Project Details	
Project Code	CMD27Ca Kaouri
Title	Decoding calcium signalling during fertilization: a data-driven mathematical modelling framework for a non-invasive IVF diagnostic tool
Research Theme	Cardiometabolic Disease
Project Type	Dry lab
Summary	In vitro fertilization (IVF) is the primary treatment for infertility, with over 2.5 million cycles performed annually worldwide. Success rates remain limited because the best embryo for transfer can only be selected after five days of culture. This project will develop a data-driven mathematical modelling framework to decode calcium signalling during fertilization using experimental data on calcium dynamics and egg movements. By establishing the relationship between calcium signalling and non-invasive measurements of egg movements, the project will enable prediction of embryo viability on Day 1, paving the way for a non-invasive IVF diagnostic that could significantly improve IVF success rates.
Description	Infertility affects millions of couples worldwide, with in vitro fertilization (IVF) remaining the primary treatment. Although more than 2.5 million IVF cycles are performed annually, success rates remain limited because embryo selection currently relies on prolonged embryo culture, with the most viable embryo typically identified only after approximately five days. Prolonged culture increases costs, places additional demands on clinical resources and may expose embryos to suboptimal in vitro conditions. There is therefore a pressing need for reliable, non-invasive methods that can predict embryo viability at a much earlier stage and improve embryo selection without compromising embryo development. A key event during fertilization is a series of intracellular calcium oscillations that activate the egg and initiate embryonic development. Experimental studies have demonstrated that these calcium signals are mechanically coupled to subtle cytoplasmic movements within the egg, which can be measured non-invasively using time-lapse microscopy. While calcium signalling itself cannot be monitored routinely in clinical practice because it requires invasive fluorescent indicators, the associated egg movements provide a unique opportunity to infer the underlying calcium dynamics without disturbing the egg. The central hypothesis of this project is that mathematically decoding calcium signalling from non-invasive measurements of egg movements will enable the identification of an early (Day 1) predictor of embryo viability. The project builds on an established interdisciplinary collaboration between the supervisory team, bringing together expertise in mathematical modelling, computational biology, developmental biology and reproductive medicine. Building on preliminary collaborative work and recent student projects, the PhD will develop a data-driven mathematical modelling framework that links intracellular calcium signalling to experimentally observed egg movements. The student will integrate mathematical modelling with experimental datasets generated by the Swann laboratory to investigate the mechanochemical coupling underlying fertilization and determine how the characteristics of egg movements can be used to infer the underlying calcium signalling.

	This presents a challenging inverse problem. Egg movements arise from complex mechanochemical interactions within the fertilized egg and are influenced by multiple spatial and temporal factors. The relationship between calcium signalling and observable movements is therefore indirect, nonlinear and subject to biological variability. Developing mathematical models capable of extracting robust information about the underlying calcium dynamics from noisy experimental observations is central to the project and represents a significant methodological challenge at the interface of mathematics, computational biology and developmental biology. The project objectives are to: -develop mathematical models describing the mechanochemical coupling between calcium signalling and egg movements during fertilization; -calibrate, validate and refine the models using experimental imaging datasets; -develop computational methods for inferring calcium signalling from non-invasive imaging of egg movements; -determine which characteristics of egg movements provide the strongest predictors of embryo viability; -assess the robustness, predictive performance and translational potential of the proposed methodology. The project provides significant opportunities for student ownership. While the overall biological question is defined, the student will lead the development of the mathematical framework, investigate alternative modelling and inference approaches, identify the characteristics of egg movements that provide the greatest predictive power, and determine the most effective model validation strategy. The student will therefore shape both the methodological direction and the scientific outputs of the project while working closely with experimental collaborators. The student will receive interdisciplinary training in mathematical modelling, scientific programming, computational methods, statistical inference, image analysis and quantitative biology. They will gain first-hand experience working alongside experimental scientists, contributing to the design and interpretation of experiments and communicating across mathematics and the life sciences. The project will provide an excellent platform for publication in leading interdisciplinary journals and for presenting research at national and international conferences. By combining mathematical innovation with experimental biology, the project aims to lay the foundation for a non-invasive IVF diagnostic capable of predicting embryo viability on Day 1, ultimately improving embryo selection and IVF success rates.
Can be completed part time?	Yes
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