BIST Barcelona Institute of Science and Technology

upf. Universitat Pompeu Fabra Barcelona

Master of Multidisciplinary Research in Experimental Sciences

List of Major Research Projects

Course 2018-2019

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 skills, and engage directly with and learn from outstanding local and international researchers.

Minor projects will be decided together with the major project supervisor after the start of the program. Students will need to choose a major research project from the following list.

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

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ICFO

Institute for High Energy Physics

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

PROJECT TAKEN!

DCEXS-1801. Controlling the cell cycle: synthesis regulators and tumor progression

Supervisor. José Ayté

Research group. Oxidative Stress and Cell Cycle Group (OSCCG)

Project Description. At the OSCCG we are ultimately interested in deciphering the mechanisms that control cell cycle progression. Inactivation of the Retinoblastoma protein (RB) leads to unregulated cell cycle progression promoting cell growth, genomic instability and aneuploidy, hallmarks of tumor progression. RB activity is achieved through binding the E2F family of transcription factors. It is well known that a tumor process is very complex, accumulating secondary mutations that eliminate the brakes to the cell cycle. Even though many regulators of the RB-E2F are known, an integrative view of all the regulatory events controlling the G1/S transition is required to anticipate putative interventions able to block proliferative processes.

The candidate will characterize the regulation of the yeast MBF complex (functional homolog of human RB-E2F). The regulated activity of this complex is also essential for the G1/S transition since cells with hyperactive MBF have genomic instability. The candidate will perform 2 whole-genomic screens searching for global regulators of MBF. We have developed a reporter strain in the laboratory that measures MBF activity in vivo as an YFP/RFP output, either on FACS or on an automated fluorescence microscope platform. This reporter strain will be introduced in a commercial yeast KO deletion library. These screenings will allow the creation of a complete map with all the MBF regulators and, by extrapolation, will establish the nodes that regulate the RB pathway. Required student background: A high motivation towards a scientific career in projects related to basic research, which is the research that is carried out in our group, is a must. Also, a solid background in Genetics, Cell Biology and Molecular Biology is a requirement to carry out this project. Since the project includes bar-code sequencing of pools of KO strains, previous experience with ultra-sequencing will be appreciated. Similarly, previous work with yeast and/or cell cycle will be a plus.

Keywords. Cell cycle, G1/S transition, replicative stress, transcription, yeast

PROJECT TAKEN!

DCEXS-1802. 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' gene therapy has 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 gene therapy 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-1803. Structural Bioinformatics

Supervisor. Baldo Oliva

Research group. Structural Bioinformatics Group

Project Description. Research of the group:

1) On the prediction of protein-protein and protein-DNA interactions: Structural analysis of docking approaches and development of new techniques towards the prediction of binding sites and the mechanisms of interface selection of protein-protein and protein-DNA interactions.

2) On the analysis of protein interaction networks and its use on bio-medicine, helping to detect potential targets and prioritization of candidate disease-genes. Development of methods to study and integrate information for different types of networks and application on the study of metastasis.

Transcription factors (TFs) play a central role in regulating gene transcription. However, the precise binding sites for most of them still remain unknown and therefore, filling this gap is an important step towards the understanding of systems-biology. A major inconvenience of experimental methods is their application is both laborious and expensive. As an alternative, computational tools can be employed to predict TF–binding sites. Our strategy is based on the structural characterization of protein-DNA specificity. We tackled the incompleteness of data by using TF–binding information from PBM experiments.

Our objective is to develop bioinformatic tools to: 1) predict and model TF-DNA bindings in enhancer and promoter regions; 2) predict the effect of mutations in both sides of the interface of the interaction; 3) obtain the theoretical best sequence of a TF targeting a DNA motif with high specificity, which in turn can be used to construct new programmable nucleases, using the scaffold of other TFs.

Expected training outcomes:

1) Extending learning on python programming and web developed tools (i.e. Django)

2) Statistical training and testing approaches of machine learning

3) Structural basis of the molecular mechanisms of protein and DNA binding

4) Transversal competences on scientific exposition ad scientific writing.

Keywords. transcription factors; molecular interactions; molecular modelling; gene regulatory network

DCEXS-1804. 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-1805. Microtubule and Cell Division

PROJECT TAKEN!

Supervisor. Lucas Carey

Research group. Single Cell Behavior

Project Description. Genetically identical organisms and cells are phenotypically heterogeneous. Within an isogenic population not all microbes are killed by an antibiotic, and not all cancer cells are killed by chemotherapy. Furthermore, the impact of any single mutation varies across individuals, with some individuals

having no consequences while others exhibit a severe disease phenotype. Work from my lab and others has shown that much of this phenotypic variability is due epigenetic heterogeneity in the intracellular states of single cells.

In our lab we take a systems biology and bioengineering approach to determine causes and consequences of non-genetic heterogeneity in proliferation, aging, mutational outcome, and drug resistance. We do so using a combination of high-throughput time-lapse microscopy, flow-cytometry and sequencing to generate data, use machine learning and data-driven mathematical models to understand the data, and perform experiments to test quantitative computationally derived hypotheses. The student will both perform experiments and analyze data. We do machine learning, quantification of subclonal mutations, genomics, build data-driven mathematical models, use high-performance computing and generate and analyze high-dimensional datasets.

Keywords. systems biology, bioinformatics, computational biology, bioengineering, machine learning

DCEXS-1806. Morphogenesis and Cell Signaling Sensory Systems

Supervisor. Berta Alsina

Research group. Morphogenesis and Cell Signaling in 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 signaling is coupled with cell components to drive cell behaviors 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.

We offer a position to undertake a PhD at the Parc de Recerca Biomèdica de Barcelona and Universitat Pompeu Fabra, one of the most dynamic research centers 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. We have also incorporated microsurgery information to assess biomechanics in tissue dynamics. 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, regeneration, neuron, brain, life-imaging,

PROJECT TAKEN!

DCEXS-1807.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-1808. 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-1809. 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 of ion fluxes in the physiology of immune cells, having a special interest in calcium and zinc signaling. Here a brief description of the two running projects in the lab:

One of the pivotal proteins the team is working with is ORMDL3, an ER transmembrane protein genetically associated to inflammatory diseases. The family of proteins ORMDLs is involved in calcium signaling and sphingolipid synthesis. Our laboratory has been pioneer in doing functional studies of ORMDL proteins and is running projects in order to offer new insights into the pathophysiological relevance of ORMDL3 in the immune system.

Zinc deficiency is considered a major public health problem worldwide. Zinc is a common structural component of proteins but free zinc cellular signals have been also described to influence several signaling cascades. In this scenario, despite the strong impact the zinc has on the immune system, there are no clear

mechanisms of how this element enters these cells and exerts its effect. The main goal of the project is to explore the function and regulation of zinc fluxes in immune cells in order to have a better understanding of zinc signals and its consequences.

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

Keywords. Biophysics, Immunology, ORMDL3, zinc, calcium

DCEXS-1810. Human Genome Diversity Group

Supervisor. David Comas

Research group. Human Genome Diversity Group

Project Description. The interests of our research are focused on the human genome diversity analysis in order to infer the (genomic and population) processes responsible for this diversity and try to establish the (population and epidemiological) consequences of the human genetic variability. Thus, our main research lines are focused on aspects of human genome diversity, population genetics, genome variation and disease susceptibility, and genome evolution and disease.

1. Population processes. Concerning population processes that have modeled the human genetic diversity, we have focused our research on the use of molecular tools to reconstruct the human population history through the phylogeny of genetic markers. Our interest has been focused on the genetic consequences at population level of human migrations and admixtures. The use of well-established phylogenies in the mitochondrial and Y-chromosome human genomes allowed us to unravel the population history of several populations. Nonetheless, we have recently used whole genome variation in the autosomes in order to establish the structure of human populations.
2. Genomic processes. Concerning genomic processes that have modeled the human genetic diversity, our research has have been focused on the relationship between human diversity and complex traits, including complex diseases. The genetic analysis in human populations of genes of biomedical interest might shed light on the evolution of these genes. In this context, we have focused our research in the analysis of genes that have been previously associated to complex diseases, such as psychiatric and immunological diseases. The analysis of these genes has allowed us to conclude that some of the failures in replicating genetic associations are due to extreme genetic differences between populations. In addition, we are also interested in other complex traits, such as height, not directly related to disease.

Keywords. Population genetics, human diversity, genome, demography, adaptation

PROJECT TAKEN!

DCEXS-1811. 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

PROJECT TAKEN!

DCEXS-1812. Cell Biology Lab

Supervisor. Pura Muñoz Cánoves

Research group. Cell Biology Lab

Project Description. Understanding stem cell regenerative decline with aging

This research project aims to investigate how stemness is maintained in quiescent adult stem cells throughout life. This is crucial to maintain organ and tissue regenerative capacity in mammals. Our recent studies in skeletal muscle stem cells (satellite cells) of healthy aged mice have shown a quiescence-to-senescence switch as an underlying mechanism of their functional (regenerative) decline (Nature 2014 and 2016) with aging.

In this project, the student will investigate: 1) the primary causes of the quiescence-to-senescence transition in aged stem cells; and 2) new strategies for stem cell rejuvenation and regenerative improvement. To this end, the student will learn basic techniques of stem cell isolation from mouse muscles by cell sorting, analysis of their quiescent status and their proliferation, differentiation and self-renewal capacity in vitro as well as in vivo by stem cell engraftment in muscle of recipient mice. Analysis of DNA damage and autophagy failure will also be analyzed in aged stem cell as a cause for their entry into senescence, using immunofluorescence and microscopy

techniques. Global gene expression combined with bioinformatics approaches will be used to uncover the molecular determinants of loss of stemness with age. Based on the results obtained, rejuvenating strategies to improve stem cell functions in aged mice will be designed. We expect that completion of these objectives will provide the student with fundamental knowledge on stem-cell biology, regeneration and aging.

Keywords. Skeletal muscle, stem cell, regeneration, aging

DCEXS-1813. 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) and the relief of common migraine. At present, the CaV2.1-selective inhibitors 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 mutant CaV2.1 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

Center for Genomic Regulation (CRG)

PROJECT TAKEN!

CRG-1801. Cell and Tissue 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-1802. Intracellular Compartmentation

Supervisor. Vivek Malhotra

Research group. Intracellular Compartmentation

Project Description. Mucins are the primary macro components of mucus, a viscous gel that coats our epithelium to protect us from allergens and pathogens. Importantly, pathological mucin hyper-secretion is a hallmark of chronic obstructive pulmonary disease (COPD), chronic bronchitis and asthma. Mucins undergo massive glycosylation at the Golgi and are packed into giant secretory granules that occupy up to 75% of cell volume. But how are mucins sorted and exported at the endoplasmic reticulum for transport to the Golgi? How are micrometre long mucins re-sorted and packed into granules at the Golgi? In the granules, mucins condense to aggregates that reach mega Daltons in mass, but how is this achieved? How is a pool of granules selected for a signal-dependent fusion to the plasma membrane? Finally, what are the mechanistic differences in trafficking of different secreted mucins such as MUC5B and MUC5AC, and a transmembrane like MUC1? Are these mucins sorted into different granules?

We will address these issues by first identifying GEnes specifically required for Mucin Secretion (GEMS) in CRISPR- and shRNA-based screening of the entire human genome in airway cells. Mucin hypersecretion could also be a result of secretory cells hyperplasia; indeed, there is a 20-fold increase in their numbers in fatal asthma. A secondary screen in 3-D airway-organoids will be used to further test the physiological relevance of GEMS and their role in controlling the numbers and organization of mucin secreting cells. We will primarily focus on GEMS that function as receptors for sorting and packing mucins at the ER and the Golgi, and those that control secretory cell hyperplasia. We have access to primary cells from patients with COPD, which is the ideal system to test if GEMS are affected in this devastating pathology. Students will learn a wide range of basic cell and molecular biology techniques, cell and organoid tissue culture, state-of-the art microscopy.

Keywords. Mucin secretion, secretory granules, COPD, asthma

CRG-1803. Design of Biological Systems*

**project not available this round*

Supervisor. Martin Schaefer, Luis Serrano

Research group. Design of Biological Systems

Project Description. Project description: Research of the lab aims at a quantitative understanding of biological systems. One question addressed in the lab is how the environment affects cancer development. It is known that microbes that live on epithelial barrier of organs (the microbiota) can modify important cellular processes such as signaling, metabolism and immune response. Furthermore, it has been observed that the microbial composition in a tumor environment changes during the process of tumor development. However, if and how microbes contribute to tumor development is unknown except for a few pathogens

(for example, for Helicobacter pylori a link to stomach cancer has been established). Here we want to identify traces of microbial exposure from cancer sequencing data and address the question how the presence of microbes in the environment of the tumor might affect cellular processes within the tumor.

The main objectives of this project are:

1.) To identify bacterial or viral RNA and DNA from tumor samples. We will compare the microbial composition of different tumor types and of healthy versus tumor samples.

2.) To correlate the presence of specific microbes in the tumor environment with the activity of specific cellular pathways in tumor samples. For this we will integrate the identified microbial DNA and RNA with heterogeneous data types from the tumor.

Keywords. Cancer genomics, microbiome, computational biology

PROJECT TAKEN!

CRG-1804. Dynamics of Living Systems

Supervisor. Nicholas Stroustrup

Research group. Dynamics of Living Systems

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

Keywords. Aging, microscopy, stochastic processes

PROJECT TAKEN!

CRG-1805. Microtubule and Cell Division

Supervisor. Isabelle Vernos

Research group. Microtubule and Cell Division

Project Description. We aim at understand how microtubules and associated proteins self-organize during cell division into a bipolar spindle that is the molecular machine that serrate the chromosomes faithfully between the nascent daughter cells. Our main objectives are:

- Unravel the mechanism by which the chromatin drives microtubule nucleation, stabilisation and organization after nuclear envelope breakdown to ensure spindle assembly.

- To understand the mechanism controlling the dynamics of the K-fibers particularly at

their minus end to ensure proper chromosome movement and alignment and segregation as well as stable bipolar spindle formation.

- To determine the role of microtubule PTMs during M-phase.

Expected training outcome:

- learn fluorescent microscopy methods (fixed and live cells)

- learn cell culture and manipulations (transfection, processing...)

- learn methods directed at identifying specific protein-protein interactions in cells (BioID, pull downs, Duolink assays ...).

- Analyzing proteomic data

- Learning about microtubule, associated proteins , kinases role and regulation during cell division

- The project will aim at identifying partners of the mitotic kinase Aurora A using a BioID approach combined with proteomics and determine how these interactions may change in tumour versus non tumour cells.

Keywords. Cell division, spindle, microtubule, kinase, RanGTP

CRG-1806. Reprogramming and Regeneration

Supervisor. Maria Pia Cosma

Research group. Reprogramming and Regeneration

Project Description. Our laboratory is studying the mechanisms controlling somatic cell reprogramming and tissue regeneration. In particular, we are studying how the Wnt/beta-catenin signaling pathway controls these processes and how cell-fusion-mediated reprogramming contributes to tissue regeneration. In particular, using super resolution microscopy we investigate how the chromatin structure changes at the set of reprogramming and differentiation. Furthermore, we are focused on studying regeneration of the central nervous system, mainly of retina and of liver in mice. The laboratory is truly interdisciplinary with expertise in stem cell biology, biophysics, gene network analysis and chromatin structure. We tackle our scientific questions using different approaches, which range from the nanoscale level observation of cell function up to the whole mouse organs. The student will be exposed to a large number of disciplines and will have the opportunity to investigate in collaboration with other members of the laboratory on a variety of basic research fields including reprogramming, stem cell renewal and tissue regeneration.

Keywords. reprogramming, stem cells, super resolution microscopy, regeneration, chromatin

Institute for Bioengineering of Catalonia (IBEC)

IBEC-1801.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-1802. Nanoprobes & Nanoswitches II

Supervisor. Pau Gorostiza and Marina Giannotti

Research group. Nanoprobes & Nanoswitches

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

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

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

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

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

IBEC-1803. 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-1804. 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

PROJECT TAKEN!

IBEC-1805. Biosensors for Bioengineering

Supervisor. Javier Ramon Azcón

Research group. Biosensors for Bioengineering

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

Objective 1. Skeletal muscle-on-a-chip. Functional skeletal muscle tissues will be engineered using micro- and nanoscale fabrication technologies with muscle precursor cells combined with hybrid biomaterials as scaffold. Engineered muscle tissues will be integrated with biosensors on a microscale chip for in vitro monitoring of their contraction induced by glucose metabolism and their protein production.

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

Expected training outcome:

- learn biomaterials synthesis and characterization (SEM, mechanical analysis, swelling)
-learn cell culture and manipulations
- 2D/3D biomimetic culture assays (3D bioprinting) and encapsulation of cells in scaffolds (tissue engineering)
- learn fluorescent microscopy methods (fixed and live cells)
- Lab-on-a-chip technology and Biosensors (optical transduction and electrochemical)

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

PROJECT TAKEN!

IBEC-1806. 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-1807. Signal and Information Processing for Sensing Systems

Supervisor. Santiago Marco

Research group. Signal and Information Processing for Sensing Systems

Project Description. Current smart instrumentation using multi-sensors and/or spectrometers provides a wealth of data that requires sophisticated signal and data processing approaches in order to extract the hidden information.

In this context, we are interested in intelligent chemical instruments for the detection of volatile compounds and smells. These systems can be based on an array of non-specific chemical sensors with a pattern recognition system, taking inspiration from the olfactory system. Some spectrometries, e.g. Ion Mobility Spectrometry, are capable of very fast analysis with good detection limits but poor selectivity. These technologies have been proposed for the fast determination of the volatolome (volatile fraction of the metabolome), instead of the reference technique of gas chromatography – mass spectrometry.

Our group develops algorithmic solutions for the automatic processing of Gas Sensor Array, Ion Mobility Spectrometry (IMS) and Gas Chromatography – Mass Spectrometry (GC-MS) data for metabolomics and food samples.

We are about to start a project in the area of breath analysis for diagnosis and monitoring of lung infections in collaboration with Hospital de Sant Pau. In this scenario we want to develop an breath sampler prototype automatically collecting end-tidal (single and multiple breaths) or dead space air fractions (multiple breaths). This result should be achieved by real time measurements of the CO2 partial pressure and airflow during the expiratory and inspiratory phases. Suitable algorithms, used to control a solenoid valve, guarantee that a Tedlar bag is filled with the selected breath fraction even if the subject under test hyperventilates. The breath sampler should have a low pressure drop (<0.5 kPa) and use inert or disposable components to avoid bacteriological risk for the patients and contamination of the breath samples.

The student will be trained in the specifics of breath sampling, design and construction of medical apparatus using sensors and actuators under control from a microcontroller platform (e.g. Arduino). He will be also trained in the uses of volatile biomarkers for the diagnosis of various health conditions.

Keywords. Metabolomics, Breath Analysis, Instrumentation, Sensors and Actuators

IBEC-1808 Bacterial Infections: antimicrobial therapies

Supervisor. Eduard Torrents

Research group. Bacterial Infections: antimicrobial therapies

Project description. New strategies to combat bacterial infections.

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 major public health concern.

We aim to explore and characterize new antimicrobial molecules that specifically inhibit new antibacterial targets. Also, we are exploring new antimicrobial strategies based on nanoparticles to deliver new and pre-existing antimicrobials with the capacity to evade the immune system and able to penetrate formed bacterial biofilms. Basic studies in microbial physiology, new vaccines, molecular microbiology and microfluidics applied to the microbiology diagnostic are also performed in our laboratory. See further details and publications at our group web page: https://sites.google.com/view/torrentslab webpage.

RESEARCH LINES and OUR GOALS:
1. Understanding the molecular basis of transcriptional regulation of the different genes involved in the bacterial DNA synthesis.
2. Unravel the molecular mechanisms of bacterial virulence and biofilm formation. Understanding the physiology of bacteria growing in a biofilm.
3. New drug delivery systems to kill bacteria living in biofilms - Treatment of chronic bacterial infections.
4. Discovery of new antimicrobial therapies to combat bacterial infections by the application of nanomedicine techniques.
5. Developing new systems to mimic bacterial wound healing infections.
6. Developing bacterial vaccines.

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

IBEC-1809. 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-1810. Smart Nano-Bio-Devices II

Supervisor. Tania Patiño

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-1811. Mechanics of Development and Disease

Supervisor. Vito Conte

Research Group. Mechanics of Development and Disease

Project Description. Our group is interested in deciphering the physical mechanisms driving processes of epithelial tissue morphogenesis in normal and pathological conditions, and to understand how these collective phenomena arise from genetic

programmes at the single-cell level. Tissue morphogenetic processes are key to the design of organoids, the metastatic transition of some instances of cancer disease and to the healthy development of embryos. During such processes, epithelial cells must generate forces, sustain tension/compression and transmit these forces through intercellular junctions in order to collectively sustain the morphing of epithelia. To address these questions, we combine experiment and theory [3-4] to quantify cell and tissue mechanics from time-lapse microscopy [1-2], which we either carry out in our own lab (in vitro) or in collaboration with other groups (in vivo). Image quantification analyses provide large data sets containing information about cellular motions and forces. By further collaborating with numerical labs (in silico), we combine theory and simulation [1-2] to integrate experimental data into computer models that we use to make predictive biomechanical analyses of tissue morphogenesis in normal and pathological conditions [1-2].

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Keywords. tissue morphogenesis; tissue biomechanics quantification; time-lapse microscopy; biophysical techniques; computational modelling;

IBEC-1812. Puripotency for organ regeneration I

PROJECT TAKEN!

Supervisor. Núria Montserrat

Research Group. Puripotency for organ regeneration

Project Description. Our group is focused in providing fundamental knowledge about human pluripotent stem cells (hPSCs) differentiation towards mesoderm derived lineages (including kidney and heart). By the generation of organoids combined to CRISPR/Cas9 tools we are now able to study processes related to early specification of mesoderm and also to model cardiac/renal disease by the incorportation of specific mutations related to the disease of study (i.e., wilms tumor, polycistyc kidney disease, among others).

In order to provide faithful models recapitulating organ-specific functions we take advantage of innovative tools providing instructive cues for organoid differentiation and maturation (i.e., 3D bioprinting, development of instructive hydrogels, among others).

The objective of this master is to profit our current model of kidney organoid differentiation for the study of early events guiding nephron patterning and segmentation. By the use of reporter lines (engineered with CRISPR/Cas9) the applicant will disect the role of Wnt-Bcat pathway in these processes. This project will also have an impact in current lines of research in our laboratory modeling Wilms Tumor disease taking advantage of hPSCs-kidney organoids.

Keywords. human pluripotent stem cells, kidney organoids, nephron, disease modeling

IBEC-1813. Puripotency for organ regeneration II

Supervisor. Núria Montserrat

Research Group. Puripotency for organ regeneration

Project Description. During embryonic development, the combined action of biochemical and mechanical cues orchestrates the growth, differentiation and morphogenesis of specialized tissues and organs. Mounting experimental evidences indicate that the physical environment together with the spatial and temporal patterning of specific biochemical inductive signals are crucial in this process. In another hand, recent studies have shown that mechanical and physical cues can regulate the self-renewal and differentiation of human pluripotent stem cells (hPSCs). Recently, the possibility to generate three-dimensional (3D) self-organized tissue structures from hPSCs, so called organoids, provides a unique scenario for studying human development and disease in vitro.

Although organoids have proved to recapitulate some morphological and functional aspects of their in vivo counterparts, the lack of matureness still represents a major roadbloack for further therapeutic use. Understanding the interplay between hPSC signaling and mechanics during organoid differentiation would set the basis for further studies aiming to modulate organoid formation and maturation.

In this master program, we will develop tissue-derived hydrogels (from human kidney tissue) for the generation of instructive materials guiding hPSCs differentiation towards kidney organoids. By the use of 3D bioprinting technology our aim is to fine-tune the mechanical and environmental milieu for the development of higher-grade kidney organoids. By the incorporation of novel chemistries and co-culture strategies we aim to develop vascularized kidney organoids for further experiments related to the screening of neprhotoxic agents.

Keywords. pluripotent stem cells, organoids, 3D bioprinting, vascularization

IBEC-1814. Biomaterials for Regenerative Therapies I

Supervisor. Oscar Castaño Linares

Research Group. Biomaterials for Regenerative Therapies

Project Description. The project aims to perform a nanostructured polymeric biomaterial to be used as an antimicrobial application in biomedical devices. It will consist of polymeric biodegradable and biocompatible nanoparticles made by nanoprecipitation and nanofibers made by the electrospinning method, which will contain antimicrobial ions such as Ag+, Cu2+ or Zn2+. The project aims to apply these materials in biomedical applications where infections not only are a problem but also are becoming nowadays a danger due to the gradual increase of bacterial resistance to antibiotics. The generated knowledge will allow us to explore for better designs and manufactures of new strategies based on instructive biomaterials for regenerative medicine, minimizing the use of antibiotics. The project involves material synthesis, structural, biological and degradative characterizations (field emission SEM, Z potential, DLS, DSC, mechanical properties, X-ray diffraction), ion release assessment and, eventually, assisted assessment of the antimicrobial potential of the constructs. Furthermore, the project also involves the improvement of other cross-curricular competencies such as team-working; oral skills to present and defend an innovative

project in front an expert audience; report preparation, scientific criteria (definition of reasonable hypotheses and develop solutions to complex problems); managing bibliographies and documentation; analyze and use technological advances in biomedical engineering to meet clinical requirements; and managing concepts and methods of advanced technologies such as nanomedicine and regenerative medicine.

Keywords. Antimicrobial properties, nanofibers, nanoparticles, metal ions, biodegradable polymers

IBEC-1815. Biomaterials for Regenerative Therapies II

Supervisor. Elisabeth Engel

Research Group. Biomaterials for Regenerative Therapies

Project Description. The group of Biomaterials for Regenerative Therapies group is devoted to the development of basic science and knowledge transfer to industry of innovative biomaterials and scaffolds for tissue regeneration.

We work on the design, fabrication and characterization of scaffolds by using different techniques such as electrospinning, 3D printing or nanoparticles, but we also elucidate the effect of the produced scaffolds on cell activation or cell reprogramming towards regeneration of a specific tissue.

The successful applicant will develop secretome loaded microparticles to achieve a controlled delivery of wound healing promoting factors. Students will learn different fabrication and characterization biomaterial techniques Furthermore, in vitro assays involving cell proliferation, migration and angiogenesis will be also included in order to evaluate the bioactivity of the developed microparticles.

Furthermore, the project also involves the improvement of other cross-curricular competences such as team-working; oral skills to present and defend an innovative project in front an expert audience; report preparation, scientific criteria (definition of reasonable hypotheses and develop solutions to complex problems); managing bibliographies and documentation; analyze and use technological advances in biomedical engineering to meet clinical requirements; and managing concepts and methods of advanced technologies.

Keywords. secretome, microparticles, skin wound healing

IBEC-1816. Biomaterials for Regenerative Therapies III

Supervisor. Soledad Perez Amodio

Research group. Biomaterials for Regenerative Therapies

Project Description. The Biomaterials for Regenerative Therapies Group works on the design, fabrication and characterization of scaffolds by using different techniques such as electrospinning, 3D printing or nanoparticles, but we also elucidate the effect of the produced scaffolds on stem cell activation or cell reprogramming towards regeneration of a specific tissue.

Regarding the cardiac tissue, the mammalian heart has always been considered a post-mitotic terminally differentiated organ, in which cardiomyocytes present at birth would persist, without further division, throughout the life of the organism. The recent identification and characterization of

resident cardiac stem cells (CSCs) changed completely the classic view of the heart as a postmitotic organ. These findings open the possibility of the heart self-healing in response to specific stimuli after a heart infarction.

This project aims the application of a new process for biomaterials fabrication (Organogels) as an in situ tissue engineering scaffold that due to its physicochemical properties is believed to have chemotactic attraction for cells and promote vascularization at the infarcted tissue. The project will explore the capability of these scaffolds as an in vivo cardiomyocytes reprogramming system. The person involved in this project will acquire knowledge in the isolation and culture of cardiac cells, as well as in the fabrication and characterization of biomaterials.

Furthermore, the project also involves the improvement of other cross-curricular competences such as team-working; oral skills to present and defend an innovative project in front an expert audience; report preparation, scientific criteria (definition of reasonable hypotheses and develop solutions to complex problems); managing bibliographies and documentation; analyze and use technological advances in biomedical engineering to meet clinical requirements; and managing concepts and methods of advanced technologies such as nanomedicine and regenerative medicine.

Keywords. cardiac tissue regeneration, biomaterials

IBEC-1817. Biomaterials for Regenerative Therapies IV

Supervisor. Oscar Castaño Linares

Research group. Biomaterials for Regenerative Therapies

Project Description. The project aims to perform a quasi-vivo model consist in an in vitro myocardial infarction will be simulated, where the cells involved in the cardiac tissue (cardiomyocytes, fibroblasts and, optionally, endothelial cells) will respond to instructive microenvironments generated by microfluidic techniques. These microenvironments will be modulated by the stimuli that are applied as drugs, biomolecules, metallic salts, partial oxygen pressure, and the device design. By the partial blocking of the oxygen source, we will cause a heart attack in part of the tissue with its consequent cell death and necrosis. We therefore will have a myocardial infarction within a cellular microenvironment on a chip. This proof of concept will allow us to immediately explore which therapies and strategies are the most appropriate for the design and manufacture of new strategies based on instructive biomaterials for infarcted tissue regeneration, minimizing the recourse of preclinical and clinical testing in animals and patients. The project involves CAD design, finite elements simulation, microfabrication, microfluidics, cell culture, biomaterial manipulation and confocal microscopy. Furthermore, the project also involves the improvement of other cross-curricular competences such as team-working; oral skills to present and defend an innovative project in front an expert audience; report preparation, scientific criteria (definition of reasonable hypotheses and develop solutions to complex problems); managing bibliographies and documentation; analyze and use technological advances in

biomedical engineering to meet clinical requirements; and managing concepts and methods of advanced technologies such as nanomedicine and regenerative medicine.

Keywords. microfluidics, cardiac tissue, tissue regeneration, biomaterial, quasi-vivo model

IBEC-1818. DAC XI: embodied models of the brain and real-world decision-making

Supervisor. Paul Verschure

Research group. SPECS

Project Description. Over the last years, at the SPECS_lab we have developed and validated a number of models of the brain and their role in real-world decision-making [Verschure 2003, Nature]. We have tested these models against neuroscience data and robot foraging tasks. The most recent version of this model is DACX [Maffei et al 2015 Neur Netw]. The goal of these models is to come to a detailed system level model of the mamallian brain and identify how it relates to behavior.

This project will advance DACX to the next level by adding new model components, in particular, the models of the superior colliculus, basal ganglia, and amygdala while further elaborating existing components of the prefrontal cortex, cerebellum, and hippocampus. This is planned to be a team effort where a number of people can work together to realize this unprecedented model of the mammalian brain. This project aims at extending an existing neural model starting from [Maffei et al 2015 Neur Net.] following goals that can be prioritized according to the student's interests and skills:

- Scaling the previous models to include other brain regions
- Validating the model by benchmarking it against animal behavioral data.
- Integrating the model in a complete cognitive architecture [Verschure 2016 Phil Trans Roy Soc] .
- Applying the model to various robotic platforms: mobile robot, the iCub, or the MineCraft videogame

Required skills:

- Programming skills (preferably python but also C, C++ are good starts)
- Some background in mathematics is an asset, e.g. Matlab
- Strong determination and a getting-things-done attitude
- Experience with machine learning and AI techniques is an asset

Keywords. Literature review, Computational modelling, Robotic implementation, Statistical analysis of results implementation

IBEC-1819. Functional and Dysfunctional Protein Association

Supervisor. Benedetta Bolognesi

Research group. Functional and Dysfunctional Protein Association

Project Description. My lab focuses on understanding the determinants of protein induced toxicity, especially, in the context of

neurodegenerative diseases. Proteins implicated in neurodegenerative diseases are able to populate multiple physical states in the cytoplasm: diffuse, liquid de-mixed, solid aggregate. This ability is mainly due to the presence of large intrinsically disordered regions that are often called prion-like domains. This project will focus on TDP-43, a protein implicated in

Amyotrophic Lateral Sclerosis (ALS), and on the effect that pathological mutations within its prion-like domain have on the physical states that the protein can acquire. We will use the yeast Saccharomyces cerevisiae as a model to measure both aggregation propensity and fitness effects of thousands of protein variants at the same time. Our approach will involve large scale fitness assays coupled to high throughput microscopy, flow cytometry and sequencing. By this means, we will be able to understand which physical state is mostly associated to pathology. We will then validate our findings in a human cell line model of ALS.

Keywords. neurodegeneration, mutational landscape, protein aggregation

PROJECT TAKEN!

IBEC-1820. Biomedical Signal Processing and Interpretation

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.

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

The Institute of Photonic Sciences (ICFO)

ICFO-1801. 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

PROJECT TAKEN!

ICFO-1802. Plasmon Nano-Optics

Supervisor. Romain Quidant

Research group. Plasmon Nano-Optics

Project Description. The Plasmon Nano-Optics (PNO) group, led by ICREA Prof. Romain Quidant, focuses its research in the the field of nano-optics, at the interface between photonics and nanotechnology. Capitalising on more than 15 years of experience, the PNO group exploits the unique optical properties of metallic and dielectric nanostructures as an enabling tool to advance different fields of science, from fundamental physics to applied biotech. The main current research directions are:

* Quantum Nano-Optomechanics: The PNO group is one of the pioneer and leading teams in a novel approach to optomechanics based on a nano-object levitating in vacuum. We study how the unique mechanical properties of this platform can contribute to (i) further understand the transition between the classical and quantum worlds as well as (ii) develop force sensors with unprecedented sensitivities.

* Lab-on-a-chip technology and Optofluidics: By combining nano-optics with biochemistry and advanced microfluidics, we develop different integrated platforms capable to contribute to the early diagnostics of diseases and pathologies.

* Metasurfaces for advanced optical functionalities and microscopy: In this research line we leverage on the optical properties of planar metamaterials to develop novel optical elements capable to push the limits of photonic elements with special emphasis on optical microscopy.

* Nanomedicine: We exploit the capability of gold nanoparticles to convert light into heat to develop novel, less invasive therapies for different diseases, including cancer.

Keywords. Nanotechnology, Photonics, multidisciplinary research

ICFO-1803. Plasmon Nano-Optics

Supervisor. Alexander Powell

Research group. Plasmon Nano Optics

Project Description. We have two project streams available, (but only the capacity to accept one student):

1. Plasmonic, photothermal mechanical actuators. Investigating the addition of plasmonic nanoparticles (PNP's) to soft materials to make bilayer actuators (BLA's).
PNP's have excellent photothermal properties and a strong, highly tunable optical resonance. They can be placed within one layer of a bilayer actuator and on illumination near their resoance they will heat up, causing the actuator to twist or bend. This effect can be used to initiate a range of motions and even create complex transformations to build "optical origami", enabling the creation of optically controlled walkers, swimmers etc. There is additional scope to research

materials that show expansion with other stimuli, and therefore design actuators and that will respond differently to various conditions.
This is a very multidisiplinary project and will involve elements of nanophysics, chemistry and engineering in a dynamic and diverse research group.

Training outcomes:

Knowledge of the physics of plasmonics and the photothermal effect, the surface chemistry of nanoparticles, the physics of soft actuators and the material properties of polymers.

Experience preparing samples containing nanoparticles, designing optical setups, testing and selecting appropriate materials for specific functions, mechanical design of actuators and shapes.

2. Shaping the plasmon modes in gold nanostructures. There has been a lot of interest in the last decade in the optical properties of plasmonic nanoparticles for fields as diverse as cancer therapy to gas detection. This has largely been driven by the high tunability of the optical resonances of metal nanoparticles allowing their resoances and electric fields to be tightly controlled, however a lingering problem is the creation of secondary modes which can detrimentally affect the spectral properties of the PNP's.

This project aims to investigate the tuning of the geometry, material and coating of metal nanoparticles in order to create strong primary and repressed secondary modes. This will be achieved firstly through simulation using COMSOL or Lumerical, then later through experiment.

There is the potential to then utilise the PNP's in a variety of exciting applications if a suitable design is found.

Training outcomes:

Knowledge of the physics of plasmonics and the photothermal effect, the surface chemistry of nanoparticles and optical simulation techniques. Experience coding and optical simulations, preparing samples containing nanoparticles, running experiments to probe optical properties, utilising nanoparticles in real-world applications.

Keywords. plasmon, nanophotonics, photothermal, actuators

ICFO-1804. Medical Optics

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

PROJECT TAKEN!

ICFO-1805. Attoscience and Ultrafast optics

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

PROJECT TAKEN!

ICFO-1806. Neurphotonics and Mechanical Systems Biology

Supervisor. Michael Krieg

Research group. Neurphotonics and Mechanical Systems Biology

Project Description. Our main research goal is to understand the importance of cell mechanical properties for health and disease on the molecular and systems level. Although failures to sense and cope with mechanical forces are linked to human diseases including peripheral neuropathies and neurodegenerative disorders, little is known about the connections between biomechanics and disease. To advance our understanding in this important field, we develop and deploy new optogenetic tools (FRET, synthetic biology and genetic code expansion) to measure piconewton force and their consequences inside cells. Due to the wealth of genetic tools available for it, we use the small round worm, Caenorhabditis elegans, with its compact nervous system consisting of only 302

neurons, its short lifespan and simple body plan, as a model. We exploit microfluidic and nanotechnological tools to apply precise forces to single cells or animals. Simultaneously we visualize mechanical forces and their consequences using optogenetic stress sensors and state-of-the-art microscopy.

Here, we propose to investigate the force transmission pathway during muscle contraction and understand how the elasticity of cytoskeletal components modulate power generation on the single cell level. We want to achieve this by a multi-tiered approach involving optogenetic stimulation and traction force microscopy. We will first concentrate on the spectrin cytoskeleton and take advantage of the wealth of molecular and mechanical information available for this system. We will culture embryonic muscle cells expressing the light gated ion channel channelrhodopsin on elastic substrates with varying stiffness. Upon delivery of blue light, we estimate the traction generated during contraction by measuring the deformation of the substrate.

The results of the proposed experiments advance our understanding of the role of protein mechanics in health and disease and more specifically shed light onto the mechanical resiliency of the cytoskeleton during collective force generation.

The student will work in an interdisciplinary setting composed of biologists, mathematician and physicist. He/She will learn basic animal handling and biological procedures, as well as data analysis protocols and engineering tools.

The minor project will be carried out in the lab of X.Trepat to prouce compliant hydrogels as cellular supports adn learn data analysis of stress transmission. The main project will be carried at ICFO.

Keywords. optogenetics, C elegans, mechanobiology, force transmission, traction force microscopy

ICFO-1807. Quantum NanoMechanics group

Supervisor. Adrian Bachtold

Research group. Quantum NanoMechanics group

Project Description. NOVEL TOPOLOGICALLY PROTECTED STATES IN 2D MATERIALS FOR QUANTUM INFORMATION.

Two-dimensional topological insulators (2DTI) hold great promises, as electron conduction in these materials flow unperturbed over very large distances. Due to time-reversal symmetry, the spin and momentum of electrons are locked at a right angle in the surface plane, making these states extremely robust to scattering, or in other words "topologically protected". Due to its two-dimensional form, the electron conduction results in helical one-dimensional edge modes which are confined to the sample boundaries. This results in the emergence of the quantum spin Hall effect phase, where counter-propagating, spin–polarized electron states can propagate at the edges of the sample. While 2DTIs have been demonstrated in embedded quantum wells, such as in bulk Hg/CdTe

hetero-structures, it has proven to be challenging to probe the quantum spin Hall effect states in these devices. The reason comes from the difficulty to fabricate electrical contacts to the edge states without degrading the material. Furthermore directly accessing these states with surface probe techniques, such as scanning probe microscopy techniques, is merely impossible, due to their confined nature. Here, we propose to use freestanding, single crystal van der Waals (vdW) monolayers with a 2DTI phase. These new systems could solve the above problems, as was shown this year for 1T'-WTe2 in two side-by-side publications [1], [2]. An even bigger advantage of vdW 2DTIs is the possibility to integrate these with other vdW materials into hetero-structures. These designed materials could have a very rich variety of emergent phases, where for example, proximity effect coupling with superconductors and/or ferromagnets could result in topological superconductors and dissipation less spintronic phases, respectively. When coupled to superconductors, 2DTI states are also candidate states for Majorana fermions - charge neutral non-abelian quasi-particles that are proposed as fault-tolerant qubit states as building blocks for quantum computation.

This will be a collaborative work between the two ICFO groups Low Dimensional Quantum Materials (LDQM - Prof. Efetov) and Quantum NanoMechanics (QNM - Prof. Bachtold).

[1] Nature Physics 13, 683–687 (2017)
[2] Nature Physics 13, 677–682 (2017)

Keywords. topological insulators, quantum spin Hall effect, van der Waals monolayers, Majorana fermions

ICFO-1808. Low-dimensional Quantum Materials

Supervisor. Dmitri Efetov

Research group. Low-dimensional Quantum Materials

Project Description. NOVEL TOPOLOGICALLY PROTECTED STATES IN 2D MATERIALS FOR QUANTUM INFORMATION.

Two-dimensional topological insulators (2DTI) hold great promises, as electron conduction in these materials flow unperturbed over very large distances. Due to time-reversal symmetry, the spin and momentum of electrons are locked at a right angle in the surface plane, making these states extremely robust to scattering, or in other words "topologically protected". Due to its two-dimensional form, the electron conduction results in helical one-dimensional edge modes which are confined to the sample boundaries. This results in the emergence of the quantum spin Hall effect phase, where counter-propagating, spin-polarized electron states can propagate at the edges of the sample. While 2DTIs have been demonstrated in embedded quantum wells, such as in bulk Hg/CdTe hetero-structures, it has proven to be challenging to probe the quantum spin Hall effect states in these devices. The reason comes from the difficulty to fabricate electrical contacts to the edge states without degrading the material.

Furthermore directly accessing these states with surface probe techniques, such as scanning probe microscopy techniques, is merely impossible, due to their confined nature. Here, we propose to use freestanding, single crystal van der Waals (vdW) monolayers with a 2DTI phase. These new systems could solve the above problems, as was shown this year for 1T'-WTe2 in two side-by-side publications [1], [2]. An even bigger advantage of vdW 2DTIs is the possibility to integrate these with other vdW materials into hetero-structures. These designed materials could have a very rich variety of emergent phases, where for example, proximity effect coupling with superconductors and/or ferromagnets could result in topological superconductors and dissipation less spintronic phases, respectively. When coupled to superconductors, 2DTI states are also candidate states for Majorana fermions - charge neutral non-abelian quasi-particles that are proposed as fault-tolerant qubit states as building blocks for quantum computation.

This will be a collaborative work between the two ICFO groups Low Dimensional Quantum Materials (LDQM - Prof. Efetov) and Quantum NanoMechanics (QNM - Prof. Bachtold).

[1] Nature Physics 13, 683–687 (2017)
[2] Nature Physics 13, 677–682 (2017)

Keywords. topological insulators, quantum spin Hall effect, van der Waals monolayers, Majorana fermions

ICFO-1809. 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 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 focus 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.

During the summer 2017 we will start a second experimental project, centered on the study of collective 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 collective effects on the atom-photon scattering. Furthermore, it constitutes a new platform for realizing quantum spin models and strongly interacting photon "gases".

We are looking for Master students 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-1810. Quantum Nano-Optoelectronics

Supervisor. Frank Koppens

Research group. Quantum Nano-Optoelectronics

Project Description. The quantum nano-optoelectronic group, led by Prof. Koppens, studies the nanophotonic and opto-electronic properties of novel two-dimensional materials (e.g. graphene), heterostructures and devices. Also novel quantum and topological materials and their interactions with light at the nano-scale are being studied. We aim to study topological phase transitions and visualize novel collective modes.

Several unique and novel techniques are exploited to confine light to nano-meter lengths scales and study physical processes at ultra-fast timescales. For example, 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. The group works closely with the Graphene Flagship program, the largest European initiative with 1 Billion Euro funding for ten years.

Keywords. Graphene, Nanophotonics, Quantum optics, optoelectronics, topology

ICFO-1811. Chip-integrated spectrometer with graphene-based photodetectors

Supervisor. Frank Koppens

Research group. Quantum Nano-Optoelectronics

Project Description. Optical Spectrometry is a powerful non-destructive, high throughput technique used extensively for a huge number of applications including threat and hazardous substance

detection, food inspection, process and environmental monitoring, quality control etc. We aim to revolutionize the spectrometer technology by introducing graphene photodetectors [1,2], which can detect visible and infrared light at the same time. See this video for a future impression of this technology: https://youtu.be/szL-ejdpNgU
The goal of this masters project is to design, build and evaluate an on-chip spectrometer where color-separation and photodetection are integrated on the chip itself. The student will work inside a multi-disciplinary team of about 10 people, with a strong international network and reputation. Tasks include the design of the spectrometer, building the device (in collaboration with other team members) and evaluation of the functionality. The students will perform simulations, work in the optics labs and perform data analysis. A unique and novel approach is being implemented, where know-how of complex optical beam propagation is beneficial for the project.

[1] Hybrid graphene-quantum dot phototransistors with ultrahigh gain. G. Konstantatos et al., Nature Nanotechnology 7, 363-368 (2012)

[2] Broadband image sensor array based on graphene–CMOS integration. Goossens et al., Nature Photonics, 11(6), 366-371. (2017)

Keywords. optics, beam propagation, graphene, photodetectors, spectrometer

ICFO-1812. Nano-photonic graphene-based infrared photodetectors

Supervisor. Frank Koppens

Research group. Quantum Nano-Optoelectronics

Nano-photonic graphene-based infrared photodetectors

Project Description. Graphene-based photodetectors have been proposed as an alternative for current technologies due to its broadband absorption properties ranging from visible, infrared and terahertz range.

In this project, we will focus on the photo thermoelectric effect which drives the photocurrent in our graphene p-n junction devices for infrared light [1].

The goal of the project is to enhance the infrared photoresponse by introducing concepts from nanophotonics. For example, by placing optical nano-antennas or by exploiting plasmons inside the graphene [2,3]. The student will design new device concepts, simulate them and is involved in the experimental process in collaboration with other group members.

The student will work inside a team and will use current state-of-art tools for determining the optical response of the photodetector such as Lumerical FDTD and Comsol. Afterwards, once obtained the optical response, it will be used as an input for the calculation of the thermoelectric response using Comsol and Python. The student will take advantage of previous work performed by the group in this field [4].

References
[1] Koppens et al., *Nature Nanotech.* **9**, 780 (2014)
[2] Low et al., *Nature Materials* **16**, 182 (2017)
[3] Kim et al. *Phys Rev. B* **90**, 165409 (2014)
[4] Kim et al. *Nature Nano.* **12**, 770-775 (2017)

Keywords. graphene, photodetectors, plasmonics, nanophotonics, antennas

ICFO-1813. Application of a quantum random number generator to simulations in condense matter physics

Supervisor. Maciej Lewenstein

Research group. Quantum Optics Theory

Project Description. Random numbers are central to fundamental research and technology developments, with applications in computation, simulations, cryptography, etc. Quantum mechanics has inherent randomness (ontic or intrinsic), as it persists even if we completely know the state of the system in consideration [1]. As it is a crucial resource for quantum technologies, a lot of scientific effort has been devoted recently to the development of quantum random generators (QRG) [2]. The goal of this project is to develop simulations (algorithms or observables) of condense matter systems that best reveal the benefit of current cutting-edge technological developments on QRGs, as opposed to conventional approach to use more and more optimized pseudo-random number generators. As a first example we study the determination of dynamical (relaxation) critical exponent of a 2D Ising model [3]. For this we use simulations in ICFO's developed Field programmable gate arrays (FPGA), which are appropriate for paralelized Monte Carlo simulations of this model. As a random number generator we use the ICFO's developed QRGs [4]. As a second example we will attempt to calculate the disordered Ising models phase diagrams, which can be seen as Ising models with random coefficients. We finally will explore the possibility to implement machine learning strategies to optimization problems by means our FPGA and the QRG.

To undertake this program one requires knowledge of condense matter systems and quantum mechanics. We will focus on the theoretical side, as the FPGA and QRG are already developed and ready to use at ICFO. It will require management of a large amount of data produced by the FPGA simulations, and it will be useful, but not crucial, some knowledge on programming FPGAs. Expected impact is to produce a proof of the technological applicability of quantum random numbers in practical problems and to set up a machine (the FPGA plus the QRG) ready to be applied to a variety of interesting open problems in condense matter and optimization problems with machine learning.

[1] *Randomness in Quantum Mechanics: Philosophy, Physics and Technology*, M.N. Bera, A. Acín, M. Kuś, M. Mitchell, and M. Lewenstein, Accepted in Reports on Progress in Physics. arXiv:1611.02176 (2016).

[2] *Quantum random number generators*, M. Herrero-Collantes and J.C. Garcia-Escartin, Rev. Mod. Phys. 89, 015004 (2017)

[3] *Linear relaxation in large two-dimensional Ising models*, Y. Lin and F. Wang, Phys. Rev. E 93, 022113 (2016).

[4] *Ultra-fast quantum randomness generation by accelerated phase diffusion in a pulsed laser diode*, C. Abellán, W. Amaya, M. Jofre, M. Curty, A. Acín, J. Capmany, V. Pruneri, and M.W. Mitchell, Optics express 22, 1645 (2014); *Generation of Fresh and Pure Random Numbers for Loophole-Free Bell Tests*, C. Abellán, W. Amaya, D. Mitrani, V. Pruneri, and M.W. Mitchell, Phys. Rev. Lett. 115, 250403 (2015).

Keywords. quantum random number generators; FPGA; condense matter systems; Randomness in physics. Machine learning

ICFO-1814. Insights on the role of Poly-ADP-ribose (PAR) in mediating chromatin phase transitions by means of 3D-single particle tracking methods

Supervisor. Maria Garcia-Parajo

Research group. Single Molecule Biophotonics

Project Description. Recent studies have shown that proteins and RNAs can assemble into a liquid phase inside the cell that is distinct from the surrounding cytoplasm. This process of phase-separation provides a principle for spatiotemporal organization in the cell and it is believed to play a major role to enhance biochemical reactions. However, very little if known on how phase-separation inside the cell nucleus occurs, and importantly, how it contributes to gene regulation.

The goal of this project is to obtain insight on the role of Poly-ADP-ribose (PAR) in mediating chromatin phase transitions in the context of hormonal gene regulation. In the nucleus, PAR polymers accumulate transiently after hormone stimulation, possibly contributing to the formation of phase-separated compartments. Using single molecule tracking we will address whether such compartments provide a mechanism to control local concentration of the progesterone receptor. The use of single molecular dynamic approaches could bring valuable insights on the process of nucleation, degree of phase separation, compartment size and distribution, and the impact of PAR-induced liquid de-mixing on chromatin remodelling and gene expression.

The specific objectives of the project are:

1) Defining and adjusting labelling & imaging conditions for single particle experiments of the progesterone receptor (PR) inside the nucleus of living breast cancer cells.
2) Record the diffusion of individual trajectories of PR inside living cells at different spatiotemporal resolutions.
3) Detailed data analysis of individual trajectories to determine diffusion coefficients, type of diffusion profiles (Brownian, anomalous, directed or facilitated diffusion) on different regions of the cell nucleus, physical sizes of compartment regions.

4) Study the effect of PARP1 inhibitors on PR diffusion and compartment sizes.

During the development of this project the student will get deep training on single molecule fluorescence microscopy, single particle tracking and statistical data analysis. The student will be embedded in a collaborative project with the group of M. Beato @ CRG, profiting from a truly multidisciplinary research and expected to actively participate on the decisions taken during the development of the project.

[1] *Randomness in Quantum Mechanics: Philosophy, Physics and Technology*, M.N. Bera, A. Acín, M. Kuś, M. Mitchell, and M. Lewenstein, Accepted in Reports on Progress in Physics. arXiv:1611.02176 (2016).

[2] *Quantum random number generators*, M. Herrero-Collantes and J.C. Garcia-Escartin, Rev. Mod. Phys. 89, 015004 (2017)

[3] *Linear relaxation in large two-dimensional Ising models*, Y. Lin and F. Wang, Phys. Rev. E 93, 022113 (2016).

[4] *Ultra-fast quantum randomness generation by accelerated phase diffusion in a pulsed laser diode*, C. Abellán, W. Amaya, M. Jofre, M. Curty, A. Acín, J. Capmany, V. Pruneri, and M.W. Mitchell, Optics express 22, 1645 (2014); *Generation of Fresh and Pure Random Numbers for Loophole-Free Bell Tests*, C. Abellán, W. Amaya, D. Mitrani, V. Pruneri, and M.W. Mitchell, Phys. Rev. Lett. 115, 250403 (2015).

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

ICFO-1815. Enlightening TANGO1

Supervisor. Maria Garcia-Parajo

Research group. Single Molecule Biophotonics

Project Description. Collagens that constitute 25 % of our dry body weight are synthesized in the endoplasmic reticulum (ER), from where they are exported along the secretory pathway for release into the extracellular space. Collagens are however too large to fit into the standard COPII vesicles of 60nm average diameter that export secretory cargoes from the ER. How are then the collagens secreted? An ER-resident transmembrane protein, TANGO1, is required for the export of collagens by modulating and physically connecting the cytosolic membrane-remodeling machinery to the collagens in the ER lumen. *eTANGO aims at providing first structural, dynamic and physical understanding of how TANGO1 export collagens.* The project will employ a multidisciplinary approach that combines state-of-the-art genetic manipulations of TANGO1 and its binding partners together with advanced single molecule optical techniques and biophysical modeling to monitor the organization and dynamics of collagen export from the ER.

ICFO-1816. Biophysics of intracellular trafficking

Supervisor. Maria Garcia-Parajo

Research group. Single Molecule Biophotonics

Project Description. The goal of the research project is to bring understanding on how proteins are transported between the different membranes of the Golgi complex and the impact of Golgi membrane organization to its function. In particular, the student will investigate the mechanisms by which secretory cargoes are processed and transported along the Golgi complex. To reach this goal, the student will use a unique multidisciplinary approach combining state-of-the-art molecular and cell biological tools with biophysical modeling. Moreover, the student will be exposed to advanced imaging techniques, including super-resolution nanoscopy and single molecule approaches.

ICFO-1817. 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-1818. Nanophotonics Theory

Supervisor. Javier Garcia de Abajo

Research group. Nanophotonics Theory

Project Description. Our group is focused on the study of the optical response of nanostructured materials. We develop theory to explain and unveil new physical phenomena associated with the interaction of light with such materials. In particular, we investigate plasmons in nanoparticles and nanostructures, as well as the interaction of these plasmons with molecules. We provide theory to interpret and extend electron-microscope-based spectroscopy. We are also interested in exploring exotic quantum and classical phenomena involving the optical response of nanostructures, such as quantum vacuum friction, collective optical modes in graphene, and molecular plasmons.

Expertise in many-body and condensed-matter theory, optical response at the nanoscale both from first-principles and based upon classical electromagnetism, interaction of fast-electrons/ions with nanostructures. Powerful computational tools for solving Maxwell's equations (boundary-element method, multiple scattering, etc.), Schrödinger's equation, and linear-response problems (e.g., RPA expansions for many different physical systems).

Research Topics:

- Nanoplasmonics
- Graphene Plasmonics
- Electron Microscope Spectroscopies
- Quantum Nanophotonics

ICFO-1819. A bright and pure photon source: strong coupling of a single molecule to a plasmonic nano-antenna cavity

Supervisor. Niek van Hulst

Research Group. Molecular NanoPhotonics

Project Description. Light is the most powerful carrier of information for our communication. More and more, single photons are explored for quantum communication. Yet most photon sources have their limits in yield and quality of the photon emitted. The main goal of this project is to craft a bright and pure singe photon source. We exploit concepts of cavity QED to boost the light field and enhance light-matter interaction with photon emitters, such as molecules and point defects. The novelty and strength of

this project is the application of nanophotonic antennas as nanocavities with deeply localised mode volumes and very high radiation efficiency. The challenge is to put the photon emitter exactly right inside the nanoscale mode volume. In the project we will use both nanofabrication at

ICFO clean room and nano-manipulation on the group's scanning antenna microscopes. Getting the positioning right, single photon output should be hugely accelerated, providing fast and pure non-classical single photon emission with brightness of 10E9 – 10E12 photons/sec: a bright on-demand and ultrafast single photon nanosources for quantum technologies. More importantly a single molecular photon sources filling a nanometer field confinement is the ideal condition for strong coupling up to several THz. We will aim to achieve this strong coupling condition at which the molecular states and the optical field enter into a superposition state, allowing to tune both the molecular and cavity response. The bright photon emission and strong coupling give rise to a plethora of fascinating effects of both scientific and technological interest.

Objectives: 1) ultrafast single photon stream > GHz; 2) coupling above 1 THz; 3) Spatial confinement < 10 nm;

Training outcome: 1) Skills: nanofabrication, nanocontrol, single photon detection, single molecule detection, super-resolution, ultrafast detection, pulse lasers, focussed ion-beam milling, e.m.-field simulations; 2) Insight: mode density, quantum-optics, plasmonic modes, optical antennas fields, photon statistics; 3) Getting prepared for a PhD project and position; 4) Report of master project culminating in a publication. Related recent literature of the group: Nature Communications 7:10411 (2016); J.Phys.Chem.Lett. 7, 1604-1609 (2016); Nature Communications. 5: 4236 (2014); NanoLetters 14, 4715-4723 (2014).

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

ICFO-1820. Medical optics group

Supervisor. Turgut Durduran

Research Group. Medical optics group

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

Institute of Chemical Research of Catalonia (ICIQ)

ICIQ-1801. Photoactive Materials

Supervisor. Emilio J. Palomares

Research group. Photoactive Materials

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

Keywords. perovskite, solar cells, quantum dots, biosensing

ICIQ-1802. Development of new chemical transformations: From organometallic mechanistic studies to catalysis

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. To develop our research projects, we apply different approaches, ranging from synthetic organic chemistry to mechanistic studies including the capture of highly reactive intermediates and a full complement of physical organic tools. Currently, the two main research lines of our lab are framed in this context. The first research line focuses on investigating the cooperative behavior of bimetallic systems for the rational development of new catalytic processes. The second research line explores the potential of cobalt catalysis, a cost-effective alternative to noble transition metals, to discover and develop innovative and more efficient transformations. 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, multiple characterization techniques, as well as physicochemical approaches. 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, Homogeneous Catalysis, Rational Design, Reaction Mechanisms

ICIQ-1803. Understanding the activation of CO2 over heterogeneous catalysts

Supervisor. Atsushi Urakawa

Research group. Urakawa Research Group

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

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

Catalan Institute of Nanoscience and Nanotechnology (ICN2)

ICN2-1801. Phononic and Photonic Nanostructures

Supervisor. Pedro David García Fernández

Research group. Phononic and Photonic Nanostructures

Project Description. The coupling of electromagnetic radiation (photons) to mechanical waves (phonons) is at the heart of solid-state quantum photonics while phonon transport at different frequencies governs crucial physical phenomena ranging from thermal conductivity to the sensitivity of nano-electromechanical resonators. To engineer and control the overlap of light management with the mechanical vibrations of matter efficiently, we make use of very precisely fabricated nanometer-scale devices. The standard way of achieving this control is to use engineered defects in periodic structures - optomechanical crystals - where the electromagnetic field and the mechanical displacement can be confined simultaneously thus enhancing their interaction. However, despite its extraordinary potential, cavity optomechanics is suffering from the limitations induced by the experimental setup commonly used to address the mechanical modes, namely the difficulty to use integrable structures.

Our main objective is to explore novel designs for optomechanical nanostructures and to develop experimental methods to address the phononic and photonic modes of nanoscale objects from free-space, and thus get rid of the limitations imposed by fibres, which will in turn enable the incorporation of optically active materials in mechanical resonators. For this goal, we make use of ultrafast pump and probe interferometry to explore mechanical vibrations in the radio-frequency range. Right now, we can probe nanostructures which are optically passive. Our aim is to fabricate structures with active light-emitting materials which will allow us to get access to the photonic properties of the system. The investigation of these systems will have an important impact on quantum information and thermal transport as well as highly sensitive force, mass and displacement detection.

This research line is included in a wider research group, the Phononic and Photonics Nanostructures group at ICN2. The expertise of the group focuses on nanoscale phonon transport at different frequencies. For example, we are interested in nanoscale thermal transport, phononic crystals and the interaction

between phonons and photons at the nanoscale. We are an international group of around 15 dedicated researchers and students in The Phononic and Photonics Nanostructures group. We continuously arrange social events and we have regular group meetings/journal clubs where we discuss recent scientific breakthroughs in our field.

Keywords. optomechanics, nanophotonics, light-emitting materials, ultrafast spectroscopy

PROJECT TAKEN!

ICN2-1802. Advanced Electron Nanoscopy

Supervisor. Jordi Arbiol

Research group. Advanced Electron Nanoscopy

Project Description.

Water oxidation is considered the bottleneck in the development of an efficient and cost-effective water splitting technology for the production of renewable fuels. One of the challenges resides in substituting heterogeneous noble metal catalysts by earth-abundant counterparts while maintaining the efficiency and performance required for technological applications. Inexpensive mixed Ni-Fe oxides, are very competitive catalysts for the oxygen evolution reaction (OER). However, a large effort is still needed to understand their mechanism; to optimize their performance; and to identify the optimum phases and geometries for implementation. This is especially relevant regarding their active surfaces. Little information is available due to some intrinsic problems: i) they are non-stoichiometric ill-defined materials whose crystal and electronic structures are unknown; ii) activity and surface structure depends on processing, varying between experiments; iii) surface structure evolves during working conditions, differentiating from bulk; iv) most surface sensitive techniques at atomic resolution need either high vacuum or ultra-low temperatures, what also affects surface structure and composition. Through this project, we will tackle this important problem taking advantage of the atomic resolution of aberration corrected transmission electron microscopy and related spectroscopies to study the surface structure of Ni-Fe oxides as a function of preparation and, remarkably, before and after electrocatalytic performance. This multidisciplinary collaboration between electrochemistry and micro/nanoscopy aims to establish the main correlations between activity and structure. Such profound understanding could be a fundamental advance in the field of water splitting and solar fuels. The above Major project will be developed at the Institut Català de Nanociència i Nanotecnologia (ICN2), which is equipped with the required instruments. The project will be supervised by Prof. Jordi Arbiol, leader of the Advanced Electron Nanoscopy Group (GAe-N).

Research Objectives. By studying the atomic resolution data, with the use of computer simulation techniques and 3D atomic modelling of the nanosystems it is

expected to obtain a direct correlation between the surface chemistry of the materials and their structural, compositional and chemical behaviour at the atomic scale.

The main objective is obtaining a model of the water oxidation mechanism by understanding the electrocatalytic performance of the studied materials down to the atomic scale.

Expected Training Outcomes. The student is expected to obtain high skills and experience in the use of cutting edge electron microscopy technology in order to be able to run and operate the instruments by him/herself.

The student will be trained on the analysis of the atomic resolution scanning transmission electron microscopy data (STEM) and the electron energy loss spectroscopy (EELS) data.

Keywords. Electron Microscopy/ Nanoscopy, in-situ/In-operando, Energy Nanomaterials, atomic scale structure, water oxidation, catalysts

PROJECT TAKEN!

ICN2-1803. Supramolecular NanoChemistry & Materials Group

Supervisor. Daniel Maspoch

Research group. Supramolecular NanoChemistry & Materials Group

Project Description. Control the supramolecular assembly of (bio)molecules, metal ions and nanoscale building blocks at the nanometer scale for the design of functional architectures with potential voids like metal-organic frameworks (MOFs) and capsules.

The NANOUP group research interests are focused on controlling the supramolecular assembly of molecules, biomolecules, metal ions and nanoscale building blocks at the nanometre scale for the design of novel functional architectures and devices. The use of supramolecular chemistry to control the fabrication of new nanomaterials is a key aspect for the future of nanoscience and nanotechnology. We use the supramolecular chemistry as the underlying approach for exploring new complex supramolecular assemblies and bioinspired architectures (mainly, metal-organic frameworks (MOFs) and vesicles) with unprecedented structures, with interesting physical and biological properties and applications (in close collaboration with several private companies) in diverse areas, including micro- and nanoencapsulation, drug-delivery systems, contrast agents and the development of novel sensors and magnetic platforms.

Keywords. Nanomaterials, Metal-organic frameworks (MOFs), Capsules, Supramolecular Chemistry, Materials Science

ICN2-1804. Theory & Simulation Group

Supervisor. Miguel Pruneda

Research group. Theory & Simulation Group

Project Description. The activities of the group are based on the theory and simulation of materials and processes at the nanoscale. There are two main aspects of this work:

1. The development of theoretical methods, numerical algorithms and simulation codes. The main activity (but not the only one) in this aspect is the paramount role of the group in the development of the SIESTA code (a program used by several thousands of researchers around the world, that has produced nearly 3000 publications). We have very strong collaborations with the other developers of SIESTA (at ICMAB, UAM, Cambridge, U. Cantabria, UPV/DIPC, BSC, and Perth), and many other groups developing theory and simulation methods. We also have an very intense and close collaboration with the "Theoretical and Computational Nanoscience Group" at ICN2 led by Stephan Roche.

2. The study of specific problems in nanoscience. In particular, much of the activity of the group in this aspect is a direct collaboration and interplay with experimental groups, both within ICN2 and worldwide.

Keywords. First-principles calculations, materials science, oxides

ICN2-1805. 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

ICN2-1806. 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. The final goal is to search for new ways to sense, and to store and process information. We focus on novel 2D and low dimensional materials that can give rise to interesting phenomena for a future generation of nanodevices.

The strategy we follow has several steps: i) first we develop methods to synthesize and nanostructure these materials; ii) in a second step we combine different scanning probe and photon and electron spectroscopic techniques (STM, XPS, ARPES, XAS, XMCD), some of them carried out in synchrotron radiation facilities; iii) as a third step, we develop methods to engineer properties and manipulate the phenomena we are interested.

The materials we currently explore comprise graphene, 2D metal-organic networks, and topological insulators. The project proposed here would be related to developing methods to tailor graphene's properties by nanostructuration:

Graphene is a gapless, diamagnetic semimetal. However, shaping graphene at the nanoscale, doping them, 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...)

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

ICN2-1807. Nanostructured Materials for Photovoltaic Energy Group (NMPE)

Supervisor. Monica Lira-Cantu

Research group. Nanoestructured Materials for Photovoltaic Energy Group (NMPE)

Project Description. Monica Lira-Cantu's research group focuses on the development of novel nanomaterials for emerging photovoltaic systems. We are experts on the synthesis of semiconductor oxides, halide perovskite and organic semiconductors (polymers) for their application of Perovskite solar cells. The fabrication methods employ low-cost and scalable solution processable techniques. The objectives for the master program includes (a) the fabrication and characterization of highly efficient and highly stable perovskite solar cells by modifying materials, interfaces and device configuration. Among the materials, we work with traditional binary oxides (e.g. TiO2, ZnO or NiO) and also with more complex compounds (e.g. doped oxides, LaSrO3, PbTiO3, etc); (b) the functionalization of oxide interfaces to enhance device lifetime and (c) To increase solar cell stability by the application of novel oxides with singular properties (ferroelectric, ferroics). The student will be able to learn the basic principles that govern perovskite solar cells, to fabricate complete devices and characterize them by electrical and stability analysis. The student will also learn to make presentations, write his/her own reports and discuss the results in public. English language is obligatory.

Keywords. Perovskite solar cells, functionalization of oxides surfaces, semiconductor oxides, stability

ICN2-1808. Nanostructured Functional Materials (Nanosfun)

PROJECT TAKEN!

Supervisor. Daniel Ruiz-Molina, Fernando Novio

Research group. Nanostructured Functional Materials (Nanosfun)

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

multifunctional systems that combine the beneficial features of purely organic and inorganic nanoparticles with improved properties for biomedical applications. Since normally they have no capacity to cross the BBB, our purpose is to construct selected nanoparticles and coat them with functional catechol-based biocompatible and biodegradable polymers. The objective is to develop a universal bioinspired coating susceptible to be functionalized with specific targeting molecules capable to interact with the specific receptors present in the BBB, thus causing an increase in the permeability of the conjugate in the brain through transcellular passive diffusion processes.

The specific objectives are: 1) Synthesis and characterization of different types of nanoparticles (i.e. silica nanoparticles, gold nanoparticles, coordination polymer particles); 2) Coating different nanoparticles with specific catechol-based polymers; 3) Study of in vitro cytotoxicity and cellular uptake ability of coated nanoparticles; 4) Functionalization of nanoparticle coatings with targeting molecules to cross BBB (i.e. small peptides, saccharides); 5) Study of nanoparticles ability for crossing BBB using in vitro models (minor project). The expected training outcomes will include the acquisition of skills in design and synthesis of new nanomaterials, chemical synthesis of organic bioinspired polymers and nanoparticle characterization. Complementarily, the student will learn different techniques of in vitro assays.

Required background. The academic background required includes an strong formation and skills in organic/inorganic synthesis, and materials/nanomaterials characterization techniques. We seek strongly motivated applicants willing to achieve a Master with high level of excellence. The applicant should ideally have a background on chemistry and materials science, oriented to nanomedicine. Knowledge of biology/biochemistry would be advisable, but not essential.

Minor project. The proposed minor project will include a 10-week research project in the Institute for Research in Biomedicine (IRB) where the applicant will learn about different in vitro models used to test the ability of nanoparticles for crossing BBB. In the research group led by Dr. Ernest Giralt (Design, Synthesis and Structure of Peptide and Proteins) the student will have the opportunity to test some of the obtained nanoparticles during the major project.

Keywords. Nanoparticles, Bioinspired coatings, BBB, Theranostics, Nanomedicine

ICN2-1809. Nanostructured Functional Materials (Nanosfun) - 2

Supervisor. Daniel Ruiz-Molina

Research group. Nanostructured Functional Materials (Nanosfun)

Project Description. Possessing a huge potential, photofunctional materials have already demonstrated a number of

interesting properties and continue to attract research attention. The main feature of this type of material can be called the ability to manipulate the final properties by creating a different type of photon upconversion (UC) systems.

Besides, the material should have photochromic properties, and one of the two photochromic states of the system should be selectively stabilized on demand for reversible interconversion direct and reverse photochromism . It also should be bear in mind, that variety of external influence can affects the stability of the material that can tend to counterbalance. Therefore, the task of obtaining materials of this class that are resistant to various types of influences is a truly serious challenge that attempts to be solved by various approaches.

The details of the project are: selection of the optimal photochromic dyes for the achievement of thermally switchable photochromism in solid materials. Control over the characteristic of phase-change medium . Determination of how the material components interact with each other, is it possible to control the existing type of dependence, is it possible to intercalate additional functional compounds into the system. Are there some changes in the properties during contact with the medium, where there is a possibility of oxidation-reduction reaction, and how this can affect the final signal. Is the material able to withstand several cycles without loss of efficiency.

Moreover,one of the aims is to obtain a new kind of material, which is suitable for using in the field of bioassay and diagnostics. This substance should not have any kind of toxicity, but at the same time demonstrate high efficiency with high stability with respect to changes in the environment and various external stimuli. The main tasks in this case are the calculation of the necessary parameters for obtaining the required material, the study of the properties of the received object, the conversion of the qualitative and quantitative characteristics of the photon upconversion (UC) systems .

Keywords. Chemistry, Functional materials, Nanotechnology

ICN2-1810. Multicomponent Heterostructured Inorganic Nanocrystals for Artificial Photosynthesis

Supervisors. Victor Puntes and Neus G. Bastús

Research group. Inorganic Nanoparticles

Project Description. Energy availability is one of the most important problems facing our civilization. Consequently, a major challenge in 21st century is the development of renewable carbon-neutral sources. The Sun is the most abundant energy source on Earth, representing by far the best alternative. While in biological systems the harnessing of solar energy is accomplished by specific proteins, nowadays inorganic semiconductor nanocrystals (NCs) can be designed to successfully address this task. However, photocatalytic materials being currently produced present serious limitations including low photocatalytic efficiency and unsatisfactory broad-band (visible-near

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

Three specific objectives are identified: 1) the production of advanced complex NCs via breakthrough advances in wet chemical synthesis, 2) the unravelling of their structure-activity relationships, in particular a comprehensive study of the relations between synthesis conditions, morphology, architecture and physicochemical properties of the material, and photocatalytic efficiency, and 3) the determination of their efficiency in real scenarios, developing new sets of characterization protocols for the study of the physicochemical evolution of NCs.

As a result, the candidate will be specifically trained to gain interdisciplinar knowledge in the design and development of inorganic nanocrystals for energy harvesting and conversion, in particular on their synthesis, characterization and evaluation of their photocatalytic properties. In addition to acquiring a broad scientific multidisplinary knowledge, the candidate will be additionally trained on education, safety, viability and sustainability of nanostructured materials, including regulation, ethics and opportunities. He/she will gain communication and technology transfer skills and will be trained from the beginning to get familiar and follow the Good Laboratory Practice and Responsible Research and Innovation principles.

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

Institute for High Energy Physics (IFAE)

IFAE-1801. Photon Detectors to measure microvascular blood flow in the brain

Supervisor. Sebastian Grinstein

Research group. IFAE ATLAS Pixel group

Project description. Our group is part of the ATLAS experiment at CERN (Switzerland). Our research is focused on accelerator-based experimental particle physics, motivated by the possibility of understanding the fundamental laws of nature at the energy frontier. Discoveries require constant refinement of the experimental instrumentation methods. Silicon detectors play a crucial role in high energy physics experiments: they are radiation tolerant, compact and offer excellent position resolution. These devices are finely segmented, with a pixelated two-dimensional array geometry. The signal generated in each pixel of the sensor by the incoming radiation has to be collected, amplified and processed. Traditionally the charge collection and the signal processing are done in two separate "pieces" of silicon, forming a hybrid detector.

However, the IFAE group has recently been working on monolithic CMOS devices, in which the sensing and signal processing mediums are the same. This offers many advantages in terms of cost, robustness and achievable position resolution. Furthermore, semiconductor detectors are being increasingly used in medical applications and, in general, as imaging systems. The group is investigating and developing monolithic CMOS sensors for soft X-ray detection at the ALBA synchrotron in Cerdanyola, and also for photon detection for medical physics. In particular, there is an ongoing effort to develop a CMOS-based sensor capable of detecting the type of photons that are used to measure microvascular blood flow in the brain through a processed developed by researchers at ICFO.

The selected candidate is expected to characterize the electrical properties of monolithic CMOS devices aimed for photon detection, and then conduct field tests at ICFO (for the minor research project). The group exploits the microelectronic infrastructure at FAE which includes clean rooms with state of the art equipment (http://www.ifae.es/cast/ingenieria/servicios-de-microelectronica-para-la-industria.html) and a dedicated gray room with electronic test-benches, a climate chamber and laser and radiation source setups.

Keywords. Silicon radiation detectors, monolithic CMOS devices, high energy physics, state of the art instrumentation, medical applications

IFAE-1802. Calibrations of X-ray Spectral Photon counting detector

Supervisor. Mokhtar Chmeissani

Research group. IFAE-Medical Imaging

Project description. IFAE has developed a dedicated X-ray spectral photon counting detector, using pixel CdTe detector bump

bonded to dedicated frontend pixel ASIC. The pixel has 6 energy levels but due to some offsets and gain spread, these 6 energy levels varies from one pixel to another. However, in every pixel and for every threshold there is an adjustable voltage correction to tune all the trigger levels to be equally for all the pixels. After achieving this equalization point, one can take X-ray images of different object with different densities and can detect minute difference. Then the detector is mounted on a linear motor, it can be used as X-ray scanner to scan large object, like the ones used in the airports The Master Student will be introduced to photon counting pixel CdTe detector, how it operates and detects X-ray photons, how the X-ray image is formed, and latter how it is analyzed. The master student will have to learn how to program with Labview. The basic program exists but it needs more development. He/she will be taught how the pixel frontend readout electronics works to have good understanding how to equalize all the thresholds for all pixels.

Keywords. Labview, Photon Counting, X-ray imaging, data-analysis

IFAE-1803. Positron Emission Tomography (PET) data collection and analysis

Supervisor. Mokhtar Chmeissani

Research group. IFAE-Medical Imaging

Project description. IFAE has built a novel PET using pixel CdTe. The project is called Voxel Imaging Pathfinder PET (VIP-PET). With pixel CdTe one can get the exact position of the impact of the gamma photon and its energy. But sometimes the gamma photon undergoes a Compton scatter process and deposit its energy in two different pixels. Given we know the position and energy precisely, one can reconstruct the Compton cone. The Master student will be introduced to pixel CdTe detector used in VIP-PET and what are the critical parameters. The research work will cover the physics of gamma photons detection and scattering in CdTe and how to compute the Compton cone and how to detect the origin of the gamma source. The intersection of 3 Compton cones will allow the determination of the point source. The master student need to develop a code using Mathematica to find the best fit.

Keywords. Labview, PET, pixel-CdTe, Compton

IFAE-1804. Calibrations of X-ray Spectral Photon counting Camera for breast biopsy

Supervisor. Mokhtar Chmeissani

Research group. IFAE-Medical Imaging

Project description. IFAE is developing a dedicated X-ray spectral photon counting detector 6 cm x 6 cm, using pixel CdTe detectors. The final use of this camera is in medical application, and mainly for breast biopsy prone table. The camera has around 250k pixels that have to be equalized and calibrated for gain variation and baseline offset. After achieving this equalization point, one can take X-ray images of the same object at different angle and with these X-ray images one can reconstruct a pseudo 3D image. This will allow the precise guiding of the biopsy needle toward a specific target point inside the breast tissue. The Master student will be introduced to photon counting pixel CdTe detector operates, detects X-ray photons, and how the images are formed. The master student will learn how to do basic programs with

Labview. He/she will be taught how to analyze the data, correct for dead pixel and equalized the pixel response. The test will be done with phantom breast.

Keywords. Labview, Photon Counting, X-ray imaging, breast-biopsy

IFAE-1805. Big Data for High Energy Physics

Supervisor. Andres Pacheco Pages

Research group. IFAE-ATLAS

Project description. The group works in the exploitation of the scientific data collected in the ATLAS detector at the LHC collider (http://atlas.cern/updates). The work of this researcher is in the support of the worldwide computing infrastructure needed to process the data and the simulation. This worldwide computing infrastructure is evolving to use more and more Supercomputers and Cloud Services. In the field of Supercomputing, we are interested to train physicists to make extensive use of the MareNostrum4 Supercomputer (#16 in the world ranking in 2017) to simulate data and use Big Data infrastructure for massive data analysis.

Keywords. LHC Grid HPC Supercomputing Simulation

IFAE-1806. Searches for Dark Matter at the LHC using Machine Learning Techniques

Supervisor. Mario Martínez Pérez (ICREA Research Professor)

Research group. IFAE-ATLAS

Project Description. The understanding of the nature of dark matter in the Universe is one of the main challenges in particle physics in the following decade. It already constitutes one of the pillars of the research program at the LHC at CERN where proton-proton collisions are produced with a center-of-mass energy of 13 TeV. If dark matter were produced in the collisions, it would be revealed in dedicated searches carried out by the different experiments. In this master thesis project, the canonical search for dark matter using mono-jet final state is convoluted with the use of state-of-the-art machine learning techniques with the aim to boost the sensitivity of the analysis to heavier dark matter candidates. The project involves the design, training and optimization of convolutional networks (similar to those use in imagine/patterns recognition challenges) to discriminate different background sources from dark matter signals, using massive Monte-Carlo simulated samples and the full Run 2 data from the LHC. The work will be developed within the framework of the ATLAS experiment and in contact with high-performance computing centers.

Keywords. LHC, CERN, dark matter, Deep Learning, Convolutional Networks, GPUs

IFAE-1807. Search for a charged Higgs boson decay into a pair of top and bottom quarks using the complete Run 2 data of the ATLAS experiment

Supervisor. Imma Riu (IFAE Research Scientist)

Research group. IFAE-ATLAS

Project Description. The ATLAS experiment at CERN's Large Hadron Collider will record proton-proton collision data at 13 TeV center-of- mass energy until the end of 2018 when a shutdown of two years will

start. Studies of the complete data sample taken since 2016 may result in hints of physics beyond the Standard Model. No charged scalar bosons exist within the Standard Model, but almost all beyond the Standard Model scenarios incorporate an extended Higgs sector with at least a pair of charged scalar bosons. For charged Higgs heavier than the mass of the top quark, the main production mode for most scenarios is in association with a top quark and the most prominent decay is into a pair of top and bottom quarks. The analysis of the complete data sample until the end of 2018 using the discriminant method developed in IFAE will be performed.

Keywords. ATLAS, Higgs boson, SUSY, detector, physics, CERN

IFAE-1808. Design and performance study of novel online multivariate event selection algorithms for Run 3 in the ATLAS experiment

Supervisor. Imma Riu (IFAE Research Scientist)

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 during the next data-taking period. New online event selections need to be designed to cope with the expected increase in event rate without reducing the acceptance of important physics signals. The installation of new electronic boards will allow to perform real time topological or multivariate selections using information from muons, electrons, taus, jets or missing transverse energy. We will design and study the performance of new multi-variate algorithms to increase the efficiency for Higgs and SUSY signals.

Keywords. ATLAS, detector, physics, trigger, selection, algorithm, multivariate, CERN

IFAE-1809. Search for H→μμ with the HGTD detector of the ATLAS experiment

Supervisor. M. Pilar Casado Lechuga (UAB Professor)

Research group. IFAE-ATLAS

Project Description: The ATLAS experiment at CERN's Large Hadron Collider is preparing an upgrade for its detector to cope with the High Luminosity upgrade of the LHC. The very high statistics of proton-proton collisions collected with the upgraded detector will allow to study physics processes so far out of reach of the sensitivity. At very high luminosity the accumulation of soft proton-proton interactions coinciding with the high-energy interaction of interest, the so-called pileup, makes the analysis more difficult. ATLAS will install a new detector with high granularity and precise timing information, the High Granularity Timing Detector (HGTD). The student will evaluate the impact of HGTD in the physics channel H→μμ, a rare decay mode of the Standard Model Higgs, where the impact of the Z boson Z→μμ background is considerable and the pileup reduction will be crucial.

Keywords. Higgs boson, HGTD, upgrade, ATLAS

IFAE-1810. 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-1811 Characterization of improved trigger system for the next LST telescope cameras

Supervisor. Òscar Blanch

Research group. Gamma Ray

Project description. The gamma-ray astrophysics group at IFAE is coordinating the construction of the camera for the large-size telescopes of CTA, the largest planned ground-based gamma-ray observatory worldwide. The first camera is being built and will be commissioned in La Palma during 2018. In parallel the construction of the following cameras has started. Some subsystems have already been shown to need some modifications, namely the lowest levels of the trigger system. Those modifications are being implemented at IFAE and they will need to be characterized. The selected candidate will participate in the characterization of the new version of the low-level trigger in the laboratory. Candidates with some experience in the laboratory, would be preferred.

Keywords. High Energy Astrophysics, Instrumentation, Cherenkov Telescope Array

IFAE-1812. Fractal dynamics and cancer growth

PROJECT TAKEN!

Supervisor. Rafel Escribano and Pere Masjuan

Research Group. IFAE Theory Division

Project Description. The dynamics of fractal and chaotic structures in nature follow the principle of minimal energy. Guided by such principle, together with a set of dissipative equations, and the notion of attractor, we shall consider the epistemology of the origin of cancer. Under certain boundary conditions, we propose to study how the pre-cancerous niche develops inspired by the chaotic evolution of dissipative systems with inhomogeneities. The tools of analytic mechanics may spell out a sequence of steps, one or more of which could be

interdicted to prevent the progression of cancer.

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

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

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

IFAE-1813. 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

Institute for Research in Biomedicine (IRB Barcelona)

IRB-1801. Biomedical Genomics

Supervisor. Nuria Lopez-Bigas

Research group. Biomedical Genomics

Project Description. Our research is focused on the study of cancer from a genomics perspective. We are particularly interested in the identification of cancer driver mutations, genes and pathways across tumour types and in the study of their potential as therapeutic targets.

Our principal research lines are focused on:

1. Understanding mutational processes by studying the observed pattern of the somatic mutations across genomic regions.

2. Finding the drivers of cancer. Identification of the genes affected by genomic alterations that drive the abnormal growth of malignant cells, as well as identification of potential driver non-coding genomic elements, such as promoters, enhancers, and non-coding RNAs.

3. Contributing to precision medicine

Our lab seeks to contribute to the advancement of precision medicine, in particular the interpretation of the genomic variants of tumours, thus facilitating the identification of therapeutic options for cancer patients.

The student would be trained in Bioinformatics and would participate in one of our research lines depending on the availability of the different projects.

Keywords. Cancer Genomics, Precision Medicine, Driver Mutations, Biomedicine, Mutational Processes

IRB-1802. Cell Division Laboratory

Supervisor. Cayetano Gonzalez

Research group. Cell Division Laboratory

Project Description. In our research group, we model cancer in flies to understand the cellular changes that drive malignant growth and to identify conserved mechanisms that might be relevant for human cancer therapy. We focus on the mechanisms of malignant transformation in larval brains. We have revealed that neuroblasts can originate tumours if the process of self-renewing asymmetric division is disrupted. We have discovered a fly model of human tumours characterized by the ectopic expression of Cancer Testis antigens and revealed a functional requirement for some of those genes for tumour growth.

We have described a method to assay the tumourigenic potential of Drosophila mutant tissues. We also maintain a very active line of research to identify new centrosomal proteins and found some with human orthologs that are linked to human pathologies. We also work on the mechanisms that bring about genome instability in Drosophila tumours. For our research, we develop and make extensive use of 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.

Keywords. malignant growth, cancer testis antigens, Drosophila, l(3)mbt, cancer therapy

IRB-1803. Molecular Modeling and Bioinformatics

Supervisor. Modesto Orozco

Research group. Molecular Modeling and Bioinformatic

Project Description. The MMB group tries to understand the functioning of living organisms from the basic rules of physics and chemistry. We are particularly interested in characterizing protein dynamics and chromatin structure in dynamics at the multiresolution level. Master student will work in the development of methodology for the description of the dynamics of chromatin in the nuclei incorporating experimental restraints from MNAseq and HiC at the single cell level. Candidate, which should have already good knowledge on scientific programing will learn a variety of simulation methods and will be in close interaction with our experimental team providing data for the simulation.

Keywords. Chromatin structure, bioinformatics, computational biology, molecular simulation, theory

IRB-1804. Cellular Plasticity and Disease

PROJECT TAKEN!

Supervisor. Manuel Serrano

Research group. Cellular Plasticity and Disease

Project Description. The unifying concept that has guided our research is that tumour suppressors protect the organism from many types of damage and regardless of the pathology that damage may cause. Protection from cancer is just one of the outcomes of tumour suppressors, others being protection from chronic diseases, nutritional overload, tissue injuries, or aging.

Tumour suppressors often trigger a cellular state known as cellular senescence, and we have pioneer the concept that cellular senescence is critical to signal tissue damage and to elicit tissue regeneration.

The key emerging paradigm is that tumour suppressors, by triggering cellular senescence, recruit inflammatory cells and

create a tissue microenvironment that favours tissue repair and regeneration.

1. Tissue regeneration in the reprogrammable mice.
We are actively studying tissue regeneration in our reprogrammable mice (where we can induce the four Yamanaka factors in vivo) and how this is affected by tissue injury, senescence and inflammation.

2. Therapeutic effects of elimination of pathological senescent cells.
We have a very original project on the use of silica nanoparticles to deliver drugs selectively into senescent cells. We are focused on their therapeutic potential in pulmonary fibrosis.

3. Manipulating and understanding pluripotency.
We have several projects aimed to manipulate and stabilize pluripotency with chemical compounds, both in mouse and in human cells. For example, we can hyperactivate the Mediator complex with a chemical compound and in this manner we can stabilize the naïve state of pluripotency in mouse and human cells. We are attempting to deliver reprogramming chemicals in vivo to enhance tissue regeneration.

4. Targeting pluripotency in cancer.
We have a strong line of research on cancer and in this regard we have identified new chemical compounds that selectively target cancer stem cells.

5. Understanding aging.
We have several projects aimed to understand the connection between metabolic pathways, tumor suppressors and aging.

Keywords. cancer; aging; cellular senescence; cellular reprogramming; tissue repair

IRB-1805. Laboratory of Molecular Biophysics

PROJECT TAKEN!

Supervisor. Xavier Salvatella

Research group. Laboratory of Molecular Biophysics

Project Description. A high resolution description of the structure and dynamics of proteins is a very useful tool to study the properties and the function of these important biomacromolecules and, most importantly, to understand how changes in sequence or environment can lead to disease.

The research work carried out at the Laboratory of Molecular Biophysics aims, on the one hand, at developing methods to probe the fluctuations of the structure of proteins by combining experimental data and molecular simulations and, on the other hand, at understanding how changes in such motions relate to the molecular recognition of proteins, to their function and disease.

After discussing potential projects with the PI the student joining the group will use the basic tools of experimental and/or computational biophysics to study the structural properties of protein molecules or protein assemblies (protein-protein complexes or phase separated proteins)

investigated by the group at the time of joining.

Possibilities include transcription factors that are therapeutic targets in oncology or proteins that are studied in collaboration with other groups at IRB. Training will be provided in any experimental or computational tools that the student may not be familiar with or that may have been recently developed by the group.

Keywords. protein structure, protein dynamics, intrinsic disorder, liquid phase separation, drug discovery, transcription, prostate cancer

PROJECT TAKEN!

IRB-1806. Genomic Instability and Cancer Laboratory

Supervisor. Travis Stracker

Research group. Genomic Instability and Cancer Laboratory

Project Description. The Tousled like kinases 1 and 2 (TLK1/2) are poorly characterized serine-threonine kinases that are regulated by the DNA damage response. The primary substrate of both kinases is the histone H3-H4 chaperone ASF1. Depletion of TLK activity leads to pronounced replication stress and renders cells more sensitive to checkpoint inhibition and PARP inhibitors. TLK activity is primarily amplified in cancer cells, in some cases correlating with patient survival. We are investigating the molecular function of the TLKs to understand their role in the control of chromatin plasticity and genome maintenance and to explore their potential as targets in cancer. The project will use a wide variety of molecular and cell biology techniques and proteomic approaches aimed at identifying their regulators and substrates and their influence on cell cycle progression, viability and sensitivity to chemotherapy.

Keywords. Nuclease kinase Seckel Syndrome, infertility, microcephaly cancer, immunodeficiency, homologous recombination, cell cycle, checkpoint, mitosis, neurodegeneration, RGMC, ciliopathy, senescence, DNA repair