MATHEMATICAL SCIENCES

Ateneo - Mathematical Modeling of Cancer Evolution

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Context of the research activity	This research aims to develop advanced mathematical models, including stochastic agent-based models, hybrid and ordinary differential equations (ODEs), integro-differential equations, and partial differential equations (PDEs), and its analysis, to understand tumor behavior, interactions with the environment, and responses to therapies within the interdisciplinary study of living systems.
Objectives	This PhD proposal focuses on multi-agent systems, where emergent behaviors and self-organization manifest at larger scales from interactions among smaller components. Particularly within an interdisciplinary approach, mathematics may help to design virtual laboratories to explore ecological, evolutionary, and behavioral dynamics. The core objective of this project is to develop, validate, and analyze mathematical models to gain a comprehensive understanding of tumor behavior, its interactions with the environment, and responses to different therapeutic approaches. The candidate will develop novel mathematical models to elucidate some relevant biological phenomena. These may include, among others, intra-tumoral heterogeneity, evolutionary selection, the influence of the tumor microenvironment (such as hypoxia), immune activation and infiltration, as well as strategies to enhance the effectiveness of therapies (such as chemotherapy, radiotherapy, immunotherapy, and oncolytic viruses), counteract therapy resistance, and optimize therapy combinations. The mathematical methods employed may encompass stochastic agent-based models, hybrid and ordinary differential equations (ODEs), integro-differential equations, and partial differential equations (PDEs). The overarching goal is to establish robust mathematical frameworks capable of dealing with multi-agent systems and scaling from individual to population levels. Methodologies will include analytical results to uncover emerging properties and long-term behaviors, as well as computational simulations of the models. The methodologies and mathematical frameworks proposed in this research endeavor are highly versatile and adaptable to deal with different applications in applied sciences.

Skills and competencies for the development of the activity	Candidates should possess solid mathematical and computational skills with a background in applied mathematics, physics, or related fields. Familiarity with biological concepts and an interest in interdisciplinary research are desirable.