generate a systematic understanding of mRNAcytoskeleton crosstalk which will significantly further our understanding of how cytoplasmic mRNA localisation is controlled.

Keywords. HT domain mapping, Next-generation-sequencing, Bioinformatics, Microtubules

Required background. The ideal candidate should have interests in both systems approaches and basic cell biological mechanisms. Existing experience in computational data analysis and molecular biology are considered a significant advantage but are not required. Specifically, the project will involve handling of large libraries of sequences in bacterial and yeast cultures, sample preparation for next-generation-sequencing (NGS), and analysis of the resulting data. The student will also gain experience in processing, analysis and representation of NGS data with tools such as Matlab, R and Python.

Minor project. The minor project is to use Illumina sequencing data to measure interaction strength and specificity. This will take place in the Single Cell Behavior lab (PI: Lucas Carey, DCEXS). The student will be trained in programming (Matlab, R or python) and in computational methods for working with sequencing data, and in mathematical modeling to convert sequencing data into biophysical measurements of affinities between domains. This project is complementary to the first part, in which the student will develop the experimental system, but
requires an entirely different skill set.

CRG-RP17.Mechanosensitive Regulation of 3D Cell Dynamics

Supervisor. Ruprecht Verena
Co-supervisor. Wieser Stefan
Research group. Cell and Tissue Dynamics

Project Description. Research in our lab is focused on the control of cell and tissue dynamics in complex 3D environments. We study how single cells process mechanochemical information and generate adaptive output dynamics such as shape change, cell polarization and migration that collectively impact on tissue development, morphogenesis and regeneration. Our lab follows a highly interdisciplinary approach combining molecular and cell biology with quantitative live cell imaging and advanced fluorescence microscopy. We use Zebrafish embryos as a model system to study complex 3-dimensional tissue rearrangements and patterning in the embryo. In this interdisciplinary project, we will study the dynamics of embryonic progenitor stem cells under mechanical stress in minimalistic 3D environments. Quantitative imaging will be used to analyze singe cell behavior and collective dynamics and self-organization in tissue mini-aggregates. Perturbation experiments will further be used to identify signaling pathways involved in cellular mechanosensing and cell motility.
Specific research areas:
1) Mechanosensitive regulation of cell dynamics and migration competence of embryonic progenitor stem cells in reconstituted 3D tissue environments; 2) Analysis of cell dynamics and self-organization in mini-tissue aggregates as a proxy for tissue development and morphogenesis; 3) Biochemical and pharmacological perturbation screen to identify mechanosensitive regulators of cell dynamics and migration competence

Keywords. Biophysics, Microscopy, Zebrafish, Progenitor stem cells, Mechanobiology

Required background. We are seeking for highly motivated students interested in an interdisciplinary Master project in the field of Cell and Developmental Biology, Mechanobiology and Bioimaging. Candidates should hold a background in Biology, Physics, Bioengineering, Biochemistry or a related

subject with proven track record of academic excellence. Training in Biophysics, microscopy and statistics is preferred but not essentially required. Candidates should however have a strong interest in live cell imaging and quantitative data analysis tools.

Minor project. During the 10-week minor project the candidate will undertake an in-depth training in advanced single molecule fluorescence imaging and image analysis at the Institute of Photonic Sciences (ICFO) in the research group of Dr. Stefan Wieser. This project will provide experimental training in superresolution (SR) microscopy on live cell embryonic progenitor cells and additional training in image data processing and statistical data analysis. SR methods will be applied to study the molecular dynamics of cytoskeletal and membrane associated proteins during mechanical stress in 3D microenvironments, in synergy with the experimental approach of the major research project.

CRG-RP18. The role of chromatin modifications in co-transcriptional splicing

Supervisor. Roderic Guigó
Co-supervisor. Sílvia Pérez-Lluch
Research group. Biologia Computacional del Processament del RNA

Project Description. The role that histone post-translational modifications play in alternative splicing (AS) is still poorly understood. Some associations between histone marks and inclusion or exclusion of particular exons have been observed when looking at individual cases1-3. However, when performing genome-wide analyses, only promoter-associated marks have been found to show correlation with differences in exon inclusion/exclusion between cell lines, likely due to interactions between alternative exons and promoters4. In this context, we aim to uncover a more general role of histone modifications in AS. We hypothesize that the few correlations observed between histone marks and AS may be due to technical details, such as the analysis of already processed transcripts or the lack of omics data on dynamic processes to analyse the co-occurrence of changes in histone tails and AS. To overcome these issues we propose the implementation of the Nascent-seq technique in our lab5, allowing for the detection of chromatin-associated RNA, putatively unprocessed, in a dynamic process, the trans-differentiation from human proB cell to macrophage6. To study the role of histone marks in AS regulation we will use our recently generated ChIPseq data on 9 histone modifications throughout the process. This project will imply both experimental work and computational analysis, giving the student the opportunity to follow the full process, from the generation to the analysis of the data, and fostering the multidisciplinary skills of the student.

Keywords. transcription, splicing, chromatin, genomics, sequencing

Required background. Degree in Biology, Biomedicine or similar, Knowledge of Computational Biology, Fluent English

Minor Project. Study of the role of chromatin modifiers in chromatin compaction during fly development by high-resolution microscopy. This project could be carried out in collaboration with Prof. Melike Lakadamyali, at the Institut of Photonic Sciences (ICFO). The student would use different Drosophila mutant strains from our lab to study the chromatin structure of developing tissues in absence of different chromatin modifiers and cofactors. Samples would be processed and analysed in the ICFO.

The Institute of Photonic Sciences (ICFO)

ICFO-RP19. Simulating Cosmological models in optical lattices

Supervisor. Alessio Celi
Research Group. Quantum Optics Theory

Project Description. In this thesis, we propose to study the evolution of a gas of relativistic Dirac fermions in time dependent metrics in two spatial dimensions. The simplest example of the latter (Friedman-Lemaître-Robertson-Walker metric) describes the expansion or the collapse of a homogen-eous and isotropous universe. If the gas is not interacting the model can be studied analyt-ically as it is described in terms of a time-dependent single particle Dirac Hamiltonian H(t). The goal is to investigate the lattice version of this Hamiltonian, which is a generalized Hubbard model, and can be thought as a deformation of artificial graphene [Tarruell2012]. As in real graphene, relativistic Dirac fermions are emerging low-energy excitons around the Dirac points, namely cone like singularities of the energy bands. The main tasks will be: 1) to find the appropriate choice of the coordinate frame and the simplest lattice formulation of H(t) that are suitable to be implemented within the scheme and setup proposed in [Boada2011] and [Rodriguez-Laguna2017], respectively; 2) to consider the continuum limit of the lattice model and the role of lattice doubling in cosmological evolution; 3) to define suitable observables that describe interesting phenomena like the "particle creation" and cosmological horizon; 4) to compare the results for fermions with respect with the one obtained in analogue models of cosmological expansions with bosons, namely Bogoliubov excitations in a Bose-Einstein condensate.

Keywords. Quantum Simulation, Ultracold atoms, Quantum field theory in curved spacetime

Required background. **Q**uantum mechanics, special relativity, introduction to ultracold atoms and field theory
Minor project. The master could be complemented with at 10-week stay at IFAE where the studient may due a mini-project on gravitational wave, or inflationary models, or on holography

ICFO-RP20. Diffuse optical neuromonitoring for brain health

Supervisor. Turgut Durduran
Research Group. Medical Optics

Project Description. Next generation diffuse optical neuro-monitors have numerous potential applications in clinics. We develop new concepts , implement them in new clinical prototypes and apply them in pilot studies. We work closely with biomedical researchers and clinicals to achieve these goals. In this project, the student will work on such a neuromonitor for new novel applications. Objective 1: Characterize a new monitor on tissue simulating standards. Objective 2: Carry out a pilot test on healthy human volunteers. Objective 3: Implement measures for clinical applicability and take steps for translation into the clinics.
The student is expected to be trained in the physics and engineering aspects of biomedical diffuse optics, in data analysis and interpretation and in translational biomedicine. He/she will have a chance to

collaborate with endusers and potentially carry out a secondment.

Keywords. biomedical optics; biophotonics; multi-disciplinary research;

Required background. Basic skills in instrumentation, numerical computing.
Minor project. To adapt an optical probe for the study of language acquisition in four month old infants and to communicate the system with EEG.

ICFO-RP21. Insights on the role of Poly-ADP-ribose (PAR) in mediating chromatin phase transitions by 3D-single particle tracking

Supervisor. Maria Garcia-Parajo
Co-supervisor. Catalina Romero (CRG)
Research Group. Single Molecule Biophotonics

Project Description. Recent studies have shown that proteins and RNAs can assemble into a liquid phase inside the cell that is distinct from the surrounding cytoplasm. This process of phase-separation provides a principle for spatiotemporal organization in the cell and it is believed to play a major role to enhance biochemical reactions. However, very little if known on how phase-separation inside the cell nucleus occurs, and importantly, how it contributes to gene regulation. The goal of this project is to obtain insight on the role of Poly-ADP-ribose (PAR) in mediating chromatin phase transitions in the context of hormonal gene regulation. In the nucleus, PAR polymers accumulate transiently after hormone stimulation, possibly contributing to the formation of phase-separated compartments. Using single molecule tracking we will address whether such compartments provide a mechanism to control local concentration of the progesterone receptor. The use of single molecular dynamic approaches could bring valuable insights on the process of nucleation, degree of phase separation, compartment size and distribution, and the impact of PAR-induced liquid de-mixing on chromatin remodelling and gene expression.
The specific objectives of the project are: 1) Defining and adjusting labelling & imaging conditions for single particle experiments of the progesterone receptor (PR) inside the nucleus of living breast cancer cells. 2) Record the diffusion of individual trajectories of PR inside living cells at different spatiotemporal resolutions. 3) Detailed data analysis of individual trajectories to determine diffusion coefficients, type of diffusion profiles (Brownian, anomalous, directed or facilitated diffusion) on different regions of the cell nucleus, physical sizes of
compartment regions. 4) Study the effect of PARP1 inhibitors on PR diffusion and compartment sizes.
During the development of this project the student will get deep training on single molecule fluorescence microscopy, single particle tracking and statistical data analysis. The student will be embedded in a collaborative project with the group of M. Beato @ CRG, profiting from a truly multidisciplinary research and expected to actively participate on the decisions taken during the development of the project.

Keywords. Single particle tracking, fluorescence microscopy, data analysis algorithms, chromatin remodelling, hormone gene regulation.

Required background. A physicist with strong affinity for biology, biophysicist or biotechnologist will be highly desirable.
Minor project. The minor project will be undertaken at the Chromatin and Gene Expression group (Beato lab) at the CRG. In this part of the project the student will contribute in two fronts: 1) Endogenous tagging of the PR receptor with a variety of self-labelling tags using CRIPSR; 2) Preliminary experiments with PARP1 inhibitors to measure difference in nuclear organization, using a previously established cell line expressing the transcription factor fused to GFP. The effect of inhibitors will be validated using expression

data from genes whose response to hormone is well known. On these 10 weeks the student will earn experience in molecular biology (plasmid construction, measurements of gene expression), design of genome editing experiments using CRISPR, tissue culture techniques and basic live cell microscopy.

ICFO-RP22. Nanophotonics of hybrid emitter-graphene systems

Supervisor. Frank Koppens
Co-supervisor. Klaas-Jan Tielrooij
Research group. Nano-optoelectronics

Project Description. The main objectives of this project are: 1. Understanding how efficiently erbium emitters couple to graphene plasmons with and without nanostructures; 2. Understanding how efficiently graphene plasmons couple to the far-field through nanostructures.
You will use a numerical Maxwell-solver software called Lumerical to study the nanophotonic properties of these hybrid systems. Through this you will gain an excellent understanding of many important concepts in nanophotonics. You will also learn important fundamentals of the intriguing physics of layered materials, in particular graphene. You will also be introduced to experimental fabrication and measurement techniques, such as dry transfer and (time-resolved) confocal microscopy. More generally, you will be prepared for starting more independent research work as a PhD student.

Keywords. Graphene, quantum, nanophotonics, plasmons, microscopy

Required background. You should have a strong interest in nanophotonics and any previous experience in this field will be valued, as well as independence and good communication skills.
Minor Project. To be discussed

ICFO-RP23. 3D Super Resolution Microscopy of Cell Migration Dynamics

Supervisor. Stefan Wieser
Co-supervisor. Verena Ruprecht
Research group. Structured Illumination Microscopy & Cell Migration

Project Description. Our team works at the interface of physics and biology. We are developing live cell super-resolution imaging techniques for 3D imaging of whole cell dynamics. We mainly focus on migration dynamics of motile cells with the aim to study the coupling between cell intrinsic versus extrinsic driving forces to fullfill behaviors like directed or persistent cell migration and the initialization and maintenance of polarization. To gain a mechanistic understanding of these processes we apply advanced imaging techniques – with a focus on sophisticated structured Illumination technologies - and data analysis tools that allow for integrating molecular dynamics with largescale cell behavior. The ultimate goal is to develop mathematical models with predictive capacity from the molecular scale to global cell behaviour and function. This is an interdisciplinary research project with the aim to apply lattice light sheet microscopy (LLSM) for visualizing live cell migration dynamics at molecular resolution. We will use different mesenchymal and amoeboid cell types to study 3D cytoskeletal dynamics and associated signaling complexes and networks with molecular resolution. This approach will allow to identify key control mechanisms regulating migratory competence and will enable to build quantitative and predictive models of dynamic cell transformation and migration behavior.

Keywords. Microscopy, Biophysics, Cell Polarization , Cell Motility, Modeling

Required background. We are looking for candidates who are highly interested in the interdisciplinary fields of Physics and Biology, specifically in the application of live cell Super-

resolution Microscopy to study dynamic cell biological processes. Training in Physics, Engineering or a related field with a focus on Biophysics, Microscopy and Mathematics is preferred but not essentially required. However, candidates should have a strong interest in Modern Biology, Imaging Techniques, Data analysis tools and Modeling.
Minor project. In this interdisciplinary project the candidate will have an initial training at the Centre of Genomic Regulation
(CRG) in the research group of Dr. Verena Ruprecht. The group of Verena Ruprecht will provide experimental training in 2D/3D cell culture assays and chamber design, embryonic progenitor stem cell culture, labelling strategies for fluorescence microscopy and long-term live cell imaging.

ICFO-RP24. Illuminating the biophysical mechanism of tension generation in neurons using optogenetic force reporters

Supervisor. Michael Krieg
Research Group. Neurophotonics And Mechanical Systems Biology

Project Description. The mechanical properties of neurons are important for the function of the nervous system. We have previously shown that neurons in the round worm C elegans are under constitutive mechanical tension which is maintained in parts by the cytoskeletal protein b-spectrin. Mutations in beta-spectrin, which interfere with network formation, lead to a loss of neuronal tension and, thus, loss of neuronal functions. The origin of this molecular tension, however, is unclear. Several hypothesis have been forward, including stretch growth or as a consequence of molecular motors such as myosins. In this project we aim to investigate the hypothesis that mechanical tension in neurons develops as a consequence of body elongation during morphogenesis. This hypothesis makes several predictions that can be tested experimentally empowered by novel optogenetic tension sensors pioneered in the group. We will use C elegans as a model organisms due to its well-enabled genetics and the wealth of biophysical tools available for it. After the first few hours of early C elegans development, embryos primarily elongate one-dimensional by epidermal stretch. We hypothesize that neurons in C elegans in the larval or embryonic stages are under low mechanical tension, which increases as the animal grows during development. To test these hypotheses, the successful applicant will first image transgenic lines expressing an optogenetic
force-reporter (b-spectrin::TSMod, Krieg et al, 2014; Kelley et al, 2015) at different stages of the animal's lifecycle. In addition to genetically encoded force-FRET reporters, we will use laser micro-dissection of individual neurons to visualize neuronal tension in living animals (Krieg, et al, 2014). In the second phase, the student will mechanically manipulate and stretch immobilized animals using microfluidic devices (Nekimken et al, 2017). We will then correlate the imposed stretch on the change in FRET efficiency. In addition to mechanical manipulations, we will take advantage of the rich repertoire of genetic modifications available for C elegans. The three aims of
this project will be summarized as follows:
1) Image spectrin tension various stages during C elegans development using genetically encoded FRET probes or laser micro dissection 2) Use microfluidic devices to mechanically manipulate living animals 3) Interfere with tension generation using cell specific mutations. Because spectrin is a conserved molecule from worms to humans, it shed light on the fundamental biophysical
origin of mechanical tension in neurons and the development of the nervous system in general. The applicant will gain expertise in confocal microscopy particularly high-resolution FRET imaging and become proficient in working with experimental model organisms such as C elegans and Drosophila. He/She will be introduced to molecular biology, cell physiology and anatomy of a living animal.

Keywords. optogenetics, neuroscience, mechanobiology, microscopy, microfluidics

Required background. We are soliciting applications from students with a background in bioengineering, biophysics but also neuroscience or quantitative cell biology. The student is expected to perform high-resolution confocal microscopy and FRET imaging and perform data analyses using in-house written programs. A solid understanding of programming and microscopy and minor knowledge in experimental cell biology is helpful to pursue this project. Background in work with model organisms and cell biology is favorable.

Minor project. The peripheral neurons of moving animals are continuously subjected to mechanical deformations. Despite being deformed several thousand times a day, neurons of the peripheral nervous system remain functional for a lifetime. To investigate the origin of this remarkable mechanostability we strive to establish an imaging assay using crawling Drosophila larvae as an experimental model organism. In this model, peripheral neurons span the entire animal and get deformed, when the larvae is translocating forward or backward. To image the deformation, we will make use of microfluidic channels that can be cast in agarose as guide-rails for moving larvae which allow non-invasive imaging of living animals at high frame rates (Heckscher et al 2012 and unpublished data). The resulting deformation of the peripheral neurons can be imaged using fluorescent markers. The goal of this mini-project is to define the modes of deformation and establish an imaging assay capable of capturing the extend of mechanical deformation in this dynamic system. In future, we strive to use optogenetic force reporters to investigate the mechanics of Drosophila neurons in details

ICFO-RP25. The gravitational Casimir effect in different geometries

Supervisor. Maciej Lewenstein
Co-supervisor. James Quach
Research Group. Quantum Optic Theory

Project Description. One of the most remarkable consequences of the non-zero vacuum energy predicted by quantum field theory, is the Casimir effect. In its most basic form, the Casimir effect is the attraction between two perfectly reflecting surfaces as a result of the restriction of allowed modes in the vacuum between them. Real bodies however are not perfectly reflecting, and the generalisation of these ideal boundary conditions to more realistic ones have been derived for the electromagnetic (EM) field, resulting in the Lifshitz formula at zero temperature. The EM field of course, is not the only field that produces the Casimir effect; in theory all fields of the quantum vacuum contribute to the Casimir effect. The gravitonic contribution to the Casimir effect has recently been derived by Quach. In this work a general framework to derive the gravitational Casimir effect is provided, but up to date has only been applied to the simple case of two infinite parallel planes at zero temperature. In this project the student will use this framework to calculate the gravitational Casimir effect for other, more sophisticated geometries e.g. planar-ball, ball-ball, ball-shell, etc. In addition the student will derive the finite temperature gravitational Casimir effect, using conventional thermal correction techniques. This work will lay the foundations for the understanding of the gravitational Casimir effect for realistic bodies in different geometries.

Keywords. Casimir effect, quantum gravity, quantum field theory

Required background. Not determined
Minor project. The minor project will be undertaken at IFAE.

ICFO-RP26. A bright and pure photon source: strong coupling of a single molecule to a plasmonic nano-antenna cavity

Supervisor. Niek van Hulst
Co-supervisor. James Hugall
Research Group. Molecular NanoPhotonics

Project Description. Light is the most powerful carrier of information for our communication. More and more, single photons are explored for quantum communication. Yet most photon sources have their limits in yield and quality of the photon emitted. The main goal of this project is to craft a bright and pure singe photon source. We exploit concepts of cavity QED to boost the light field and enhance light-matter interaction with photon emitters, such as molecules and point defects. The novelty and strength of this project is the application of nanophotonic antennas as nanocavities with deeply localised mode volumes and very high radiation efficiency. The challenge is to put the photon emitter exactly right inside the nanoscale mode volume. In the project we will use both nanofabrication at
ICFO clean room and nano-manipulation on the group's scanning antenna microscopes. Getting the positioning right, single photon output should be hugely accelerated, providing fast and pure non-classical single photon emission with brightness of 10E9 – 10E12 photons/sec: a bright on-demand and ultrafast single photon nanosources for quantum technologies. More importantly a single molecular photon sources filling a nanometer field confinement is the ideal condition for strong coupling up to several THz. We will aim to achieve this strong coupling condition at which the molecular states and the optical field enter into a superposition state, allowing to tune both the molecular and cavity response. The bright photon emission and strong coupling give rise to a plethora of fascinating effects of both scientific and technological interest.
Objectives: 1) ultrafast single photon stream > GHz; 2) coupling above 1 THz; 3) Spatial confinement < 10 nm;
Training outcome: 1) Skills: nanofabrication, nanocontrol, single photon detection, single molecule detection, super-resolution, ultrafast detection, pulse lasers, focussed ion-beam milling, e.m.-field simulations; 2) Insight: mode density, quantum-optics, plasmonic modes, optical antennas fields, photon statistics; 3) Getting prepared for a PhD project and position; 4) Report of master project culminating in a publication. Related recent literature of the group: Nature Communications 7:10411 (2016); J.Phys.Chem.Lett. 7, 1604-1609 (2016); Nature Communications. 5: 4236 (2014); NanoLetters 14, 4715-4723 (2014).

Keywords. Single Photon emitter, NanoPhotonics, Optical Antenna, Single Molecule Detec.

Required background. Exact Sciences; Physics; Engineering; Nanotechnology; Physical Chemistry. Interest in experimental research, nanotechnology, quantum phenomena. Assertiveness and group spirit. **Minor project.** The minor project is to be determined. Depending on exact background of the student a minor project will be explored and defined serving best added value for both studetn and the major project. Suggestions by student are welcome.

ICFO-RP27. Numerical investigation of graphene plasmons waves with Matlab implemented Finite-difference frequency-domain (FDFD)

Supervisor. Frank Koppens
Co-supervisor. Klaas-Jan Tielrooij
Research group. Nano-optoelectronics

Project Description. Solving Maxwell's equation numerically allows to predict the behavior of opto-electronics systems when an analytical solution does not exist or cannot be easily solved. Finite-difference frequency-domain (FDFD) is a powerful and fast tool, with many advantage over commercially available

software. The aim of the project is to numerically study the behavior of graphene plasmons electromagnetic waves, in various configurations with other 2D materials, using Matlab implemented FDFD code. The student will obtain knowledge in numerical optical/electromagnetic methods, light-matter interaction with Graphene and 2D materials, and Matlab.

Keywords. FDFD, graphene plasmons, Matlab, optics

Required background. Solid background in electromagnetics/optics, good level of Matlab programming
Minor project. To be determined.

ICFO-RP28. Two-dimensional quantum wells and their fundamental excitations

Supervisor. Frank Koppens
Co-supervisor. Peter Schmidt
Research group. Nano-optoelectronics

Project Description. Graphene and related materials have emerged as promising candidates for future optoelectronic devices. In particular, different materials can be combined to form so-called van der Waals heterostructures, whose properties can be tailored by choosing adequate materials and thicknesses. Recently ultrafast photodetectors, LEDs, and solar cells have been demonstrated consisting only of a few atomic layers. The goal of this master thesis project is to fabricate and measure van der Waals heterostructures in order to demonstrate and probe fundamental excitations of electrons within two-dimensional materials. In particular, we will probe the transitions between the ground and excited states of an infinite square well potential, formed by a two-dimensional semiconductor and adjacent electrical insulators. The project will focus on device fabrication, characterization and measurements, but will also include numerical simulations. The master student will therefore get to know cutting edge measurement and fabrication techniques, as well as a profound knowledge of numerical methods. Suitable candidates should be highly motivated and have a solid background in photonics and solid-state physics.

Keywords. Optics, optoelectronics, 2D materials

Required background. Suitable candidates should be highly motivated and have a solid background in photonics and solid-state physics.
Minor project. To be determined.

Institute of Chemical Research of Catalonia (ICIQ)

ICIQ-RP29. Continuous flow processes via plasmon-assisted photocatalysis

Supervisor. Miquel A. Pericàs
Co-supervisor. Romain Quidant (ICFO)
Research Group. Prof. Pericàs Research Group

Project Description. Owing to their unique optical properties, noble metal nanoparticles (MNPs) have shown a great potential as photocatalysts. Plasmon-assisted photocatalysis has become a very dynamic research topic. On the other hand, the field of photo-catalysis is currently investing much effort into the concept of flow chemistry. The main motivation behind this approach is to scale-up reactions to large volumes, overcoming one of the key issues of scaling-up organic photochemistry in batch reactors: light penetration through the solution is limited by the high absorption of the catalyst and falls off rapidly away from the lamp. Moreover, photochemical processes performed in continuous flow solve problems of over-irradiation of formed product or the irradiation of large volumes of flammable solvents, for instance. The master project involves the development of heterogeneous catalyst based on noble metal nanoparticles for their application in photoredox catalytic reactions in flow chemistry.
The main research objectives will be: 1) the synthesis and characterization of supported metal nanoparticles (MNPs); 2) new experiment design using high throughput experimentation (HTE); 3) the application of supported species on designed photocatalyzed reactions in continuous flow.

The student will be involved in a multidisciplinary project working on cutting-edge fields as are the plasmonassisted photocatalysis and flow chemistry, as well as innovative techniques as the use of HTE and nanomaterials. The present project will provide excellent scientific skills and knowledge about the research fields mentioned before, as well as training on the use of technical equipment during their stay at ICIQ and ICFO. Moreover the student will be trained in soft skills such as scientific communication, networking and team group skills.

Keywords. Photocatalysis, Plasmonics, flow chemistry, scientific training

Required background. We are looking for talented graduate students from any nationality, with an excellent academic record, enthusiastic interest in chemical research and solid working knowledge of English, preferably with a background in organic chemistry, materials or related studies.
Minor project. The minor project will be carried out at ICFO, under the supervision of Prof. Romain Quidant. During this stay, the student will synthesize and characterize different supported metal nanoparticles (MNPs), and test their catalytic activity. The student will learn how to work with nanomaterials as well as different microscopy characterization techniques as SEM and TEM. Furthermore, the student will learn about photophysic processes and their study

ICIQ-RP30. Synthetic carriers for amino acid transport across lipid bilayers

Supervisor. Pablo Ballester Balaguer
Co-supervisor. Manuel Palacín Prieto
Research Group. Multidisciplinary Supramolecular Chemistry

Project Description. There is considerable interest in the study of synthetic carriers for the transport of small molecules and ions across lipid bilayers due to the strong relation between several human diseases (e.g. cystic fibrosis, diabetes, etc) and transmembrane transport misregulation. The overarching aim of this project is to evaluate the properties of calix[4]pyrrole scaffolds as carriers for the transport of amino acids and other biologically relevant small polar molecules across lipid bilayers of vesicles. Concretely, the project aims to (i) prepare calix[4]pyrrole structures and screen their binding ability for different biologically relevant molecules in solution, and (ii) prepare liposomes embedding these calix[4]pyrrole structures into the lipid bilayers, to finally evaluate their potential as carriers for amino acids transport (e.g. proline). We expect that the obtained results will serve as proof-of-concept for the use of calix[4]pyrrole scaffolds as membrane carriers for biologically relevant and polar small molecules. The candidate will have the opportunity to join Prof. Ballester group at the ICIQ, working in the area of organic and supramolecular chemistry, and experience an ambitious program based on training-through-research not only in synthesis of organic molecules but also in their characterization and evaluation of their potential applications as membrane carriers. Soft skills development (i.e. scientific writing and communication) will be also promoted.

Keywords. transport, amino acids, liposomes, membrane carrier, calix[4]pyrrole

Required background. Candidates should have a BSc degree in Chemistry with excellent academic record and good communication skills including good command of spoken and written English. Motivation and strong commitment to multidisciplinary scientific research will be also a requisite.
Minor Project. The interdisciplinary nature of the project will be ensured by performing a short research stay at IRB under the supervision of Prof. Palacín, expert in Biochemistry and Molecular Biology. During the minor project at IRB, the candidate will learn 1) how to prepare and characterize liposomes with embedded synthetic carriers in the membranes, 2) how to study, measure and quantify amino acid transport using radiolabelled amino acids, and finally, 3) how to detect and quantify transport using fluorescence techniques. This hands-on training will be valuable for design and synthesis of more elaborated synthetic carriers and fluorophores with enhanced properties for the transport and recognition of biologically relevant guests

ICIQ-RP31. Understanding the activation of CO2 over heterogeneous catalysts

Supervisor. Atsushi Urakawa
Research Group. Urakawa Research Group

Project Description. The main aim of the project is to elucidate the steps during the activation of CO2 over solid (heterogeneous) catalysts by means of vibrational spectroscopy (possibly with some experiments using synchrotron X-ray) to understand the key material factors determining the reactivity and product selectivity in catalytic transformation of CO2. The student will be equipped with practical skills to synthesize and characterize catalyst materials, to test in a catalytic reactor, and to study materials and chemical species residing at catalytic gas-solid and possibly solidliquid interfaces under working conditions (high temperature and pressure) by spectroscopic means.

Keywords. heterogeneous catalysis, in situ / operando spectroscopy, CO2 conversion

Required background. Background in chemistry, material science, physical chemistry, physics or chemical engineering would be appropriate, ideally with great interests in understanding fundamental aspects of reactions at surfaces. Interests in heterogeneous catalysis, spectroscopy and programming for advanced data processing would be highly valued.

Minor project. 1) Catalyst preparation and evaluation for CO2 hydrogenation to methanol and other products, 2) Continuous dimethyl carbonate synthesis from CO2 and methanol, 3) Unsteady-state operation for CO2 capture and conversion, 4) Photocatalytic CO2 conversion and water splitting, 5) Electrocatalytic water splitting and electrolysis-assisted hydrogenation, 6) - Spectroscopic study of heterogeneous catalytic reactions

ICIQ-RP32. Advanced Quantum Nanomaterials for OptoDevices

Supervisor. Emilio Palomares
Research Group. Nanomaterials and devices

Project Description. The researcher will work on the synthesis and characterization of novel materials with quantum and/or semiconductor properties (ie. luminescence, magnetism, conductivity...). The materials will be fully characterized and, later on, tested in optoelectronic devices (ie. LEDs, solar cells, nanobioprobes...). The researcher will be involved in each step of the project : synthesis-device preparation-device characterization-theory. Thus, it is a
high multidisciplinary project which requires talented applicants that enjoy working in a team of physicists, chemists, materials chemists, biologists, and engineers.
Keywords. perovskites, semiconductor, solar cells, energy, nanoparticles

Required background. We are looking for pro-active and talented applicants that enjoy working on a high multidisciplinary research environment with chemists, physicists, materials chemists, biologists and engineers. High level of English is a must. It is also an advantage to know programming using Matlab, Python or Mathematica.

Minor project. The 10 -week minor project will be understanding and using advanced photo-induced transient spectroscopy on complete devices to evaluate efficiency losses. The system is set-up at ICIQ but the student will learn the basis to set-up his/her own system, understanding the transient signals, design experiments and evaluate the efficiency losses on their devices.

Catalan Institute of Nanoscience and Nanotechnology (ICN2)

ICN2-RP33. Nanocatalysts for Water Splitting and Renewable Energy at Atomic Scale (RESCALE)

Supervisor. Jordi Arbiol
Co-supervisor. José Ramón Galán-Mascarós
Research Group. Advanced Electron Nanoscopy (GAeN)

Project Description. Water oxidation is fundamental in the development of an efficient water splitting technology for the production of renewable fuels. One of the challenges resides in substituting heterogeneous noble metal catalysts by earthabundant counterparts while maintaining the efficiency and performance required for technological applications. Inexpensive mixed Ni-Fe oxides, are very competitive catalysts for the oxygen evolution reaction (OER). However, a large effort is still needed to understand their mechanism; to optimize their performance; and to identify the optimum phases and geometries for implementation. This is especially relevant regarding their active surfaces. Little information is available due to some intrinsic problems: 1) they are non-stoichiometric materials whose crystal and electronic structures are unknown; 2) activity and surface structure depends on processing; 3) surface structure evolves during working conditions. Through this project, we will tackle this important problem taking advantage of the atomic resolution of aberration corrected transmission electron microscopy and related spectroscopies to study the surface structure of Ni-Fe oxides as a function of preparation, before and after electrocatalytic performance. This multidisciplinary collaboration between electrochemistry and micro/nanoscopy aims to establish the main correlations between activity and structure. Such profound understanding could be a fundamental advance in the field of water splitting and solar fuels. The above Major project will be developed at the Institut Català de Nanociència i Nanotecnologia (ICN2), which is equipped with the required instruments. The project will be supervised by Prof. Jordi Arbiol, leader of the Advanced Electron Nanoscopy Group (GAe-N) at ICN2.
Research Objectives: 1) by studying the atomic resolution data, with the use of computer simulation techniques and 3D atomic modelling of the nanosystems it is expected to obtain a direct correlation between the surface chemistry of the materials and their structural, compositional and chemical behaviour at the atomic scale.
2) The main objective is obtaining a model of the water oxidation mechanism by understanding the electrocatalytic performance of the studied materials down to the atomic scale.
Expected Training Outcomes: 1) Obtain high skills in the use of cutting edge electron microscopy technology in order to be able to run and operate the instruments by him/herself. 2) Training on the analysis of the atomic resolution scanning transmission electron microscopy data (STEM) and the electron energy loss spectroscopy (EELS) data, 3) From the knowledge of the structure and composition at the atomic scale, the student will learn how to create 3D atomic models of the nanostructured catalysts that will be used as input for computer simulations.

Keywords. Advanced Transmission Electron Microscopy, atomic scale structure, water oxidation, catalysts, nanomaterials

Required background. The student should have a major background in Physics, Chemistry, Materials Science, Nanoscience and Nanotechnology or related disciplines.
Background reading Enhanced activity and acid pH stability of Prussian blue-type oxygen evolution electrocatalysts processed by chemical etching. Lijuan Han, Pengyi Tang, Alvaro Reyes-Carmona, Barbara Rodriguez-Garcia, Mabel Torrens, Joan Ramon Morante, Jordi Arbiol, Jose Ramon Galan-Mascaros Journal of the American Chemical Society, 138, 16037-16045 (2016)
Synergistic Effects in 3D Honeycomb-like Hematite Nanoflakes/Branched Polypyrrole Nanoleaves Heterostructures as High-Performance Negative Electrodes for Asymmetric Supercapacitors. Peng-Yi Tang, Li-Juan Han, Aziz Genç, Yong-Min He, Xuan Zhang, Lin Zhang, José Ramón Galán-Mascarós, Joan Ramon Morante, Jordi Arbiol Nano Energy, 22, 189-201 (2016)
Minor project. The Minor project will be carried out at Institut Català d'Investigació Química (ICIQ) under supervision of Prof. José Ramon Galán-Mascarós. During the Minor project, the student will learn how to grow and chemically characterize metal-oxide catalysts. Once the nanomaterials will be grown, the student will test them as electrocatalysts for oxygen evolution reaction (OER), to correlate their function with the atomic resolution studies to be performed as Major project at ICN2.
Task 1) Preparation of thin layers of ternary metal oxides (NixFeyOx) on appropriate substrates by different fabrication methods: co-precipiation, calcination electrodeposition, or plasma-assisted deposition. All catalysts will be structurally characterized by X-ray diffraction, Raman and XPS, prior to analyze their electrocatalytic properties.
Task 2) Electrocatalytic activity will be determined from half-cell experiments, including dynamic and steadystate techniques (EIS). Corrosion/stability tests will be performed for all important phases/processing to provide "used" electrodes for microscopy analysis during the Major project.

ICN2-RP34. Design and development of advanced multifunctional hollow nanoparticles for Imaging, sesing and therapy.

Supervisor. Victor Puntes
Co-supervisor. Neus Bastús
Research Group. Inorganic Nanoparticles Group

Project Description. Inorganic nanoparticles (NPs) which can simultaneously perform multiple functions, such as diagnosis with imaging modalities and complementary therapeutic strategies are emerging as potential probes in nextgeneration biomedical applications. These multifunctional platforms are advanced NPs with a high level of compositional and structural complexity. Among them, noble-metal hollow NPs comprise a novel class of nanostructures possessing hollow interiors and porous walls that can be used as innovative biomedical platforms for sensing, delivery, imaging and raditotherapy. The sensing, imaging and the radiosensitization potentialities of these NPs arise from their strong plasmonic fields (in comparison with solid counterparts), large and tunable absorption/scattering cross-sections, and the large X-ray extinction coefficient of Au respectively. Moreover, hollow NPs are candidates for photothermal therapies because their plasmon band can be tuned into the nearinfrared (where the attenuation of light by blood and soft tissue is greatly reduced), with absorbed photons being converted into phonons that produce a localized temperature increase. The general purpose of this project is to design and develop complex noble metal hollow NPs which an improved applicability in biomedicine. The specific objectives involve: 1) the controlled high yield synthesis of these NPs, in particular their uniformity in size,

dimension of void interiors and chemical composition, 2) their functionalization with specific biomolecules, 3) the study of their physicochemical stability (aggregation, corrosion, dissolution and protein corona) after dispersion in biological environments and 4) the evaluation of their use in sensing, delivery, imaging and therapy.
As a result, the candidate will be specifically trained to gain an interdisciplinar knowledge in the design and development of nanocrystals for biomedicine. In addition to acquiring a broad scientific multidisplinary knowledge, the candidate will be additionally trained on education, safety, viability and sustainability of nanostructured materials, including regulation and ethics. He/she will gain communication and technology transfer skills and will be trained from the beginning to get familiar and follow the Good Laboratory Practice and Responsible Research and Innovation principles.

Keywords. Inorganic hollow nanoparticles, biomedicine, sensing, imaging, therapy.

Required background. The candidate will work in a very interdisciplinary and international environment. Preferably, the candidate should have a solid background in chemistry, physics, biology, materials science, or nanoscience. Experience in chemical synthesis, functionalization and evaluation of the physiochemical properties of inorganic nanoparticles will be positively valued. High English level is required.
Minor project. This master project has been designed to cover a complete multi and interdisciplinary research, including materials science, chemistry, biology and physics. This requires both the understanding of the parameters that control their synthesis and their influence on the relevant fundamental physicochemical properties and mechanisms involved in the biomedical application of interest. In this regard, potential minor projects may involve the development of models for the study of the optical properties of hollow NPs (ICFO, Javier Garcia de Abajo), and/or the understanding of the chemical and physical behavior of these advanced hollow NPs in biological environments (IRB).

ICN2-RP35.Multicomponent heterostructured inorganic nanocrystals for artificial Photosynthesis

Supervisor. Victor Puntes
Co-supervisor. Neus G. Bastús
Research Group. Inorganic Nanoparticles

Project description. Energy availability is one of the most important problems facing our civilization. Consequently, a major challenge in 21st century is the development of renewable carbon-neutral sources. The Sun is the most abundant energy source on Earth, representing by far the best alternative. While in biological systems the harnessing of solar energy is accomplished by specific proteins, nowadays inorganic semiconductor nanocrystals (NCs) can be designed to successfully address this task. However, photocatalytic materials being currently produced present serious limitations including low photocatalytic efficiency and unsatisfactory broad-band (visible-near infrared) light absorption.
In this context, this research project aims to address the challenge of identifying, designing and producing a new generation of NC-based photocatalysts that integrate dissimilar materials in a unique multicomponent heterostructured system with controlled architecture and advanced functionality. The objective is to produce advanced complex NCs via breakthrough advances in wet chemical synthesis and to determine their efficiency in real scenarios, developing new sets of characterization protocols for the study of the physicochemical evolution of NCs. As a result, the candidate will be specifically trained to gain interdisciplinar knowledge on the design and development of inorganic nanocrystals for energy harvesting and conversion, in particular on their synthesis, characterization and evaluation of their

photocatalytic properties. In addition to acquiring a broad scientific multidisplinary knowledge, the candidate will be additionally trained on education, safety, viability and sustainability of nanostructured materials, including regulation, ethics and opportunities. He/she will gain communication and technology transfer skills and will be trained from the beginning to get familiar and follow the Good Laboratory Practice and Responsible Research and Innovation principles.

Keywords. Inorganic heterostructured nanocrystals, artificial photosynthesis, wet-chemistry synthesis, structure-activity relationship, photocatalytic performan

Required background. The candidate will work in a very interdisciplinary and international environment. Preferably, she/he should have a solid background in chemistry, physics, materials science, and/or nanoscience. Experience in chemical synthesis, characterization and evaluation of the physiochemical properties of inorganic nanoparticles (optical, catalytic and/or electric) will be positively valued. High English level is required.

Minor project. This master project has been designed to cover a complete multi and interdisciplinary research, including physics, materials science, chemistry and engineering. This requires both the understanding of the parameters that control the NC synthesis and the influence of these parameters on the relevant fundamental mechanisms involved in catalysis. A potential minor project involves the evaluation of the performance of the NC-based photocatalysts in specific goal reactions, including water splitting and direct synthesis of organic fuels (ICIQ, Antoni Llobet). This represents an important point for the clear understanding of the mechanisms of reaction and their correlation with the physicochemical properties of the NCs. In this regard, the synergetic experience and facilities of both research activities may be of crucial importance for the successful implementation of the project.

ICN2-RP36. Light-emitting optomechanics

Supervisor. Clivia Marfa Sotomayor-Torres
Co-supervisor. Pedro David García Fernández
Research Group. Phononic and Photonic Nanostructures

Project Description. The coupling of electromagnetic radiation (photons) to mechanical waves (phonons) is at the heart of solid-state quantum photonics while phonon transport at different frequencies governs crucial physical phenomena ranging from thermal conductivity to the sensitivity of nano-electromechanical resonators. To engineer and control the overlap of light management with the mechanical vibrations of matter efficiently, we make use of very precisely fabricated nanometer-scale devices. The standard way of achieving this control is to use engineered defects in periodic structures - optomechanical crystals - where the electromagnetic field and the mechanical displacement can be confined simultaneously thus enhancing their interaction.
During this project, we will explore novel designs for optomechanical nanostructures and we will measure their mechanical and photonic properties in the lab. We will make use of ultrafast pump and probe techniques to explore the mechanical vibrations. In addition, the structures will contain active light-emitting materials which will allow us to get access to the photonic properties of the system. Our goals are: 1) Explore novel designs for optomechanical structures, 2)measure the effect of the mechanical modes in the light-emission properties of these materials, 3) measure the effect of the photonic modes in the lifetimes of the mechanical resonances.

Keywords. optomechanics, quantum wells, ultrafast pump-and-probe techniques.

Required background. Solid-state physics and Optics.
Minor Project. To be determined

ICN2-RP37. 2-D coordination polymers with light upconverting properties

Supervisor. Daniel Ruiz-Molina
Co-supervisor. Claudio Roscini
Research Group. Nanostructured Functional Materials

Project Description. The project consists of the synthesis of new 2-D coordination polymers (2D-CP) with light upconversion (UC) properties. Because UC based on triplet-triplet annihilation (TTA) involves bimolecular processes (TT energy transfer and TTA), most of works are reported in liquid solutions where interactions between sensitizer and emitter molecules are highly favoured. However, for practical applications (NIR absorbing photovoltaic cells, biological markers), solid UC materials are needed and new approaches are proposed. Recently, in Nanosfun, efficient UC from phase change material (PCM) solutions was obtained upon suitable aggregation of the active molecules induced by the PCM solidification. In this project an alternative PCM-free strategy based on 2D-CP is proposed. The UC dyes will be part of the 2D-CP structure (metal complex and ligand) or non-covalently intercalated between 2-D layers. The stacking between 2 or more layers of the 2-D material should guarantee the proximity between the dyes and therefore efficient UC in solid state. The aims of the project are therefore: 1) the synthesis and characterization (chemical and morphological) of 2-D polymers with UC active dyes; 2) observation of UC properties in the solid state. This project involves the learning on two very hot topics: 2-D polymers and UC. The student will receive an interdisciplinary training spanning from polymer synthesis to several characterization techniques (microscopy, UV-Vis and emission spectroscopies).

Keywords. upconversion, coordination polymers, 2-D materials, fluorescence, annihilation

Required background. 1) Knowledge of basic concepts on electronic excited states and transitions, emission (fluorescence, phosphorescence) and absorption spectroscopies, 2) some experience in synthesis and morphology characterization of micro/nanostructures (optical and electronic microscopy, dynamic light scattering), 3) enthusiastic with strong interest in research, 4) Good written and spoken English.
Minor project. This project will be focused on the synthesis of metal-organic frameworks (MOFs) and will be carried out in the Institute of Chemical Research of Catalonia (ICIQ) in the Dr. Alexandr Shafir's research group. Recently they reported on new and tuneable synthetic strategies for zirconium-based MOFs, a family of materials which, due to an unusually good stability, are promising in catalysis and gas storage applications. The student will stay in a leading researh center and will be trained on the synthesis and chemical characterization of these materials. He/she will also learn on the tunability of the structural (particles dimensions) and chemical properties of MOFs by changing the ligand and/or other synthesis conditions

ICN2-RP38. Delivery of Targeted Coordination Polymer Nanoparticles Across the Blood-Brain Barrier

Supervisor. Daniel Ruiz-Molina
Co-supervisor. Fernando Novio
Research Group. Nanostructured Functional Materials (NanoSFun)

Project Description. Brain delivery of therapeutic and diagnostic agents remains a challenge because of the blood-brain barrier (BBB). The development of novel nanomaterials provides new and powerful tools for imaging, diagnosis and therapy into

the brain. Recent advances in the development of hybrid nanomaterials constructed via metal-ligand coordination bonds have afforded novel multifunctional materials that combine the beneficial features of purely organic and inorganic nanoparticles with improved properties for biomedical applications. Since they have no capacity to cross the BBB, our purpose is to construct specific biocompatible and biodegradable Coordination Polymer Nanoparticles (CPNs) decorated on the surface with peptides capable of interacting with the specific receptors present in the BBB, thus causing an increase in the permeability of the conjugate in the brain through transcellular passive diffusion processes.
The specific objectives are: 1) Synthesis and characterization of biocompatible CPNs; 2) Coupling of specific peptides on CPNs surface; 3) Study of in vitro cytotoxicity and cellular uptake ability of CPNs; 4) Study of CPNs ability for crossing BBB using in vitro models (minor project). The expected training outcomes will include the acquisition of skills in design of new nanomaterials, chemical synthesis of coordination polymers and nanoparticle characterization. Complementarily, the student will learn different techniques of in vitro assays.

Keywords. Coordination Polymers, Nanoparticles, BBB, Theranostics, Nanomedicine

Required background. The academic background required includes an strong formation and skills in organic/inorganic synthesis, and materials/nanomaterials characterization techniques. We seek strongly motivated applicants willing to achieve a Master with high level of excellence. The applicant should ideally have a background on chemistry, biology and materials science, oriented to nanomedicine.
Minor project. The proposed minor project will include a 10-week research project in the Institute for Research in Biomedicine (IRB) where the applicant will learn about different in vitro models used to test the ability of nanoparticles for crossing BBB. In the research group led by Dr. Ernest Giralt (Design, Synthesis and Structure of Peptide and Proteins) the student will have the opportunity to test some of the obtained nanoparticles during the major project.

ICN2-RP39. Functionalization of oxide and halide perovskite surfaces to enhance the stability of Perovskite Solar Cells

Supervisor. Monica Lira-Cantu
Research group. Nanostructured Materials for Photovoltaic Energy Group

Project description. Perovskite solar cells (PSCs) constitute the latest breakthrough in photovoltaic technology. The interest behind PSC devices lies in their high power conversion efficiency, nowadays at 22%, achieved in only a few years. A main drawback is their lifetime stability which should surpass 20 years of lifetime. Oxide semiconductor shave shown to provide high device stability to PSCs when working as barrier layers. A good oxide surface quality is known to provide the required interface properties for highly stable and high efficient perovskite solar cells. Defects, such as oxygen vacancies, act as recombination centres resulting in poor device stability. In this work, the student will learn about the passivation of surface defects at the interface between oxides and halide perovskites materials. The passivation of defects will take place through the use of appropriate self-assembled monolayers (SAMs) where a careful selection of anchoring groups will bond to the oxide surface or to the halide perovskite surface. This process will ensure an optimal passivation of the surface defects reducing or eliminating recombination centers and enhancing device lifetime. The student will learn about the basic principles related to solar cell working mechanisms and the different techniques applied for the synthesis and characterization of materials.

Keywords. Interfaces, functionalization, perovskite soalr cells, semiconductor oxides, energy

Required background. The student should have background in chemistry, physics, materials science or chemical engineering. English mandatory. Excellent interpersonal skills, experience in planning and organisation of experimental work, and an excellent ability to work in teams are strong assets.

Minor project. Characterization of interfaces and solar cells by complementary characterization techniques. The project will include the application of specific characterization techniques to understand interfaces and the role they play in solar cell efficiency and device lifetime. The characterization techniques to be employed are impedance spectroscopy, transient studies, CELIV, Kevin-prove, and morphology characterization such as SEM, TEM and AFM.

ICN2-RP40. Host-Guest Chemistry and Catalysis with Soluble Metal-Organic Framework Nanoparticles

Supervisor. Daniel Maspoch
Co-supervisor. Arnau Carné-Sánchez
Research Group. Supramolecular NanoChemistry and Materials Group

Project Description. The master candidate will be integrated in a project that aims to develop new synthetic methodologies to generate monodisperse, tunable and water stable MOFs in the range of 2 to 10 nm, becoming the first generation of soluble ultra-small MOFs. Therefore, the first part of project will entail the design, synthesis and characterization of selected MOFs at the ultra-small scale. The strategy to achieve this goal will consist on altering the nucleation and growth process of the selected MOFs to generate monodisperse crystals with the desired size range by promoting fast nucleation processes (i. e. high temperature and concentration, use of base...) while restricting their growth by means of capping agents or reaction quenching. The second part of this project will consist on exploring the unique characteristics of the newly developed ultra-small MOFs. We will explore these new materials for catalysis and host/guest chemistry of molecules in liquid state. During the development of the PhD thesis, the candidate will acquire knowledge on several synthetic methods and will be trained in the use of several techniques, such as nuclear magnetic resonance (1H NMR, 13C NMR), infrared spectroscopy (FT-IR), X-ray diffraction, scanning electron microscopy (SEM), transmission electron microscopy (TEM), thermogravimetric analysis (TGA), elemental analysis CHNS, gas sorption among many others. In addition, he will also benefit from the complementary services that ICN2 offers, since the Institute has optimized its internal communications strategy and streamlined its workflow. Overall, this proposed PhD project will be very multidisciplinary, training the applicant in the field of Nanotechnology (both in terms of synthesis and characterization), Crystallography, Catalysis and Materials Science.

Keywords. Nanoparticles; Metal-Organic Frameworks; Porosity; Catalysis; Host/Guest Chemistry

Required background. The candidate must have a chemistry, nanotechnology or chemical engineering bachelor degree.

Minor project. The master candidate will performed the minor project in the Group of ICREA Prof. Víctor Puntes at the ICN-2, where he/she will be trained in the synthesis and characterization of ultrasmall nanoparticles. In this stage, the student will acquire knowledge in myriad characterization techniques such as SEM/TEM and DLS as well as in the synthesis of inorganic nanoparticles of various compositions, sizes and shapes

ICN2-RP41. Graphene/paper-based sensor operating through mobile phone for diagnostics application

Supervisor. Arben Merkoçi
Research Group. Nanobioelectronics and Biosensors

Project Description. Technologies that facilitate diagnostics, drug discovery, food safety, defense, security, and environmental monitoring are of great interest to industry, government initiatives, and research scientists. Biosensing has become an important approach within these technologies. Interestingly, nanomaterials enable engineering and manipulating of unprecedented biosensing systems based on transducing phenomena occurring at the nanoscale. In this context the main objective of this PhD project is to design an innovative paper-based sensor that integrates exfoliated graphene modified with receptors (ex. antibody, aptamer) and operates through simple on-off optical detection system. The idea is to obtain a simple to use and sensitive enough sensing system integrated within a mobile phone ensuring its use as point of care device. The system will take advantages of photoluminescent properties of graphene and other 2D materials, quenching capabilities between donor/acceptor nanomaterials/nanoparticles beside specific interaction with biological receptors. The candidate will get training in the design and fabrication of nanobiosensors, nanomaterials preparation and functionalisation, a series of cutting edge nanotechnology tools for deep characterisations of materials and platforms, in addition to application in real sample so as to achieve a nanobiosensor with TRL of 4-5, that will be achieved also through collaboration with other research group members with complementary expertise.

Keywords. Graphene, nanobiosensor, diagnostics, mobile-phone biosensor, quantum dots.

Required background. This is a multidisciplinary project. The candidate will be working in cooperation with other colleagues with different skills. The candidate should have academic background in one (or more) of the following: chemistry, biochemistry, biotechnology, material science, optics, physics, electronics and related fields.
Minor project. "Nanoparticle (NP)/Quantum dot (QD) synthesis & related nanometrology". The student will be trained in nanomaterials synthesis such as QDs or metallic NPs. Of great importance will be the nanometrology aspects of the particles. NPs stability either in suspension or dried forms will be studied. Different factors that affect the physical properties such as composition, size, forms, used ligand and solvent, temperature etc. will be studied and new NPs preparation and storage strategies will be proposed. Of special interest will be the study between the obtained NPs with various other (nano)materials to be used as platforms in sensors and biosensors. The project will be developed in either Inorganic Nanoparticles Group at ICN2 or at ICIQ

ICN2-RP42. Topological phonon waveguides.

Supervisor. Clivia M. Sotomayor-Torres.
Research Group. Phononic and Photonic Nanostructures.

Project Description. The emerging field of topological matter, as one of matter's states, has caught the imagination of the condensed matter physicist. At play are fundamental concepts of symmetry and quantum physics, which hold the promise of lossless transport of energy under very special conditions of dispersion relations and gap states for a given excitation of matter governing photonic, mechanical, acoustical, superconducting and, more recently, phononic properties. Interest in topological matter is exacerbated by the prospect of robustness, conferred to the topological states making immune to defects in the crystal. The recent work on topological

phononics has been mainly theoretical with a handful of experiments reporting rather large and cumbersome structures sustaining
states with frequencies in the range of at most 20 kHz. To increase the frequency the physical realization of a topological phononic structure must significantly the reduced feature sizes of patterned solids. Only then the prospect of fault-tolerant phonon-based signal propagation may get closer. Why phonons? This excitation is one of the lowest energy ones in solids and is ubiquitous, so harnessing its propagation as a signal could be a breakthrough in information and communication technologies. The aim of this project is to test topological phononic concepts in a silicon-based phonon waveguide. During the project we will design a 2-dimensional simple structure to act as a phonon waveguide, participate in its nanofabrication (it will be outsourced) and measure phonon propagation using a newly developed phonon source in our group and a detector suitable for the achieved frequency ranges.
Our goals are: 1) Design topological phononic samples to demonstrate phonon waveguiding, 2) Set up the experiment to compare phonon waveguiding, with existing components in the laboratory, in phononic and topological phononic waveguides, 3)Demonstrate phonons robustness against purposely designed defects in the waveguide.

Keywords. phonon band structures, topological matter, phonon waveguides

Required background. Solid-state physics, quantum mechanics, excellent experimental methodology.
Minor Project. To be determined

Institute for High Energy Physics (IFAE)

IFAE-RP43. Understanding the cosmic web with galaxy clusters, filaments, and voids

Supervisor. Ramon Miquel
Co-supervisor. András Kovács
Research Group. Observational Cosmology

Project description. The large-scale structure of the Universe shows a rich and complicated structure of galaxy clusters, filaments, and voids. The formation and evolution of this cosmic web is governed by unknown substances, dark matter and dark energy, that cosmologists wish to map and analyze. The IFAE observational cosmology group is analyzing the data taken by the Dark Energy Survey and PAU massive galaxy surveys to try to understand the properties of the mysterious dark components. In the first part of the project, the student will be able to participate in different data analyses such as cosmic web decomposition methods including void finder tools and filament finding algorithms with simple python programming and machine learning. The next level will involve measurements of various cosmological observables such as weak gravitational lensing around galaxies (a sensitive probe of dark matter), imprints of voids and superclusters on the cosmic microwave background radiation, and, in particular, tests of environment-dependent galaxy properties.

Keywords. cosmic web; dark matter; dark energy; observational cosmology

Required background. Basic knowledge of python programming, statistics and astronomy would be advantageous.

Minor project. The programming and modeling knowledge that the student will gain about cosmic web decomposition methods is directly transferrable to any kind on interdisciplinary research that deals with network analyses. We suggest that synergies may be found with the 'Cell and Developmental Biology' programs at CRG and IRB. Here is an illustrative picture: https://www.dropbox.com/s/vegx8nh5ceqn2s9/Cosmic%20web%20vs%20neural%20network.jpg?dl=0

IFAE-RP44.Gauge/Gravity correspondence applied to Condensed Matter

Supervisor. Oriol Pujolas
Research group. IFAE Theory Division

Project Description. The Gauge/Gravity (or holographic) correspondence is a new and powerful tool to describe strongly coupled Quantum Field Theories and, more generally, strongly correlated systems. This tool employs methods derived from general relativity that can be used to model a wide variety of transport phenomena in condensed matter problems including high temperature superconductivity, strange metal behaviour and other quantum phases of matter. These holographic methods are well enough understood nowadays that the linear transport and linear response parameters (and their dependence on external parameters like temperature or chemical potential) can model quite efficiently a very broad range of materials that exhibit exotic features like criticality and strong correlations. It has been recently recognized that the same holographic methods can be employed to compute also

the nonlinear response, and this offers potentially a set of correlations between different observables that could well apply for the strongly correlated materials. This project will concentrate on studying nonlinear response observables. Specifically, the first main goal is to compute the nonlinear conductivity of strange metals using the gauge/gravity duality techniques. The second main goal is to cross-correlate the nonlinear response with the linear conductivity in order to identify relations between them.
The main training objectives are to learn and master the holographic correspondence and the techniques that it offers based on gravitational and black hole physics to model and perform transport computations of condensed matter systems. This project fits naturally within a growing collaboration between the IFAE Theory Division and the ICFO Labs led by Lewenstein and Acin, focusing on the interplay between Quantum theoretical and Holographic tools to study strongly correlated systems.

Keywords. Gauge/Gravity correspondence; Holographic Duality; Condensed matter physics; Strongly correlated materials

Required background. For this project, good knowledge of classical and quantum mechanics is required. In addition, basic knowledge of either 1) General Relativity or 2) Quantum Field Theory will be useful. Basic skills in numerical and symbolic computation tools such as Mathematica will also be useful.
Minor project. Given that this research project addresses part of the research goals of a recently initiated collaboration between the IFAE Theory Division and the ICFO Labs led by Lewenstein and Acin, it is most natural to perform the associated Minor project in these Labs at ICFO. The most natural Minor project would be to complement the same goals with the tools offered by Quantum theoretical methods studied and developed at these ICFO Labs. The proposed theme of the Minor project, then, is "Quantum-theoretical methods for strongly correlated quantum matter", which would focus on the recent developments of Tensor Network States (TNS), entanglement entropy, and the so-called Holographic States. These provide a complementary set of tools that are intended to study the same type of strongly correlated quantum matter systems. Expected training objectives are to master some of the techniques of Tensor Network States to compute physical observables such as correlators of the modeled systems, and to understand the possible connections between holographic and TNS.

IFAE-RP45. Ion Time Projection Chamber with Graphene detection

Supervisor. Federico Sanchez
Co-supervisor. Sergio Valenzuela
Research Group. IFAE-neutrinos

Project Description. Graphene resistivity is modified under the presence of electric fields. This property can be used to design (charged) ion sensors. The presence of charge attached to the graphene will alter its resistivity and will amplify the signal by an amount that is proportional to the change in resistivity and the time the charge is attached to the sensor. This property can be used as a readout in a Time Projection Chamber. In those detectors, the gas is ionised by radiation. The pairs of ion and electron are separated due to the presence of intense electric fields, reducing the recombination. Charges drift to the anode and cathode where they can be measured. Traditionally the electrons are used for the readout because they are easier to amplify in gas, but the readout of ions has several advantages: they are less affected by absorption (charge attenuation) during the drifting, they are less affected by scattering so they normally move in the gas following the lines of electric field between the anode and the cathode. These properties would improve the energy and the position resolution of the detector. Another advantage of ion over electron readout is that in the second the presence of a gas mixture (quencher) is

normally required to control the avalanche amplification process, this gas mixture absorbs most of the light produced during the primary ionisation. An ion readout technology based on graphene will not require the gas mixing allowing the direct detection of the light. This technology might have applications in several fields of basic research like direct dark matter detection and neutrino interactions but also other applications related to X-ray and gamma-ray detection for medical imaging and border control. This project aims at testing several graphene configurations to implement ion readout based on graphene as a gas detector at IFAE. The graphene sensors will be designed by IFAE and ICN2 researchers in order to hold the ion charge for a time to allow for a sizeable change in the current across the sensor in presence of a bias voltage. In case of successful results, the characterisation in terms of energy and position resolutions can be investigated. The project is a common effort from the ICN2 for the graphene synthesis and sensor fabrication and IFAE to carry the measurements of the performance.

Keywords. Ion, Graphene, TPC, Nanotechnology, Imaging with ionising radiation

Required background Physics undergraduate
Minor project. The minor project will consist on the synthesis of several graphene sensors in different configurations that will be tested later at IFAE.

IFAE-RP46. Development of novel perovskites sensors for X-ray and gamma detection applications for medical imaging.

Supervisor. Federico Sanchez
Co-supervisor. Emilio Palomares (ICIQ)
Research Group. IFAE-neutrinos

Project Description. We aim to develop radiation detectors based on novel materials with high Z values (alike those values reported for CdTe) that may improve the detection limits of an actual PET system and reduce the cost considerably. The improvement of the detection limit of PET systems will allow detecting millimetre size tumors improving the nowadays best resolution PET scanners. The materials proposed in ZPro are hybrid and inorganic perovskite (CsPbBr3), which have recently been proposed for high energy radiation detection. The project will concentrate on the characterisation of perovskites synthesised at the ICIQ as gamma detectors. Measurements of energy resolution, noise, leakage current are basically unknown and they are fundamental to evaluate the potential of this new technology. The work will be done at ICIQ during the synthesis of the diodes and at IFAE during the characterisation. These studies will be done under various conditions, with and without bias, and for different diode configurations.

Keywords. Perovskites, PET, Medical Imaging, X-Ray detection

Required background. Undergraduate in Physics or Chemistry. Knowledge of electronics as user and data analysis.
Minor project. The minor project will be developed at the ICIQ for chemical synthesis of the perovskites. This work will be done at the E. Palomares group at ICIQ. Several configurations will be developed. The synthesis process is fundamental to provide high quality diodes and to develop new concepts of integrating the sensors with the readout electronics.

IFAE-RP47. Fractal dynamics and cancer growth

Supervisor. Rafel Escribano
Co-supervisor. Pere Masjuan
Research Group. IFAE Theory Division

Project Description. The dynamics of fractal and chaotic structures in nature follow the principle of minimal energy. Guided by such principle, together with a set of dissipative equations, and the notion of attractor, we shall consider the epistemology of the origin of

cancer. Under certain boundary conditions, we propose to study how the pre-cancerous niche develops inspired by the chaotic evolution of dissipative systems with inhomogeneities. The tools of analytic mechanics may spell out a sequence of steps, one or more of which could be interdicted to prevent the progression of cancer.

The main research objectives consist on understanding classical chaos from the analytic mechanics' point of view, develop a dictionary to translate such learnings to the epistemology of the origin of cancer, and explore the conditions for which cancer growth emerges from initial conditions within such perspective.

Within this project, the student will learn classical mechanics, basics of carcinogenesis, and computer programming adapted to chaotic dynamics.

Keywords. Chaotic systems, fractal structures, inhomogeneities, carcinogenesis, metastasis

Required background. Basic knowledge of classical mechanics and computer programming is required.

Minor project. A minor research project should be conducted at the Institute for Research in Biomedicine (IRB Barcelona) with the group of Dr. Eduard Batlle about the colorectal cancer growth. The hands-on study on the molecular mechanisms and the initiation of colorectal cancers from early stages to the formation of aggressive tumors will complement the computing models studied during the major project based on the evolution of a fractal structure.

IFAE-RP48. Large-scale correlations and cancer cell metastasis

Supervisor. Rafel Escribano
Co-supervisor. Pere Masjuan
Research Group. IFAE Theory Division

Project Description. The study of the behavior of large and complex stochastic systems can be undertaken using the mean field theory within statistical mechanics. In this context the interaction of all the other elements into one singular individual is approximated by an averaged effect. As soon as large-scale correlations appear, specially between spatially separated fluctuating and frozen regions, the system may develop critical points and the theory becomes inhomogeneous. Boundary conditions and critical phenomena are important elements to understand the system growth and evolution. In this project, we propose to study large-scale correlations as an inhibitor mechanism of control cell division during tumor progression and metastasis. We take advantage of the expertise of Dr. Roger Gomis' group on understanding how cells read and transform cell division, differentiation, movement, organization and death signaling into changes in cell behavior. The main research objectives are then the study of field theory in presence of inhomogeneities, explored using computer models, and applied to tumor progression and metastasis with a final goal to understand whether inhibition of large-scale correlations may yield a better control of cell growth.

Keywords. Statistical mechanics, large-scale correlations, inhomogeneities, metastasis

Required background. A background on thermodynamics and statistical physics is required.

Minor project. A minor research project in the Institute for Research in Biomedicine within the group of Dr. Roger Gomis is considered. This minor project should provide a hands-on experience of a direct application of large-scale correlations in tissue dynamics and tumor growth and allow to test the theoretical models computationally developed against cancer cell metastasis.

Institute for Research in Biomedicine (IRB Barcelona)

IRB-RP49. Growth control during normal development, tissue homeostasis and tumorigenesis

Supervisor. Marco Milán
Research group. Development and Growth Control Laboratory

Project Description. During the development of multicellular organisms, body growth is controlled at the scale of the organism by the activity of long-range signaling molecules, mostly hormones. These systemic factors coordinate growth between developing tissues and act as relays to adjust body growth in response to environmental changes. In target organs, long-range signals act in concert with tissue-autonomous ones to regulate the final size of a given tissue. The interplay between systemic and tissue-autonomous signals contributes to defining the final size of a tissue or organ. Drosophila imaginal discs, simple epithelial invaginations that grow one thousand fold in mass and cell number, are probably one of the best model systems to analyze at the genetic and molecular level the control of size in a growing epithelium. We use the wing imaginal disc to dissect the cellular and molecular mechanisms underlying the regulation of tissue growth. We take an integrative approach as we aim to understand how the final size of the developing wing is achieved not only during normal development but also in stress conditions. In this regard, we are dissecting the cellular and molecular mechanisms underlying the homeostatic capacity of the tissue to several insults (with a special interest in genomic instability) and its potential impact in tumorigenesis. This integrative approach helps to understand the robust interplay between systemic and tissue-autonomous signals in normal development or in stress situations, and contributes to identifying emerging stress signaling molecules transiently induced to compensate for tissue loss that can contribute to tumorigenesis in a condition of chronic expression.

Keywords. Drosophila, growth control, morphogens, systemic hormones, tumorigenesis, genomic instability

Required background. Grade in biology and/or genetics
Minor project. The minor project consists in using the Drosophila adult structures to carry out a small genetic screening to find new genes involved in growth control during normal development

IRB-RP50. Gene expression (re)programming by the CPEB-family of RNA-binding proteins

Supervisor. Raúl Méndez
Research Group. Translational control of cell cycle and differentiation

Project description. The primary interest of our group is to understand the molecular mechanisms that dictate alternative 3' UTR formation and the temporal and spatial translational control of specific mRNAs during cell cycle progression and chromosome segregation, senescence and related pathologies. Cell cycle progression is programmed, at least in part, by stored silent mRNAs whose translation is specifically regulated by sequences located at their 3´-untranslated regions (3´-UTRs) and their binding proteins. Our work in the past years

has focused on three main questions: First, to elucidate the mechanisms underlying the translational control by cytoplasmic polyadenylation cis-acting elements and trans-acting factors. Second, to define how this translational control circuit regulates cell cycle progression by establishing a molecular circuit, stabilized by positive and negative feed-back loops. Third, to explore the contribution of these mechanisms in the reprogramming of gene expression in cancer.
Keywords. Gene expression, translational control, cell cycle, cytoplasmic polyadenylatio

Required background. biochemistry or cell and molecular biology, bioinformatics or animal models,
Minor project. To be determined

IRB-RP51. Synthetic carriers for amino acid transport across lipid bilayers

Supervisor. Manuel Palacín Prieto
Co-supervisor. Pablo Ballester
Research Group. Amino acid Transporters and Disease

Project Description. There is considerable interest in the study of synthetic carriers for the transport of small molecules across lipid bilayers due to the strong relation between several human diseases (e.g. cystic fibrosis, diabetes, etc) and transmembrane transport misregulation. The goal of this project is to evaluate the properties of calix[4]pyrrole scaffolds as carriers for the transport of amino acids and other biologically relevant small polar molecules across lipid bilayers. Concretely, we aimed to 1) prepare and characterize liposomes with embedded calix[4]pyrrole synthetic carriers, and 2)study amino acid transport using radiolabelled amino acids, or 3)fluorescence techniques. We expect that this project will serve as proof-of-concept for the use of calix[4]pyrrole scaffolds as membrane carriers for small polar molecules. The master candidate will join Prof. Palacín group at the IRBBarcelona, working in the area of biochemistry and perform his/her 6-month long major project under optimum conditions in a modern and stimulating environment, with access to state-of-the-art technological resources. The candidate will experience a program based on training-through-research. Soft skills development (i.e. training in scientific writing and communication skills, gender and diversity in research, supervision and management) will be also promoted in order to enhance the career perspectives and employability of the awarded candidate.

Keywords. transport, amino acids, liposomes, membrane carrier, calix[4]pyrrole.

Required background. Candidates should have a BSc degree in Biochemistry or Biotechnology with excellent academic record and good communication skills including good command of spoken and written English. Motivation and strong commitment to multidisciplinary scientific research will be also a requisite.
Minor project. A minor project will be carried out at ICIQ under the supervision of Prof. Ballester for 10-weeks. The candidate will be trained in 1) the synthesis, purification and characterization of organic receptors and 2) the evaluation of their potential application. The aim is to screen the binding ability of different synthetic carriers with different guests with biological relevance. The candidate will acquire skills in NMR, UV-vis spectroscopy, Isothermal Titration Calorimetry or mass spectrometry. This exposure to a research field different from the one related to his/her major project will be relevant for the multidisciplinary formation of the candidate and will equip he/she with skills to face problems from different points of view.

IRB-RP52. Using Drosophila model to understand malignant growth

Supervisor. Cayetano González
Research Group. Cell Division Laboratory

Project description. We model cancer in flies to understand the cellular changes that drive malignant growth and to identify conserved mechanisms that might be relevant for human cancer therapy. We focus on the mechanisms of malignant transformation in larval brains where we have found that neural stem cells can originate tumours if the process of self-renewing asymmetric division is disrupted, and that some tumour types are driven by the ectopic expression of germline proteins. We work on the mechanisms that bring about genome instability in Drosophila tumours and try establishing the actual extent to which such lesions contribute to tumor progression. We develop and make extensive use of advanced microscopy techniques. The goal of this Master project is the characterisation of genes that we have recently found to be required for malignant growth in our tumour models. The Master student will take part in ongoing molecular, biochemical and microscopy studies.
The Master student is expected to take full part in lab seminars and scientific discussions and will acquire hands on experience in Drosophila research. S/he will also gain training in experiment design.

Keywords. Drosophila; neural stem cells; tumour; cell division; germline genes

Required background. Not determined
Minor Project. To be determined

IRB-RP53. Physiological relevance and evolution of a tRNA chemical modification enzyme.

Supervisor. Lluís Ribas de Pouplana
Research Group. Gene Translation Laboratory
Project Description. One of the most poorly understood aspects of translation is the role of the numerous base modifications that tRNAs accumulate in their structure. We have demonstrated that the codon composition of highly expressed human genes is enriched in triplets recognized by modified tRNAs. Thus, a new mechanism for the control of gene expression arises based on the relationship between the codon composition of any given gene and the existing pool of modified tRNAs in the cell (1). We have started a detailed biochemical and cellular characterization of a human tRNA deaminase as the initial phase of a broad characterization of all aspects of this enzyme (2). We have generated deep-seq trancriptomics and proteomics data sets that need to be analyzed, and we are also interested in the phylogenetic analysis of the components of the deamination machinery.
We are looking for a student with good command of Omics data analysis techniques to analyze our data sets with the goal of identifying the impact of tRNA deamination upon the proteome.
1. Rafels-Ybern et al. (2015) 'Distribution of ADAT-Dependent Codons in the Human Transcriptome.' IJMS 16:17303-14.
2. Torres AG et al. (2015) 'Inosine modifications in human tRNAs are incorporated at the precursor tRNA level.' NAR 43:5145-57.
3. Novoa EM et al. (2012) 'A role for tRNA modifications in genome structure and codon usage' Cell. 149(1):202-13.
Keywords. Proteome, Genome, transfer RNA, modifications
Required background. Computational skills required.
Minor project. The student could investigate the impact of deamination defects upon the expression of extracellular matrix proteins, such as keratin.

IRB-RP54. Molecular mechanisms of signal integration in tumorigenesis

Supervisor. Angel R. Nebreda
Research Group. Signaling and Cell Cycle

Project Description. We are investigating molecular mechanisms of tumorigenesis, specially regarding how the p38 MAPK signaling pathway regulates cell viability, proliferation and invasion, using a combination of biochemical approaches and studies in human cancer cell lines. An important question is how this signaling pathway contributes to the ability of tumor cells to bypass normal controls. We also use genetically modified mice, which allow the inactivation of this pathway in a regulated and tissue-specific manner, and chemical inhibitors to investigate physiological functions of p38 MAPKs and their role in lung, colon and breast cancer, as well as the connection between inflammation and tumorigenesis. We are very interested in the identification of therapeutic opportunities based on the modulation of p38 MAPK signaling. Moreover, we are studying the regulation and functions of a new family of proteins named RINGO that can activate the cell cycle kinases Cdk1 and Cdk2.

Keywords. signal transduction, cell regulation, cancer cell, tumor microenvironment

Required background. Not specified
Minor project. To be determined

IRB-RP55. Precise antibody-drug conjugation via carbohydrate-boronic acid recognition

Supervisor. Ernest Giralt
Co-supervisor. Macarena Sánchez Navarro
Research Group. Design, synthesis and structure of peptides and proteins

Project Description. Antibody-drug conjugates (ADCs) are a new family of biotherapeutics with great potential since it combines the specificity of monoclonal antibodies (mAb) with the power of cytotoxic drugs. The synthesis of ADCs are limited. To expand the current methods available we propose to take advantage of the mAb structure to prepare ADCs through a carbohydrate orienting strategy. Boronic acids have high selectivity for carbohydrates. Our approach envisage the use of polyethylene glycol compounds bearing a boronic acid at the one end and a reactive group, electrophile in our case, at the other. The idea is that upon carbohydrate recognition by the boronic acid, the nucleophiles of the protein, mainly lysines, will attack to the electrophile incorporating it to the mAb structure. In this manner, functionalization points along the IgG can be incorporated with the advantage of controlling the proximity to the paratope and the maximum number of drugs incorporated.
The main objectives of this projects are:
1) Synthesis of the boronic-peg-electrophile unit, 2) Optimization of the electrophile transfer reaction on selected mAb, 3)Functionalization of the mAb with the selected drug and characterization of the constructs.
During the development of this project the student will get deep training on organic synthesis in solution, as well as, purification and characterization techniques (chromatographic techniques, NMR, etc). In addition, deep training in proteomic MS analysis will be provided.

Keywords. Antibody-drug-conjugate, protein modification, proteomics

Required background. A chemist, biologist or pharmacist will be highly preferred. Experience in organic synthesis in solution will be highly appreciated.
Minor project. The minor project will consist on complete characterization of the ADCs prepared and will be undertaken under the supervision of Eduard Sabidó at CRG. In first place, analysis of the intact mass of the modified antibodies will be performed. If necessary enzymatic deglycosylation steps will be included in order to facilitate the experiment. By this analysis the number of

reactive groups, in first place, and drugs, in second place, will be obtained. Later, a bottom up strategy will be used, meaning, antibodies will be subjected to proteolytic digestion (with different enzymes) prior to analysis by mass spectrometry. The state-of-art Orbitrap Fusion Lumos mass spectrometer will be used for such application.

IRB-RP56. Deciphering BBB-shuttle peptide mechanism. Getting insight into brain penetration.

Supervisor. Ernest Giralt
Co-supervisor. Meritxell Teixidó
Research Group. Design, synthesis and structure of peptides and proteins

Project Description. Peptide BBB-shuttles are molecular vectors able to increase the brain uptake of compounds that are not able to reach the brain alone. Full understanding of the mechanism under which this brain uptake take place is mandatory . Recently we have described a BBB-shuttle, SGV, by biopanning of a phage display library against a human BBB cell-based model. SGV undergoes clathrin mediated endocytosis. By sequence alignment, similarities between
SGV and two already described BBB-shuttles (TGN and GYR), with unknown transport mechanism, were found.
The aim of this project is to analyze the transport mechanism used by TGN and GYR and compare it with SGV in order to assess if they share similar paths for internalization.
The project could be dissected in 3 objectives: 1) Synthesis of the 3 peptides conveniently functionalized and labelled, 2)Assessment of endocytosis mechanism on brain endothelial cells, mouse or human capillary endothelial cells (bEnd.3 or hCMEC/D3). Different inhibitors will be used to establish the mechanism. Flow cytometry will be the technique of choice to compare the different peptides, 3) Verification of transport mechanism by human BBB cell model transport assay.

During the development of this project the student will get deep training on peptide synthesis, purification and characterization, as well as, in the bases of molecular biology (cell culture tech., FACS). In addition, the student will be asked to actively participate on the decisions taken.

Keywords. Brain delivery, peptide BBB-shuttle, endocytosis, confocal microscopy

Required background. A chemist, biologist or pharmacist will be highly preferred. Experience on basic cell culture techniques will be appreciated.
Minor project. The minor Project will be undertaken under the supervision of María García Parajo at ICFO and will consist on the evaluation, by microscopy techniques, of the internalization mechanism used by the selected peptides. In first place, the student will analyze, by confocal fluorescence microscopy, the internalization of the peptides of interest on the selected cells lines. In second place and if time allows, super resolution microscopy, in particular, Stimulated Emission Depletion or STED, will be used in order to assess organelle distribution of the peptide inside the cell.
During this minor project the student will learn the principles of microscopy together with quantitative image analysis.