EPSRC DTP PhD Research Project

Project Title: Protein Quantum Logic Gates

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Location: LSI, Streatham campus, Exeter

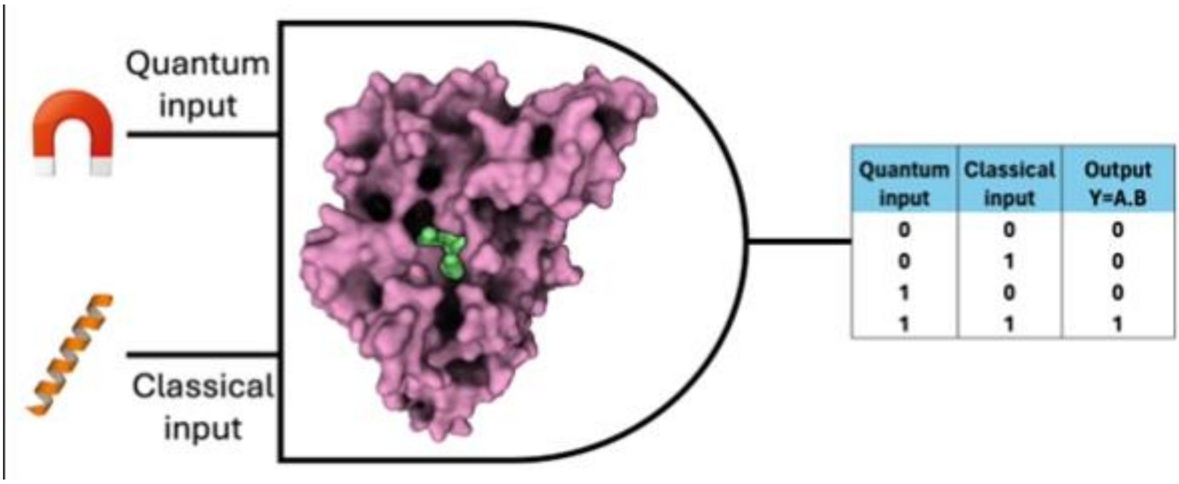
PhD Programme: PhD Biosciences

Project Description:

Nature computes efficiently using dynamic molecular interactions between proteins and their environment. Living organisms utilise interactions between proteins and other biomolecules to perform complex computations while dissipating tiny amounts of free energy (100 kBT is the typical potential energy barrier) per operation. We want to learn how these dynamic interactions result in logical outputs and ultimately build bio-molecular computers.

Nature has evolved an impressive ability to sense the weak (20-50 µT) geomagnetic field. This is transduced by quantum mechanical means, exploiting pairs of radical ions formed within cryptochrome proteins, which act as a 'molecular compass'. We have developed assays to quantitatively measure magnetosensation at the radical pair and at a transduced downstream site in a given protein. We are, therefore, in an exciting position to measure how changes to the composition of a protein, or changes in its environment, impact its ability to sense – by quantum mechanical means – an applied magnetic field and to transduce that into a classical biochemical signal.

A diagram of a protein molecule



Description automatically generatedGenerative AI protein design tools enable us to engineer molecules with new properties. Since 2020, new tools (AlphaFold2; RF Diffusion; Chroma) have been created which, coupled with scalable dynamical network models, enable us to engineer a protein to gain a defined ligand-binding response. We propose to couple this to the magnetosensitive response in a target protein whereby both stimuli together will produce a unique output state. This will result in a protein logical AND gate.

We will aim to establish a proof of principle for a unit of protein computation with quantum control over one of the inputs. Ultimately, this will form the basis of (i) new understanding for how noisy biological systems combine quantum and classical control elements to transduce a signal and (ii) biocompatible and genetically encoded quantum logic gates that could be used to build larger circuits in order to do computation using proteins.

This project aligns with the EPSRC Quantum Technologies Theme strategy to “focus on supporting world-leading research into novel quantum technologies” and to develop individuals with “high level skills required to help support new sectors of the economy”: it will open a new avenue of “quantum” in the context of biology, train a postgraduate student in quantum mechanics theory and simulation, cross-disciplinary quantum biology applications and provide them a timely and cutting-edge expertise in the current generation of AI protein design tools. The project represents a rare opportunity to “support translation of quantum technology research towards potential application”: the proteins output here will form the basis for genetically encoded protein computing. For example, there would be widespread potential in biotechnology for magneto-genetic control to complement existing opto-genetics. The student will gain cross-disciplinary skills that are a strong basis for a future career in fundamental research or commercial science and engineering: they will become expert in optical biophysics, analytical chemistry, millisecond time-resolved mass spectrometry and the use of AI protein design tools. As a result, the student will have a breadth of excellent directions for their future career.

References:

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Project specific enquiries:

If you have project specific enquiries please contact the lead supervisor named above.