BIST Barcelona Institute of Science and Technology

upf. Universitat Pompeu Fabra Barcelona

Master of Multidisciplinary Research in Experimental Sciences

List of Major Research Projects

2019-2020

CRG Centre for Genomic Regulation · IBEC Institute for Bioengineering of Catalonia · ICFO · ICIQ Institute of Chemical Research of Catalonia · ICN2 Catalan Institute of Nanoscience and Nanotechnology · IFAE Institute for High Energy Physics · IRB Barcelona Institute for Research in Biomedicine

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.

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

DCEXS-1901. 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-1902. 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-1903. Developmental Neurobiology

Supervisor. Cristina Pujades

Research group. Developmental Neurobiology

Project Description. A long-standing goal of developmental biology is to understand how multiple cell types are generated and maintained in highly organized spatial patterns. Our group explores the mechanisms underlying the organization of cells into highly developed structures in the Nervous System, with special attention to the patterning of cell lineages.

The Central Nervous System is initially subdivided into regions with distinct identity that underlies the generation of a specific set of cell types, each of which must arise at the right time and place and in the correct proportions for normal development and function. We focus our studies on the embryonic development of the hindbrain, as a model to study how cellular compartments operate during brain development, and how cell diversity is generated. Our goals are to unveil when and how brain progenitors commit to a given fate, how they behave once committed, and how cell fate decisions are regulated to generate the distinct cell lineages. We use zebrafish embryos as model system because permits functional genetic studies to be combined with 3D+time in vivo imaging.

Keywords. cell specification, cell lineage, Central Nervous System, developmental biology, imaging

DCEXS-1904. 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-1905. Biophysics of the Immune System

Supervisor. Rubén Vicente García

Research group. Biophysics of the Immune System

Project Description. The main interest in our group is to understand the role that ion fluxes play in the immune system physiology, having a special interest in calcium and zinc signalling. The project we offer for a master student is focus on the role of zinc in immune cells. Zinc deficiency is considered a major public health problem worldwide causing an increase of mortality and morbidity by recurrent infections. Zinc is a common structural component of proteins, besides free zinc cellular signals have been also described to influence several signalling cascades. In the laboratory we have generated a T lymphocyte KO model for zinc transporter that fails to activate. In this scenario, despite the strong impact the zinc has on the immune system, there are no clear mechanisms of how this metal exerts its effect in the cell. The main goal of the project is to explore the function and regulation of zinc fluxes in immune cells at cellular and systemic level.

The student will join a team of biophysicists with expertise on ion fluxes monitored by fluorescence microscopy and electrophysiology. During the project the student will learn the basic biophysical language and will be trained in different

techniques to monitor ion fluxes in living cells, including molecular biology techniques, flow cytometry and confocal microscopy. Moreover, the project will require transcriptome data analysis to dissect specific pathways involved in zinc signalling.

Keywords. biophysics, immunology, zinc, transcriptomics.

DCEXS-1906. 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-1907. Laboratory of Molecular Physiology

Supervisor. José Manuel Fernández Fernández

Research group. Laboratory of Molecular Physiology

Project Description. Human mutations in the P/Q-type voltage-gated calcium channel (CaV2.1) cause multiple neurological disorders including both familial and sporadic hemiplegic migraine (FHM/SHM). These mutations induce a gain of CaV2.1 channel function leading to hyper-excitation of neurons in the cerebral cortex to favor initiation and propagation of cortical spreading depression (CSD). CSD is a key process in the origin of migraine: it is the physiological substrate of the migraine aura and it has also been proposed to trigger the headache phase itself. Accordingly, there are pharmacological evidences suggesting that reduction of

CaV2.1 activity (for example by medicinal plants) has therapeutic potential in the treatment of Hemiplegic Migraine (HM) available are peptide toxins. They are not suitable therapeutic tools due to both undesirable side effects and limited utility for in vivo studies.

In collaboration with researchers from the Sussex Drug Discovery Centre (School of Life Sciences, University of Sussex, Brighton, UK), we have identified 6 structurally distinct and novel classes of small organic molecules with higher selectivity for CaV2.1 inhibition (over the blockade of other CaV channels) as prospective hits from which to develop HM therapeutic tools. In particular, one of them does not affect the function of the wild-type (WT) "healthy" CaV2.1 channel at low micromolar concentrations, but it shows inhibitory action on a FHM mutantCaV2.1 disease relevant channel, reducing the gain-of-function induced by the pathogenic mutation.

We now aim to evaluate the consequences of CaV2.1 inhibition by these new compounds on excitatory (glutamatergic) synaptic transmission and CSD using in vitro studies on both primary cultures of cortical neurons and cortical slices obtained from WT and available FHM knock-in mice (expressing FHM mutant CaV2.1 channels), in order to validate their therapeutic potential for future preclinical and clinical studies.

Keywords. CaV2.1 channel, hemiplegic migraine, excitatory glutamatergic synapsis, cortical spreading depression

and the relief of common migraine. At present, the CaV2.1-selective inhibitors

DCEXS-1908. Gene expression in immune cells

Supervisor. Cristina López-Rodríguez and José Aramburu

Research group. Gene expression in immune cells

Project Description. Characterization of gene regulatory mechanisms that confer macrophage population identity. Macrophages are immune sensor cells present in every tissue of the body that play central roles in homeostasis, pathogen elimination, and disease. These cells have the ability to adapt to a multitude of environmental changes, something that is reflected by the specific gene expression signature expressed by each different population of tissue resident macrophages. In this regard, selection and establishment of enhancer elements regulating gene transcription is a dynamic and plastic process in which the activation of intracellular signalling pathways by factors present in a macrophage's microenvironment play a determining role. The enhancer repertoire of these cells underlies both the cellular identity of a given subset of resident macrophage population and their ability to dynamically alter, in an efficient manner, gene expression programs in response to homeostatic and pathologic signals. Notably, transcription is a local and functional process at active enhancers, where enhancer RNAs, or

eRNAs, are tightly correlated with transcription of protein-coding genes. Enhancers also establish physical contacts with key gene regulatory regions under their control, an association that despite being studied extensively using chromosome conformation capture analysis (3C), is still poorly understood at the molecular level. We aim at dissecting novel mechanisms that contribute to the selection and function of enhancers in macrophages. We plan to study how enhancers in macrophages are formed and how they function, and also analyse their connection with the genes they control. This study will lead to a better understanding of human diseases as cancer, autoimmunity and obesity, which are driven by unbalanced macrophage responses.

Keywords. Gene expression, enhancer, inflammation, macrophage

DCEXS-1909. Morphogenesis and Cell Signalling Sensory Systems

Supervisor. Berta Alsina

Research group. Morphogenesis and Cell Signaling Sensory Systems

Project Description. During the formation of tissues and organs, cells change shape, move, interact with other cells and communicate in order to create a 3D organ in which cells are correctly positioned and differentiated. It is still a mystery how cell signalling is coupled with cell components to drive cell behaviours in a coordinated manner. Our laboratory investigates several aspects of organogenesis, in particular of the sensory systems and brain. On one hand we are interested in studying the dynamics of cell rearrangements during organ formation through the combination of 4D imaging and genetic perturbations. We have uncovered new cellular and molecular principles involved in the formation of organ cavities (Hoijman et al., 2015 Nature Commun) and the organization of a neurogenic domain (Hoijman et al., 2017 eLife). On the other hand, we are interested in the deciphering the interaction between vasculature and neurons in development and also in disease (such as stroke) and identify possible factors fundamental for the regeneration of neurons and hair cells (Rubbini et al., 2015). We use the zebrafish as a model system, thanks to its transparency and feasibility to life-image cellular processes, the conservation of fundamental genes, the availability of transgenic lines and mutants and the possibility of generating of new mutants by crispr technology. Finally, the zebrafish has a broader regenerative potential than mammals and thus, by unravelling its regenerative mechanisms, one can hope to extend this knowledge to mammals for a better regeneration.

The Parc de Recerca Biomèdica de Barcelona and Universitat Pompeu Fabra, one of the most dynamic research centres of the south of Europe. The institute counts with a large aquatic, advanced light microscopy and genomic core facilities. Our lab has set up the technology for high spatial and temporal resolution imaging of cell dynamics at the tissue and single cell level. The student will learn the main

principles of tissue and organ formation, will manipulate zebrafish embryos, develop new tools of genetic engineering and gene editing by crispr, learn sophisticated in vivo imaging technologies.

Keywords. Zebrafish, Morphogenesis, Live-Imaging, Crispr, Cell Communication

DCEXS-1910. 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-1911. Live-cell structural biology

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 centered 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-1912. 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-1901. Mechanosensitive cell dynamics

Supervisor. Verena Ruprecht

Research group. Cell and Tissue Dynamics

Project Description. Research in our lab is focused on the control of cell and tissue dynamics in complex 3D environments. We study how cells process mechanochemical information and modulate cellular dynamics during tissue development, morphogenesis and regeneration. Our lab follows a highly interdisciplinary approach combining molecular and cell biology with quantitative live cell imaging and advanced fluorescence microscopy. We use Zebrafish embryos as a model system to study complex three-dimensional tissue rearrangements and patterning in the embryo. Simplistic biomimetic in-vitro assays are further applied to investigate cellular behavior under defined ex-vivo conditions. In this interdisciplinary project, we will investigate the mechanosensitive dynamics of embryonic progenitor stem cells in reconstituted 3D tissue environments. Advanced fluorescence imaging and quantitative image analysis approaches will be applied to study live-cell cytoskeletal dynamics under mechanical stress. Biochemical and pharmacological perturbation screens will further be used to identify signaling pathways involved in cellular mechanosensing and cell motility. Results of this study will provide new insight into the biomechanical regulation of cell dynamics and multi-cellular self-organization during tissue development and morphogenesis.

Key technologies and training outcomes:

- Handling of Zebrafish model system and primary embryonic progenitor stem cells

- 2D/3D biomimetic culture assays

- Quantitative time-lapse imaging of cell dynamics

- Advanced live-cell fluorescence microscopy and image analysis

The project is ideally suited for highly motivated candidates that wish to pursue an interdisciplinary research project in the field of Cell Biology, Developmental Biology and Biophysics. Applicants should have a strong interest in advanced fluorescence microscopy, biomimetic culture assays and quantitative data analysis. Candidates ideally hold a background in Life Sciences, Biophysics or a related subject with proven track record of academic excellence.

Keywords. Zebrafish, Progenitor Stem Cells, Advanced Fluorescence Microscopy, Mechanobiology, Cell Motility

CRG-1902. Transcriptomics of Vertebrate Development and Evolution

Supervisor. Manuel Irimia

Research group. Transcriptomics of Vertebrate Development and Evolution

Project Description. Research in our lab is focused on understanding the roles that alternative splicing and other mechanisms of transcriptomic diversification play during vertebrate embryonic development and adulthood. In particular, we are very interested in learning how a special type of alternative exons, the microexons, contribute to the development and function of our brain. Microexons are highly conserved tiny exons (3-27nt) that are switched on during neuronal differentiation in vertebrates. Microexons impact proteins involved in various aspects of neuron physiology and differentiation, where they sculpt the surfaces of binding domains, often modulating protein-protein interactions in a neuron-specific manner.

Most microexons are specifically regulated by the neural splicing factor nSR100/SRRM4. Knockout mice for Srrm4 show dramatic microexon misregulation and severe neurodevelopmental defects in both the central and peripheral nervous system, and most die soon after birth. Furthermore, microexon alterations have been associated with autism spectrum disorders (ASD) in humans. Interestingly, mice with reduced levels of Srrm4 expression recapitulate many hallmarks of ASD, including altered social behaviour. However, which specific microexons are responsible for these behavioural defects remains unknown.

To identify these microexons, we have developed a CRISPR-Cas9 KO screen in zebrafish, generating so far over 20 lines in which individual conserved neural microexons have been deleted. Among several other phenotypic analyses, our main goal is to test these mutants for defects in social behaviors. The proposed Master project will therefore involve working together with a PhD student that has set up in the lab a battery of experimental tests to analyze alterations in social interactions, locomotion, anxiety, stimulus-sensing response among others. The project will allow the candidate to learn how to work with zebrafish as a model organism (genetics and manipulation), how to perform different behavioral assays, and to analyze, interpret and discuss the data.

References

https://www.ncbi.nlm.nih.gov/pubmed/25525873

https://www.ncbi.nlm.nih.gov/pubmed/27984743

https://www.ncbi.nlm.nih.gov/pubmed/28193864**Keywords.** transcriptomics, autism, zebrafish, development, neurobiology

CRG-1903. Computational Biology of RNA Processing I

Supervisor. Roderic Guigó and Sílvia Pérez-Lluch

Research group. Computational Biology of RNA Processing

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

Keywords. Chromatin, Transcription, Alternative Splicing, Differentiation, Development

CRG-1903. Computational Biology of RNA Processing II

Supervisor. Roderic Guigó

Research group. Computational Biology of RNA Processing

Project Description. The student will be in charge of expanding/optimizing our RNA sequencing data analysis pipeline, developed in-house as part of the international GENCODE project (https://www.gencodegenes.org/). In order to complete the reference GENCODE annotation catalog of human genes, our lab is generating massive amounts of cDNA sequencing data, using Capture Long-Seq (http://dx.doi.org/10.1038/ng.3988) coupled with the PacBio and Oxford Nanopore platforms. Our data processing pipeline consists in a python-based Snakemake workflow (https://github.com/julienlag/LR-Seq), at the core of which lies tmerge (https://github.com/julienlag/tmerge), a Perl program that builds gene models by integrating various sequencing datasets.

tmerge requires algorithmic optimization in order to keep up with the large amounts of long cDNA reads we expect to produce over the next years. It might be necessary to re-write it entirely, preferably in C/C++.

Since the project is currently focused on long noncoding RNAs, an enigmatic group of genes, there are also many, more biology-focused, questions to be addressed, for example: (1) What is the effect of high-throughput re-annotation of hitherto poorly characterized genomic regions on the overall expression quantification of genes; (2) Comparative analysis of lncRNA genes in human, mouse and chimp: How conserved are lncRNAs among these 3 species, at the sequence, structural and syntenic level? How conserved are their expression programmes?; (3) Integrated analysis of lncRNAs in the human and mouse genomes: Is there a relationship between lncRNA expression and genome organization (e.g. expression of neighboring genes, enhancer-based regulation, three-dimensional genome structure)?

The student will have the opportunity to learn about integrative genome analysis, cutting-edge sequencing data processing techniques, high-performance computing, modern workflow management systems and programming languages (e.g., Python, Snakemake, C/C++, Perl, R, Bash, etc.), all in a dynamic, prestigious international consortium environment.

Keywords. pipeline lncRNA algorithmics genomics transcriptomics

CRG-1904. Computational Biology of RNA Processing III

Supervisor. Roderic Guigó and Marina Ruiz-Romero

Research group. Computational Biology of RNA Processing

Project Description. Our research aims to understand how dynamics in transcription and chromatin permits un-differentiated cells to get specific fates that will result in to diverse cell types with specific tissue identities. During development, most tissues undergo striking changes in order to develop into functional organs. In this scenario, regulation of gene expression turns to be essential to determine cell fate and tissue specificity. Using computational and experimental approaches, we described a gene regulatory program, conserved in different tissues, along cell differentiation during fly development. Among these genes, we identified chromatin architectural proteins that could be key responsible for chromatin settlement and, ultimately, for coordination of gene regulation and cell fate specification. These chromatin modifiers mediate interactions between distal regions in the genome and define chromosome territories that connect regulatory elements while establishing a chromatin three-dimensional organization linked to functional genome regulation.

The main objective of this project is to define the chromatin structural arrangements that occur during Drosophila development and characterize the function of architectural proteins in cell

differentiation. We have designed an interdisciplinary proposal in which:

1) The student will get involved in genomic data exploration, to investigate transcriptional conserved changes in varied processes of differentiation in Drosophila melanogaster and other species.

2) She/he will implement high-resolution native-HiC protocol for Drosophila tissues, to determine dynamics of strong local interactions between regulatory regions during cell fate commitment.

3) Finally, distinct molecular and genetic tools, such knockout lines, ectopic expression lines, clonal analysis, advanced fluorescence microscopy image analysis or real time PCR will be applied to identify the role of diverse architectural proteins in gene regulation and described their function in chromatin reorganization during development.

Training outcomes: Get familiar with genomic data exploration and analysis, set-up a breakthrough technique by implementing high-resolution native-HiC protocol in fly, learn Drosophila genetics and current molecular techniques for gene functional studies.

Keywords. Chromatin conformation, cell differentiation, Drosophila melanogaster, architectural proteins, gene regulation.

CRG-1905. 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. Chromatin conformation, cell differentiation, Drosophila melanogaster, architectural proteins, gene regulation.

CRG-1906. 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. Chromatin conformation, cell differentiation, Drosophila melanogaster, architectural proteins, gene regulation.

CRG-1907. Evolutionary Processes Modeling

Supervisor. Donate Weghorn

Research group. Evolutionary Processes Modeling

Project Description. We develop mathematical models to describe evolution in cancer and the human population. Mutations provide the substrate on which selection for fitness can act. Using statistical models, we can analyze the distribution of mutations across the genome to infer whether they have an effect on fitness. In cancer, the identification of these mutations allows to detect novel cancer driver genes, while in humans they may point to disease genes.

Necessary prerequisites for the Master's work are a strong interest in mathematics and statistics as well as familiarity with writing computer code. Familiarity with

biology, evolution, and population genetics would be beneficial. The expected training outcome of the thesis is the ability to analyze and quantitatively describe biological and sequencing data, with the goal of extracting signals of selection or discovering mutational processes.

Keywords. mathematical modeling, population genetics, cancer evolution, DNA sequencing data analysis.

INSTITUTE FOR BIOENGINEERING OF CATALONIA (IBEC)

IBEC-1901.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-1902. Nanoprobes & Nanoswitches II

Supervisor. Marina Giannotti and Pau Gorostiza

Research group. Nanoprobes & Nanoswitches

Project description. Protein mediated electron transfer (ET) is essential in many cellular biological processes like 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-1903. Nanoprobes & Nanoswitches III

Supervisor. Marina Giannotti

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-1904. Targeted Nanotherapeutics and Nanodevices

Supervisor. Silvia Muro

Research group. Targeted Nanotherapeutics and Nanodevices

Project description. Novel drug nanocarriers improve the solubility, circulation, biodistribution, and overall

performance and safety of therapeutic agents. Their functionalization with targeting moieties further 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 contributes to this caveat. The project will focus on examining specific targeting of drug nanocarriers in more complex and physiologically relevant co-culture models, providing guidance for future design of translational nanomedicines. 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; polymer nanocarriers; receptor targeting; controlled transport; cell models

IBEC-1905. Analysis of multichannel respiratory sounds under different respiratory manoeuvres in healthy subjects and pulmonary disease patient

Supervisor. Raimon Jané

Research group. BIOSPIN

Project Description. The group's research addresses the design and development of advanced signal processing techniques and the interpretation of biomedical signals to improve non-invasive monitoring, diagnosis, disease prevention and pathology treatment.

Our main objective is to improve diagnosis capability through the characterization of physiological phenomena and to enhance early detection of major cardiac and respiratory diseases and sleep disorders. We propose and design new signal processing algorithms and develop new biosignal databases for patients with Obstructive Sleep Apnea, Chronic Obstructive Pulmonary Disease, Asthma, Chronic Heart Failure and Stroke.

To validate the clinical information of new surface signals, we have developed specific invasive/non-invasive protocols and animal models. The group focuses its research in a translational way to promote the transfer of our scientific and technological contributions. Currently, our

prototypes are used in hospitals for research purposes and for future industrial developments.

The group is well connected with public and private hospitals with which it performs applied and translational research. The main research laboratory has full equipment for acquisition and processing of biomedical signal, to test new sensors and to define clinical protocols (preliminary tests with control subjects).

The expected training outcomes are the design of new signal processing algorithms and their application to new biosignal databases, with the collaboration of our hospital partners, including the validation of clinical information of new non-invasive signals.

This project will include the analysis of spatial distribution of respiratory sounds and their relationship with different obstructive respiratory diseases.

Keywords. Multimodal biomedical signal processing, Respiratory and cardiac diseases, Sleep disorders, Neurorehabilitation

IBEC-1906. 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-1907. 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-1908. Smart Nano-Bio-Devices II

Supervisor. Tania Patiño and María Guix

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-1909. Nanomalaria

Supervisor. Xavier Fernàndez-Busquets

Research group. Nanomalaria

Project Description. Whereas nanomedical approaches to cure pathologies that are prevalent in high per capita income regions are intensively researched, there is an astonishing lack of nanomedicines being developed to treat the main cause of death in the impoverished world: infectious diseases, among which malaria is prominent. The unmet medical and patient need of malaria eradication will not be achieved unless the targeted delivery of new drugs is vastly improved. Encapsulation of drugs in targeted nanovectors is a rapidly growing area with a clear applicability to infectious disease treatment, and pharmaceutical nanotechnology has been identified as a potentially essential tool in the future fight against malaria. Liposomes in particular are an ideal platform to develop single-component drug delivery systems for antimalarial combination therapies, due to their capacity to incorporate in a single nanostructure molecules with widely diverging characteristics (and antimicrobial mechanisms), namely, hydrophilic drugs in their aqueous core and lipophilic drugs in their lipid bilayer.

In addition to carrying the active ingredients, an optimal nanovector should be designed to have specificity towards the cell type where therapeutic activity has to be unleashed. Using glycophorin A as target present in both malaria-parasitized and non-parasitized erythrocytes, the IC50 of drugs encapsulated in immunoliposomes is significantly decreased, most likely due to the prophylactic effect of loading antimalarial compounds into erythrocytes when these have not yet been infected by Plasmodium. The Master student will work on the design of a glycophorin A-targeted immunoliposome coencapsulating lipophilic and water-soluble drugs, with the objective of exploring the capacity of nanocarriers to be developed into new

antimalarial combination therapies at the nanoscale. The techniques to be used include liposome technology, Plasmodium falciparum in vitro cultures, fluorescence confocal microscopy, flow cytometry, and cryogenic electron microscopy. Eventually, experiments with living mosquitoes are contemplated within the framework of the NANOpheles project (http://euronanomed.net/wp-content/uploads/2018/08/NANOpheles-new.pdf).

Keywords. malaria; immunoliposomes; targeted drug delivery; Plasmodium falciparum; nanomedicine

IBEC-1910. 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-1911. 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 preexisting 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-1912. The Mutational Landscape of a Prion-Like Domain

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 protein 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 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-1913. Artificial organs in host-pathogens interactions

Supervisor. Josep Samitier-Marti

Research group. Nanobioengineering

Project Description. The human immune system has evolved refined molecular patterns for discriminating infectious agents from both normal- and abnormal-self. The microbial non-self recognition is based on the ability of the host to recognize conserved microbial epitopes that are unique to microorganisms, and that are not produced by the host. Such interaction is the prelude for complex molecular downstream cascade pathways regulating the pathogen invasion processes, which are still rather unexplored. The aim of this project is to re-create and artificial human granuloma - the hallmark of tuberculosis infection - and to locally model host-pathogens interaction. The candidate will first set-up methods to build artificial organs using combination of matrigel and bio-printing techniques. Then, he/she will study how the infection induced by specific pathogens can tailor protein distributions in the host. We will focus on: (i) how the actin and tubulin differently distribute in the cytosol of infected cells compared to healthy cells, and how (ii) focal-adhesion clusters change their spatial distribution upon infection. To do this, the candidate will combine advanced imaging techniques (confocal, SIM, Aeryscan and potentially STORM) with computational analyses for quantifying the protein localization. The final aim will be that of understanding how host cells (macrophages) tailor their protein distribution upon infection, and how this happens in a 3D organdie-like system.

Keywords. host-pathogens interaction; imaging infection; macrophages differentiation; protein clustering

IBEC-1914. Molecular Bionics

Supervisor. Giuseppe Battaglia

Research group. Molecular Bionics

Project Description. In collaboration with a postdoc, you will work on designing polymersomes with therapeutic applications and on understanding how they navigate and interact with biological materials. Polymersomes are an exciting class of cell membrane-inspired materials with potential applications ranging from building synthetic, biomimetic materials to treating brain cancer. Our interests range from fundamental science to applications and spin-outs into industry.

You will work in one (or all) of the following areas:

1. The Physics of Polymersome Self-Assembly

Understanding and optimising polymersome self-assembly is crucial for advancing both fundamental science and translation to applications. Our current efforts focus on simulations of polymersome self-assembly and the two-dimensional phase separation behaviour they exhibit, as well as developing new experimental methods for the controlled production of polymersomes.

2. Engineering the Chemical Topography of Complex Polymersomes

By functionalising polymersomes with specific surface groups, biomolecules, or transmembrane pores, we can control how polymersomes interact both with each other and living matter. You will apply these concepts to advance the functional properties of our polymersomes, allowing us to guide their self-assembly into complex structures, or to target therapeutically relevant structures such as tumours.

3. The Behaviour of Polymersomes in Printed Biomaterials

A new area of interest for our group is the use of 3D printing to create complex, model, biomimetic and biological materials (e.g., organs, blood vessels) that test how polymersomes perform in the real world. You will both design these printed model systems, as well as use and develop microscopy and image analysis techniques to understand the behaviour of polymersomes within them.

All necessary training will be provided, and no particular prior knowledge is required. Rather, we encourage creative applicants with a desire to think outside the box and who want to contribute to the knowledge and output of a group working at the forefront of bioengineering.

Keywords. Self-Assembly, Biomedicine, Therapeutics, Polymers, 3D Printing

IBEC-1915. Characterisation of motion in chemical gradients

Supervisor. Giuseppe Battaglia

Research group. Molecular Bionics

Project Description. Suspensions of micron-scale objects are found throughout the chemical processing industry, in biological and physiological systems, in geology, and in food processing; to name but a few examples. Objects on this scale are sensitive to their local chemical environment and are known to move in response to external chemical gradients due to the phenomenon of diffusiophoresis. The physical mechanisms that drive this motion are subtle, can vary depending on the specifics of the system and are often challenging to distinguish from one another. Furthermore, the ubiquity of chemical gradients cannot be overstated. Concentration gradients are established wherever there is a chemical reaction, whenever a solid material dissolves, when two materials mix or demix, or when sedimentation, evaporation or crystallisation occurs; and this list is far from exhaustive. Therefore, understanding the response of suspended particles to chemical gradients is of fundamental importance to a wide range of fields: academic, industrial and technological. Through developing this understanding we can begin to harness diffusiophoresis for controlled transport of micro- and nanoscale objects. For instance, a drug-carrier that can sense and move up gradients in a specific chemical can be designed to deliver its payload in a targeted manner. Similarly, diffusiophoresis may find applications in separating complex mixtures.

Working in close collaboration with a postdoctoral researcher, you will employ state-of-the-art optical imaging and manipulation techniques to quantitatively measure diffusiophoretic velocities and forces in a range of soft matter systems which may encompass hard and soft colloids, emulsion drops and vesicles. Careful experimental design and sensitive force measurement will allow us to distinguish between the different mechanisms driving motion in chemical gradients and enhance the fundamental understanding of these phenomena and inform the technological development of drug delivery vehicles.

Keywords. diffusiophoresis, chemotaxis, colloids, optics, soft matter

IBEC-1916. 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

THE INSTITUTE OF PHOTONIC SCIENCES (ICFO)

ICFO-1901. 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 behavior 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 behavior.
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 behavior and cell differentiation.

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

ICFO-1902. 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 analyzed 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-1903. 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-1904. 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-1905. 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-1906. All-optical interrogation of synaptic transmission in C elegants

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-1907. 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-1908. Nano-photonics and nano-optoelectronics with graphene, related two-dimensional materials and exotic quantum materials

Supervisor. Frank Koppens

Research group. Quantum Nano-Optoelectronics

Project Description. We exploit the extraordinary topological properties of novel two-dimensional materials, its heterostructures and other quantum materials in order to control light at the nanoscale in a radically new way. One of the main objectives is to generate non-reciprocal nanoscale optical fields (plasmons) that propagate in only one

direction and implement topologically protected plasmons such that they move around defects and corners. At the same time, visualizing and controlling electromagnetic excitations will be used as a tool to unravel extraordinary phenomena in exotic quantum materials. Topological nano-photonics is a new paradigm for novel quantum materials and will enable novel future applications in miniaturised photonic isolators, diodes and logic circuits and could lead to completely new concepts for communication systems, optical transistors and optical information processing.

We use near-field imaging techniques for infrared and THz light, and exploit ultra-fast lasers at low temperatures.

In addition to the new science and physics, the group develops new concepts for photo-detection, imaging systems, optical modulation, nano-scale light processing and switching, as well as flexible and wearable health and fitness devices. We aim to build prototypes of these disruptive technologies, in collaboration with industry.

Keywords. Nano-photonics, 2d-materials, graphene, quantum phenomena

ICFO-1909. Application of a quantum random number generator to simulations in condense matter physics

Supervisor. Maciej Lewenstein

Research group. Quantum Optics Theory

Project Description. Our group is currently working on cutting edge projects to harness the interface between machine learning (ML) and theoretical physics, both classical and quantum, to further understanding in both fields.

ML models have been shown to be robust, powerful and highly adaptable tools for systems with staggering complexity, often encountered in physics. During the past year, our group has contributed to this field, proving that state-of-the-art ML algorithms can be used to characterize phase diagram of various systems. Nowadays, most ML algorithms used in physics are based on supervised learning, where the machine is trained over datasets using previously acquired knowledge as input. However, if one wants to explore new physics with ML, such input may not exit, and one should explore methods of unsupervised learning, which in physics hasn't been developed heavily yet.

ML and the theory of statistical mechanics have many mathematical similarities and both have been furthered by mutual exchange. A recently proposed idea is studying the connection between specific ML algorithm called convolutional neural networks and the advanced statistical mechanics concept called Renormalization Group (RG). A combination of ML and RG might lead to powerful general purpose techniques for phase transitions in physics and beyond.

ML in physics is an interdisciplinary field, which allows a Master student excellent opportunities to learn fundamental concepts and understand their breadth and applicability through the lenses of different fields of research coming together. Because this field is very young

and dynamic, fundamentals required can be picked up quickly, making it very well suited for the scope of a Master thesis. We propose that in such project, the potential Master student learns the fundamentals of ML and then explores one of the many possible angles of deepening ML in physics, dependent on the student's personal skill, preferences and the future development of the field.

Keywords: Quantum Physics, Machine Learning, Renormalization Group, Phase transition

ICFO-1910. Ultracold Quantum Gases

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 or magnetism.

Our group has currently a fully operational quantum gas apparatus. There, we have recently focused on the study of ultra-dilute quantum liquids obtained from mixtures of potassium Bose-Einstein condensates. 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. We are currently pursuing the study of these liquids, exploring how the behaviour of the system is modified when, instead of using a mixture of two Bose-Einstein condensates, each of the particles is put in a coherent superposition of two internal atomic states.

At the end of 2018, we started the design and construction of a second experimental apparatus. In this project, we plan to explore collective effects in atom-photon interactions. To this end, we will realize closely-spaced arrays of strontium atoms trapped in optical tweezers and coupled to resonant light. This new type of quantum light-matter interface opens interesting perspectives for the realization of improved quantum memories and atomic clocks, exploiting cooperative effects on the atom-photon scattering. Furthermore, it constitutes a new platform for realizing quantum spin models and strongly interacting photon "gases".

We offer Master thesis projects on the two experiments. They will be focused on the design and development of a sub-system that will then be integrated in the main 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-1911 Ultrafast Dynamics In Quantum Solids

Supervisor. Simon Wall

Research group. Ultrafast Dynamics in Quantum Solids

Project Description. Ultrafast Dynamics of Quantum Solids (UDQS) investigates the properties of materials, such as high temperature superconductors, through their non-equilibrium electron, lattice and spin dynamics on femtosecond timescales (1x10-15s) and nanoscale length scales (1x10-9m). To do this we combine cutting edge optical and X-ray experimental techniques.

Our main research topics are as follows:

1) Nanoscale X-ray holographic imaging

We use coherent X-ray light sources to image quantum materials on the nanometer length scale. By exploiting the resonances of the constituent atoms in the soft X-ray region, we can explore how element specific defects and strain dictate the properties of these materials. One of the challenges in operating in this regime is that X-ray lens are difficult to manufacture. To overcome this limitation we exploit a lens-less imaging technique in which we replace the lens with numerical techniques to convert measured diffraction patterns into real space images. We work towards improving this technique so that we can capture dynamics in these materials on the nanoscale.

2) Phonons in quantum materials

We exploit the fact that short pulses of light can be used to induce coherent phonon displacements in quantum materials with large amplitudes. These displacements are macroscopic and significantly larger than can be made through temperature changes. By monitoring how these phonons decay, we can understand the nature of the electron-phonon and phonon-phonon interactions, interactions which are key for understanding materials such as high temperature superconductivity.

3) Spins in quantum materials

The dynamics of the spin degree of freedom play a key role in many quantum materials, but are difficult to measure. We combine non-linear optical spectroscopy with resonant X-ray techniques to investigate how electronic excitation perturbs spin order. This interaction is vital for testing Mott-Hubbard models of quantum materials in real systems.

ICFO-1912. 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

INSTITUTE OF CHEMICAL RESEARCH OF CATALONIA (ICIQ)

ICIQ-1901. Pérez-Temprano Group

Supervisor. Mónica H. Pérez-Temprano

Research group. Pérez-Temprano Group

Project Description. The Pérez-Temprano group is focused on moving transition metal catalysis to the next revolution: the rational design and development of innovative transformation based on experimental knowledge-driven approaches. We want to contribute to tackle some of the major challenges that our world faces, such as global warming or minimizing the impact of chemical synthesis. In this context, we are interested in accessing cyclometalated transition metal complexes since they play a crucial role in a wide variety of scientific areas such as organic synthesis, material science or biomedicine. Here, we propose to synthesize different cyclometalated Co(III) complexes in order to explore their reactivity and further utilization as chemotherapeutics or in solar energy conversion devices.

One of the main goals of our group is to offer students the possibility of gaining skills about cutting-edge research in a broad range of fields that will serve them throughout their scientific careers, by developing the ability to do creative scientific research under high ethics. Therefore, we are looking for a highly motivated Master student with a solid background in Chemistry, to join our appealing research program. The student will be exposed to a wide range of disciplines including organic and organometallic chemistry or multiple characterization techniques. The student will learn basic skills such lab techniques, how to handle air-sensitive materials, design experiments, make presentations, write reports or discuss the results in public.

Keywords. Sustainable Chemistry, Catalytic Activity, Material Science, Biomedicine Applications

ICIQ-1902. Development of C-H-Amination Reactions for Alkaloid Total Synthesis

Supervisor. Kilian Muñiz

Research group. Muñiz Group

Project Description. Our laboratory is currently interested in the design of new green amination methodology for the defined construction of C-N bonds from alkenes and alkanes. A major portion of this work uses benign halogen catalysis under photochemical initiation. This comprises preformed halogenated amines as well as their in situ formation. The ultimate goal of our occupation with amination reactions is to devise new and useful approaches to carbon-nitrogen bond formation. This particular project now aims to use direct C-H amination reactions of alkanes developed in our laboratory in order to devise novel entries into biologically relevant alkaloid structures of higher complexity. Throughout the course of the project, the candidate will have the chance to work on ground-

breaking new synthetic methodology development and their immediate application to small target structures. The topic comprises both the development of new synthetic methodology and the contribution to the total synthesis of molecules with biological or medicinal interest and with a significantly shorter number of steps than usually employed.

Candidates will therefore gain knowledge at the forefront of synthetic methodology development, of physical-organic chemistry within mechanistic elucidation, of the emerging field of photocatalysis as well as of synthesis and handling of aminated hydrocarbons/alkaloid building blocks. They will be trained in state of the art organic laboratory work, compound analysis and, besides enjoying laboratory research and team-work, will gain a high degree of independent problem solving.

Keywords. Amination, Alkaloids, Homogeneous Catalysis, Oxidation, Photochemistry

ICIQ-1903. Design, Construction, and Investigation of Chromophore-Protein Assemblies to Convert Solar Energy to Fuel

Supervisor. Elisabet Romero

Research group. Elisabet Romero Group

Project Description. Our aim is to develop a new generation of bio-inspired macromolecular systems able to convert solar energy to fuel. The group objective is to design and construct chromophore-protein assemblies based on abundant and biodegradable materials with the capacity to absorb, transfer and convert sunlight into electrochemical energy with high efficiency. To achieve that, we will implement the design principles of Photosynthesis aiming to recreate the most sophisticated principle used by plants: Quantum Coherence.

The static and dynamic properties of the newly created assemblies will be studied by several methods, with a strong focus on spectroscopic techniques [time-resolved: Two-Dimensional Electronic Spectroscopy (2DES), Transient Absorption, Time-correlated Single Photon Counting (TCSPC); steady-state: Absorption, Fluorescence, Linear and Circular Dichroism, Stark, Raman, FTIR, Fluorescence Line-Narrowing (FLN)].

Ultimately, the optimized assemblies will be integrated into solar cells to generate electricity. In addition, the most efficient assemblies will be coupled to catalysts to construct devices able to achieve the cost-effective solar-energy conversion to fuel. In this manner, we will provide a renewable and safe energy solution towards a sustainable future.

Within this multidisciplinary project, which involves Synthetic Biology and Biophysics, the student will gain expertise on chromophore and protein design, on the preparation and purification of chromophore-protein assemblies, and will acquire extensive knowledge about spectroscopic methods, including advanced ultrafast laser techniques.

Keywords. Biophysics, Synthetic Biology, Ultrafast Laser Spectroscopy, Quantum Coherence, Energy and Electron Transfer

CATALAN INSTITUTE OF NANOSCIENCE AND NANOTECHNOLOGY (ICN2)

ICN2-1901. 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

ICN2-1902. Advanced Electronic Materials and Devices

Supervisor. Jose A. Garrido

Research group. Advanced Electronic Materials and Devices

Project Description. The group focuses on material science, technology and devices of novel electronic materials, with a strong emphasis on graphene and other 2D materials (MoS2). The group also works towards the development of technological applications based on these materials such as flexible electronics, bioelectronics and neural interfaces, biosensing,, etc.

The activities cut across different scientific aspects, from the fundamentals (the physics of devices and semiconductors) to materials (growth of graphene and 2D materials by CVD, surface functionalisation, advanced characterisation), through to devices (fabrication technology, nanofabrication) and applications (biosensors, neural implants and biomedical technologies, etc).

The group's main research lines are:
- Fundamental electronic and electrochemical phenomena of novel materials, such as graphene and other 2D materials
- Preparation (CVD) of high quality films

of 2D materials. Technology and nanofabrication for advanced electronic devices and systems based on these materials.

- Bioelectronics and biomedical technologies: cell bioelectronics, neural interfaces, neuroprosthetics and implants.
- Electronic and electrochemical biosensors based on 2D materials.

Students will be trained in several of the following areas of research: CVD of 2D materials, thin film fabrication in cleanroom environment, device physics and device characterization, bioelectronics, neural interfaces.

Keywords. 2D materials, flexible electronics, bioelectronics, medical devices, neural interfaces, neural implants

ICN2-1903. 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

ICN2-1904. Ultrafast heat spreading in novel two-dimensional systems

Supervisor. Klaas-Jan Tielrooij

Research group. Ultrafast Dynamics in Nanoscale Systems

Project Description. Two-dimensional materials that can be delaminated down to the atomic limit, such as graphene and MoSe2, have recently given rise to highly exciting novel physical phenomena. The same is true for very thin layers of topological insulators, such as Bi2Te3, where charge carriers in topologically protected states can travel unhindered. In this project, you will study the transport of both charge and heat in these novel two-dimensional material systems. These studies are aimed at unravelling new physics and, in the long run, could find useful applications.

You will get hands-on experience in working with these new material classes, in particular learning exfoliation of layered materials, dry transfer, and various nanofabrication techniques. You will also be introduced to state-of-the art techniques for studying charge and heat transport, in particular Raman thermometry, and newly developed techniques based on ultrafast laser pulses, which allow for monitoring heat and charge transport "in real time".

This project is connected to the BIST Ignite project 2DNanoHeat, which is a collaboration between the groups of Valenzuela, Sotomayor and Tielrooij at ICN2 and Van Hulst and Koppens at ICFO.

Keywords. Heat, ultrafast, nano, two-dimensional, topological

INSTITUTE FOR HIGH ENERGY PHYSICS (IFAE)

IFAE-1901. Performance study of novel online multivariate event selection algorithms for Run 4 in the ATLAS experiment

Supervisor. Imma Riu

Research group. IFAE-ATLAS

Project Description. The ATLAS experiment at CERN's Large Hadron Collider is currently recording proton-proton collision data at 13 TeV center-of-mass energy. During 2019 and 2020 both the detector and accelerator will be upgraded thus allowing to increase the collision energy and luminosity. A further upgrade will be performed in ~2025 and will allow a significant increase in luminosity with events resulting in many simultaneous interactions. New online event selections need to be designed to cope with the expected increase in event rate while not significantly reducing the acceptance of important physics signals. Studies of newly designed and optimized online algorithms running through events with the expected number of simultaneous interactions need to be performed to achieve a final efficient identification of muons, electrons, taus, jets and missing transverse energy. New real-time topological or multivariate selections are possible and need to be investigated. We will study and optimize the performance of new trigger algorithms to have good efficiency for Higgs and SUSY signals.

Keywords. ATLAS, detector, physics, CERN

IFAE-1902. Impact of high-granularity timing detectors in the search for the Standard Model Higgs boson produced in the vector boson fusion mode and decaying into a pair of tau leptons with a lepton and a hadron in the final state

Supervisor. M. Pilar Casado

Research group. IFAE-ATLAS

Project Description. The student will evaluate the background in the search for the Standard Model Higgs boson produced in the vector boson fusion mode and decaying into a pair of tau leptons with a lepton and a hadron in the final state. He/she will also optimize the analysis based in signal acceptance and analysis significance. Finally the impact of the high-granularity timing detector (HGTD) will be assessed and the signal strength of the analysis will be determined in the high-luminosity LHC inner detector configuration. The results will be part of important ATLAS publications and will strengthen the case for using a HGTD in the forward region of the ATLAS detector.

Keywords. ATLAS, detector, physics, Higgs, CERN

IFAE-1903. Searches for new phenomena in events with production of four top quarks with the ATLAS detector at the Large Hadron Collider based on multi-class Boosted Decision Trees

Supervisor. Aurelio Juste and Nicola Orlando

Research group. IFAE-ATLAS

Project Description. Identification of four top quarks production in the ATLAS detector at the Large Hadron Collider represent a golden experimental channel to look for new phenomenon at the electroweak scale. The four top-quarks experimental signature is characterised by a prominent topology featuring at least four b-tagged jets and up to twelve jets in each proton-proton collision event. In the Standard Model (SM), four top quarks are non-resonantly produced mainly via strong interactions. Four top-quark production in scenarios beyond the SM (BSM) can be mediated by new yet unobserved degrees of freedom, such as scalar or vector resonances, with unknown mass. The lack of detailed knowledge about the heavy mediators leads to searches which can be either not well optimised for discovery or overcomplicated due to the dependence of the expected BSM signature from the unknown properties of the new degrees of freedom, leading to several dissimilar signal hypotheses to be investigated.

Multi-class machine learning classifiers offer a natural ground for overcoming the complexity of searches for multiple signal hypotheses. The goal of this research project is to search for new resonances in an experimental topology consistent with four top-quark production by using multi-class supervised machine learning algorithms, such as Boosted Decision Trees, in the ATLAS experiment at the Large Hadron Collider.

Keywords. ATLAS, detector, physics, Hadron collider

IFAE-1904. Searches for flavour-changing neutral-current interactions between the top quark and the Higgs boson in the ATLAS experiment at the Large Hadron Collider

Supervisor. Aurelio Juste and Nicola Orlando

Research group. IFAE-ATLAS

Project Description. Searches for flavour-changing neutral-current (FCNC) interactions of the top quark with the ATLAS detector at the Large Hadron Collider are of primary relevance as probes of the accidental flavour symmetry of the Standard Model (SM). In several popular SM extensions featuring new particles and forces, the FCNC interactions of the top quark can be enhanced by more than ten orders of magnitude making their possible observation a striking evidence for physics beyond the Standard Model (BSM). Top-quark FCNC interactions occur between first or second generation quarks, q, and a Z or a Higgs boson; when considering FCNC top-Higgs interactions, two experimental signatures are possible: the first characterised by the production of a single top in association with a Higgs boson (tH), the second

involving the production of a top-quark pair with subsequent decays of the top quark into a Higgs boson first- or second-generation quark (tt□WbHq). For such topologies, when considering the dominant Higgs boson decay mode in a pair of bottom quarks, the main SM background originates from top-quark pairs.

While the tH and tt□WbHq processes both represent a clear evidence for BSM physics, the dynamics involved is in general different for the two topologies and depends on the exact BSM realisation in nature; thus, the ability to distinguish between possible tH and tt□WbHq signals is an important step towards a more insightful interpretation of the Large Hadron Collider data.

The main objective on this research project consists of investigating multi-class deep neural networks to perform a multi-classification task with the objective of achieving a simultaneous separation between the investigated FCNC signatures, tH and tt□WbHq, and the leading SM background from top quark pairs.

Keywords. ATLAS, detector, physics, Hadron collider, Higgs

IFAE-1905. Searches for generic new phenomena in events with one lepton, multiple jets and b-tagged jets in the ATLAS experiment at the Large Hadron Collider with unsupervised machine learning methods

Supervisor. Aurelio Juste and Nicola Orlando

Research group. IFAE-ATLAS

Project Description. New interactions involving third-generation quarks are a common feature of several extensions of the Standard Model (SM) that attempt to address the hierarchy problem in the Higgs and Yukawa sectors. A testing ground for such beyond-the-SM interactions is naturally provided by experimental signatures with production of multiple top and bottom quarks. In data samples characterised by the presence of one lepton, multiple jets, and multiple b-tagged jets, the main SM background arises from production of top-quark pairs with or without associated jets. The variety of signatures of possible exotic phenomenon demands the design of highly flexible and model independent search methods. In this context, the main objective of unsupervised machine learning tasks is to recognise previously unknown data patterns in a generic manner. Complementary to supervised machine learning methods, unsupervised learning algorithms allow detecting discrepancies with expected SM background.

This research project aims at investigating unsupervised machine learning methods to identify possible new features in the

data collected by the ATLAS experiment at the Large Hadron Collider.

Keywords. ATLAS, detector, physics, Hadron collider, Higgs

IFAE-1906. Optimisation of the modelling of flaring light curves and its application to Lorenz Invariant Violation analyses

Supervisor. Manel Martinez and Elena Moretti

Research group. GAMMA RAYS

Project Description. The analysis of arrival times of photons as a function of energy in flaring episodes of astrophysical sources is currently one of the best tools to constrain Lorenz Invariant Violation, and hence Quantum Gravity theories. Unfortunately for most of these sources there are no models yet predicting the complex time structure (light curve) of these flares and the inference of it from the date is rather cumbersome. In this work we want to explore the optimization of the use of Histograms and Kernel Density Estimators (KDE) for the inference of the light curves of any source. The outcome of this study shall provide rules for the construction of histograms and KDE for any data in general.

Keywords. Gamma rays, Quantum Gravity, KDE, physics

IFAE-1907. 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.cta-observatory.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/2018-10-telescope-cherenkov-array-site-debut.html). LST-1 is equipped with a 23-m diameter dish, and is the most advanced telescope of its kind worldwide. The commissioning phase of the telescope has just started, and is expected to span the most part of 2019. The goal of this master thesis project is to contribute to the commissioning of the LST-1 camera, and of the full telescope, through the analysis of the data recorded during the first observations. 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-1908. Gravitational Redshifts systematics from assigning galaxies into halos

Supervisor. Marc Manera

Research group. Cosmology

Project Description. Galaxies live in dark matter halos. In a given halo, the galaxies that live at the center of the halo sit on a deeper gravitational potential that the ones that live at the outskirts of the halo. The difference in the gravitational potential of these galaxies produces a shift in the measurement of the galaxy redshifts. This shift is known as gravitational redshift, and it has the potential to test gravity models. Unfortunately, due to the peculiar velocities of galaxies, sometimes, when we observe a galaxy that is nearby two dark matter halos, we are not confident to which of the halos the galaxy belongs to. As a consequence, the measurement of the gravitational redshift becomes less accurate. In this project, the student will look at how the measurements of Gravitational Redshifts are affected by our incomplete understanding of the galaxy assignment to halos. This project requires a considerable amount of coding which can be done either in Python, Fortran or C.

Keywords: Cosmology, Cosmic Web, dark matter, dark energy

IFAE-1909 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-1910 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

INSTITUTE FOR RESEARCH IN BIOMEDICINE (IRB BARCELONA)

IRBB-1901. 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 tumors. 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, tumor-like, cellular behaviors 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 tumors. 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 tumor-like overgrowths, and systemic hormones promoting tumor malignancy, as revealed by chronic blockade of developmental timing, cachexia and eventual animal lethality. The active invasive behavior 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 tumor. The results will pave the way for the functional identification of the Achilles' heel of most solid tumors.

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-1902. MMB

Supervisor. Modesto Orozco

Research group. MMB

Project Description. We are a group working in the development and application of theoretical methods to describe functioning 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 small 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-1903. Epitranscriptomics in human disease

Supervisor. Lluís Ribas de Pouplana

Research group. Gene Translation Laboratory

Project Description. To characterize the the role of RNA modifications in the regulation of human inflammation.

We are using a new model for human inflammation based on human tissues presenting inflammation gradients. We will use this tissue to study how chemical modifications in transfer RNAs vary along the inflammation gradient. The final desired outcome is the discovery of the functional roles that modified RNAs play in the regulation of the inflammatory response.

Training outcome:

The student will learn to manipulate human tissue, purify RNA and characterize it biochemically, prepare RNA samples for RNA-seq experiments, and analyze RNA-seq data.

Keywords. Human inflammation, epitranscriptomics, transfer RNA

IRBB-1904. Stem Cells and Cancer

Supervisor. Salvador Aznar Benitah

Research group. Stem Cells and Cancer

Project Description. The project aims at studying how metastatic stem cells function and how they are influenced by the content of fat in our diet. The student will be involved in a project which combines state-of-the-art large scale genomics, proteomics, computational approaches, mouse models of cancer, and patient-derived tumours. She/he will work together with senior postdocs, PhD students and Bioinformaticians

.Keywords. metastatic stem cells, fatty acids, epigenetics, diet, -antimetastatic therapy

IRBB-1905. 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 a fly model of human tumours 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). We have described a method to assay the tumourigenic potential of Drosophila mutant tissues (Nat Protoc, 2015). We also work on centrosomal proteins with human orthologs that are linked to cancer and other human pathologies (Nat Commun, 2011; Nat Cell Biol, 2013; Curr Biol, 2015; Philos Trans Roy Soc, 2014; JCB, 2018).

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, Drosophila, centrosome, cancer therapy

IRBB-1906. Complex metabolic diseases and mitochondria

Supervisor. Antonio Zorzano

Research group. Complex metabolic diseases and mitochondria laboratory

Project Description. A major focus of our research is the link between autophagy and energy metabolism. In particular, we are interested in the analysis of the mechanisms that govern autophagy, and how dysfunction triggers metabolic disease. Autophagy is a tightly regulated process that degrades defective cellular organelles and is essential for eukaryotic cell homeostasis. Defects of the autophagic machinery in metabolic tissues including adipose tissue, muscle and liver, are associated with metabolic disorders such as obesity and insulin resistance. In addition, there is a crosstalk between autophagy and the endosomal pathway, and autophagosomal formation requires a fully functional endosomal machinery. We propose that by unraveling the molecular mechanisms that control the

relationship between autophagy and endosomal dynamics we will contribute to the understanding of the molecular basis of metabolic disorders. The identification of novel proteins implicated in the regulation of this process is major goal of the Complex metabolic diseases and mitochondria laboratory.

The Master student will have the opportunity to join a stimulating project and to learn a wide variety of molecular and cell biology techniques and this will contribute to expand his/her knowledge in the biology arena.

Keywords. Obesity, Diabetes, Autophagy, Endosomal dynamics, Metabolism

IRBB-1907. Biomedical Genomics Group

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

IRBB-1908. Signaling and Cell Cycle

Supervisor. Angel Rodriguez Nebreda

Research group. Signaling and Cell Cycle

Project Description. Main interest is understanding cell regulation mechanisms, especially regarding how cells interpret different signals to elaborate the appropriate responses. Studies focus on signal transduction by p38 MAPKs and their role in tumorigenesis. We use a combination of biochemical approaches and studies in cancer cell lines to investigate how this

signaling pathway contributes to tumor cell homeostasis. We also use genetically modified mice, which allow the inactivation of p38 MAPK signaling in a regulated and tissue-specific manner, as well as chemical inhibitors to elucidate physiological functions of p38 MAPKs and their role in breast, lung and colorectal cancer initiation and progression. We are very interested in the identification of therapeutic opportunities based on the modulation of p38 MAPK signaling.

Current topics:

- Stress-activated protein kinases
- Cancer cell homeostasis and chemoresistance mechanisms
- Cross talk between cancer cells and stromal cells
- Targeted cancer therapies

Keywords. signal transduction, protein kinase, cancer cell, tumor microenvironment, targeted therapy