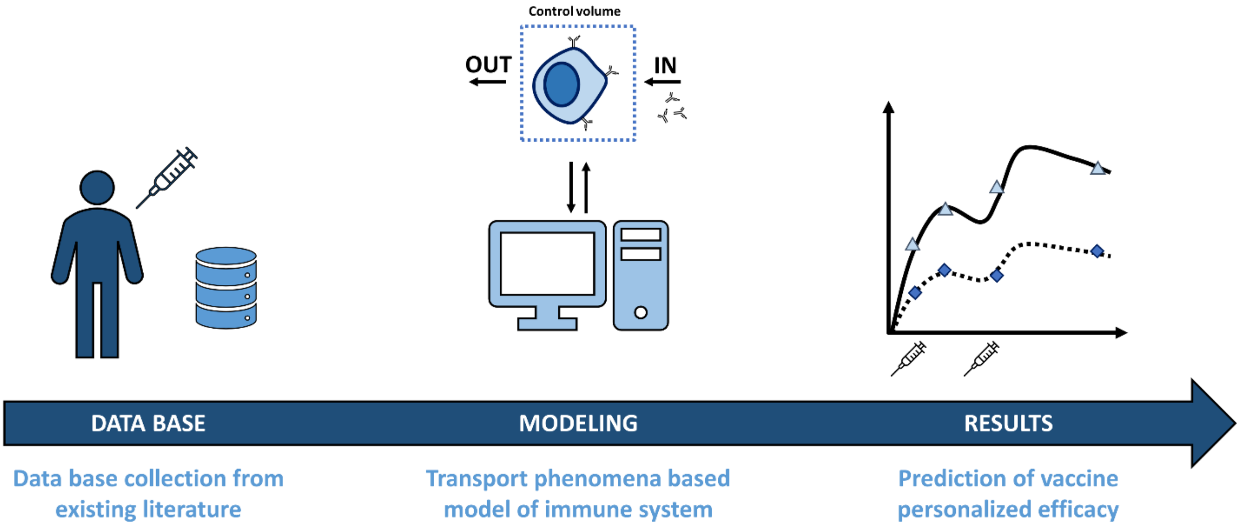
Mechanistic insight on vaccine efficacy: A transport phenomena based approach

Carmine Schiavone – Advisor: Prof. Sergio Caserta

Curriculum: Ingegneria Chimica



Vaccination has revolutionized modern medicine, saving millions of lives each year and leading to the eradication of smallpox, near elimination of poliomyelitis, and a substantial decrease in the incidence of diseases such as diphtheria, tetanus, pertussis, measles, mumps, and rubella[1]. Despite these remarkable achievements, the development of vaccines remains an intricate and challenging process, heavily reliant on a comprehensive understanding of the immune system's complex coordination and the numerous factors that come into play during the immune response[2,3]. This variability is influenced by factors such as age, sex, gut microbiota, and geographical location. Despite the significant progress made in vaccine development, the process is still lengthy and expensive, with an estimated total cost that is of around 800 million dollars[4]. With such a high cost it becomes imperative to optimize the vaccine development.

Mathematical models can provide a key role in untangling the network of interactions of the immune system. While AI and statistical models excel at pattern recognition and prediction they often lack the interpretability and mechanistic insight, which are crucial for informed decision-making in vaccine design. Given the multiscale and multitemporal nature of the immune response we believe that a transport phenomena based model is the best suit to address this problem[5,6].

In this research project, our objectives are as follows:

- Develop an advanced multiscale model of the human immune response after vaccination, capable of predicting crucial factors like antibody concentration. The model will also address sources of variability across individuals.

- Calibrate the model using existing databases to estimate baseline parameters for different population categories (e.g., age, sex, ethnicity). This calibration process will provide quantitative correlations of vaccine efficacy for each category.

- Utilize the established model and parameters to offer personalized recommendations for optimal dose quantity and frequency to each patient. Additionally, we aim to develop personalized vaccination protocols based on individual characteristics.

In conclusion, this PhD research project seeks to employ mathematical models, rooted in transport phenomena, to enhance our understanding of immune response mechanisms. By using this model, we aim to shed light on previously ambiguous aspects of how the immune system operates.

References

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carmine.schiavone@unina.it