Agent-Based Simulation of CAR-T Cell Therapy Using BioDynaMo

A 2025 GSoC project

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About Me: Education & Experience

🎓 Academic Background

- 4th year student in **Pure Math & Computer Engineering**
- Currently doing an erasmus in **TU Eindhoven**

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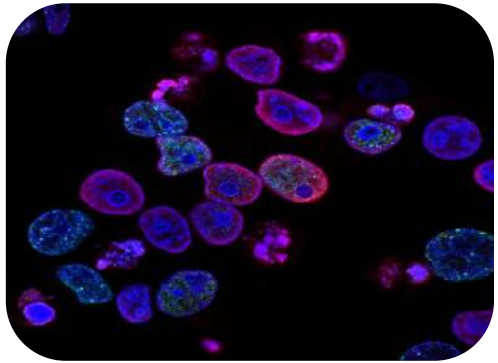
🧪 Research & Work Experience

- Part-time researcher in AI-related projects at **University of Seville**
- **Team Polar**, a student group developing an autonomous rover

CAR-T Therapy & the Challenge

- A type of immunotherapy that engineers T-cells to **recognize and kill cancer cells**
- Proven effective in **blood cancers**
- **Struggles in solid tumors** due to:
  - T-cell exhaustion
  - Limited infiltration
  - Immunosuppressive tumor microenvironments: Hypoxia, Tregs, Cytokines…



Project Overview: CAR-T Simulation in BioDynaMo

Agent-based simulation using the high-performance, open-source simulation platform **BioDynaMo** including:

- T-cell migration, proliferation, and tumor cell killing
- **Solid** tumors and **hematological** cancers
- Modeling of tumor **microenvironment components** and other related **biological phenomena**
- Development of **custom scripts** for:
  - Visualizing tumor progression/regression,
  - Quantifying CAR-T efficacy,
- Exploration of **therapy strategies** including:
  - CAR-T dosage and administration timing
  - Performance benchmarking for different therapeutic scenarios

Personal Motivation: Why this project?

- Combine **math & computer engineering skills** in by developing agent-based simulation
- Inspired by a course on mathematical and computational modeling for oncology: **MôLAB**
- Fascinated by **CAR-T** cell dynamics & immunotherapy strategies

- High-impact project with the potential to **support researchers** and clinicians worldwide
- Help **optimize treatment strategies** for complex tumor environments
- Enjoy working in **research-oriented environments** and on scientific projects.

Project Implementation Overview

🧪 Phase 1: Initial Setup & T-cell Dynamics

- **Literature Review:** Identify and replicate existing CAR-T models
- **Lotka-Volterra Model:** Basic predator-prey dynamics (CAR-T vs Tumor)
- **Tumor Variants:** Simulate different tumor types, incl. solid & leukemia

🧬 Phase 2: Advanced Cell Behavior & Microenvironment

- **Apoptosis & Exhaustion:** Refined CAR-T lifespan and activity
- **Chemotaxis:** CAR-T cells navigate toward tumors
- **Hypoxia Modeling:** Impact of oxygen levels on tumor & CAR-T behavior

🛡️ Phase 3: Immune Evasion & Visualization

- **Immune Suppression:** Add Tregs and cytokines to simulate resistance
- **Data Visualization:** Spatial/temporal dynamics & analysis tools

📊 Phase 4: Validation & Delivery

- **Real Data Comparison:** Match simulation to biological data
- **Documentation:** Generalized, modular code with strong usability
- **Final Report:** Detailed scientific write-up and scenario demos

Goals & Impact

🎯 Goals:

- Create a **modular, scalable**, and **reusable** (well documented) simulation
    - Include a few different scenarios and types of cancer as examples of usage
- **Scientific-style** report:
    - Benchmark performance and compare therapy strategies
    - Check our models by replicating real patient data

🌎 Impact:

- A **flexible**, **open-source** tool for **immunotherapy research**
- Brings us one step closer to more **effective therapies for solid tumors**