BIST

Barcelona Institute of Science and Technology

upf. Universitat Pompeu Fabra Barcelona

Master of Multidisciplinary Research in Experimental Sciences

Major Project List 2020/2021

bist.eu/master

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 of a PI from one of the participating institutions.

Major Research Project: 6-month long project carried out under the supervision. 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.

Information for Applicants

*Applicants are requested to list 5 major projects in order of preference. The Selection Committee will assign major projects based on said list as well as the Committee's evaluation of the student's candidature, the supervisors' assessments and the adequacy of the project to the candidate's profile.

**Second Call applicants who state preference for a project assigned in the previous round will be informed and requested to submit new projects before the closing of the call.

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THE DEPARTMENT OF EXPERIMENTAL AND HEALTH SCIENCES (DCEXS-UPF)

DCEXS-2001. Translational Synthetic Biology

Supervisor. Marc Güell

Research group. Translational Synthetic Biology

Project Description. Our group aims to leverage synthetic biology and gene editing to generate technologies with therapeutic potential. Our ability to modify genomes has profoundly affected how we perform scientific research, and future therapies. Emergent consequences of reinventing biology have already started to reach society. For example, engineered human immune T cells (CAR-T) cure cancers with outstanding performance, or 'ex vivo' applied gene editing technologies have successfully cured severe genetic diseases such as 'bubble boys' or sickle cell disease. Biological technology will have a growing influence in our lives. We have lines of research in developing precise tools for applied gene editing technologies and in skin microbiome based therapeutics.

-Precise editing of mammalian genomes: Despite enormous progress, precise introduction of new alleles in mammalian genomes still results difficult. Our goal is to explore novel alternatives to precisely re-write genomes safely and efficiently.
-Microbiome engineering: The skin is populated by numerous microorganisms which affect host health. We aim to develop precise genetic methodologies to modulate skin microbiome population to enable novel therapeutic strategies for skin disease and wellbeing.

Keywords. CRISPR, synthetic biology, genetic engineering, gene therapy, microbiome

DCEXS-2002. Dynamical Systems Biology

Supervisor. Jordi Garcia-Ojalvo

Research group. Dynamical Systems Biology

Project Description. The Dynamical Systems Biology laboratory of the Universitat Pompeu Fabra studies the dynamics of living systems, from unicellular organisms to human beings. The lab uses dynamical phenomena to identify the molecular mechanisms of a large variety of biological processes including cellular decision-making, spatial self-organization and tissue homeostasis. We use experimental biochemical and electrophysiological data to constrain computational models of living systems, and thereby unravel the underlying molecular circuitry of physiological processes. Using a combination of theoretical modelling and experimental tools including time-lapse fluorescence microscopy and microfluidics, we investigate dynamical phenomena such as pulses and oscillations, and study how multiple instances of these processes coexist inside cells and tissues in a coordinated way. At a larger level of

organization, we use conductance-based neural models to explain the emergence of collective rhythms in cortical networks, and mesoscopic neural-mass models to link the structural properties of brain networks with their function.

Keywords. Quantitative biology, biophysics, statistical physics, nonlinear dynamics, complexity

DCEXS-2003. Uncovering the clonal dynamics of the hindbrain: balancing proliferation and differentiation

Supervisor. Cristina Pujades

Research group. Development of the Central Nervous System

Project Description. Our main goal is to understand how spatiotemporally coordinated cell progenitor specification and differentiation occurs alongside morphogenesis to construct the functional brain. Thus, we need to blend the information provided by morphogenesis and tissue growth studies -balancing progenitors vs. differentiated cells-, with the reconstruction of cell lineages, with the demand to incorporate the time as a crucial factor. We make use of the zebrafish embryo because it allows to combine high-resolution in vivo imaging with the genome-editing technology. We take advantage of complementary approaches such as 4D-imaging, functional perturbations, clonal growth studies and transcriptomics in order to fill the void between gene regulatory networks and tissue architecture.

The specific objective of the project is to uncover the clonal growth dynamics of the hindbrain in order to understand how cell proliferation and cell differentiation are balanced. For this we will life-monitor the whole embryonic hindbrain upon time and compare the growth of specific progenitor cell populations with the overall growth, using genetic clonal experiments combined with a Machine Learning platform for their analysis. These results will provide us insights into the mechanisms of segregation of progenitors within the hindbrain and how brain morphogenesis and growth are coordinated.

To explore how different groups of progenitors contribute to the growth of the hindbrain, zebrafish transgenic embryos will be used allowing for fluorescent life-monitoring clonal growth. To get insight into the growth of the tissue and the specific progenitor cell populations we will assess: i) clonal growth, and ii) morphological spatial variability of the clones. Clone tracking will allow deciphering modes of clonal behaviour (symmetric vs. asymmetric divisions). We will develop a Machine Learning approach for cell motion pattern recognition and allocation, since an automatised, accurate segmentation and tracking framework will represent an improvement to identify distinct modes of growth and movement patterns.

The student will learn the experimental skills for 4D-imaging and cell-tracking, and the computational tools to extract biological insights from big-data analyses.

Keywords. brain morphogenesis, 4D-imaging, zebrafish, clonal growth

DCEXS-2004. Molecular Physiology Laboratory

Supervisor. Francisco José Muñoz

Research group. Molecular Physiology Laboratory

Project Description.

1. Group: Dr. Francisco J. Muñoz (University lecturer; Pubs: 64; Total Citations: 2244; h-index: 25) is focused on the study of the production, aggregation and cytotoxicity of amyloid ß-peptide (Aß) in Alzheimer's disease (AD) and its regulation by oxidative stress and nitric oxide.
2. Proposed Project: AD is due to the Aß aggregation inside the brain. Aß is produced by the enzyme BACE1 that cleavages the amyloid precursor protein (APP). Both APP and BACE1 are localized in the lipid rafts enriched with GM1 ganglioside. GM1 has been suggested to favour Aß aggregation therefore contributing to synaptic impairment. We propose that during aging there is a GM1 increases. Thus GM1 clusters could be promoting BACE1 amiloydogenic activity. An increase of the concentration of Aß in neuron extracellular matrix will favour Aß oligomerization by binding GM1.

3. Preliminary results:

- Aged primary cultured of hippocampal neurons have high levels of GM1.

- The binding of Aß to GM1 is increased when asialyzated.

- Aggregated Aß in synapses favours the production of nitro-oxidative stress. Peroxynitrite stabilizes Aß oligomers, the most toxic forms of Aß aggregates, impairing NMDA Rc function.

- We have designed synthetic peptides with a sequence similar to that of albumin that impairs amyloid aggregation in brain. C-term from albumin impairs Aß aggregation and protects neurons.

4. Expected training outcomes:

- To acquire the necessary skills to become an independent researcher in the field of neurodegeneration.

- To reach scientific goals in a high quality environment through a laboratory equipped with state-of-the-art equipment for the biochemical, neurobiology (imaging, tissue culture) and electrophysiology studies.

- To expand considerably his/her scientific and technological base.

- To achieve not only an assortment of both theoretical and practical aspects of research but also the critical thinking and managing skills necessary to move his/her scientific career forward and become an international scientific researcher.

Keywords. Alzheimer's Disease; Amyloid; GM1; hippocampal neurons; aging

DCEXS-2005. Zinc imbalance and cancer progression

Supervisor. Rubén Vicente García

Research group. Laboratory of Molecular Physiology-Biophysics of the immune system

Project Description. The human body contains 2–3 g of zinc. In the cell, aside from being a structural component of many proteins, zinc plays a role as a second messenger regulating different signalling cascades involved in proliferation, migration and differentiation. Several transporters (Zip and ZnT family) and zinc binding proteins work in a coordinated way to tightly regulate cytosolic zinc concentrations. Zinc dysregulation has been described in several kinds of cancers affecting both, the patient zinc serum levels and tumour zinc content. The expression of certain zinc transporters has been correlated with the stage, progression of tumours and acquisition of pro-metastatic features. However, the underlying mechanisms behind zinc imbalance and cancer progression are not fully understood. The project is based on a multidisciplinary approach combining molecular biology, biophysics and nanotechnology. The students will acquire skills in different techniques of all these different disciplines.

Keywords. zinc, cancer, transporter, metastasis

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DCEXS-2006. Integrative Biomedical Materials and Nanomedicine Lab

Supervisor. Pilar Rivera Gil

Research group. Integrative Biomedical Materials and Nanomedicine Lab

Project Description. Our research lies at the crossroads between nanoscience and biomedicine, the field of nanobiomecine. We convert basic research findings on nanobiotechnology into new approaches addressing biomedical challenges. We fabricate multifunctional biomaterials by integrating selected building-blocks into one single system depending on the application's requirements and considering the biophysicochemical properties of the nanomaterial. We target independently two areas: diagnostics and therapeutics of diseases but also simultaneously by creating a theranostic tool towards a more personalized medicinal approach of diseases. We focus on understanding and engineering the nanomaterial-biological system interface. We use state of the art material and biological/molecular characterization methods to find predictive patterns of cellular outcomes after exposure to nanomaterials for translational medicine.

The main research lines are:

Engineering nanomaterials for diagnosis/sensing
Engineering nanomaterials for controlled release
Exploring the therapeutic value of novel nanomaterials
Engineering the nanomaterial-biological interface

Keywords. Nanomedicine; Optical biosensing; Nanomaterials; Controlled release; Theranostics

DCEXS-2007. Hypoglycosylation Of Voltage-Gated And Mechanosensitive Ion Channels: New Pathological Mechanisms And Therapeutic Targets For Neurological Disorders In Phosphomannomutase 2 Deficiency (PMM2-CDG)

Supervisor. José Manuel Fernández Fernández

Research group. Laboratory of Molecular Physiology

Project Description.

"Phosphomannomutase Deficiency (PMM2-CDG) is the most frequent congenital disorder of N-linked glycosylation (CDG). PMM2-CDG symptoms include severe neurological alterations. Progressive atrophy of the cerebellum is usually found in all PMM2-CDG patients, leading to the ataxia cerebellar syndrome. Also, the stroke-like episode (SLE) is one of the unpredictable and serious neurological complications occurring in PMM2-CDG. Mechanisms underlying both SLE and cerebellar syndrome in PMM2-CDG are unknown and there are no guidelines for their prevention, detection and treatment. We have recently identified the neuronal voltage-gated Ca2+ channel CaV2.1 as a potential target of glycosylation defect in the Central Nervous System of PMM2-CDG patients, and an important contributor to SLEs and cerebellar syndrome in PMM2-CDG. Besides, we found that mild cranial trauma is a potential SLE trigger in PMM2-CDG patients. In this respect, mechanosensitive Piezo channels have been suggested to underlie the transduction of different mechanical forces into a variety of neurological responses in the brain.

Our overall objective is to study how hypoglycosylation affect the function of neuronal CaV2.1 and Piezo channels, and its relevance in neurological alterations linked to PMM2-CDG by using heterologous expression systems and neurons from wild-type and PMM2-CDG knock-in mice. Similar analysis will be performed in fibroblasts of patients with PMM2-CDG and healthy volunteers, and iPSC-derived neurons from those fibroblasts, to directly assess the degree of hypoglycosylation and dysfunction of CaV2.1 and Piezos in patients with distinct neurological phenotypes (moderate versus severe), and initiate a study of correlation with their clinical and genetic report. Finally, we will test the capability of novel CaV2.1 modulators to revert hypoglycosylation effects, thus establishing a proof of concept to develop in the future a specific treatment for neurological events in PMM2-CDG."

Keywords. Hypoglycosylation; neuronal voltage-gated calcium channels; mechanosensitive Piezo channels; Phosphomannomutase Deficiency (PMM2-CDG); electrophysiology

DCEXS-2008. In vivo mapping of the neuronal circuity related to vestibular and auditory sensory function

Supervisor. Berta Alsina

Research group. Morphogenesis and Cell Signaling Sensory Systems

Project Description. The inner ear capturing auditory and balance information though specialized hair cells transmits the sensory information to the brain through bipolar neurons. We have investigated though high-resolution imaging and genetic perturbations the development of the sensory neurons of the inner ear in zebrafish (Hoijman et al. 2017 eLife, Taberner et al. biorxiv). This information is currently also being mapped with spatial transcriptomic data to discriminate between different neuronal subtypes. However, it remains unexplored how different stimuli activate specific neurons of the ganglion and how neuronal activity is mapped into the brain. Neuronal activity can be monitored in vivo by the use of GCAMP, a genetically encoded calcium sensor. The project aims at imaging at high spatial and temporal resolution the patterns of neuronal activity in the statoacoustic ganglion and the hindbrain when specific neurons are activated or specific stimuli are presented to the zebrafish. For this aim, the student will use a transgenic line expressing GCAMP5G in neurons, will learn how to image neuronal activity in vivo and will collaborate with a laboratory with expertise in photochemically activation of neuronal receptors. Moreover, analysis of behaviour will also be assessed when specific populations of neurons are activated in order to integrate neuronal circuit maps with behaviour output. We aim for a student highly motivated in neurobiology, imaging and circuitry to undertake this challenging project.

Keywords. optogenetics, in vivo imaging, neural activity, zebrafish

DCEXS-2009. Monitoring oxidative stress in living cells – use of genetically encoded reporters to determine H2O2 levels linked to signalling and disease

Supervisor. Elena Hidalgo

Research group. Oxidative Stress and Cell Cycle Group

Project Description. General objectives: Intracellular peroxides are important drivers of both toxicity and signalling events. Several genetically encoded fluorescent probes have been developed to monitor H2O2 fluctuations in response to endogenous and exogenous oxidant sources. We have recently developed a new reporter, based on the fission yeast H2O2 sensor Tpx1 fused to a redox sensitive GFP, which is more sensitive to peroxide fluctuations that any other reporter characterized so far. We aim at comparing its behaviour in response to genetic and environmental interventions. The candidate will characterize the regulation of our H2O2 reporter in different S. pombe backgrounds and in different biological situations, such as during chronological aging or cell cycle progression, to assess the role of moderate intracellular H2O2 fluctuations as drivers of these processes.

Furthermore, an unprecedented experiment in the redox field will be to use our fluorescent reporter in different biological models (ranging from bacteria to human cells), to compare intracellular H2O2 levels using the same protein sensor.

Expected training outcomes: training on cellular biology, molecular biology and fluorescence microscopy will be acquired during project execution.

Keywords. Redox biology, aging, H2O2, yeast

DCEXS-2010. Engineering Intracellular Nanotools To Image Protein Structures In Vivo: Resolving The Mechanism Of Exocytosis

Supervisor. Oriol Gallego

Research group. Live-cell Structural Biology

Project Description. Our group develops new methods of fluorescence microscopy that allow the study of macromolecular complexes directly in living cells beyond the limits of current approaches.

Understanding the molecular mechanisms that drive life (and those that lead to death) requires structural characterisation of the protein machinery sustaining the biology of the cell, both in a healthy and in a pathological situation. Historically, structural biology has been largely centred around in vitro approaches. However, the degree of knowledge acquired to improve human health will be determined not only by the precision of the experimental measurements but also by their proximity to a physiological context. Therefore, to undertake future investigations relevant for biomedicine it will be necessary to perform structural biology experiments in living cells.

The aim of the project is to develop new genetically-encoded nanotools to boost the power of quantitative fluorescence microscopy. In collaboration with the group of Alex De Marco, at the Monash University (Australia), we will also asses the implementation of these new nanotools in cryo-electron tomography. During the progression of the project the student will acquire a strong expertise in gene editing tools, advanced light microscopy and image analysis. Depending on the student's skills and interest, the project could also involve in silico integration of acquired data to model 3D structures of large protein complexes controlling cell growth.

Keywords. Genetic engineering, light microscopy, molecular mechanisms, cell growth

DCEXS-2011. Cancer Biology

Supervisor. Ana Janic

Research group. Cancer Biology

Project Description. The tumour suppressor gene p53 is mutated in half of the human cancers. Given the difficulties in developing strategies for targeting wild-type or mutant p53, further understanding of its basic biology is required for successful clinical translation. The present project focuses on understanding the complexity of the p53 network in tumour suppression in different contexts, in order

to determine which p53 downstream function should be targeted for treatment of different tumour types, without targeting p53 itself. The successful candidate will be involved in the use of a wide variety of experimental techniques, including mouse models of cancer, tissue/tumour pathology, CRISPR-Cas9 gene-editing technology, next-generation sequencing, molecular biology, cell culture and flow cytometry.

Keywords. Cancer, tumour suppression, p53, DNA damage

CENTER FOR GENOMIC REGULATION (CRG)

CRG-2001. Reconstituting tissue self-organization and collective cell dynamics in early embryonic development via 3D synthetic culture methods

Supervisor. Verena Ruprecht

Research group. Cell and Tissue Dynamics

Project Description. The Ruprecht lab studies multi-scale dynamics of cell and tissue organization in early embryogenesis. We have a key focus on understanding biological self-organization, cell and tissue shape formation and dynamic cell behaviour in 3D tissues. Our lab follows a highly interdisciplinary approach combining molecular and cell biological tools with advanced biophysical methods and quantitative live cell imaging approaches.

In this research project, we will establish synthetic 3D culture methods that enable to mimic tissue self-organization of early embryonic development in synthetic culture environments. During gastrulation, an unstructured mass of pluripotent embryonic stem cells undergoes cell fate specification and acquires a defined shape, laying the foundation for the future body plan. Morphodynamic shape formation depends on precise spatio-temporal positioning of three distinct germ layers (mesoderm, ectoderm and endoderm) that give rise to different organs of the organism. Both chemical signals (morphogens) and physical stimuli (as geometry, cell density, adhesion and cell deformation) serve as information signals to instruct cell fates and dynamic cell behaviour. Recent work from our lab has identified that mechanical tissue crowding and geometrical boundary constraints from the 3D tissue environment critically influence dynamic cell migration behaviour (Ruprecht et al., Cell 2015). These results highlight the relevance of mechanosensitive signalling pathways and cellular adaption to physical tissue parameters in early embryogenesis. In this research project, we will address how multicellular tissue dynamics and self-organization is controlled by mechanical and physical processes in early embryogenesis. We aim at identifying key molecular and cellular modules that enable cellular information processing of physical tissue parameters and how they regulate single and collective cell dynamics to build the shape of an embryo.

Keywords. Biological Self-organization, Multicellular dynamics, Cytoskeleton, Mechanobiology, Biophysics

CRG-2002. Trans-generational epigenetic influences on mutation outcome

Supervisor. Ben Lehner

Research group. Genetic Systems

Project Description. "Many detrimental mutations only cause disease in a subset of their carriers, a phenomenon known as incomplete penetrance. Further, individuals often display variable expressivity of a disease, ranging from

mild to severe health impairments. Animal studies show that incomplete penetrance and variable expressivity are still present in the absence of environmental or genetic variation, with inter-individual variation in gene expression during development able to predict to some extent whether an individual is affected or not by an inherited mutation [1, 2]. We hypothesized that an additional influence on mutation penetrance and expressivity might be the environment or physiological state of an individual's parents or even previous generations. To test this hypothesis, we have established an automated screening platform to quantify how environmental perturbations in previous generations influence the outcome of inherited mutations in C. elegans. We identified several environmental factors that altered mutation outcome in subsequent generations that were never directly exposed to the environmental challenge. Your master thesis project will investigate possible molecular mechanisms underlying the multi-generation memory of environmental perturbations. To this end, you will use transgenic C. elegans lines, time-lapse microscopy, protein biochemistry, as well as genetic techniques."

References:

1. Burga, A., Casanueva, O., and Lehner, B. Nature, 480, 250-253 (2011)

2. Casanueva, O., Burga, A., and Lehner, B. Science, 335, 82-85 (2012)

Keywords. epigenetic inheritance, C. elegans

CRG-2003. Understanding the molecular basis of neuronal 3'UTR length-dependent mRNA sorting

Supervisor. Sebastian Maurer

Research group. Cytoskeleton dependent RNA localisation mechanisms

Project Description. The Maurer Lab wants to understand the biochemical processes that drive the generation of neuronal mRNA distributions. Thousands of mRNAs are transported into axons and dendrites and their local translation at the right location is important for neuron development, polarization and synaptic plasticity which underlies long-term memory formation. How motor proteins such as kinesins and dynein recognise their mRNA cargo and transport them to their destination is not understood. The Maurer lab develops new single-molecule assays in microfluidic chambers to assemble neuronal mRNA transport complexes from purified components. Through this approach, the Maurer Lab recently revealed the essential building blocks of a minimal mammalian mRNA transport system and their function (Baumann et al. bioRxiv, 2019). To further understand which different mRNA transport pathways exist, the Maurer Lab develops new high-throughput protein-protein and protein-RNA interaction assays (Yang et al. Nature Communications, 2018).

The project the successful candidate will work on is based on a validated result from our high-throughput protein interaction screen. We identified a new link between a nuclear mRNA transport

factor and different motor proteins. The candidate will work with a PhD student in the lab to characterise these new interactions with pure proteins and RNAs to understand how they interact and assemble into functional complexes. To this end, the student will learn how to design recombinant protein expression constructs, how to purify proteins with different techniques and how to fluorescently tag proteins. Furthermore, the student will be trained in bioanalytical techniques to quantify affinities between proteins and proteins and RNAs. Finally, if time permits, the student will learn how to design and conduct Total-Internal-Reflection-Microscopy (TIRF-M) coupled in vitro reconstitution experiments to analyse the function of purified factors during mRNA transport.

Keywords. Neuronal mRNA localisation, motor proteins, RNA binding proteins, single-molecule microscopy, biophysics

CRG-2004. Understanding the molecular basis for bidirectional neuronal mRNA transport

Supervisor. Sebastian Maurer

Research group. Cytoskeleton dependent RNA localisation mechanisms

Project Description. The Maurer Lab wants to understand the biochemical processes that drive the generation of neuronal mRNA distributions. Thousands of mRNAs are transported into axons and dendrites and their local translation at the right location is important for neuron development, polarization and synaptic plasticity which underlies long-term memory formation. How motor proteins such as kinesins and dynein recognise their mRNA cargo and transport them to their destination is not understood. The Maurer lab develops new single-molecule assays in microfluidic chambers to assemble neuronal mRNA transport complexes from purified components. Through this approach, the Maurer Lab recently revealed the essential building blocks of a minimal mammalian mRNA transport system and their function (Baumann et al. bioRxiv, 2019). To further understand which different mRNA transport pathways exist, the Maurer Lab develops new high-throughput (HT) protein-protein and protein-RNA interaction assays (Yang et al. Nature Communications, 2018).

The successful candidate will help to design new approaches to reveal which different mRNA transport pathways exists in induced mammalian neurons. To this end, the student will work closely together with a PhD student and use CRISPR-Cas9 to create cell lines with degron-tagged candidate proteins, which were detected as potential mRNA-cargo adapters by our HT-screening approaches. To enable live cell imaging of mRNA transport dynamics, the student will further validate molecular beacons on in vitro transcribed mRNAs and help to implement mRNA live-imaging protocols. If time permits, the project further foresees to generate photo-cleavable motor proteins which have to be first validated in vitro before they will be used as a tool in induced neurons to test which motor are responsible for axonal or dendritic mRNA localisation.

Keywords. Neuronal mRNA localisation, live cell imaging, protein and RNA

biochemistry, auxin-induced degrons, photo-inactivation

CRG-2005. X-chromosome reactivation in iPSCs and mouse embryos

Supervisor. Bernhard Payer

Research group. Epigenetic Reprogramming in Embryogenesis and the Germline

Project Description. In our lab, we are studying how epigenetic information is erased during mammalian development. In particular, we study epigenetic reprogramming of the X-chromosome in mouse embryos, induced pluripotent stem cell (iPSC) and in the germ cell lineage in vivo and in vitro. Using a multidisciplinary approach, we want to gain insight into how epigenetic reprogramming is linked to its biological context, with long-term implications for regenerative and reproductive medicine.

In this project, the prospective student would study the function of candidate factors for X-chromosome reactivation in iPSCs and early mouse embryos. The project will involve iPSCs reprogramming and monitoring X-chromosome activity using an XGFP-reporter. Using knockdown and/or CRISPR deletion, the mechanism will be studied, by which the candidate acts on epigenetic reprogramming and at which stage X-reactivation is affected. The student will learn a number of methods including iPSC reprogramming, shRNA knockdown, FACS analysis, immunohistochemistry, RNA-FISH, qPCR, etc.

Besides adding a piece to the X-reactivation puzzle, the student will be immersed within a young team inside a dynamic international research environment at CRG, which will help her/him to gain skills furthering his/her scientific career.

Keywords. Pluripotency, Epigenetics, iPSC-reprogramming, X-chromosome reactivation

CRG-2006. Epigenetic reprogramming in mammalian germ cells

Supervisor. Bernhard Payer

Research group. Epigenetic Reprogramming in Embryogenesis and the Germline

Project Description. In our lab, we are studying how epigenetic information is erased during mammalian development. In particular, we study epigenetic reprogramming of the X-chromosome in mouse embryos, induced pluripotent stem cell (iPSC) and in the germ cell lineage in vivo and in vitro. Using a multidisciplinary approach, we want to gain insight into how epigenetic reprogramming is linked to its biological context, with long-term implications for regenerative and reproductive medicine.

In this project, the student would work with germ cells from mouse embryos and/or differentiated in vitro from embryonic stem cells (ESCs). The in vitro approach has the advantage of providing more material and being more amenable to perturbation. On the other hand, germ

cells from embryos can provide the accurate biological context for testing the applicability of our findings from the in vitro system. Momentarily, we use this two-system strategy to elucidate the signals and mechanisms responsible for X-reactivation in mouse and human germ cells.

Besides adding a piece to the X-reactivation puzzle, the student will be immersed within a young team inside a dynamic international research environment at CRG, which will help her/him to gain skills furthering his/her scientific career.

Keywords. Keywords: Germ cells, Epigenetics, X-chromosome reactivation, reproduction.

CRG-2007. Dynamics of Living Systems

Supervisor. Nicholas Stroustrup

Research group. Dynamics of Living Systems

Project Description. Our research group seeks to link the macroscopic symptoms of aging to their molecular origins. In aging, a variety of mechanisms contribute at short, medium, and longtime scales. Furthermore, aging appears to involve a substantial degree of random chance. To tackle this complexity, we incorporate techniques from a wide range of fields– molecular genetics, reliability engineering, bioinformatics, statistical physics, survival analysis, high-throughput imaging, and stochastic modelling. Focusing on C.elegans as a model system, we seek to develop experimental and computational methods in parallel to help us characterize where, when, and why aging occurs, and how we might effectively intervene in its progression.

Objectives: contribute to the development of our high-throughput imaging technology Training outcomes: learn how to work with a complex experimental apparatus involving hardware, software, and biological components.

Keywords. Aging, microscopy, stochastic processes

INSTITUTE FOR BIOENGINEERING OF CATALONIA (IBEC)

IBEC-2001.Nanoprobes & Nanoswitches I

Supervisor. Pau Gorostiza

Research group. Nanoprobes & Nanoswitches

Project description. One of the group's research lines is focused on developing nanoscale tools to study biological systems. These tools include instrumentation based on proximity probes, such as electrochemical tunneling microscopy and spectroscopy (ECSTM, ECTS), atomic force microscopy (ECAFM) and single molecule force spectroscopy (SMFS) that we apply to investigate electron transfer in metal oxides and individual redox proteins. These studies are relevant to the development of biosensors and molecular electronics devices. Recent advances include the following projects: methods for nanoscale conductance imaging under electrochemical control, measurement of the nanomechanical stability and electron transfer distance decay constants of individual redox proteins. Based on our development of nanoscale field-effect transistors using redox proteins, we have recently published a method to measure conductance switching in proteins "wired" between two electrodes and their current-voltage characteristics.

The objective of the research line on nanoswitches is to develop molecular switches that are regulated with light in order to manipulate and functionally analyze receptors, ion channels and synaptic networks in the brain. These tools are synthetic compounds with a double functionality: They are pharmacologically active, binding specifically to certain proteins and altering their function, and they do so in a light-regulated manner that is built in the same compound usually by means of photoisomerizable azobenzene groups. Recent projects in this area include the development of light-regulated peptide inhibitors of endocytosis named TrafficLights and the synthesis of small molecule photochromic inhibitors to manipulate several G protein-coupled receptors like adenosine A2aR and metabotropic glutamate receptors mGlu5. In addition, some of these light-regulated ligands also bear an additional functionality: a reactive group for covalent conjugation to a target protein. Examples include a photochromic allosteric regulator of the G protein-couple receptor mGlu4 that binds irreversibly to this protein and allows photocontrolling its activity in a mouse model of chronic pain and a targeted covalent photoswitch of the kainate receptor-channel GluK1 that enables photosensitization of degenerated retina in a mouse model of blindness. We also demonstrated for the first time two-photon stimulation of neurons and astrocytes with azobenzene-based photoswitches.

Students can expect to learn the relevant techniques for the proposed project in one of the research lines (from

electrochemistry to scanning probe microscopies and surface functionalization; from synthetic chemistry to electrophysiology and fluorescence imaging, in vitro and in vivo) and to work independently within a team of highly multidisciplinary and motivated researchers.

Keywords. electrochemistry, redox proteins, photosynthetic complexes, optogenetics, photopharmacology

IBEC-2002. Nanoprobes & Nanoswitches II

Supervisor. Pau Gorostiza

Research group. Nanoprobes & Nanoswitches

Project description. Protein mediated electron transfer (ET) is essential in many biological processes, like cellular respiration or photosynthesis. The exceptional efficacy of these processes is based on the maximization of donor/acceptor coupling and the optimization of the reorganization energy.

Single molecule techniques can provide physical information on biological processes with molecular resolution and allow the integration of experimental set-ups that reproduce the physiological conditions. They provide information free from averaging over spatial inhomogeneities, thus revealing signatures that are normally obscured by the ensemble average in bulk experiments.

The general goal is to evaluate at the single molecule level the specific conditions that allow for an effective protein-protein ET. We use scanning probe microscopies, SPMs (scanning tunneling and atomic force microscopies and spectroscopies -STM and AFM-), to evaluate immobilized proteins under electrochemical control.

The student will perform studies at the nanoscale using SPMs to measure ET currents and interaction forces between partner proteins, under controlled environmental and biologically relevant conditions (electrochemical potential, temperature, pH, ionic environment). The student will learn to work with SPMs but also on protein immobilization protocols, surface functionalization, electrochemical studies. He/she will also learn on bibliographic search, data treatment and presentation (written and oral) of the results. The student will incorporate to the Nanoprobes & Nanoswithces research group and will actively participate in the meetings and discussions. He/she will acquire basic competences related to the experimental work in a multidisciplinary lab on nanobiotechnology.

Keywords. Proteins; electron transport; scanning probe microscopies; single molecule; interactions

IBEC-2003. Nanoprobes & Nanoswitches III

Supervisor. Pau Gorostiza

Research group. Nanoprobes & Nanoswitches

Project description. Cell processes like endocytosis, membrane resealing, signaling and transcription, involve conformational changes which depend on the chemical composition and the physicochemical properties of the lipid membrane. These properties are directly related to the lateral packing and interactions at the molecular level, that govern the membrane structure and segregation into nano (or micro) domains. The better understanding of the mechanical role of the lipids in cell membrane force-triggered and sensing mechanisms has recently become the focus of attention. The local and dynamic nature of such cell processes requires observations at high spatial resolution. Atomic force microscopy (AFM) is widely used to study the mechanical properties of supported lipid bilayers (SLBs). We investigate the physicochemical and structural properties of lipid membranes combining AFM and force spectroscopy (AFM-FS) under environmentally controlled conditions. We use simplified model membranes including several lipid representatives of mammalian or bacterial cells. We also study the mechanical properties of lipid membranes from nanovesicles with technological applications, like drug delivery.

The general goal is to assess the structure, phase behavior and nanomechanical properties of model membranes, including the presence of glycosphingolipids related to specific pathologies, and associate them to their role processes at the cellular level. The student will be involved in the design and building of supported lipid membranes, and their characterization using force spectroscopy (indentation and tube-pulling) based on AFM. The student will be trained on lipid vesicles and membranes preparation, surfaces functionalization, and to work with SPMs techniques. He/she will also learn on bibliographic search, data treatment and presentation (written and oral) of the results. The student will incorporate to the Nanoprobes & Nonsnitches research group and will actively participate in the meetings and discussions. He/she will acquire basic competences related to the experimental work in a multidisciplinary lab on nanobiotechnology.

Keywords. lipid membrane; biophysics; atomic force microscopy; force spectroscopy; nanomechanics

IBEC-2004. Improving site-specific targeting of nanomedicines for treatment of lung or brain diseases

Supervisor. Silvia Muro

Research group. Targeted Nanotherapeutics and Nanodevices

Project description. Novel drug nanocarriers improve the solubility, biodistribution, and overall performance and safety of therapeutic agents. Their functionalization with targeting moieties enables site-specific drug delivery to

selected cells. Although this paradigm is easily achieved in cell mono-culture models, in vivo specificity of targeted vehicles remains a challenge. The complexity of the physiological environment within the body and its diversity in cellular phenotypes contribute to this. The project will focus on examining specific targeting of nanocarriers in complex and physiologically relevant co-culture models, providing guidance for future design of nanomedicines. This will be examined for one of two relevant organs: (1) the brain, a part of the central nervous system very difficult to reach from the circulation due to the blood-brain barrier, vs. (2) the lung, a peripheral organ which receives full cardiac output after i.v. injection. Different diseases affecting each organ require targeting drugs to particular cell types, but not all, for which the project will broadly help design more precise systems for efficiency and safe treatment. Three aims will be encompassed, including (a) biological characterization a new co-culture cell model, (b) synthesis and characterization of targeted nanocarriers, and (c) examination of the specific interaction of said nanocarriers with said co-culture models vs. more classical systems. Techniques to be used include solvent-evaporation methods for polymer nanoparticle synthesis, dynamic light scattering, electrophoretic mobility and electron microscopy for nanoparticle size/shape and surface charge, human cell culture and fluorescence microscopy to visualize nanoparticle-cell interactions, and image analysis algorithms for semiquantitative measurements. Additional experiences to be gained include training on research safety and ethical conduct, participation in the process of designing, executing, recording and reporting of research, oral and written communication skills, authorship if publishable results are used for conference presentations or article submissions, and overall participation in a stimulating, interdisciplinary and innovative research program.

Keywords: Drug delivery, nanocarriers, site-specific targeting, multicellular models, lung or brain disease

IBEC-2005. Development of computational Solutions for Ion Mobility Spectrometry Data Analysis

Supervisor. Santiago Marco

Research group. Signal and Information Processing for Sensing Systems

Project Description. In the group we develop full computational workflows for the analysis of metabolomics data based on NMR, GC-MS or LC-MS techniques. Gas Chromatography-Ion Mobility Spectrometry is a novel technique for the analysis of the volatile fraction of the metabolome. Based on previous research at the group, the main aim is to produce an R-package that integrates basic GC-IMS signal processing. The student will get training in signal processing in the R technology and in the development of software packages.

Keywords. Data Analysis, Signal Processing, R language, Metabolomics

IBEC-2006. Equivalence of chemical measurement methods

Supervisor. Santiago Marco

Research group. Signal and Information Processing for Sensing Systems

Project Description. In the development of new sensors and instruments it is important to compare their performance against gold reference techniques. This requires the comparison of the measurement accuracy provided by their respective calibration models. This comparison is carried out with statistical techniques. There are several methodologies to determine the equivalence of measurement methods. The student will survey the state of the art and implement those methodologies in Python/R/matlab and apply those to a practical problem. These techniques are essential for the standardization of novel measurement methods in areas such as clinical chemistry or environmental monitoring.

Keywords. Calibration, Regression, Statistics, Programming, Standardization

IBEC-2007. Integrative Cell and Tissue Dynamics

Supervisor. Xavier Trepat

Research group. Integrative Cell and Tissue Dynamics

Project Description. We aim at understanding how physical forces and molecular control modules cooperate to drive biological function. We develop new technologies to map and perturb the main physical properties that determine how cells and tissues grow, move, invade and remodel. By combining this physical information with systematic molecular perturbations and computational models we explore the principles that govern the interplay between chemical and physical cues in living tissues. We study how these principles are regulated in physiology and development, and how they are derailed in cancer and aging. Our group is composed of physicists, engineers, biologists and biochemists.

During the Master's project, the student will learn how to work in a multidisciplinary and dynamic environment. He/she will participate in projects involving advanced technologies in bioengineering, cell biology, organoid biology, microscopy, mechanobiology, and microfluidics. He/she will also be exposed to computational methods in image processing and modeling. The two main research lines where the student can be involved are (1) mechanobiology of tumour-stroma interactions and (2) dynamics of three-dimensional epithelial sheets.

Keywords. mechanobiology, cancer, organoid, epithelium, microscopy

IBEC-2008. Smart Nano-Bio-Devices I

Supervisor. Samuel Sánchez

Research group. Smart Nano-Bio-Devices

Project Description. Active Nano-particles in nanomedicine: smart drug delivery systems

The development of active drug delivery systems will revolutionize the way we treat some diseases and reduce the side effects of extensive drug release in patients. This project aims at designing of nanoparticles and nanosystems made of organic and/or inorganic materials (e.g. polymeric nanoparticles or mesoporous nanoparticles). Those nanoparticles will become motile (named Nanobots) through the conversion of chemical energy released from catalytic reactions into kinetic energy. Nanobots will specifically transport therapeutic agents to target locations in a controllable manner using external control or internal gradients in vitro and eventually in vivo.

Nanobots will be functionalized for specific binding to target cells, and modified for triggering the release of drugs in located targets. Due to the high expectations and fast developement of this field, we aim at fundamental understanding of motion at the nanoscale, validate the nanotoxicity of nanobots and to transfer this radically new proof-of-concept to the hospital. The student will develop broad skills in a highly multidisciplinary and international group. Mainly, the synthesis of nanoparticles, bio-functionalization, cell culture, fluorescent imaging and cell internalization experiments. We seek for enthusiasts with interest in nanomaterials and drug delivery systems, specially from Chemistry, Biochemistry, Materials science, Biology, Biotechnology, Engineering background and physics.

Keywords. nanomachines, nanoparticles, drug delivery, nanobots, self-propulsion

IBEC-2009. Smart Nano-Bio-Devices II

Supervisor. Samuel Sánchez

Research Group. Smart Nano-Bio-Devices

Project Description. IBEC's Smart Nano-Bio-Devices group focuses in the minituarization and design of new bio-devices and advanced materials that bridge the gap between chemistry, biology, material science and physics, which can have relevant applications in the robotics, biomedical or environmental fields. The group has wide experience in the design and fabrication of smart nano- and micro-motors and actuators and also investigates the integration of artificial microstructures with living cells and biomaterials (hybrid bio-robots) based on 3D bioprinted skeletal muscle tissue. The project consists on the fabrication (using state-of-the-art 3D bioprinters) of hybrid bio-robotic devices or Bio-Bots, that can act as walkers or swimmers, combining artificial components (hydrogels, smart polymers, magnets, nanoparticles) and biological moieties (skeletal muscle tissue). Depending on the background and skills of the student, the individual objectives can be: i) synthetizing and characterizing new combinations of (nano-

structured) materials (either artificial polymers or hydrogels for cell encapsulation), their 3D-printability, their biocompatibility and effects on cell differentiation and maturation; ii) further studying capabilities of hybrid bio-bots, such as adaptability, self-healing or response to external stimuli; iii) using optogenetics techniques to stimulate skeletal muscle cells with blue light and studying their controllability, local stimulation or differences with respect to electrical stimulation. The student will join a highly multidisciplinary team and project, and thus will learn techniques ranging from cell culture and tissue engineering to material science, chemistry, physics and engineering. Students from all sorts of background (material science, biomedical engineering, physics, biology, chemistry...) with multidisciplinary interests are welcome.

Keywords. Bio-Hybrid Robotic Systems, Nano-structured Biomaterials, 3D-Bioprinting, Engineered Skeletal Muscle Actuators

IBEC-2010. Selection of DNA aptamers against Plasmodium falciparum early blood stages

Supervisor. Xavier Fernàndez-Busquets

Research group. Nanomalaria

Project Description. "The World Health Organization Global Technical Strategy for Malaria 2016-2030 lists the universal access to malaria diagnosis as an essential part of the strategic framework that should eventually lead to eradicating the disease, since knowing parasitemia and parasite species is crucial in order to select the most appropriate drug treatment. Currently, national malaria programs rely on light microscopy and rapid diagnostic tests, which are not sensitive enough to detect low parasite density infections (sub-microscopic malaria in which patients are usually asymptomatic) that are crucial in the transmission dynamics. Molecular techniques can detect sub-microscopic malaria, but are inadequate for massive use because of elevated costs or need for highly trained staff. Therefore, new diagnostic methods are needed in order to advance towards malaria eradication. Antibody production often involves the use of laboratory animals and is time-consuming and costly, especially when the target is Plasmodium, whose variable antigen expression complicates the development of long-lived biomarkers. To circumvent these obstacles we are applying in our group the Systematic Evolution of Ligands by EXponential enrichment (SELEX) method to the rapid identification of DNA aptamers against late stages of Plasmodium falciparum-infected red blood cells, to be used in future diagnosis devices.

The Master student will work on the design of a SELEX method for the selection of DNA aptamers against early blood stages of P. falciparum, which are the main parasite forms present in the circulation. This new generation of aptamers can offer a better diagnosis alternative compared to late stages, which are sequestered on the capillary walls and therefore less abundant in blood. The techniques to be used include P. falciparum in vitro cultures, fluorescence confocal microscopy, flow cytometry, and electron microscopy.

Eventually, the generation of aptamers against mosquito stages of the parasite is contemplated within the framework of the NANOpheles project (http://euronanomed.net/wp-content/uploads/2018/08/NANOpheles-new.pdf).

Keywords. Malaria; Plasmodium falciparum; aptamers; SELEX

IBEC-2011. Bacterial infections: antimicrobial therapies I

Supervisor. Eduard Torrents

Research group. Bacterial infections: antimicrobial therapies

Project Description. Infectious diseases are the leading cause of death worldwide. Disease-causing bacteria that resist antibiotic treatment are now widespread in every part of the world and have reached "alarming levels" in many areas as stated by the World Health Organization. "The problem is so serious that it threatens the achievements of modern medicine," entering to A post-antibiotic era in which common infections and minor injuries can kill. Nowadays, bacterial biofilm-based infections have emerged as a significant public health concern.

Our research objective is understanding why bacteria form biofilm and produce a chronic infection. We aim to understand which are the molecular mechanisms for bacteria to express specific genes under biofilm formation to identify ideal antimicrobial targets. We aim with this information to identify different specific inhibitors to inhibit bacterial growth in biofilms and eradicate chronic bacterial infections.

Our laboratory is multidisciplinary with the use of very different techniques and research fields. The student will be trained in specific molecular biology, cell biology, advanced microscopy, microbiology, biofilms as well as bacterial genetics techniques.

Keywords. infectious diseases, biofilm, antimicrobials, antibiotic multiresistant, bacterial genetics

IBEC-2012. Bacterial infections: antimicrobial therapies II

Supervisor. Eduard Torrents

Research group. Bacterial infections: antimicrobial therapies

Project Description. Control of chronic lung infections and clearance of well-formed biofilms remain tedious and extremely difficult to treat, with only a few therapeutic options nowadays available in clinics. This difficulty in treating infections has become an alarming problem with a global impact currently affecting hundreds of millions of children and adults worldwide. Additionally, and aggravating the problem, most of the biofilm-related infections are caused by multispecies biofilms.

The primary objective of the group is to combine different disciplines, such as nanotechnology, bioengineering, and microbiology to develop new strategies, in terms of diagnosis, personalized therapies and novel therapeutic approaches, against chronic lung infections through development of new drug delivery systems

to remove pre-existing bacterial biofilms and develop mimetic cell biology systems for diagnostic to improve the treatment and bacterial biofilm research.

Our laboratory is multidisciplinary with the use of very different techniques and research fields. The student will be trained in specific cell biology, nanoparticle synthesis and characterization, advanced microscopy, microbiology, and biofilm methodologies. Students from different backgrounds are welcome (biomedical engineering, biology, biotechnology, pharmacy, chemistry, etc.).

Keywords. Nanoparticles, infectious diseases, biofilm, antimicrobials, antibiotic multiresistant

IBEC-2013. Deep Mutagenesis of Prion-Like Domains

Supervisor. Benedetta Bolognesi

Research group. Protein Phase Transitions in Health and Disease

Project Description. Many proteins implicated in neurodegenerative diseases including Alzheimer's disease, Parkinson's disease and Amyotrophic Lateral Sclerosis (ALS), contain Prion-like domains. Prion-like domains are intrinsically disordered regions that can drive proteins to populate multiple physical states in the cytoplasm: diffuse, liquid de-mixed, solid aggregate. Pathological mutations affect these equilibria in ways we cannot yet understand or predict. In this project we will use deep mutagenesis to quantify the effects of all possible mutations in a prion-like domain implicated in ALS. For thousands of protein variants we will measure how mutations affect both the physical state acquired by the protein and its effect on cell viability, thanks to a systematic approach that couples large scale selection assays to high-throughput DNA sequencing. As a result, we will decipher how alterations in protein sequence translate into different physical states and how those can lead to cellular toxicity and disease.

The lab provides opportunities of training ranging from yeast genetics to confocal microscopy and statistical analysis of big data. After discussing with the supervisor, the student will be able to choose which skills to strengthen the most. The student will for sure receive training in performing large selection assays in S.cerevisiae as well as in mammalian cell lines. In addition the student will take part in the analysis of the sequencing data and in the biophysical validation of our findings.

Keywords. Prions, Deep mutagenesis, Liquid Phase Separation, Intrinsic Disorder, Protein Aggregation

IBEC-2014. Nanoscopy for Nanomedicine

Supervisor. Lorenzo Albertazzi

Research group. Nanoscopy for Nanomedicine

Project description. Nanoscopy for Nanomedicine group uses super resolution microscopy (SRM) to track nanomaterials with therapeutic potential in the biological environment and to visualize the interactions with blood components, immune system and target

cells. The understanding of materials-cell interactions is the key towards the development of novel nanotechnology-based therapies for treatment of cancer and infectious diseases.

Super resolution microscopy methods allow to achieve a resolution down to few nanometers and are therefore ideal to visualize nanosized synthetic objects. Super resolution microscopy provides a molecular picture of structure-activity relations and represents a guide towards the design of innovative materials for nanomedicine. Specially, we believe that SRM could be crucial in studying the selectivity and targeting of nanomaterials.

Objectives:

- Characterization of the nanomaterials in vitro using super resolution microscopy.
- Study the targeting effect of the nanomaterial comparing its interaction with cancer cells or healthy cells using super resolution microscopy.
- Computational simulations to model drug delivery.

The student will be trained in:

1. The synthesis of functional nanoparticles and nanofibers
2. Learning the use of super resolution microscopy
3. The biological evaluation of the nanoparticles efficacy for drug delivery

Keywords. Nanoscopy, Nanomedicine, drug delivery, super resolution microscopy

IBEC-2015. Developing organ-on-a-chips for the study of diabetes type II

Supervisor. Javier Ramón Azcón

Research group. Biosensors for Bioengineering (B4b)

Project Description. "Biosensors for Bioengineering group (B4b) is a multidisciplinary research group, led by Prof. Javier Ramon, focused in the development of Organs-on-a-Chip. One of our lines of research aims to engineer a new in vitro model to mimic the insulin-mediated skeletal muscle glucose metabolism. To this aim, muscle tissues and pancreatic islets will be engineered and combined in a multi-organ-on-a-chip approach to study the insulin secretion of pancreatic islets and the glucose-induced contraction of muscle tissues. In a multidisciplinary approach, we will make use of micro- and nanoscale fabrication technologies developed by our research group and will integrate novel biosensing technology to monitor metabolic processes relevant in diabetes. Engineered tissues will benefit from novel scaffolds and will be integrated with bioreactors, an electrical stimulator and biosensors to detect the glucose consumption, myokine secretion from skeletal muscle cells, insulin production and effects of some target drugs for T2D treatment on both tissues.

Objective 1. Skeletal muscle-on-a-chip. Functional skeletal muscle tissues will be engineered using micro- and nanoscale fabrication technologies with muscle precursor cells combined with hybrid biomaterials as scaffold. Engineered muscle tissues will be integrated with biosensors on a microscale chip for in vitro

monitoring of their contraction induced by glucose metabolism and their protein production.

Objective 2. Pancreas islets-on-a-chip. To engineer fully functional pancreatic islets microscale technology and integrate them with biosensors on a microscale chip for in vitro real-time monitoring of their functionality.

Expected training outcome:

- learn biomaterials synthesis and characterization (SEM, mechanical analysis, swelling)

- learn cell culture and manipulations

- 2D/3D biomimetic culture assays (3D bioprinting) and encapsulation of cells in scaffolds (tissue engineering)

- learn fluorescent microscopy methods (fixed and live cells)

- lab-on-a-chip technology and Biosensors (optical transduction and electrochemical)"

Keywords. Organs-on-a-Chip, tissue engineering, biosensors, 3D bioprinting, biomaterials

THE INSTITUTE OF PHOTONIC SCIENCES (ICFO)

ICFO-2001. Live Cell Superresolution Microscopy & Embryonic Stem Cells

Supervisor. Stefan Wieser

Research group. Live Cell Superresolution Microscopy & Embryonic Stem Cells

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 onto the behaviour of early embryonic stem cells (ES cells) and immune cells under physical force to understand the fine-tuned mechanisms providing tissue homeostasis, normal development and cell differentiation under complex environmental conditions. One objective is to unravel the mechanosensation of the nucleus which has recently been realized as a mechanosensation platform regulating transcription and cell differentiation. The second objective is to unravel the actomyosin-plasma membrane contribution in compression induced cell transformation and migration competence. Our recent work highlighted profound changes in cortical actin network organization and myosin II-mediated cellular contractility under compression that triggered rapid changes in cell morphology and migration competence (Ruprecht et al, CELL 2015). 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 behaviour.
In this highly interdisciplinary research within the BIST master program you will learn the fundamentals of live cell super resolution microscopy using structured illumination microscopy and localization microscopy. In collaborations with the lab of Verena Ruprecht (CRG) you will be trained in handling embryonic stem cells in order to prepare cells for high resolution imaging. Using the recently developed piezo driven microconfiner to compress cells and isolated nuclei you will image cortical actin/myosin and membrane constituents as well as nucleoskeleton elements at single molecule resolution. This approach will allow you to identify key control mechanisms regulating mechanosensation competence and will enable you to build quantitative and predictive models of dynamic cell transformation, migration behaviour and cell differentiation.

Keywords. Microscopy, Superresolution, Stem Cells, Mechanosensation, Modeling

ICFO-2002. Medical Optics I

Supervisor. Turgut Durduran

Research group. Medical Optics

Project Description. ICFO-Medical Optics group developed techniques based on near-infrared diffuse optics that are being translated to the clinics to measure tissue physiology in neuro-critical care and in oncology. These devices deliver laser light and detect the diffuse photons in order to calculate the laser speckle statistics. These statistics are then analysed by a physical model of photon propagation in tissues to quantify parameters such as microvascular blood flow. In this project, we will test next generation single-photon counting avalanche photo-diodes developed in collaboration with IFAE as highly-sensitive fast detectors. If successful, these detectors will pave the way to next generation novel systems.

The minor project will be at IFAE in design and testing of these detectors.

The expected training outcome is a trans-disciplinary experience in biomedical optics, novel detector technologies and in translational aspects of introducing new technologies to clinical use.

Keywords. biomedical optics; singlephoton detectors; biophotonics

ICFO-2003. Medical Optics II

Supervisor. Turgut Durduran

Research group. Medical Optics

Project Description. How does the cerebrovascular reactivity vary over days and weeks? Non-invasive, longitudinal diffuse optical neuro-monitors based on diffuse correlation spectroscopy and near-infrared spectroscopy allow us to study this topic and relate to our findings on pathological conditions (ischemic stroke, traumatic brain injury, carotid stenosis and chronic sleep apnea). This project will study this aspect by measuring healthy volunteers and carry out diffuse optical data analysis, biostatistical analysis and define the healthy variation.

Keywords. neuroimaging; laser speckles; biomedical optics; diffuse optics.

ICFO-2004. Medical Optics III

Supervisor. Turgut Durduran

Research group. Medical Optics

Project Description. Validation and testing of compact components for diffuse correlation spectroscopy analysis and define the healthy variation.

Keywords. Neuro-monitoring, biomedical optics, diffuse optics, medical devices.

ICFO-2005. Medical optics group IV

Supervisor. Turgut Durduran

Research Group. Medical Optics

Project Description. Diffuse optical instrumentation for translational and clinical biomedical research: develop state-of-the-art biomedical instrumentation for translational and clinical research. These range from portable, hybrid systems that combine diffuse correlation spectroscopy (DCS) with near-infrared diffuse optical spectroscopy (NIRS-DOS) to laser speckle based animal images. We have industrial, biomedical and clinical relationships that drive the specifications of these systems.

Keywords. Biomedical - diffuse correlation spectroscopy

ICFO-2006. All-optical interrogation of synaptic transmission in C elegans

Supervisor. Michael Krieg

Research group. Neurphotonics and Mechanical Systems Biology

Project Description. Proper localization and activity of synaptic proteins is critical for neuronal communication and synaptic transmission. Mutations in the transmission machinery responsible for various congenital diseases, including ALS and neuropsychological disorders. Here we propose to use C elegans as a model system to understand how mechanical properties of neurons influence synaptic transmission at the neuromuscular junction (NMJ). We specifically ask the question whether or not structural components of the synaptic cytoskeleton, such as microtubules and the actin/spectrin cytoskeleton are involved in signal transmission. To understand this problem, we will take advantage of an all-optical interrogation, in which we selectively activate motorneurons optogenetically using novel light-gated ion channels, while reading out muscle activation by genetically encoded reporters for voltage and calcium activity. We will first record muscle signals after a careful titration of a controlled number of photons and later repeat these measurement in animals forced into given body postures. Once we charazterized the dose-response curve, we will expand these analyses into specific disease models of muscular dystrophies of synaptic transmission mutants hypothesized to involve changes in the synaptic cytoskeleton.

The selected applicant will learn basic method in C elegans maintenance and optogenetics. She/He will also learn how to handle microfluidic devices to impose given body postures to living animals and use photonic tools to measure photon numbers at the focal plane during the optogenetic delivery protocol. All disciplines are welcome to apply, but a basic understanding of image processing and microscopy is useful.

Keywords. Synaptic Transmission, Optogenetics, Photonics, Calcium Imaging, Neuroscience

ICFO-2007. Engineering superconductivity in twisted bilayer graphene.

Supervisor. Adrian Bachtold

Research group. Bachtold group

Project Description. Two-dimensional (2D) monolayers have generated a huge research interest in the past years. The discovery of graphene was awarded with the 2010 Nobel Prize in physics. Very recently, it was realised that twisted bilayer graphene represents a promising platform for understanding the elusive properties of unconventional superconductivity. Better understanding high-temperature superconductors may allow physicists to reach superconductivity at room temperature. This would likely have an enormous impact on our society, since it could dramatically reduce energy consumption in many devices and electricity distribution. Here, we propose to explore new types of twisted bilayer graphene devices in order to understand how superconductivity emerges from the strong correlation between electrons.

When two graphene lattices are overlaid and tilted, they can interfere to create a moiré pattern with a long period. At a small angle of about 1.1°, it was showed that the twisted bilayer graphene stack becomes superconducting. At this "magic" angle, the energy dispersion of electrons becomes flat and the electron-electron interaction parameter becomes large. By tuning the carrier density, the twisted bilayer graphene stack becomes a Mott insulator. These properties are similar to those of cuprates and other high-temperature superconductors. Graphene has two key advantages compared to these materials. First, the band structure of monolayer graphene is simple and well understood. Second, the Fermi energy can be tuned by simply adjusting the voltage applied to the gate electrode in order to characterize the whole phase diagram of electrons. The goal of our research is to fabricate new types of electrical devices based on twisted monolayers in order to understand the physics that leads to superconductivity

Keywords. Superconductivity, twisted bilayer graphene, cryogenics, nanofabrication, electrical measurements

ICFO-2008. Hot Atoms 1

Supervisor. Morgan Mitchell

Research group. Atomic Quantum Optics

Project Description. "Our group studies the interactions between light and the quantized electronic states of atoms. Ground electronic states of alkali atoms in the gas phase, in particular, can be extremely sensitive to magnetic fields. Using knowledge of the atomic physics, we investigate how these systems can be used as "magnetometers" to detect and measure weak magnetic fields, yielding a noise floor as low as 10^(-15) tesla. The term "weak" is relative to both present technological limits and fundamental quantum limits of existing magnetic sensors.

We seek to develop atomic magnetometers in several areas. Current projects in our lab include: (i) Development of microfabricated alkali vapor magnetometers, targeted at wearable magnetoencephalography (MEG) devices that localize the sources of neural currents in the brain; (ii) testing "quantum enhancement" approaches, such as polarization squeezing, that have the potential to surpass standard quantum noise limits in magnetometers; (ii) application of alkali-atom magnetometers to detect nuclear magnetism and nuclear magnetic resonance (NMR) signals in the sub-earth's field regime for spectroscopy and chemical analysis.

The student will have the opportunity to learn about cutting-edge devices in quantum sensing and magnetometry within the environment of an international research team. The project will provide a strong experimental element involving some combination of building, modifying and operating a rubidium magnetometer, to address a scientific question. The project may also require simulations of the atomic physics behaviour on a computer. The students will also develop transferable skills in programming (C/C++) data processing (python), computer-aided design and report writing."

Keywords. Magnetometry, Atomic sensors, Rubidium vapors, Quantum optics, Magnetic Resonance

ICFO-2009. Quantum simulation with ultracold atoms

Supervisor. Leticia Tarruell

Research group. Ultracold Quantum Gases

Project Description. "In recent years ultra-cold atomic gases have emerged as a novel platform for the study of quantum many-body systems. Exploiting these gases, it is possible to synthesize quantum matter of highly controllable properties (interactions, dimensionality, potential landscape, etc.) in table-top experiments. In our group, we use them to explore experimentally collective phenomena originally studied in condensed-matter physics, such as superfluidity, superconductivity, magnetism, or topological order.

Our group has currently a fully operational quantum gas apparatus. There, we focus on the study of two-component potassium Bose-Einstein condensates with adjustable interactions, with two major research lines. On the one hand, we create ultra-dilute quantum liquids in Bose-Bose mixtures. These liquids are eight orders of magnitude more dilute than liquid helium, and form droplets that are self-bound in the absence of any external confinement. Their existence is a direct manifestation of quantum fluctuations in very weakly interacting systems, which makes them ideal testbeds for understanding the role of quantum correlations in quantum many-body physics [Cabrera et al., Science 359, 301-304 (2018)]. On the other hand, we generate artificial gauge fields for neutral atoms, and make them behave as if they were charged particles. We have very recently realized a vector potential that is not static, but instead displays a back-

action from matter. This allows us to generate exotic chiral solitons, which only exist when moving along one direction. Our long-term goal here is to engineer dynamical gauge fields in the laboratory.

In summer 2019, we started the construction of a second experimental apparatus. In this project, we aim at realizing artificial solids exploiting ultracold strontium atoms trapped in optical lattices – artificial crystals of light created by interfering laser beams – and manipulating and imaging them on the single-atom level. In the future, we will exploit this setup to both mimic strongly correlated materials (such as high-temperature superconductors and fractional quantum Hall systems), and to explore collective effects in atom-photon interactions.

We offer Master thesis projects on the two experiments. They will be focused on the design and development of a sub-system to be integrated in the experimental apparatus. For these projects, we are looking for candidates with a good background in quantum optics, atomic physics or condensed-matter physics, and a strong motivation for setting up and conducting challenging experiments in a team of three to four people. We offer training in a broad range of cutting-edge experimental techniques (from optics, electronics, ultra-high vacuum technology and computer control to quantum state engineering), as well as in theoretical atomic, quantum, statistical, and condensed matter physics.

Keywords. Quantum gases, quantum optics, atomic physics, quantum simulation

ICFO-2010 Single-molecule microscopy tools to study intra-Golgi membrane traffic

Supervisor. Maria Garcia-Parajo

Research group. Single Molecule Biophotonics

Project Description. We are an interdisciplinary group studying intracellular membrane morphology and dynamics, with a special focus on understanding the secretory pathway. We combine advanced microscopy techniques (single-molecule fluorescence and super-resolution nanoscopy), molecular and cell biology tools, with theoretical biophysics approaches to tackle highly controversial or still mysterious fundamental topics in cell biology with a clear pathophysiological relevance.

This MSc project will verse on understanding the dynamics of the Golgi complex. The Golgi complex is the central organelle responsible of protein transport to various parts of the cell and the post-translational modification of newly synthesized proteins from the endoplasmic reticulum required for their maturation. The Golgi complex is made up of a stack of flattened membranous cisternae, each of which has a different biochemical composition allowing for the sequential modification of the secretory proteins while they traffic across the Golgi stack. However, the study of intra-Golgi membrane dynamics using conventional microscopy tools has been challenging due to their highly dynamic nature and reduced dimensions. As a result, a clear understanding of the how proteins are transported between the different Golgi cisternae is still lacking. Nonetheless,

different models have been proposed and one of the major discrepancies between the main ones is that they predict a different content of intra-Golgi transport carriers. Do they transport secretory cargoes forward (vesicular transport model) or do they move Golgi-resident enzymes backwards (cisternal maturation model)?

The role of the MSc student will be to perform a set of innovative assays that combine different avant-garde molecular and cell biological techniques, such as the retention using selective hooks (RUSH)-system, with state-of-the-art microscopy and nanoscopy tools, such as STED, STORM or intracellular single particle tracking (iSPT). The data obtained will be analysed using advanced quantitative imaging analysis to finally cast light on how intra-Golgi membrane traffic works.

Keywords. Intra-Golgi transport / Cargo wave synchronization / Super-resolution microscopy / Single particle tracking

ICFO-2011. Attosecond Molecular-movies with Inner-Shell Electrons

Supervisor. Jens Biegert

Research group. Attoscience and Ultrafast Optics

Project Description. The aim of our research is the development of tools and establishment of methodologies for investigation of the ultrafast events that are caused by electrons inside atoms, molecules, solids and biological matter. The power of attoscience and ultrafast optics lies in the incredible time resolution that gives access to observing the triggering events that are caused by electronic rearrangement and ultimately lead, at hugely varying temporal scales, to molecular dissociation, chemical reactions, excitonic energy transfer or even biological function.

We regularly offer projects within the various research fields and projects of our group.E.g., if you would like to discover extreme nonlinear optics and ultrafast lasers or if you are interested in attosecond dynamics, this is the place to ask! We also have several projects related to numerical simulations, electronic circuit design and data acquisition. You will join our research group and take part in the daily activities, discuss your project, research literature, propose a way to realize some tasks and present your work.

Keywords. Attoscience, Ultrafast Lasers, Extreme Nonlinear Optics

ICFO-2012. Real time 3D video tracking of nanoparticle motion confined in an optical trap

Supervisor. Michael Krieg

Research group. Neurophotonic & Mechanical Systems Biology

Project Description. The group recently set up an optical trapping platform for mechanical manipulation of nanoparticles in aqueous solutions. In order to infer and measure forces in this configuration, tracking of the particles with angstrom accuracy is of utmost importance. During this project, the successful applicant will work with experienced users to implement a camera-based video tracking of xyz motion of nanoparticles, with the aim to

perform real-time force and displacement measurements on immobilized biomolecules and cells. During the master thesis, the applicant will learn the essentials of optical trapping and LabView programming. Opportunities to collaborate with other BIST centres (IBEC, CRG) are available. A strong computational background and basic knowledge in instrument automation is a plus.

Keywords. optical tweezer, mechanobiology, video tracking, neuroscience

ICFO-2013. Frontiers of Quantum Information Science, Quantum Simulations and Many Body Physics

Supervisor. Maciej Lewenstein

Research group. Quantum Optics Theory

Project Description. The MSc student will join one of the running research projects in the ICFO-QOT. The concrete choice will depend on the current efforts in the group (that change adjusting to scientific needs), student's preferences and preparation, availability of supervisor/co-supervisor and resources for a specific theme. At this stage ICFO-QOT can absorb one MSc student in this area. QOT-ICFO studies and develops in particular

1) General mathematical theory of quantum correlations, with focus on quantumness, coherence, entanglement and non-locality of states of many body systems.

2) Relations between quantum many body phenomena (quantum phase transitions, quantum criticality, quantum localization, superconductivity, isolating states, topological order and topological phenomena.

Keywords. quantum information, quantum simulations, many body physics

ICFO-2014. Cavity quantum electrodynamics

Supervisor. Frank Koppens

Research group. Quantum Nano-optoelectronics

Project Description. This project will explore the extreme limits of light-matter interactions. We exploit the ability to confine light to subwavelength cavities able to confine light to extremely subwavelength volumes on the order of just a nanometer. This unprecedented degree of confinement, as we have demonstrated very recently, gives rise to very high fields and dramatically enhanced coupling between the cavity modes and nearby quantum entities. The goal of this research project will be to investigate the resultant quantum behaviors enabled by these cavities with spectrally resolved optical measurements. The objective is to touch upon the unexplored physics of the ultra-strong coupling between light and matter. The master's student will acquire optical measurement and nanofabrication skills, working on cutting edge experimental research.

Keywords. Polaritons, QED, Nanophotonics, ultra strong coupling

ICFO-2015. Hyperfocusing infrared light for sensitive photodetection

Supervisor. Frank Koppens

Research group. Quantum Nano-optoelectronics

Project Description. Graphene based photodetectors have been proposed as an alternative of current technologies due to its broad band absorption properties ranging from visible to terahertz range, low electronic heat capacity and its hot electron cooling time in the picosecond timescale [1], which enables graphene as an interesting platform for ultrafast photodetection. In this work, propose to combine graphene pn junctions photodetectors [2, 3] with metallic nanostructures that serve as launchers-guiders for hyperbolic phonon polaritons to achieve hyperfocusing of the incident mid-infrared light and to boost light-matter interactions. We will use 2D materials that present long lifetimes polaritons, such as hBN and MoO3 [4].

The goal of the thesis is to develop a novel platform for infrared photodetection for exploring fundamental and applications aspects that can be used in a wide range of areas (molecular sensing, optical communications, etc.). The photodetectors will be characterized by optical techniques including scanning near-field optical microscopy (s-SNOM). The student will be able to use current state-of-art tools for nanofabrication of the photodetectors, Van der Waals heterostructure assembly of two-dimensional materials and to perform opto-electronic measurements in the mid-infrared (mid-IR) range. The student will take advantage of previous work performed by the group in this field [2, 3, 4].

References:

[1] Koppens et al. Nature Nano. 9, 780-793 (2014)

[2] Castilla et al. Nano Lett. 19, 5, 2765-2773 (2019)

[3] Castilla et al. In preparation (2019)

[4] Woessner et al. npj 2D Mater Appl 1, 25 (2017)

Keywords. photodetection, nanophotonics, 2D materials, graphene

ICFO-2016. Single photons from two-dimensional materials

Supervisor. Frank Koppens

Research group. Quantum Nano-optoelectronics

Project Description. Very exciting quantum optical properties of materials that are only one atom thick have been discovered only during the last few years. These so-called two-dimensional materials showed, surprisingly, emission of light photon-by-photon, instead of a continuous photon stream. This single photon emission has so far not been fully controlled.

This project aims to generate single photon sources in 2D materials in a controllable manner. Several approaches will be investigated, including the shaping and patterning of the materials. The project, which will be carried out with a PhD student or postdoc, involves the manipulation of the materials, the

measurements of photoluminescence at low temperatures and the analysis of experimental data.

This project is a step forward in the realization of on-chip quantum devices for quantum integrated photonic circuits to facilitate the development of secure quantum communication protocols, the scaling up of quantum computers and simulators, and the invention of novel quantum sensing applications.

This project is part of the Quantum flagship, a 1000 Million Euro initiative by the EC to bring quantum technologies to high maturity.

Keywords. 2D materials, quantum emitters

INSTITUTE OF CHEMICAL RESEARCH OF CATALONIA (ICIQ)

ICIQ-2001. Machine Learning Techniques in Electro-Catalysis

Supervisor. Núria López

Research group. Theoretical Heterogeneous Catalysis

Project Description. The project will be devoted to explore several different types of machine learning techniques to materials that can be employed as electrocatalysts to reuse CO2 and thus mitigate climate change.

Keywords. Machine learning; Density Functional Theory, CO2 reduction; energy; programming

ICIQ-2002. Nanomaterials for energy applications

Supervisor. Emilio Palomares

Research group. Photoactive Materials

Project Description. The group's research is focussed in photoactive materials for energy and biosensing applications. Currently the projects where the applicant can work will be perovskite solar cells or biosensing for infectious diseases. The applicant will learn how to prepare and characterize materials with optical and electrical properties. Moreover, the applicant will prepare and measure devices. The applicant will benefit of an outstanding multidisciplinary environment with chemists, physicists, biologists and electronic engineers.

Keywords. perovskite, solar cells, quantum dots, biosensing

CATALAN INSTITUTE OF NANOSCIENCE AND NANOTECHNOLOGY (ICN2)

ICN2-2001. Advanced Electron Nanoscopy

Supervisor. Jordi Arbiol

Research group. Advanced Electron Nanoscopy (GAeN)

Project Description. Quantum technology is supposed to be the biggest revolution that has to happen on the next few years, implying a wide range of fields such as computational and health sciences, energy applications and even the generation of extra-secure communications and encrypting. It will come to stay and deeply change everyone's life. This project aims to focus on the materials science that is behind quantum computation. However, multiple approaches that compete with each other, (as are carried and sponsored by the main computation companies, i.e. Microsoft, Google, IBM, Intel) are being pursued in order to reach the final common goal of the process, which is the fabrication of a fully functional and commercial quantum computer.

Our research group is closely collaborating with Microsoft on its particular approach to achieve this enormously ambitious goal, which is taking advantage of Majorana pairs as the building blocks for the generation of qubits, which are the fundamental units of information in quantum computation.

According to theoreticians, the configuration that would suit this application the most is the interface between a semiconductor and a superconductor, and an appropriate way to build them is to arrange them in a nanowire, which creates the so-called concept of proximitized nanowires. More concretely, the semiconductor thought to present the best properties would be InSb (although different approaches are being done with InAs, too), and Al or NbTiN are usually used as the superconductor, due to their theoretical transition to topological phase under certain chemical potential and external applied magnetic field conditions. In fact, reaching the material's topological phase is a fundamental requirement to achieve the Majorana Zero Modes (MZMs), and for them to materialize it is mandatory to create thoroughly ordered and epitaxial heterojunctions, as well as perfectly grown materials (as well as specific requirements for each of the materials implied), that avoid the disorder-based scattering that can prevent the transition or even the failure of the topological regime. As mentioned before, the major project would be devoted to the atomic resolution (S)TEM characterization and further structural and elemental analysis of these devices, as a fundamental part of the global process of optimization of the system for the best achievement of the conditions stated previously.

Incredible efforts are being made to avoid the so unwanted decoherence of the electrons and to directly apply the signatures of MZMs (basically conductance peaks) into real devices for quantum computing, as up to date, the total number and stability of the created qubits is not enough for a functional quantum processor. By the way, these qubits are based on binary gates that control the interaction between the Majorana pairs, and it is actually this interaction what can produce the quantum phenomenon based on the superposition of states. Indeed, direct observation of the theoretical properties of the MZMs is still lacking, which is really challenging but encouraging too, to be able to help to achieve this as soon as possible.

The general goal of the project would be the structural and compositional atomic scale analysis, mainly via STEM and related electron spectroscopy techniques of the primordial materials involved in the creation of the Majorana-based qubits. In this way, the initial data obtain will help to perform a structural and atomistic modelling of these nanostructures, in order to achieve a higher understanding of their nature and how the nanofabrication processes affect their integrity, obtaining a deep knowledge on their growth mechanisms and further physical properties. All the knowledge obtained will eventually give useful feedback to the device's manufacturers that will help to create higher quality devices and more stable quantum states.

Keywords. Quantum nanomaterials, atomic models, scanning transmission electron microscopy

ICN2-2002. Atomically precise graphene nanostructures for optoelectronics

Supervisor. Aitor Mugarza and Cesar Moreno

Research group. Atomic Manipulation and Spectroscopy Group

Project Description. Our group aims to understand and manipulate electronic, magnetic and optical phenomena at the atomic scale, with the final goal of searching for new ways to sense, and to store and process information. The project proposed here focuses on developing methods to tailor graphene's properties by nanostructuration.

Graphene is a gapless, diamagnetic semimetal. However, shaping graphene at the nanoscale, doping, and controlling the atomic structure of their edges can lead to magnetism, or to the induction of electronic and optical gaps. We nanostructure graphene by growing 2D nanoislands and 1D nanoribbons on metallic surfaces, and explore their singular properties. We later transfer them to insulating templates to test their applicability in electronic and optical devices.

The scientific activity of this project is related to the synthesis and characterization of graphene nanoribbons, with the main objectives being:

- Synthesis of nanoribbons with unconventional edge structure and atomically controlled dopants

- Structural, electronic and optical characterization by scanning tunnelling microscopy and spectroscopy (STM/STS), X-ray photoelectron spectroscopy (XPS), and Raman.

The candidate will be carrying out his own experiments in all task related to the project, always with the help of experienced senior researchers. He/she will gather experience on:

- On-surface self-assembly and chemical methods to synthesize 2D materials

- Scanning tunneling microscopy (STM)

- X-ray photoelectron techniques (XPS)

- Low-energy electron diffraction (LEED)

-Ultra-high vacuum techniques (vacuum components, evaporation of precursors, single crystal preparation...)

Recent related publications of the group:

1. Moreno, C. et al. On-surface synthesis of superlattice arrays of ultra-long graphene nanoribbons. **Chem. Commun.** 54, 9402–9405 (2018).

2. Moreno, C. et al. Bottom-up synthesis of multifunctional nanoporous graphene. **Science** (80-.). 360, 199–203 (2018).

3. Parreiras, S. O. et al. Symmetry forbidden morphologies and domain boundaries in nanoscale graphene islands. **2D Mater.** 4, 025104 (2017).

4. Garcia-Lekue, A. et al. Spin-Dependent Electron Scattering at Graphene Edges on Ni(111). **Phys. Rev. Lett.** 112, 066802 (2014).

Keywords. graphene nanoribbons, atomic scale manipulation, materials synthesis, electronic spectroscopy, scanning probe microscopy

ICN2-2003. Complex Inorganic Nanocrystals For Artificial Photosynthesis, Biogas Production And Fuel Cells

Supervisor. Victor Puntes

Research group. Inorganic Nanoparticles Group

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. In this context, the main idea of the research project is to address the long-term challenge of identifying, designing and producing a new generation of complex NCs that integrate dissimilar materials in a unique multicomponent heterostructured system with controlled architecture and advanced functionality.

Three specific objectives are identified: 1) the production of advanced complex NCs via breakthrough advances in wet chemical synthesis, 2) the unravelling of their structure-activity relationships, in particular a comprehensive study of the relations between synthesis conditions, morphology, architecture and physicochemical properties of the material, and photocatalytic efficiency, and 3) the determination of 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 interdisciplinary knowledge in the design and development of inorganic nanocrystals for energy harvesting and conversion, in particular on their synthesis, characterization and evaluation of their catalytic 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 nanocrystals, artificial photosynthesis, biogas, fuel cells, catalytic performance.

ICN2-2004. Nanoremediation: Emerging-Micropollutants And Nanopharmaceuticals

Supervisor. Victor Puntes

Research group. Inorganic Nanoparticles Group

Project Description. The development of functional colloidal inorganic NCs has increased exponentially offering a "toolbox" ready to be used in a wide range of applications, such as environmental remediation. One important group of compounds and personal care products which are regarded as a rising environmental problem, is pharmaceutical pollutants, which persistence to processes of human metabolism is very high. The development of advanced oxidation process (AOPs) represents a hopeful and effective way for the degradation of pharmaceuticals. Among them, catalysis and photocatalysis using inorganic NCs as an advanced oxidation technique has been a focus of research during the last two decades aiming at improving its performance, robustness and recyclability.

In this context, the main idea of the research project is to design and development synthetic protocols for the colloidal synthesis of complex nanocrystals with advanced functionalities for the efficient catalytic degradation of pharmaceutical pollutants. Three specific objectives are identified: 1) the production of advanced complex NCs via breakthrough advances in wet chemical synthesis, 2) the unravelling of their structure-activity relationships, in particular a comprehensive study of the relations between synthesis conditions, morphology, physicochemical properties of the material, and 3) the determination, in real scenarios, of their efficiency in the catalytic degradation of specific pharmaceutical pollutants.

The research project integrates the development of new synthetic methods with its structural characterization, monitoring of synthesized material properties and the study of its reactivity, including the post-synthetic modifications that take place upon interactions with the surrounding complex environment (aggregation, dissolution, corrosion) with the aim to determine the final NC's

functionality in operando conditions. As a result of this combined study, it is expected to produce robust and easy-to-process NCs in a wide range of sizes, shapes, and configurations that can be directly used for the efficient catalytic degradation of pharmaceutical pollutants.

Keywords. Inorganic nanocrystals, nanoremediation, wet-chemistry synthesis, pharmaceutical pollutants, catalysis.

ICN2-2005. New Transfection Agents And Nanoparticle-Antioxidant Adjuvants For Inflammatory Related Diseases

Supervisor. Victor Puntes

Research group. Inorganic Nanoparticles Group

Project Description. Inorganic nanoparticles (NPs) are emerging as potential probes in next-generation biomedical applications. Among them, cerium oxide nanoparticles (CeONPs) has emerged as a fascinating and lucrative material in biological fields such as bioanalysis, biomedicine, drug delivery, and bioscaffolding. CeONPs have received much attention because of their excellent catalytic activities, which are derived from quick and expedient mutation of the oxidation state between Ce4+ and Ce3+. The cerium atom has the ability to easily and drastically adjust its electronic configuration to best fit its immediate environment. Being a mature engineered nanoparticle with various industrial applications, CeONP was recently found to have multi-enzyme, including superoxide oxidase, catalase and oxidase, mimetic properties that produce various biological effects, such as being potentially antioxidant towards almost all noxious intracellular reactive oxygen species.

The general purpose of this project is to design and develop CeO2 NPs, study their catalytic mechanisms, multi-enzyme-like activities, and potential applications in biological fields. The specific objectives involve: i) the controlled high yield synthesis of these NPs, in particular their uniformity in size and chemical composition, ii) their functionalization with specific biomolecules, iii) the study of their physicochemical stability (aggregation, corrosion, dissolution and protein corona) after dispersion in biological environments and iv) the evaluation of their use in inflammatory related diseases.

As a result, the candidate will be specifically trained to gain 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. CeO nanoparticles, biomedicine, nanoenzimes, inflammation, catalysis.

INSTITUTE FOR HIGH ENERGY PHYSICS (IFAE)

IFAE-2001. Enhanced ATLAS Level-1 trigger capabilities with Artificial-Intelligence regression on Field-Programmable Gate Array architecture.

Supervisor. Imma Riu and Nicola Orlando

Research group. IFAE-ATLAS

Project Description. The ATLAS trigger system is a crucial component of the experiment. It is responsible for selecting events of interest at a recording rate of approximately 1 kHz from up to 40 MHz of collisions at the Large Hadron Collider (LHC). The Level-1 (L1) trigger is the first rate-reducing step in the ATLAS trigger system with an output rate of up to 100 kHz and decision latency of less than 2.5 microseconds. In the L1 system, an important role is played by the Level-1 Topological Processor (L1Topo). It selects interesting events by applying kinematic and angular requirements on electromagnetic clusters, hadronic jets, muons and total energy reconstructed in the ATLAS apparatus. This results in a significantly improved background event rejection rate and improved acceptance of physics signal events. During the current LHC shutdown, upgraded L1Topo modules are being installed benefiting from a larger processing power available for the implemented algorithms. They exploit the latest generation of the Xilinx Ultrascale+ FPGA, XCVU9P-2FLGA2577E, characterized by large input bandwidth, up to ~3Tb/s per module, and large processing power. The objective of this research project is to improve the event reconstruction at L1 by using state-of-the-art Artificial Intelligence (AI) algorithms to solve regression tasks; the event properties are inferred by training a suitable AI model on bitwise data representing the recorded event in the ATLAS detector prior to the high-level reconstruction. The AI model will use the L1Topo capability for fast evaluations in a single FPGA operation by means of look-up tables.

Keywords. ATLAS, detector, physics, Hadron collider

IFAE-2002. Impact of high-granularity timing detectors in the search for the Standard Model Higgs boson produced in the vector boson fusion process and decaying into a pair of tau leptons

Supervisor. M. Pilar Casado

Research group. IFAE-ATLAS

Project Description. The ATLAS experiment will start a phase with high intensity data collection in 2025. The amount of recorded data will be increased by a factor 10. Specialized detectors will be placed to cope with the new conditions, specially to handle the overlap of different events in the same beam-crossing, pile-up. The high granularity timing detector (HGTD) will be one of these detectors, located at ±3.5m from the interaction point, with inner radius 12 cm and outer radius 64 cm. HGTD will provide timing measurements of charged particles from the interaction cross and will help in jet algorithms,

particle reconstruction and in b-tagging. Furthermore, the impact of HGTD is currently being evaluated in physics analyses where the presence of jets is important in the forward region, as Higgs produced in vector boson fusion with taus in the final state. The student will implement the analysis for a pair of taus produced in the above process decaying into a lepton and a hadron. The analysis will be cross-checked with on-going Run 2 studies. Finally, the effect of HGTD will be assessed and the results will be part of an ATLAS publication covering VBF H -> tau tau with taus decaying to all possible topologies.

Keywords. ATLAS, detector, physics, Higgs, CERN

IFAE-2003. Commissioning of the first Large-Size Telescope of the Cherenkov Telescope Array

Supervisor. Oscar Blanch and Abelardo Moralejo

Research group. GAMMA RAYS

Project Description. The Cherenkov Telescope Array (CTA, https://www.ctaobservatory.org) is the next generation ground-based observatory for gamma-ray astronomy at very-high energies (from 20 GeV to > 100 TeV). The gamma-ray astrophysics group at IFAE has played a leading role in the construction of the first of the four large-size telescopes of CTA-North observatory, dubbed LST-1, which was inaugurated on October 10th 2018 at the Roque de los Muchachos in the island of La Palma (https://phys.org/news/201810-telescope-cherenkov-array-sitedebut.html). LST-1 is equipped with a 23-m diameter dish, and is the most advanced telescope of its kind worldwide. The telescope is currently in its commissioning phase, which is expected to extend until mid-2020. The goal of this master thesis project is to contribute to the analysis of the first scientific observations of the LST-1 telescope, particularly those of known bright gamma-ray sources, with the purpose of fully characterizing the instrument's performance. We are searching for a student with good programming skills, preferentially with some experience in the use of Python.

Keywords. Gamma ray, physics, Cherenkov Telescope Array

IFAE-2004. Quantum annealing with coherent superconducting qubits

Supervisor. Pol Forn

Research group. QUANTIC

Project Description. Quantum annealing is a technique developed to perform adiabatic quantum computing in a real, open quantum system. The computation typically involves evolving the Hamiltonian of the system from an initial trivial scenario towards a more complex final one. The final state of the system can be mapped to the value of a given cost function. The final Hamiltonian of the system is built in such a way that its lowest energy eigenvalue corresponds to the minimum of the cost function, thereby obtaining the solution to a certain optimization problem codified in the values of the cost function. This type of quantum algorithm is very versatile and does not require quantum

error correction. A quantum annealer is thus considered an analogic quantum computer with a big potential to display a quantum speedup in the not-so-distant future. Superconducting quantum bits are ideal candidates to be building blocks of quantum annealers. The tunability of their parameters, the flexibility to scale up to large-sized systems combined with their long coherence times, make superconducting qubits a suitable choice to embed adiabatic quantum computing protocols. The IFAE group on Quantum Computing Technology started to operate in 2019 with the goal to develop a quantum annealing prototype using superconducting qubits as its core technology. This project will focus on joining the efforts to build the first generation of prototype quantum annealers consisting of two superconducting flux qubits coupled through an rf-SQUID coupler. The MsC candidate will join the team efforts in circuit design, device characterization and measurements. The main goal is to obtain evidence of quantum annealing performed with two superconducting flux qubits with a long coherence time.

Keywords: Quantum computation, superconducting qubits, quantum annealing

IFAE-2005 Large-scale correlations and cancer cell metastasis

Supervisor. Rafel Escribano and 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

IFAE-2006 Fractal dynamics and cancer growth

Supervisor. Rafel Escribano and 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

IFAE-2007 Avalanche Photodiodes for Medical Diffuse Optics

Supervisor. Sebastian Grinstein

Research Group. IFAE Instrumentation Group

Project Description. "Medical diffuse optical methods utilize near-infrared light to probe into the tissues and obtain information about its absorbers and scatterers. The diffuse light carries information about the movement of red cells which can be used to measure blood flow. In this relatively new technique a laser shines light into the subject tissue and an extremely sensitive detector extracts the signal to obtain the desired measurements. However, to date, these systems are limited by the sensor technology, they are not cost-effective, they are bulky for wearable implementations and they cannot easily be scaled up.

The IFAE group has ample experience in developing semiconductor detectors for high energy physics experiments. Recently we have been working on monolithic CMOS devices, in which the sensing and signal processing mediums are the same. This technology can also be exploited to develop avalanche photo-diodes, targeting specific designs for diffuse optics. This offers many advantages in terms of cost, robustness and miniaturization.

In the course of this program, the selected candidate will work on the development of the system to operate these novel avalanche photo-didoes, carry out their characterization in the IFAE laboratory and also test them at ICFO on tissue simulating phantoms.

Keywords. Biophotonics, Avalanche photo-diodes, CMOS sensors

IFAE-2008 The PAU Survey: the potential of narrow-band observations for revealing the true panoply of different galaxy types

Supervisor. Malgorzata Siudek

Research Group. Cosmology Group

Project Description. Machine learning techniques will be crucial for the analysis of galaxy populations in the impending era of big data in astronomy. The student will be able to learn about machine-learning, including developing galaxy classification schemes using (un)supervised clustering algorithms. These deep state-of-the-art methods will be applied to the PAU Survey (PAUS), an innovative photometric survey with 40 narrow bands at the William Herschel Telescope. This multi-filter data has the potential to conduct novel galaxy evolution studies allowing for a detailed description of different galaxy types and their properties. Machine learning tools can efficiently extract relevant information from very large and complex datasets such as PAU. In the era of large deep surveys, they are the optimal approach compared to standard methods or color-color diagrams. A solid background in programming is beneficial.

Keywords. galaxies; machine learning

IFAE-2009 Gravitational Waves detection using Deep Learning with LIGO/Virgo data

Supervisor. Mario Martínez

Research Group. VIRGO

Project Description. The discovery of gravitational waves (GWs) by the LIGO/Virgo interferometers has opened a complete new field for testing fundamental physics and cosmology. Events are interpreted as originated from the coalescence of binary systems made of black holes and/or neutron stars. The detail study of such events provides a unique opportunity to perform stringent tests of general relativity, the potential identification of primordial black holes as candidates for dark matter, and the study of the early universe via GW signals from inflation. In addition, in the case of neutron star events, the combination with electro-magnetic signals from identified galaxies provides a new an independent measurement of the expansion rate of the universe. The detection of GWs relies on the pattern recognition of the GW signal embedded in the data, which makes it an ideal environment for the adoption of an artificial intelligent approach. In this master thesis, a project is proposed for using state-of-the-art machine learning techniques, in the form of convoluted neutral networks, for the identification of events in the LIGO/Virgo data streams. The project involves the design, training

and optimization of neural networks to discriminate background events from GW signals, using massive simulated signal templates and the full LIGO/Virgo dataset. The work will be developed within the framework of the LIGO/Virgo experiments and in contact with high-performance computing centers.

IFAE-2010 The ESA Euclid Dark Energy Survey

Supervisor. Cristóbal Padilla

Research Group. EUCLID

Project Description. Euclid is a mission for the European Space Agency (ESA) Cosmic Vision (CV) 2015-25 programme to explore how the Universe evolved over the past 10 billion years to address questions related to fundamental physics and cosmology on the nature and properties of dark energy, dark matter and gravity, as well as on the physics of the early universe and the initial conditions which seed the formation of cosmic structure. The satellite is expected to be launched in the first half of 2022 by a Soyuz ST-2.1B rocket and then travel to the L2 Sun-Earth Lagrangian point for a six years mission. To accomplish its goals, Euclid will carry out a wide survey of 15,000 deg2 of the sky free of contamination by light from the Milky Way and the Solar System and a 40 deg2 deep survey to measure the high-redshift universe. The complete survey represents hundreds of thousands of images and several tens of Petabytes of data. With these images Euclid will probe the expansion history of the Universe and the evolution of cosmic structures by measuring the modification of shapes of galaxies induced by gravitational lensing effects of dark matter and the 3-dimension distribution of structures from spectroscopic redshifts of galaxies and clusters of galaxies. In this project, we will use machine learning techniques such as Convolutional Neural Networks to identify the galaxies and improve de-blending algorithms the Euclid simulated images and/or Generative-Adversarial Networks to make fast simulations of images and Cosmologies. This work will serve to prepare the scientific analysis tools and be ready when Euclid produces its first images after launch.

Keywords. Cosmology, Dark Energy, Space, ESA, Machine Learning, Neural Networks, Image Processing, Galaxies, Universe Evolution

INSTITUTE FOR RESEARCH IN BIOMEDICINE (IRB BARCELONA)

IRBB-2001. Development and Growth Control Laboratory

Supervisor. Marco Milán

Research group. Development and Growth Control Laboratory

Project Description. Chromosomal Instability (CIN), defined as an increased rate of changes in chromosome structure and number, is a feature of most, if not all, solid tumours. Our lab has recently developed an epithelial model of CIN in Drosophila where the relevant cell populations and pertinent cell interactions involved in the response of an epithelial tissue to CIN have been identified and where the molecular mechanisms driving emerging, tumour-like, cellular behaviours have started to be elucidated. In this model of CIN, cross-feeding interactions between two well defined populations, highly aneuploid cells and proliferating cells, increase each other size and contribute to the unlimited growth potential of CIN tumours. CIN-induced aneuploidy promotes a cell autonomous epithelial to mesenchymal (EMT)-like cell fate transition associated with a highly invasive behaviour and the entry into a senescence-like state. This senescence-like state is characterized by a cell cycle arrest in G2 and a well-defined senescence associated secretory phenotype (SASP) that includes mitogenic molecules inducing tumour-like overgrowths, and systemic hormones promoting tumour malignancy, as revealed by chronic blockade of developmental timing, cachexia and eventual animal lethality. The active invasive behaviour of highly aneuploid cells is characterized by the expression of Matrix Metalloproteinases (MMPs) and the production of dynamic actin-rich cellular protrusions and membrane blebs.

We are currently combining genomic approaches, life imaging, and high-throughput genetics to identify and functionally characterize the full genetic program underlying the observed cellular behaviours during the initiation and evolution of a CIN tumour. The results will pave the way for the functional identification of the Achilles' heel of most solid tumours.

Master students will be integrated into one of these research lines and directly supervised by the Principal Investigator. The students will have absolute independence to design and experimentally perform their own project, will participate in weekly lab meetings and program seminars, and will gain experience in genetics, advanced microscopy and experimental design.

Keywords. Drosophila as a model in Cancer, Chromosomal Instability, EMT, Senescence.

IRBB-2002. MMB

Supervisor. Modesto Orozco

Research group. MMB

Project Description. We are a group working in the development and application of theoretical methods to describe the function of biological systems. The project we can offer is within our basic research line of study of the connection between DNA physical properties and chromatin functionality. In particular we offer a project on the study of the three dimensional structure of chromatin: Development and validation of multiscale physical models for the representation of DNA and chromatin.

Keywords. Modeling, Chromatin structure, DNA Structure, Bioiphysics

IRBB-2003. Understanding stress adaptation from yeast to mammalian cells

Supervisor. Eulàlia de Nadal

Research group. Cell Signaling

Project Description. "The main focus of our group is to understand how cells detect and respond to environmental changes. We have focused our studies on the characterization of the stress signal transduction pathways, especially those controlled by MAP kinases of the Hog1/p38 family, also known as the stress-activated MAP kinases (SAPK). Using S. cerevisiae budding yeast as a model organism, as well as mammalian cells, we study the molecular mechanisms required to respond to changes in the extracellular environment and which are the adaptive responses required for cell survival. Our main research lines are:

1. SAPK signaling: Using quantitative data in single cells and mathematical modelling, together with mutational analyses, we study the basic signalling properties of stress-responsive MAP pathways and how to alter them.

2. SAPK targets: Using proteomics, biochemistry and genetics, our main goal is to identify new targets for SAPKs and thus widen our understanding of cellular adaptation to stress. This information is expected to facilitate the characterization of the bases of adaptation in eukaryotes. We are also using genome wide CRISPR screening to identify essential genes for stress adaptation.

3. Cell cycle control: SAPKs act in several phases of the cell cycle to allow prompt response to extracellular stimuli and the maintenance of cell integrity. We are uncovering the mechanisms by which Hog1 and p38 SAPKs regulate the cell cycle.

4. Regulation of mRNA biogenesis: SAPKs control critical steps of mRNA biogenesis and are thus key regulators of stress-responsive gene expression. Our main aim is to determine the contribution of multiple factors to overall gene expression in response to stress.

Keywords. Stress adaptation, Signalling, SAPK, single cell analysis, cell cycle regulation, transcriptional regulation

IRBB-2004. Cell Division Laboratory

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 (Nat Rev Cancer, 2013). Over the last years we have made a number of significant contributions to this field. We have found that neuroblasts can originate tumours if the process of self-renewing asymmetric division is disrupted (Nat Genet, 2005). We have discovered that brain tumours that originate in l(3)mbt mutants larvae are characterized by the ectopic expression of "Cancer Testis"/"Germ Line" antigens and showed for the first time that some of those genes are essential for tumour growth (Science, 2010; Open Biol Roy Soc, 2017). Recently we have revealed that l(3)mbt mutant brain tumours are strongly dimorphic, being more aggressive in males than in females. This tendency is in line with what is known for a wide range of human cancer types, for which the striking male predominance remains unexplained. We have found out that Drosophila experimental models of malignant growth may serve to investigate the cell biological axes that control sex-linked tumour dimorphism. We have identified potential regulators of sex-linked tumour dimorphism and showed that these genes may serve as targets to suppress sex-linked malignant traits (Science Advances, 2019). We have also described a method to assay the tumorigenic potential of Drosophila mutant tissues (Nat Protoc, 2015).

Research in our laboratory is fundamentally multidisciplinary, combining the newest molecular biology and genetic analysis methods with biochemistry, genomics, proteomics, electron microscopy, and advanced light microscopy techniques.

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 and analysis.

Keywords. malignant growth, cancer testis antigens, sex-linked tumour dimorphism, Drosophila, cancer therapy

IRBB-2005. Complex metabolic diseases and mitochondria

Supervisor. Antonio Zorzano

Research group. Complex metabolic diseases and mitochondria laboratory

Project Description. A major focus of our laboratory is the analysis of the role of mitochondrial fusion proteins or autophagy partners in the control of energy metabolism, and in the development of pathology. We have recently reported that the mitochondrial fusion protein Mitofusin 2 (MFN2) binds phosphatidylserine and controls the transfer of this phospholipid from the endoplasmic reticulum (ER) to mitochondria. In addition, we have documented that a deficient mitochondrial phosphatidylserine transfer causes chronic liver disease. Based on these

relevant findings we propose to identify additional proteins that participate in the transfer of phospholipids from ER to mitochondria, and to analyse their functional interaction with MFN2.

The Master student will have the opportunity to join a stimulating project and to learn a wide variety of molecular and cell biology techniques, mouse models of disease, and patient-derived samples. The student will work together with postdoctoral fellows, and PhD students, and she/he will have an autonomous project with freedom to design it. The student will participate in weekly laboratory meetings and institute seminars, and will gain experience in experimental design, biochemistry, cell biology and molecular biology.

Keywords. Metabolic diseases, Cancer, Mitochondrial Function, Lipid Metabolism, Autophagy.

IRBB-2006. Signalling and Cell Cycle

Supervisor. Angel Rodriguez Nebreda

Research group. Signalling and Cell Cycle

Project Description. The group is interested in how cells interpret different signals to elaborate the appropriate responses. An important part of the work focuses on the p38 MAPK signalling pathway, and our group has made major contributions to understanding the mechanisms of signal integration by this pathway. We have also provided in vivo evidence for the implication of p38 MAPKs in homeostatic functions, beyond the stress response, and have shown how dysregulation of this pathway may contribute to cancer and other diseases. Recently, we have demonstrated important roles for p38 MAPK signalling in tumour initiation and progression as well as in the resistance to chemotherapeutic drugs using both genetic mouse models and patient-derived xenografts. Our work combines genetically modified mice, which allow the inactivation of p38 MAPK signalling in a regulated and tissue-specific manner, with the use of chemical inhibitors, studies in cancer cell lines and biochemical approaches. Overall, an important aim of our work is the identification of therapeutic opportunities based on the modulation of p38 MAPK signalling.

Ongoing projects in the group address the following topics:

- Cancer cell homeostasis and chemoresistance mechanisms

- Cross talk between cancer cells and stromal cells

- Targeted cancer therapies

Keywords. MAP kinase, signalling network, cancer cell homeostasis, tumour microenvironment, chemotherapy resistance, targeted therapy

IRBB-2007. Biomedical Genomics

Supervisor. Nuria Lopez-Bigas

Research group. Biomedical Genomics Group

Project Description. In addition to contributing to finding drivers of cancer and precision medicine, our group is focused on understanding mutational processes by analysing tumour genomes. By studying the observed pattern of somatic mutations across genomic regions, we are able to explore the basic cell mechanisms that produce them. The interplay between these mechanisms, such as internal and external insults that damage DNA, chromosomal replication, transcription, and DNA repair mechanisms, leads to mutational processes that give rise to heterogeneous patterns of somatic mutations across the genome. Our efforts are now focused on generating nucleotide-resolution genome-wide maps of DNA damage and repair upon exposure to chemotherapeutic agents.

General objectives:

1. Establish alkylating agent toxicity in selected cell lines

2. Generate nucleotide-resolution maps of DNA damage after treatment

3. Obtain mutation profiles upon DNA damage in wild type and DNA repair-mutant cells

Expected training outcomes:

1. Learn how to culture cells and perform toxicity assays

2. Functional validation of DNA damage: immunofluorescence and comet assay

3. Generate DNA repair deficient mutant cell lines by CRISPR/Cas9

Keywords. DNA damage, DNA repair, mutational signature, cancer, chemotherapy

The BIST research centres are:

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