Admission to the PhD program in Pharmaceutical Sciences XLII cycle, A.A. 2026/2027– Research Projects.

Thematic 1
Curriculum: Pharmaceutical Technology and Nutraceuticals
Title: "Design and Synthesis of Hybrid Inorganic–Organic Piezoelectric Composites as Bone Cements for Regenerative Medicine"
Project supervisors: Prof. Anna Donnadio and Prof Morena Nocchetti, anna.donnadio@unipg.it
Abstract. Conventional polymethyl methacrylate bone cements suffer from poor osseointegration, free monomer cytotoxicity, and exothermic setting reactions. Addressing these limitations, this project targets injectable or 4D-printable hybrid organic–inorganic piezoelectric bone cements mimicking the hierarchical architecture of native bone. A stimuliresponsive biodegradable hydrogel matrix based on gelatin methacrylate or chitosan will govern injectability, adaptive shape morphing, setting kinetics, mechanical compliance and cell-friendly microenvironment, while a nanostructured calcium phosphate phase will confer intrinsic bioactivity. Novel two-dimensional fillers, layered double hydroxides, zirconium phosphate–phosphonates and MXenes, will be synthesized and surfaceengineered to act as multifunctional reinforcing agents, ion reservoirs and piezoelectric transducers. Controlled release of osteogenic ions (Mg^{2+}, Sr^{2+},Ga^{3+}, Ti^{4+}) will direct mesenchymal stem cell differentiation, while the piezoelectric response of the composite under physiological mechanical loading will provide continuous electrostimulation of bone-forming cells. The result is a trifunctional platform combining mechanical reinforcement, ionmediated osteogenesis and mechano-electric smart behaviour.

Thematic 2
Curriculum: Early Phase Drug Discovery
Title: "Design, Synthesis and Functional Characterization of Chemical Tools Targeting Distinct Conformational States of IDO1."
Project supervisors: Prof. Antonio Macchiarulo and Prof Emidio Camaioni; antonio.macchiarulo@unipg.it

Abstract. IDO1 represents a paradigmatic example of both the opportunities and limitations associated with current enzyme targeted therapeutic strategies. As the rate limiting enzyme in tryptophan catabolism, IDO1 regulates immune homeostasis and immunosurveillance through the production of bioactive metabolites. Its dysregulation is implicated in cancer, autoimmune, and neuroinflammatory disorders, making it an established therapeutic target. However, the limited clinical success of IDO1 catalytic inhibitors has revealed a critical gap in understanding the full complexity of its biological functions. The PhD research project integrates medicinal chemistry, chemical biology, and advanced biophysical and biochemical approaches to generate chemical tools able to selectively bind and modulate distinct conformations of IDO1. These compounds will be optimized through iterative design and validated using comprehensive biophysical and biochemical assays. The project is expected to establish general principles for targeting the non-canonical functions of IDO1, paving the way for next generation immunoregulatory strategies.

Thematic 3
Curriculum: Early Phase Drug Discovery
Title: "Development of innovative catalytic processes"
Project supervisors: Prof. Luca Sancineto and Prof Ornelio Rosati; luca.sancineto@unipg.it

Abstract. Our project aims to pioneer innovative catalytic processes for the development of flexible, eco-friendly, and stereoselective transformations. In particular, organoselenium compounds will be employed as biomimetic catalysts in ring-forming reactions and oxidative transformations. Chiral catalysts will be designed to transfer the enantiomeric information to the substrate with high fidelity. In addition, biomacromolecules will be explored both as catalysts and as templates for reactivity control.
Notably, we will investigate Target-Guided Synthesis (TGS), a bioorganic strategy that leverages the catalytic properties of a biological target to promote the in-situ assembly of its own inhibitors from a pool of properly functionalized fragments. Throughout the project, we will prioritize the optimization of synthetic methodologies in accordance with green chemistry principles. Design of Experiments (DoE) paradigms will guide our optimization strategy, enabling a holistic and multivariate approach that goes beyond traditional univariate methods.

Thematic 4 (reserved for Janssen Cilag Spa employees)
Curriculum: Pharmaceutical Technology and Nutraceuticals
Title: "Strategies for Oral Solids Drug Manufacturing Process Optimization"
Project supervisors: Prof. Luana Perioli (academic), Dott.ssa Brunella Paola De Vivo (J&J Innovation Medicine, - Janssen-Cilag S.p.A)

Abstract. The manufacturing Process Optimization ensures that during the entire lifecycle pharmaceutical products are safe, high-quality, cost-effective, and consistently produced, while meeting strict regulatory requirements and enabling efficient lifecycle management. This project focuses on process optimization in oral solid dosages pharmaceutical manufacturing through implementation of Process Analytical Technology (PAT). The initiative leverages Near-infrared (NIR) spectroscopy using the Brimrose Luminar AOTF 4030 to enable real-time monitoring of critical process parameters and material attributes. A data-driven approach will be also applied to improve process understanding, identify variability sources, and optimize key process conditions. Integration of NIR-PAT allows enhancement of in-line control, supporting timely decision-making and reducing reliance on off-line testing. The project delivers improved process robustness, reduced variability, and strengthened control strategies, ultimately enhancing product quality and supporting efficient, scalable, and compliant manufacturing processes.

Thematic 5 (reserved for I.r.t.a.l. - Istituto di Ricerca Traslazionale per l'Apparato Locomotore – S.r.l employees)
Curriculum: Pharmaceutical Technology and Nutraceuticals
Title: "Biocompatibility Validation of Next-Generation Antimicrobial Nanoparticles Against Bacterial Biofilms"
Project supervisors: Prof. Aurelie Schoubben (academic), Dott. Roberto Tiribuzi (I.r.t.a.l.)

Abstract. The emergence of antimicrobial resistance represents one of the most critical challenges in contemporary biomedicine. This project contributes to validating modular and tunable antimicrobial nanocarriers to eradicate resilient bacterial biofilms. Aligned with the Safe-and-Sustainable-by-Design (SSbD) paradigm, this research establishes a reproducible framework for the biocompatibility and toxicological assessment of selected nanoparticles. Key methodological achievements include standardizing a robust human haemolysis assay to identify non-haemolytic concentration ranges and implementing advanced both in vitro (HDF/MG63 cells) via XTT, LDH, and Trypan Blue assays and in ovo on CAM (chicken Chorioallantoic Membrane) models for multiparametric toxicity screening. Ultimately, through a multidisciplinary integration of nanobiotechnology, cell biology, and translational toxicology, this project combines methodological standardization with advanced biological validation to establish a new generation of safe, effective, and sustainable clinical nanotherapeutics.

Thematic 6 (reserved for ITEL Telecomunicazioni srl employees)
Curriculum: Pharmaceutical Technology and Nutraceuticals
Title: "Design and GMP manufacturing in aseptic way of a radiopharmaceutical based on 18F-Flotufolastat"
Project supervisors: Prof. Luana Perioli (academic), Dott.ssa Anna Tolomeo (ITEL Telecomunicazioni Srl, divisione radiofarmaci)

Abstract. The radiotracer 18F-Flotufolastat recently received its first U.S. marketing authorization for use in positron emission tomography (PET) imaging in oncology, specifically for patients with prostate cancer presenting suspected metastases or biochemical recurrence based on PSA levels. Phase III LIGHTHOUSE and SPOTLIGHT studies demonstrated its ability to detect distant metastatic lesions and significantly improve recurrent prostate cancer upstaging. As a PSMA-targeting radiopharmaceutical, 18F-Flotufolastat exploits the high expression of prostate-specific membrane antigen on prostate cancer cells, enabling detailed whole-body imaging of micro-metastatic disease and treatment response assessment. The tracer is labeled with fluorine-18, characterized by a 110-minute half-life, making synthesis and distribution time-critical. It is synthesized in a rapid single-step isotopic exchange process from flotufolastat gallium triflate precursor. The project aims to implement the aseptic production of 18F-Flotufolastat at ITEL Telecomunicazioni using sterile-compliant raw materials and procedures.

Thematic 7 (reserved for Magi's Lab S.r.l employees.)
Curriculum: Pharmaceutical Technology and Nutraceuticals
Title: "Development and Validation of a Salivary and Blood Multi-Omic Platform for Guideline-Based Personalisation of Nutrition and Training in Young Athletes"
Project supervisors: Prof Elisabetta Albi (academic), Dott. Matteo Bertelli (Magi's Lab S.r.l.)

Abstract. This doctoral research project aims to develop and validate a multi-omic computational platform for the personalised optimisation of nutrition and training in healthy young athletes. The platform will integrate phenotypic data, anthropometric and body-composition measurements, training characteristics, physiological parameters, and biological profiles derived from genomic, proteomic and metabolomic analyses performed on saliva and blood samples.
The project is based on a systems biology framework, in which the athlete is considered as an integrated biological system influenced by sex, age, type of sport, training load, genetic background, metabolic adaptation, inflammatory status, oxidative stress, muscle recovery and body-composition goals. This multi-omic and translational approach is fully aligned with the scientific foundations of a PhD programme in Pharmaceutical Sciences, connecting molecular profiling, biomarker discovery, computational modelling, personalised prevention and health-oriented intervention strategies.
The study will include a cohort of 500 student-athletes. All participants will undergo a complete phenotypic and biological assessment, including dietary intake, physical activity and training data, sport classification according to aerobic or anaerobic predominance, sex and age stratification, anthropometric measurements, body mass index, bioelectrical impedance analysis, weight, height, neck, chest, waist and wrist circumferences, resting and post-exercise heart rate, and resting and post-exercise respiratory parameters. In the same cohort of 500 participants, genomic, proteomic and metabolomic analyses will be performed, including the calculation of a polygenic risk/trait score based on approximately 780 SNPs relevant to metabolism, body composition, inflammation, oxidative stress, recovery capacity and sport-related adaptation.
The computational model will first apply international guidelines for sports nutrition and training according to the athlete's sex, age, sport type, body composition and specific objective, such as increasing lean mass, maintaining body composition, reducing fat mass, improving recovery or optimising performance. These guideline-based recommendations will then be refined through a biologically informed personalisation layer derived from the multi-omic data. In this framework, genomic, proteomic and metabolomic information will be used to modulate the standard guideline-based recommendations within predefined safety limits, with an expected personalisation range of approximately ±15% compared with generic recommendations.
A selected subgroup of 20 student-athletes will undergo repeated assessments at three time points, T0, T1 and T2, in order to evaluate longitudinal changes in biological markers, training response, metabolic

adaptation and recovery profiles. This longitudinal subgroup will allow the model to assess intra-individual variation over time and to test whether multi-omic biomarkers can improve the prediction of individual responses to nutrition and training interventions.
The platform will combine rule-based guideline models with machine learning approaches, including LASSO, Elastic Net and XGBoost, to estimate individual response trajectories and generate personalised nutrition and training recommendations. The doctoral project will also include the development of a prototype mobile application for the delivery of personalised recommendations and the exploratory integration of VOC sensor technology for rapid monitoring of metabolic and recovery-related signals in the sports setting.

Thematic 8 (financed by Molecular Discovery ltd)
Curriculum: Early Phase Drug Discovery
Title: "Development and application of Artificial Intelligence methods to support drug design"
Project supervisor: Prof Maria Letizia Barreca
Abstract. The PhD project aims to develop and apply advanced artificial intelligence methodologies to support the rational discovery of new drugs through the integration of heterogeneous data and innovative computational approaches. The research activities will include the collection, integration, curation, and standardization of chemical, biological, and structural data from different sources to generate high-quality datasets for the training, validation, and interpretation of predictive models.
The project will integrate ligand-based and structure-based approaches by combining machine learning and deep learning techniques with computational chemistry and bioinformatics tools. Depending on the specific research focus and pharmacological targets, the project may involve the development and validation of one or more predictive models for biological activity, pharmacokinetic (ADME), and toxicity prediction, as well as structure-based models for predicting ligand–receptor interactions and binding affinity. The developed methodologies will be validated on pharmacologically relevant targets, contributing to innovative computational strategies that accelerate and improve the efficiency, reliability, and rationality of the drug discovery process.

Thematic 9 (financed by Biostherapy SpA)
Curriculum: Early Phase Drug Discovery
Title: "Comparative Analysis of Artificial and Natural Molecules: Synthesis Energy and Biodegradability"
Project supervisor: Prof Claudio Santi

Abstract This research project aims to comparatively analyze artificial and natural molecules, with a particular focus on the energy required for their synthesis and their biodegradability. The objective will be to investigate how molecular structure and origin influence the energy demand of production processes and their environmental impact throughout the life cycle.
The study will be developed through a multidisciplinary approach based on the integration of data reported in the scientific literature with chemical and spectroscopic evaluations. Different classes of compounds employed in industrial, pharmaceutical, and advanced material applications will be examined by comparing synthesis processes, associated energy costs, and behavior during environmental degradation processes. Spectroscopic analyses will allow the characterization of the structural and chemical properties of the molecules, correlating them with stability, reactivity, and biodegradability.
The project will be aimed at assessing the environmental impact associated with the production and use of synthetic compounds in comparison with natural ones, highlighting the advantages and limitations of both categories. In particular, it is hypothesized that many artificial molecules, designed to ensure high performance and chemical stability, require energy-intensive synthetic processes and exhibit greater environmental persistence than natural compounds.
The expected results will contribute to the development of criteria for the design of more sustainable molecules and materials, promoting green chemistry strategies aimed at reducing the energy and environmental impact of production processes and evaluating the potential of using compounds of natural origin.

Thematic 10 (financed by Biostherapy SpA)

Curriculum: Pharmaceutical Technology and Nutraceuticals
Title: "Precision Nutrition in Clinical Medicine: Toward a New Paradigm of Lifestyle Personalization Through Multi-Omics Tools for Identifying and Modulating Physiological State"
Project supervisor: Prof Francesco Galli
Abstract. Precision nutrition represents one of the major advancements in preventive medicine and lifestyle management, moving beyond a standardized nutritional approach in favor of personalized interventions based on an individual's biological, physiological, metabolic, and behavioral characteristics. However, in real-world clinical practice, nutritional personalization is often limited by the use of static parameters, poor integration between clinical and molecular data, and the difficulty of translating complex information into operational decisions.
This doctoral project aims to develop a precision nutrition model applicable to real-world medicine, based on the dynamic identification of an individual's physiological state and its modulation through targeted lifestyle interventions. To this end, the project will integrate multi-omic tools—such as transcriptomics, metabolomics, and, where available, other omics levels—with nutritional, anthropometric, biochemical, clinical, behavioral, and digital data.
Through a multidimensional and longitudinal approach, the project aims to identify integrated physiological profiles associated with metabolic adaptation, vulnerability, or resilience. These profiles will help define personalized nutritional and behavioral strategies, while monitoring individual responses to interventions over time and assessing their sustainability in real-world clinical settings. Specific case studies will include research on experimental models (cell cultures and organoids) and intervention trials using vitamin formulations and natural products under various conditions of pathophysiological relevance.
The project therefore aims to contribute to the development of a new paradigm for lifestyle personalization, in which nutrition is not considered an isolated intervention but a dynamic tool—guided by clinical and multi-omic data—to identify, interpret, and modulate individual physiological status, with the goal of promoting health, prevention, and long-term metabolic adaptation.

Thematic 11(co-financed by Sterling Spa and prof Stefano Giovagnoli)
Curriculum: Pharmaceutical Technology and Nutraceuticals
Title: "Leveraging microfluidic technology for the development of biohybrid-biomimetic nanoparticles";
Project supervisor: Prof Stefano Giovagnoli
Abstract. Biohybrid-biomimetic nanoparticles represente the fourth generation of nanocarriers which combines the delivery capacity of nanosystems to travel across barriers and biological compartments and the targeting and biofunctional features of biological membrane components with enhanced biocompatibility. These novel nanovehicles are thereby capable of exerting a potential functional effect in addition to the capacity to transport active compounds to desired targets. This project aims at developing such biohybrid and biomimetic systems starting from lipid nanoparticle technology coupled with extracellular vesicles derived components. Such task will be accomplished by employing a microfluidic technology that allows precise control over nanoparticle assembling processes and bears intrinsic translational features. Such systems will be investigated thoroughly for oral, inhaled as well as nasal delivery of selected active compounds.