CARTopiaX: Extending a Next-Generation Platform for Computational Cancer Biology

2026 Google Summer of Code project

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About Me: Education & Experience

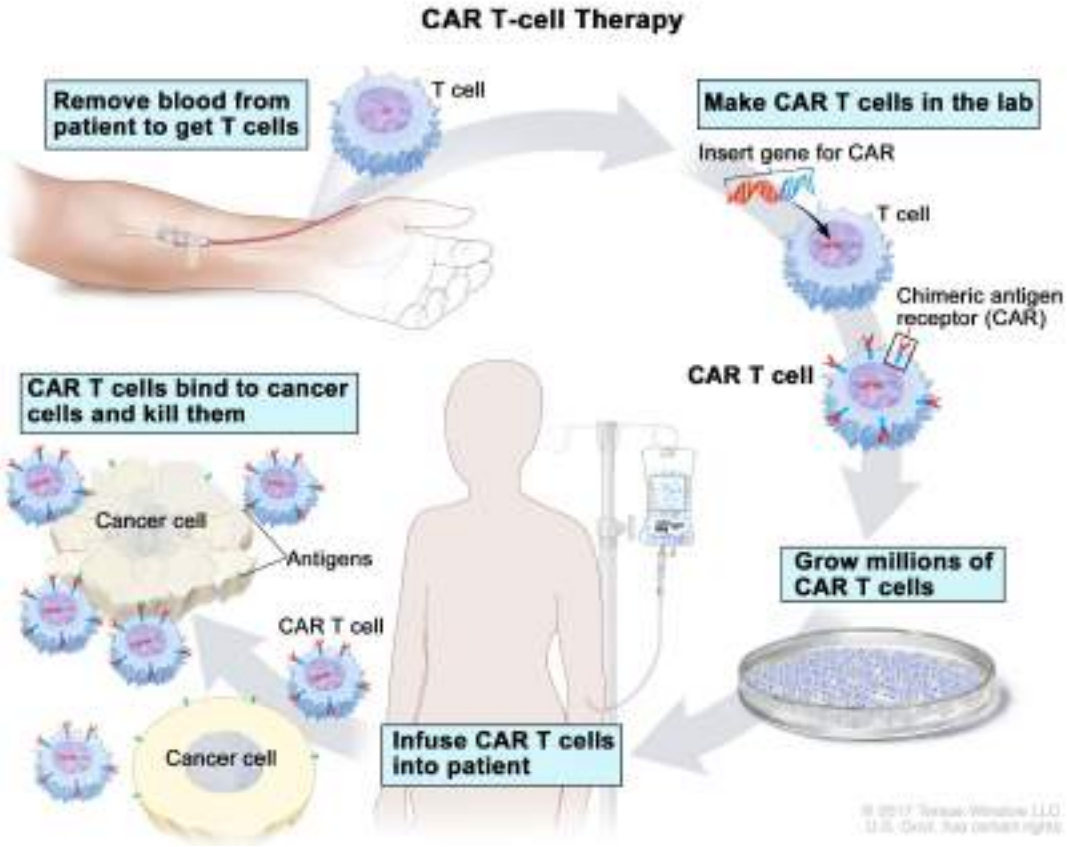
🎓 Academic Background

- 5th year student in **Pure Math & Computer Engineering**
- Looking forward to doing a **master's in Data Science & AI after summer**

🧪 Research & Work Experience

- Part-time researcher in AI-related projects at the **University of Seville**
- **Team Polar**, a student group developing an autonomous rover
- **CARTopiaX: Google Summer of Code 2025** in the **Compiler Research** group, CERN-HSF

CAR T-cell Therapy

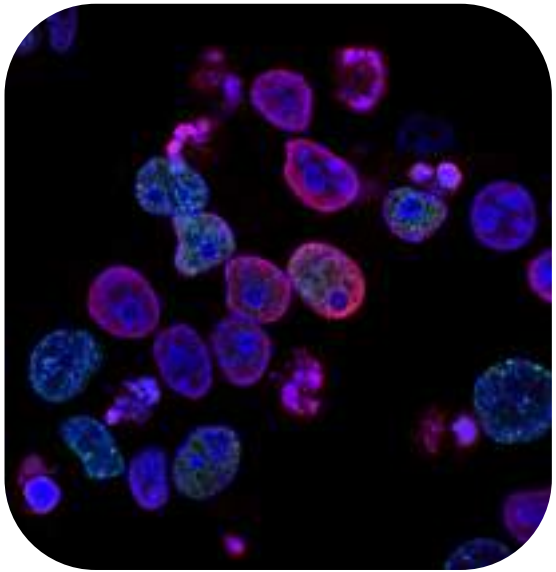


CAR T-cell therapy: A type of immunotherapy that engineers T-cells to recognize and kill cancer cells.

Image ref: https://www.cancer.gov/publications/dictionaries/cancer-terms/def/car-t-cell-therapy

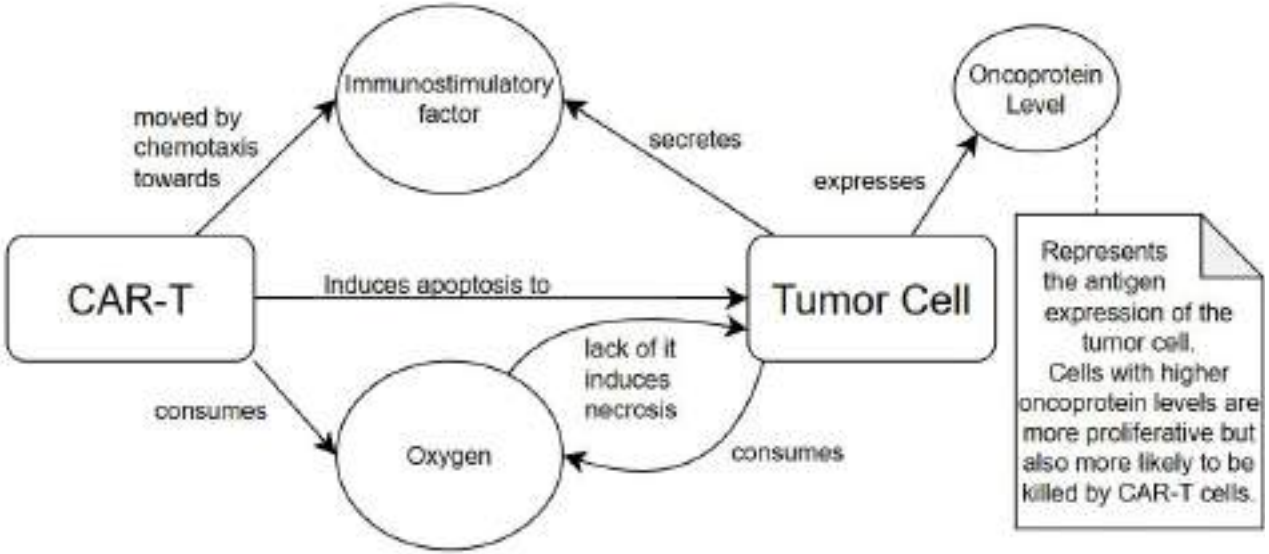
CAR T-cell Therapy: the Challenge

- It has been proven effective in **leukemia** and other **blood** cancers.
    - In the literature, many **robust models**, typically based on differential equations, simulate CAR T treatment in blood cancers.
- However, CAR T still **remains limited in solid tumors** due to unique tumor microenvironmental factors.
    - Researchers need models to try different treatment techniques and scenarios in order to improve CAR T performance; however, **very few models** exist.



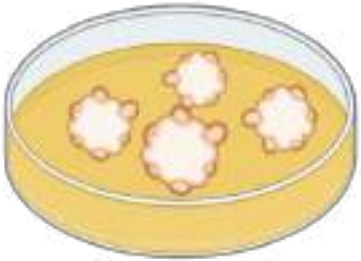
CARTopiaX

- **Agent Based Model (ABM)** built on BioDynaMo, a high-performance **open-source platform** for **large-scale**, **high-performance** and **modular** biological modeling
- **Mathematical framework** from the Nature paper "*In silico study of heterogeneous tumour-derived organoid response to CAR T-cell therapy*" (2024)

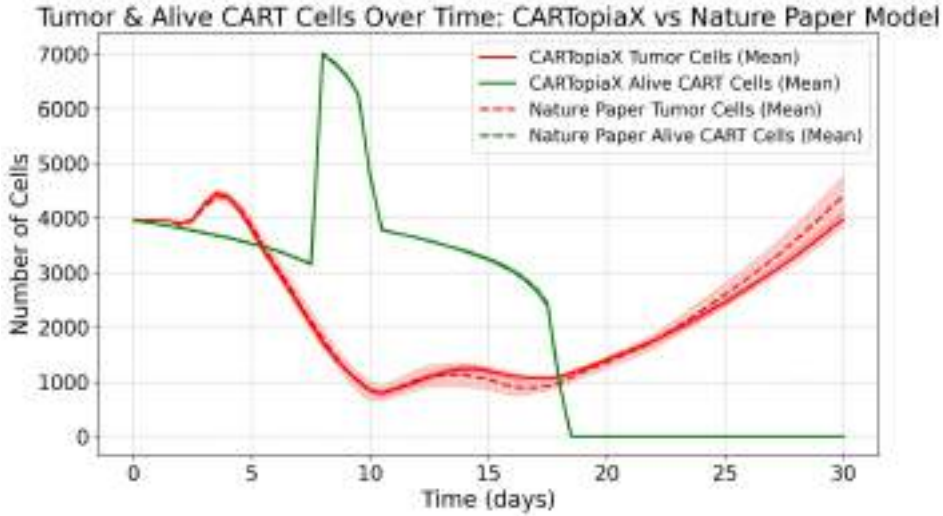


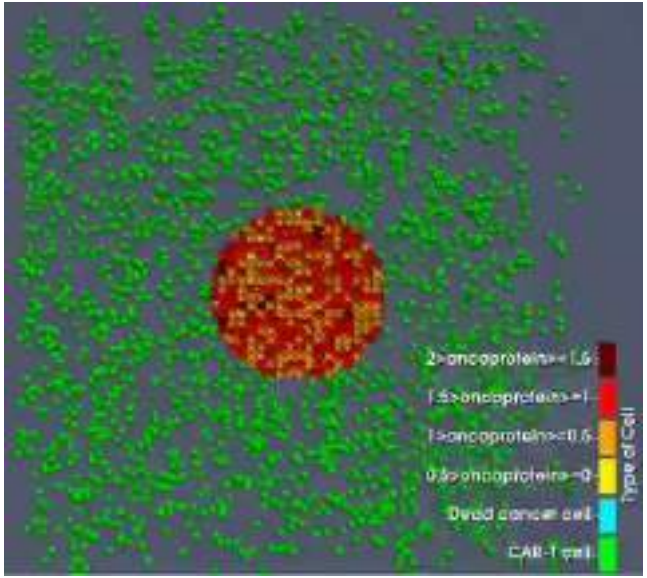
CARTopiaX

CARTopiaX repository



- CARTopiaX successfully implements the model from the Nature paper and **reproduces its findings**, thereby replicating real-world experimental data.
- Enables evaluation of multiple therapeutic strategies **without the cost or time of laboratory experiments**.





Visualization of a sliced tumor with CAR-T cells (in green) in ParaView

GSoC 2026 objective: Extend CARTopiaX

- Select an **interesting biological phenomenon** from CAR T-cell research
- Extend CARTopiaX to **reproduce experimental observations** and calibrate it using wet-lab data
- Some of the extension directions identified through the **literature review** include:
  - **Agents**
    - Additional **immune populations** (PBMCs, macrophages, MDSCs)
    - Physical barriers made of **healthy stromal cells** (Fibroblasts and CAFs)
    - Tumor heterogeneity, **cancer types** and **antigen loss/re-expression**
  - **Microenvironment**
    - **Cytokine** signaling and immunosuppression
    - **Hypoxia** and lack of nutrients effects
    - **Vascularization** and nutrient diffusion
    - **ECM viscosity** and **hydrogel barriers**
    - **ECM degradation** and **heat-induced microenvironment modulation**
  - **Rules & Dynamics**
    - **Immune suppression** and **exhaustion** mechanisms
    - Antigen-dependent recognition and **immune evasion**
    - **Chemotaxis** and **infiltration** dynamics
    - Macrophage **phagocytosis**
    - ECM **permeability** evolution
    - **Hypoxia-induced necrosis** and cell-state transitions

Project Implementation Plan

📚Phase 1: Literature Review & Data Acquisition

- **Select a scientific study** based on the expected impact
- Obtain **usable wet-lab data**
- Clean the data and **extract metrics** suitable for model fitting and evaluation

🛠️ Phase 2: Model Expansion

- Add required **agent** populations
- Implement relevant **microenvironment factors**
- Define new biological **rules and dynamics**
- **Adapt model** structure to the selected phenomenon

⚙️ Phase 3: Model Calibration & Optimization

- Define **fitness functions** using error metrics (e.g., MSE/RMSE) for model fitting
- Implement and **apply efficient methods** for high computational cost **optimization** (Bayesian optimization, evolutionary algorithms…)
- **Reduce cost** via early stopping, simplified simulations and staged calibration
- Parameters estimation

📊 Phase 4: Validation & Delivery

- Validate model with **multiple stochastic runs**
- Perform **sensitivity analysis**
- Assess robustness and reproducibility
- Summarize findings in a **scientific report** towards a research paper.

Goals & Impact

- **Extend CARTopiaX** with new CAR T-cell biological phenomena
- **Replicate real wet-lab data** in silico
- Build simulation setups for **hypothesis-driven exploration** in CAR T-cell research
- Showcase CARTopiaX as a **flexible and extensible computational framework**
- Provide the experimental section of an impactful **publication in computational oncology**