Jim Gatheral Travel Scholarship Report 2025–2026

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About me

My name is Mariam Al Mudarra. I am a PhD student in Applied Mathematics at the University of Glasgow, supervised by Dr Ariel Ramírez Torres and Dr Raimondo Penta in the School of Mathematics and Statistics. My research is on the mechanical modelling of cancer, and in particular on the evolution of solid tumours in a continuum mechanics framework. I was awarded the 2025 Jim Gatheral Travel Scholarship to support a research visit to the Department of Mathematics at Temple University (Philadelphia, USA), where I worked with Prof. Gillian Queisser in the College of Science and Technology. The visit ran from **16 January 2026 to 28 March 2026**, just over ten weeks.

Figure 1: Wachman Hall, home of the Department of Mathematics at Temple University.

Why I applied for the travel scholarship

My PhD is about modelling solid tumours through a system of coupled nonlinear integro-differential equations. These equations describe how mechanical deformation and the reaction–diffusion of chemical agents such as nutrients and drugs interact inside the tumour. An important feature of the model is that it includes memory effects. In solid tumours, the elevated interstitial fluid pressure and the dense extracellular matrix create spatial and temporal heterogeneities in drug availability, so the tumour's response to a drug does not depend only on the current drug concentration, but on the whole history of exposure. We describe this in the model through a time-convolution integro-differential operator that couples the therapeutic response to the drug history.

Including this memory term makes the model much harder to solve numerically. The memory term introduces nonlocal coupling in time between the mechanical and chemical fields, and implementing this coupling in the commercial software we had been using turned out to be difficult. To go further, we needed to move to a finite element open source environment where the weak formulation of the system, the nonlinear solver and the history dependent terms can all be written and modified directly. In practice, that means rebuilding the whole simulation pipeline from scratch, which is a large piece of work on top of the rest of the PhD research.

Professor Queisser's group at Temple has strong expertise in high-performance computing for biological systems and in numerical methods for PDE based models of complex biological processes. This is exactly the expertise I needed at this stage of my project. The Jim Gatheral Scholarship made it possible to spend an extended period of focused work alongside this group.

Details of the visit

I spent just over ten weeks in Philadelphia. I stayed in a studio apartment, which was a short walk from Temple's main campus. The Department of Mathematics is in Wachman Hall, and my office was there throughout the visit.

The main rhythm of the visit was a weekly meeting with Professor Queisser. In those meetings, we reviewed my progress, discussed the next technical step and agreed on tasks for the following week. In between, I worked on the numerical implementation on my own, but I could talk to Professor Queisser or to other people in the department whenever I needed to.

The technical objective of the visit was to build a working simulation of the baseline version of our tumour-growth model in an open source software package called FEniCS. The model I'm working with consists of several coupled equations that together describe how a tumour deforms, how fluid moves through it, how it grows, and how nutrients and drugs reach it. On top of that, the model includes a memory term that the commercial software we had been using could not handle. The plan for the visit was to set aside the memory term for now and first build a reliable simulation of the rest of the model in FEniCS. Once that foundation is in place, adding the memory term would be a much more manageable task. Professor Queisser and I agreed on this plan at the start of the visit, and it shaped the whole ten weeks.

FEniCS turned out to be a good tool for this. Its main advantage is that the code stays very close to the mathematical equations, so the step from writing the equations on paper to writing them in the simulation is much shorter than in most other frameworks. This is particularly valuable for my project, because the memory term I want to add later has a complicated mathematical form, and I want to be able to translate it into code as directly as possible.

During the visit, I built a working implementation of the model in FEniCS. I started from existing FEniCS codes for similar tumour-growth problems that are available in the literature and adapted them step by step to our setting. I then tested the implementation on a simple cubic geometry. I ran the simulations first with uniform material properties, to check that the simulation picked up the expected change in tumour shape and that all the coupled quantities (pressure, nutrient concentration, cell density, deformation) behaved consistently with one another. These were sanity checks on the solver rather than predictions of real tumour behaviour.

To be clear about what the visit did and did not produce: the full memory-dependent version of the model is still not implemented, and that was never the plan for ten weeks. The numerical values from the simulations are also preliminary. What I came away with is a working FEniCS version of the baseline model. With this in place, adding the memory term later should be much more straightforward. That is the main technical outcome of the visit.

Outside of work, I had the chance to see a bit of Philadelphia. The walk up Benjamin Franklin

Parkway to the Philadelphia Museum of Art (and, of course, the Rocky steps) quickly became my favourite weekend route, and the view from the top of the steps down the Parkway towards City Hall is one I will remember. Inside the museum, I particularly enjoyed the medieval arms and armour collection, and I was quietly amused to find a fifteenth century sword labelled *Made in Scotland*. It was an unexpected reminder of Scotland in the middle of a Philadelphia museum. Fairmount Park and the smaller green spaces near Temple were also a welcome break from a week spent in front of a terminal, and they made the longer stretches of intensive work easier to sustain.

Figure 2: Philadelphia Museum of Art, at the top of Benjamin Franklin Parkway. A fifteenth-century sword, in the museum's arms and armour gallery.

Impact of the travel scholarship

The Jim Gatheral travel scholarship had a real impact on my research. Our simulations were running on a commercial finite element platform that was not well suited to the memory dependent part of my model, and moving the work to an open-source framework was something I had been planning to do anyway. Doing this in Glasgow on my own, alongside the rest of the PhD, would have taken considerably longer time. Ten weeks of focused work at Temple, with regular technical guidance from Professor Queisser, gave me time to learn FEniCS properly and to run the first simulations of the model.

The scholarship also made possible a personal connection with a research group whose interests are close to ours but whose technical approach is different. Professor Queisser and I have discussed the possibility of a joint publication once the full memory-dependent implementation gives results of sufficient quality, and we have agreed to stay in touch as the project develops.

On a more personal level, this was my first long research visit outside the United Kingdom. It has made me much more confident about working in an international research environment. Arriving alone in a new country, finding my way in an unfamiliar department, and fitting into a different research culture for a couple of months is not something I had done before, and it is an experience I will draw on for the rest of my career.

Acknowledgements

I am deeply grateful to the donors of the Jim Gatheral Travel Scholarship and to the University of Glasgow for making this visit possible. Without the scholarship, a visit of this length, long enough to actually build something, would not have been feasible, and it has opened up real opportunities for my future career.

I would like to thank the PGR Service for their assistance throughout the application and administrative process. I am grateful to my supervisor, Dr Ariel Ramírez Torres, both for his support of the application and for his continued guidance throughout the project. My sincere thanks also go to Professor Gillian Queisser for hosting me at Temple University, for the weekly meetings that shaped the work, and for the welcome of his department during my stay in Philadelphia.

This was my first long research visit abroad, and it is not one I will forget.