Research projects

Julio César Pérez Sansalvador
jcp.sansalvador@inaoep.mx
https://ccc.inaoep.mx/~jcp.sansalvador/

Coordinación de Ciencias Computacionales

Ciencias y Tecnologías Biomédicas

INAOE

Julio César Pérez Sansalvador

ABOUT ME

01 Bachelor, Computer Science, BUAP, MX

02 Master, Computer Science, INAOE, MX

03 PhD, Mathematical Sciences, The University of Manchester, UK

Julio César Pérez Sansalvador

MORE ABOUT ME

01 — Bachelor, Computer Science, BUAP, MX

02 — Master, Computer Science, INAOE, MX

03 — PhD, Mathematical Sciences, The University of Manchester, UK

Member of Scientific Organizations

Society for Industrial and Applied Mathematics

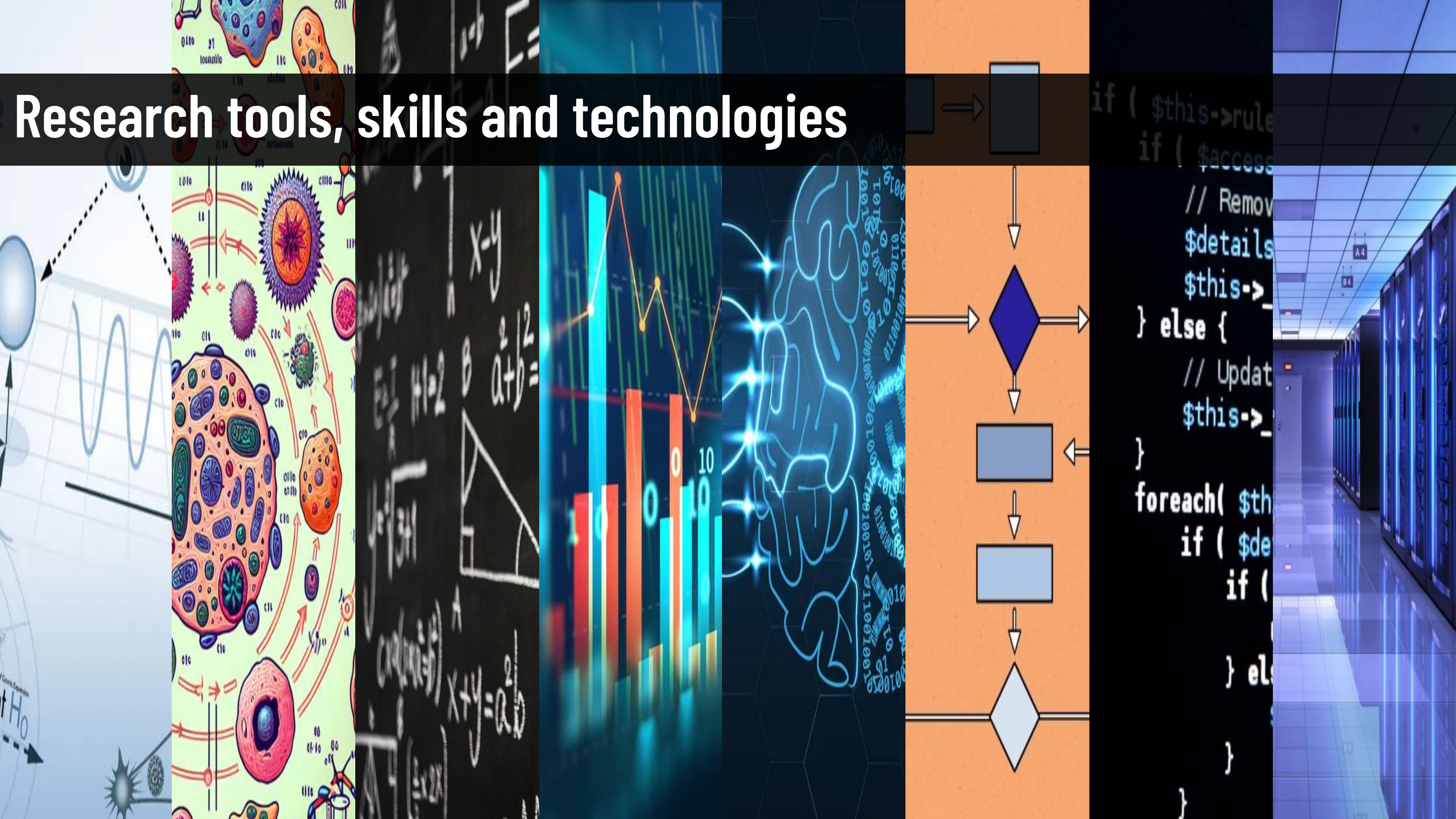
American Association for Cancer Research

SNII - Nivel I desde 2020

SOCIEDAD MATEMATICA MEXICANA

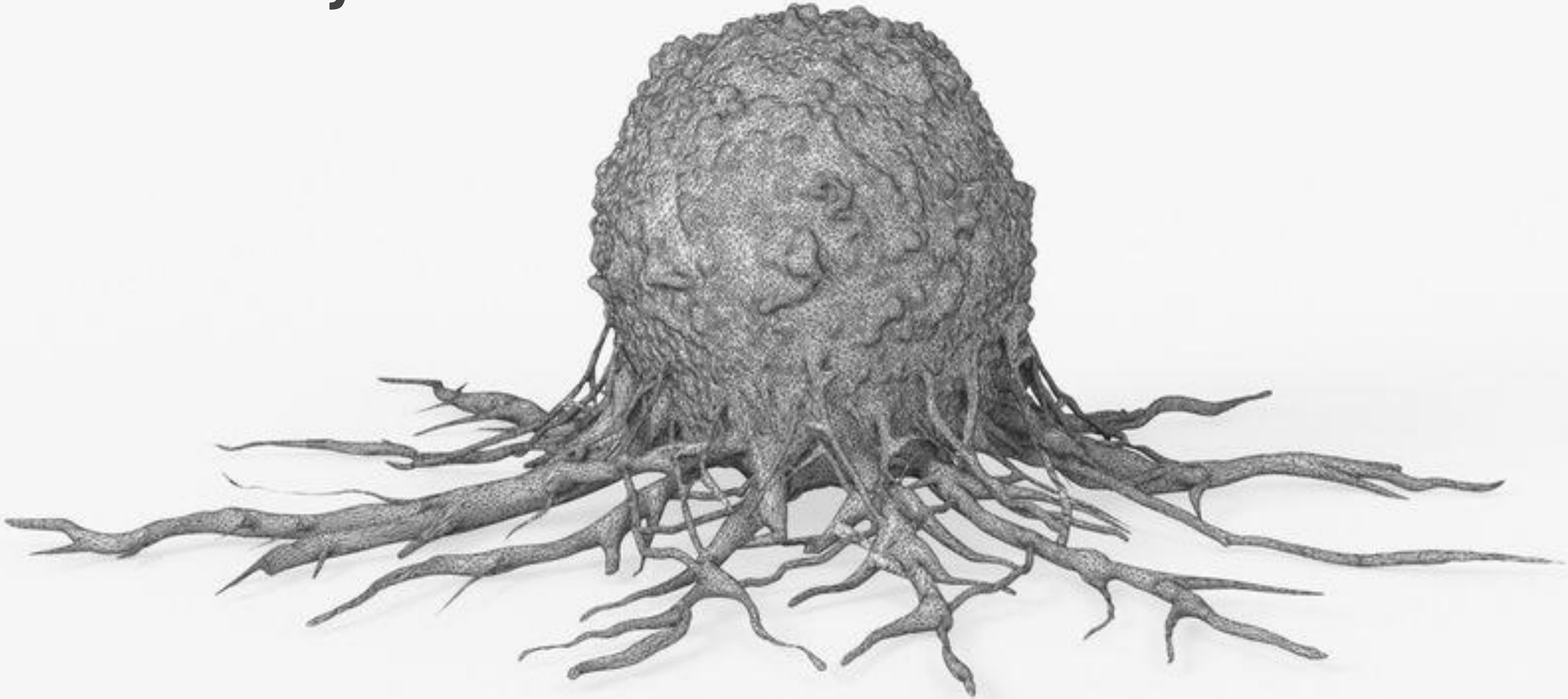
Advance the understanding of the fundamental mechanisms and governing laws of biological and physical phenomena

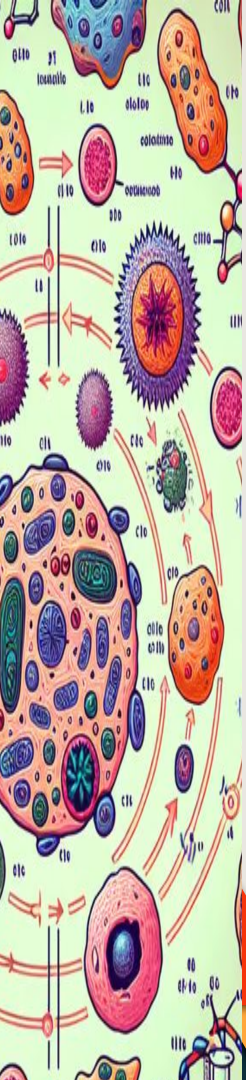
Research tools, skills and technologies

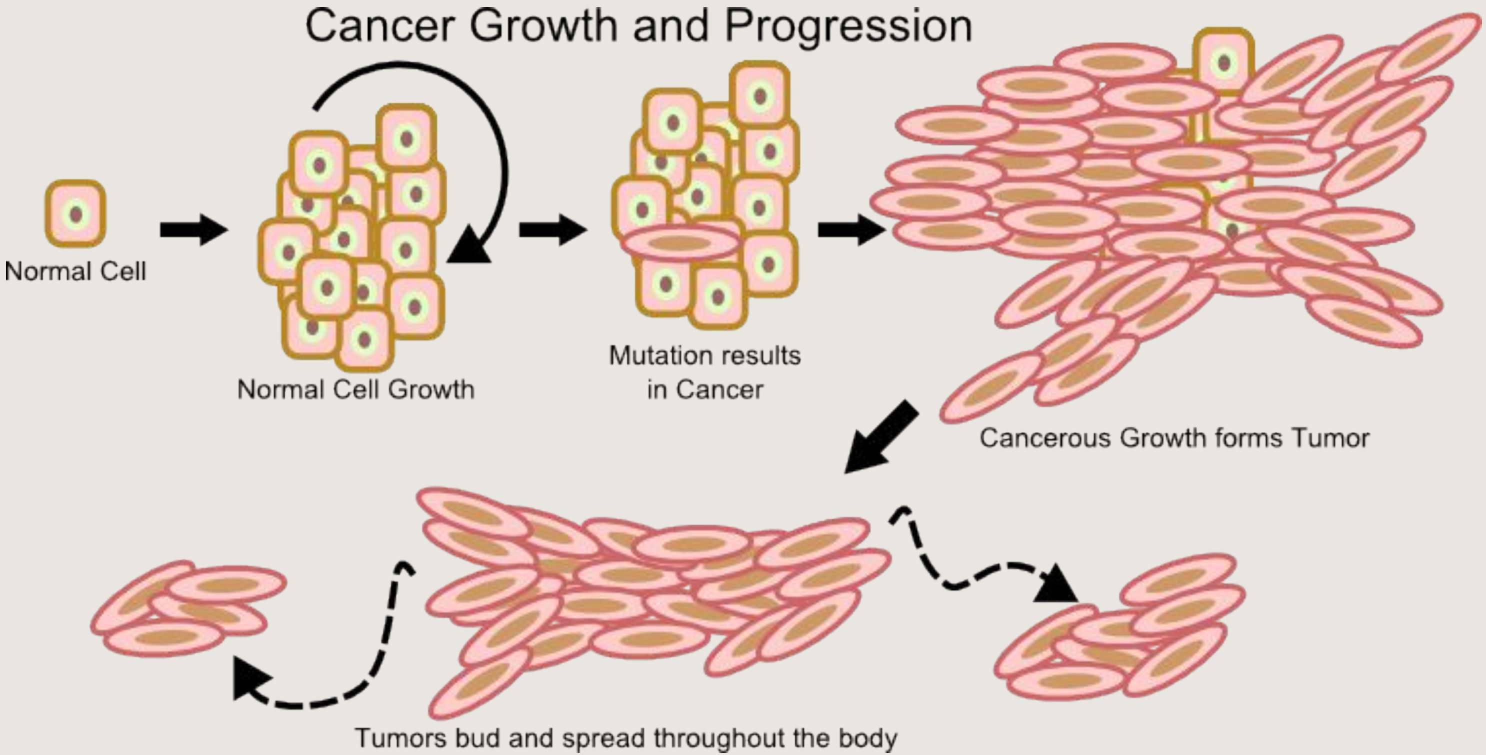


Current research projects

Cancer dynamics






Cancer Growth and Progression
Normal Cell
Normal Cell Growth
Mutation results in Cancer
Cancerous Growth forms Tumor
Tumors bud and spread throughout the body

Mathematical models for cancer growth

$$\frac{dT}{dt} = rT \text{, exponential growth (initially)}$$

$$\frac{dT}{dt} = rT(1 - \frac{T}{K}) \text{, limited by space and nutrients (later)}$$

$$\frac{dT}{dt} = rlog(\frac{K}{T})T \text{, variable saturable growth (Gompertz model)}$$

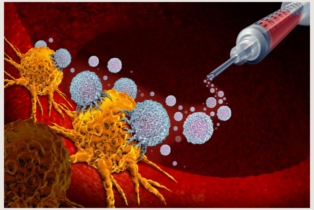
$$\frac{\partial c(x,t)}{\partial t} = D \cdot \nabla^2 c(x,t) + f(x,t) + G(x,t)$$

$G =$

Surgery

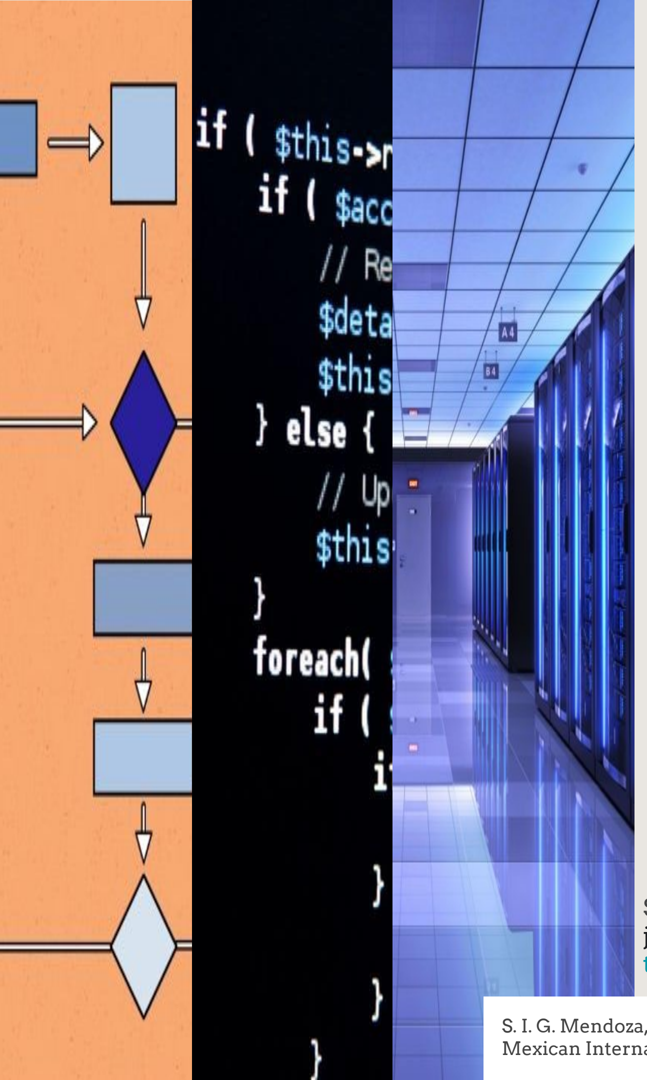
Chemotherapy

Radiotherapy



Immunotherapy

Anyue Yin *et. al.*, A Review of Mathematical Models for Tumor Dynamics and Treatment Resistance Evolution of Solid Tumors, CPT: Pharmacometrics & Systems Pharmacology, 8 (10), 2019. https://doi.org/10.1002/psp4.12450



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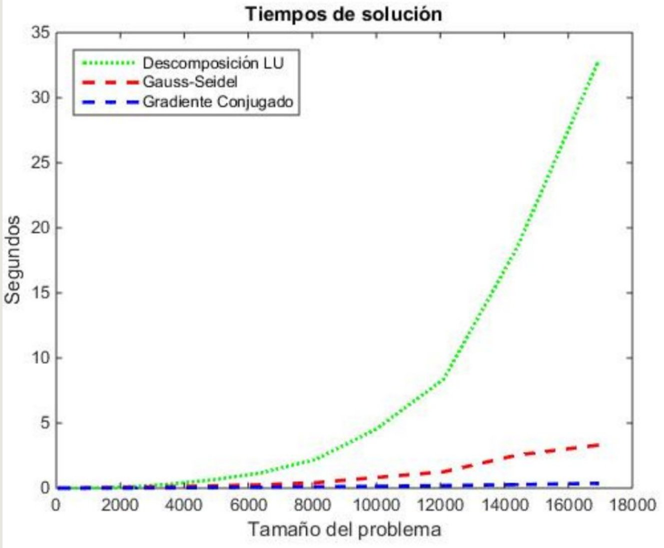
Numerical methods for solving PDEs
Preconditioning
Parallel/HP Computing



Conferences > 2022 IEEE Mexican Internation...

Efficient numerical solution of the brain glioblastomas proliferation-invasion model

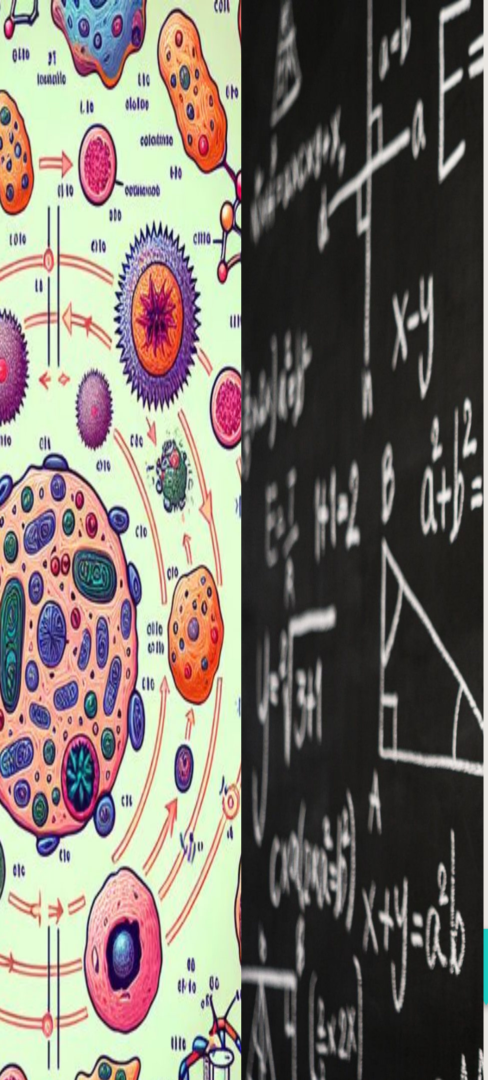
Publisher: IEEE Cite This PDF

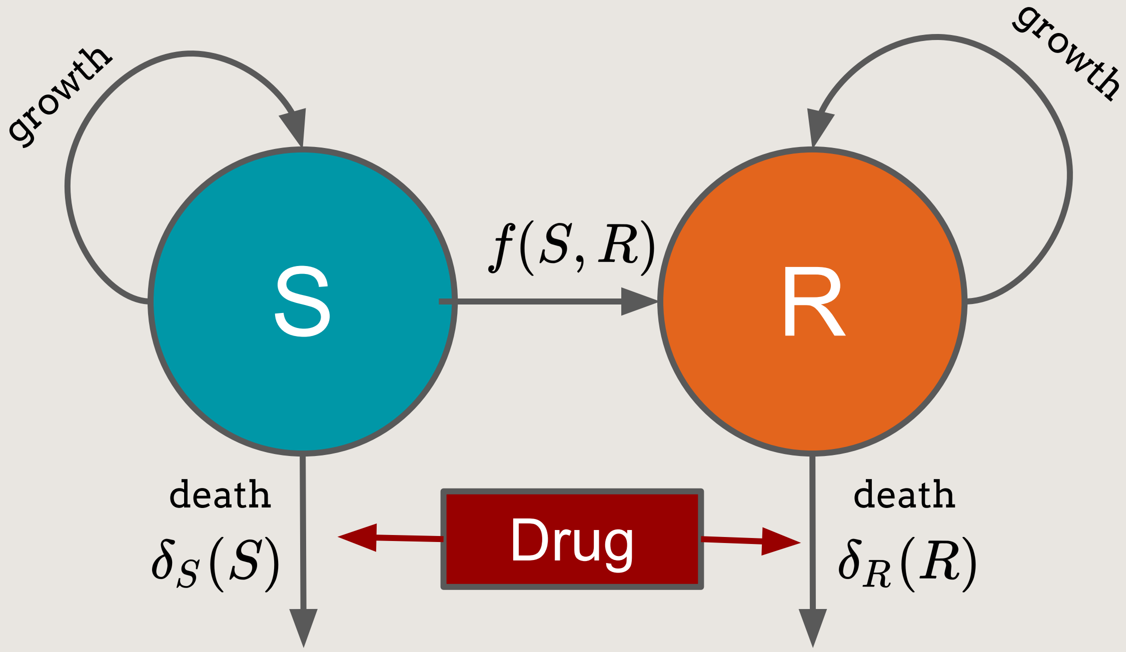
Sandra Indhavani García Mendoza ; Julio César Pérez Sansalvador ; Gustavo Rodrígue... **All Authors**

Sandra Indhavani García Mendoza, **Master Thesis**, Instituto Nacional de Astrofísica, Óptica y Electrónica, jointly supervised with Gustavo Rodríguez Gómez, Efficient iterative numerical method for the solution of the proliferation-invasion model of brain glioblastoma, **2023**

S. I. G. Mendoza, J. C. P. Sansalvador and G. R. Gómez, "Efficient numerical solution of the brain glioblastomas proliferation-invasion model," 2022 IEEE Mexican International Conference on Computer Science (ENC), Xalapa, Veracruz, Mexico, 2022, pp. 1-5, doi: 10.1109/ENC56672.2022.9882922

Sensitive-Resistance Drug Models





Sensitive-Resistance Drug Models

$$\frac{\partial S(\mathbf{x},t)}{\partial t} = D\frac{\partial^2 S(\mathbf{x},t)}{\partial \mathbf{x}^2} + r_S S(\mathbf{x},t)\left(1-\frac{S(\mathbf{x},t)+R(\mathbf{x},t)}{K}\right) - f(S(\mathbf{x},t),R(\mathbf{x},t)) - \delta_S(S(\mathbf{x},t))$$

$$\frac{\partial R(\mathbf{x},t)}{\partial t} = D\frac{\partial^2 R(\mathbf{x},t)}{\partial \mathbf{x}^2} + r_S R(\mathbf{x},t)\left(1-\frac{S(\mathbf{x},t)+R(\mathbf{x},t)}{K}\right) + f(S(\mathbf{x},t),R(\mathbf{x},t)) - \delta_R(R(\mathbf{x},t))$$

Spatial diffusion | Intrinsic growth | Transition rate from S to R | Cell's death

- Numerical methods for solving PDEs
- Physics Informed Neural Networks for solving PDEs

Miguel Cruz Gama, **Doctoral Thesis (in progress)**, Instituto Nacional de Astrofísica, Óptica y Electrónica, jointly supervised with Gustavo Rodríguez Gómez, *Physics Informed Neural Networks for the Numerical Solution of nonlinear evolutive PDEs*

Edgar Martínez Pascual, **Doctoral Thesis (in progress)**, Instituto Nacional de Astrofísica, Óptica y Electrónica, jointly supervised with Gustavo Rodríguez Gómez, *Physics Informed Neural Networks for the Numerical Solution of Physical based PDEs*

Sensitive-Resistance Drug Models

$$\frac{\partial S(\mathbf{x},t)}{\partial t} = D\frac{\partial^2 S(\mathbf{x},t)}{\partial \mathbf{x}^2} + r_S S(\mathbf{x},t)\left(1 - \frac{S(\mathbf{x},t)+R(\mathbf{x},t)}{K}\right) - f(S(\mathbf{x},t), R(\mathbf{x},t)) - \delta_S(S(\mathbf{x},t))$$

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Spatial diffusion | Intrinsic growth | Transition rate from S to R | Cell's death

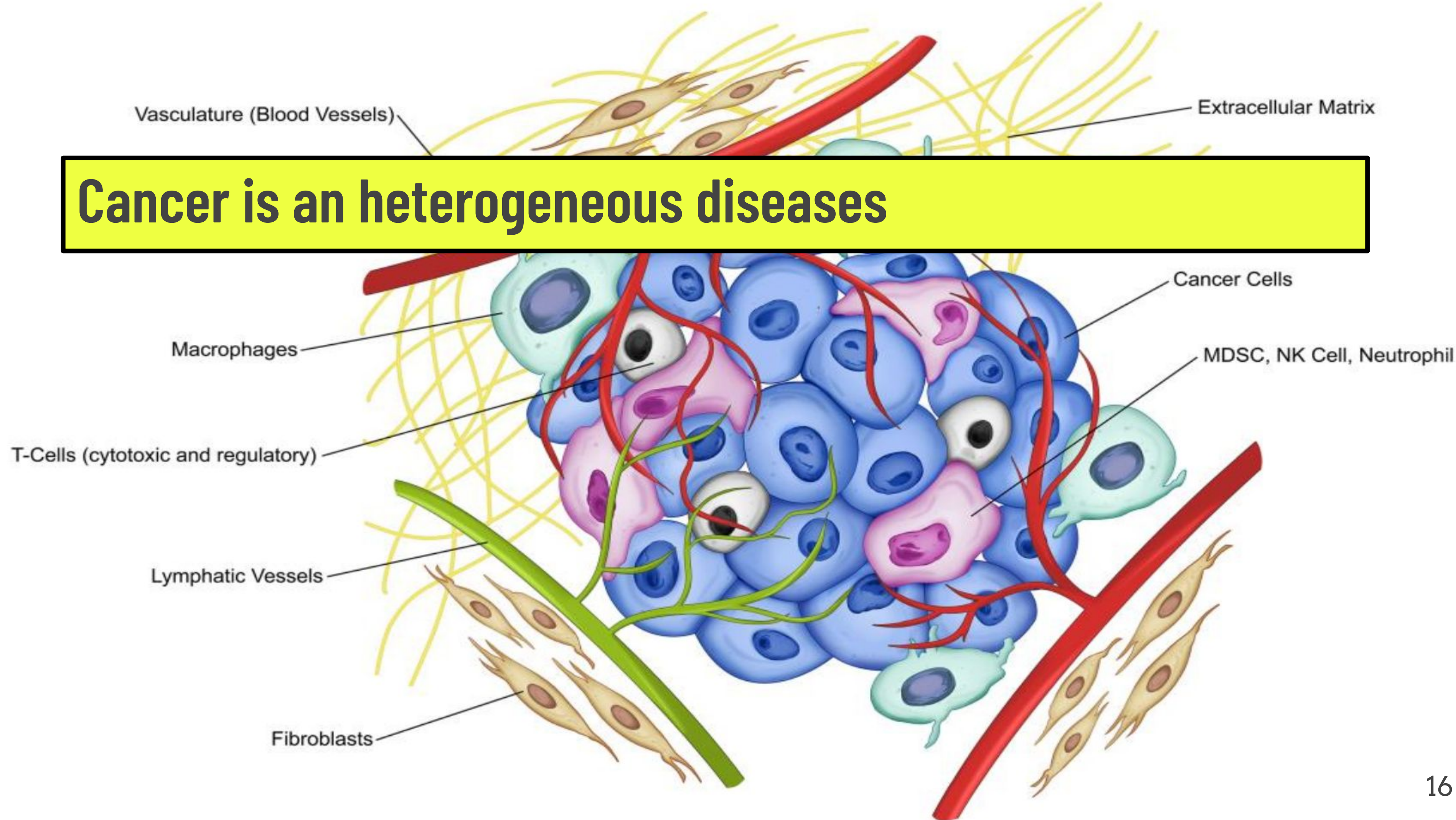
- Numerical methods for solving PDEs
- Physics Informed Neural Networks for solving PDEs

Miguel Cruz Gama, **Doctoral Thesis (in progress)**, Instituto Nacional de Astrofísica, Óptica y Electrónica, jointly supervised with Gustavo Rodríguez Gómez, *Physics Informed Neural Networks for the Numerical Solution of nonlinear evolutive PDEs*

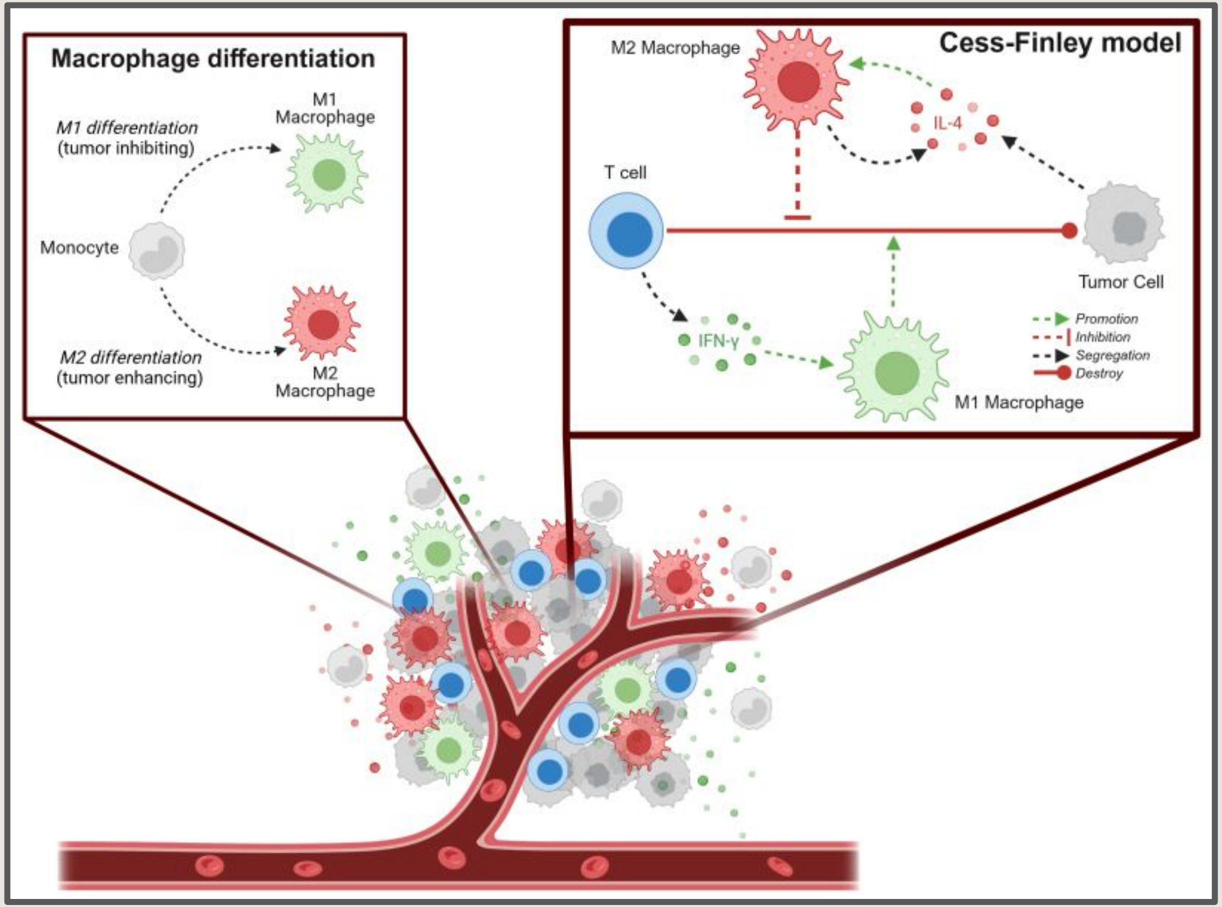
Edgar Martínez Pascual, **Doctoral Thes**
jointly supervised with Gustavo Rodríg
Solution of Physical based PDEs

PDEs based models represent cancer as an homogeneous diseases!

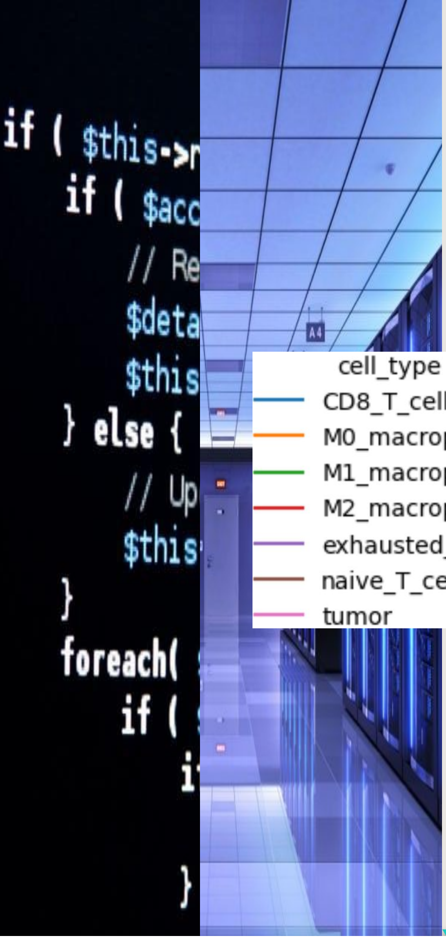
Cancer is an heterogeneous diseases

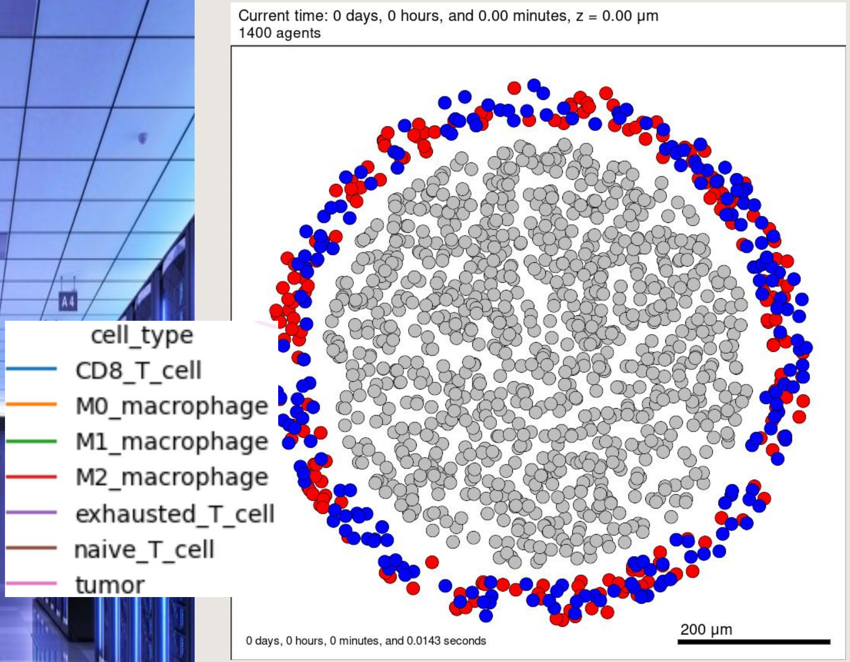


Off-Lattice Parallel Simulation for Tumor immunosurveillance

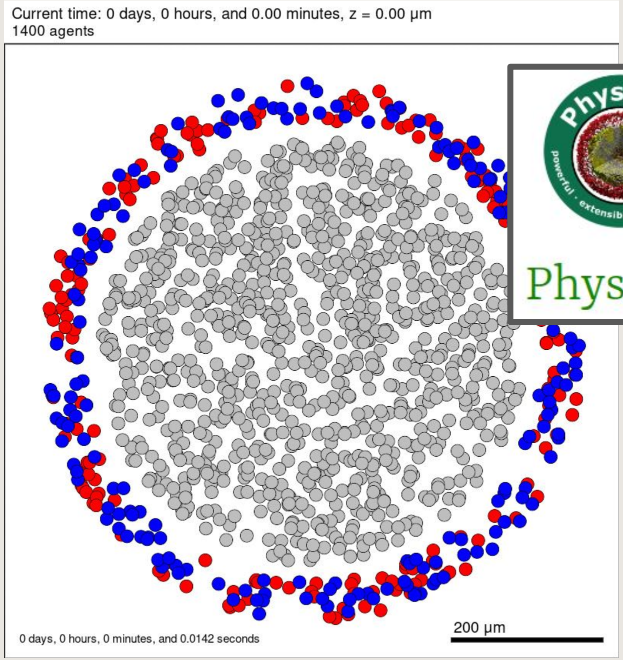


Model based on Colin G. Cess and Stacey D. Finley, Multi-scale modeling of macrophage - T cell interactions within the tumor microenvironment, PLOS Computational Biology, 2020, https://doi.org/10.1371/journal.pcbi.1008519





Cess and Finley based model extended with Johnson

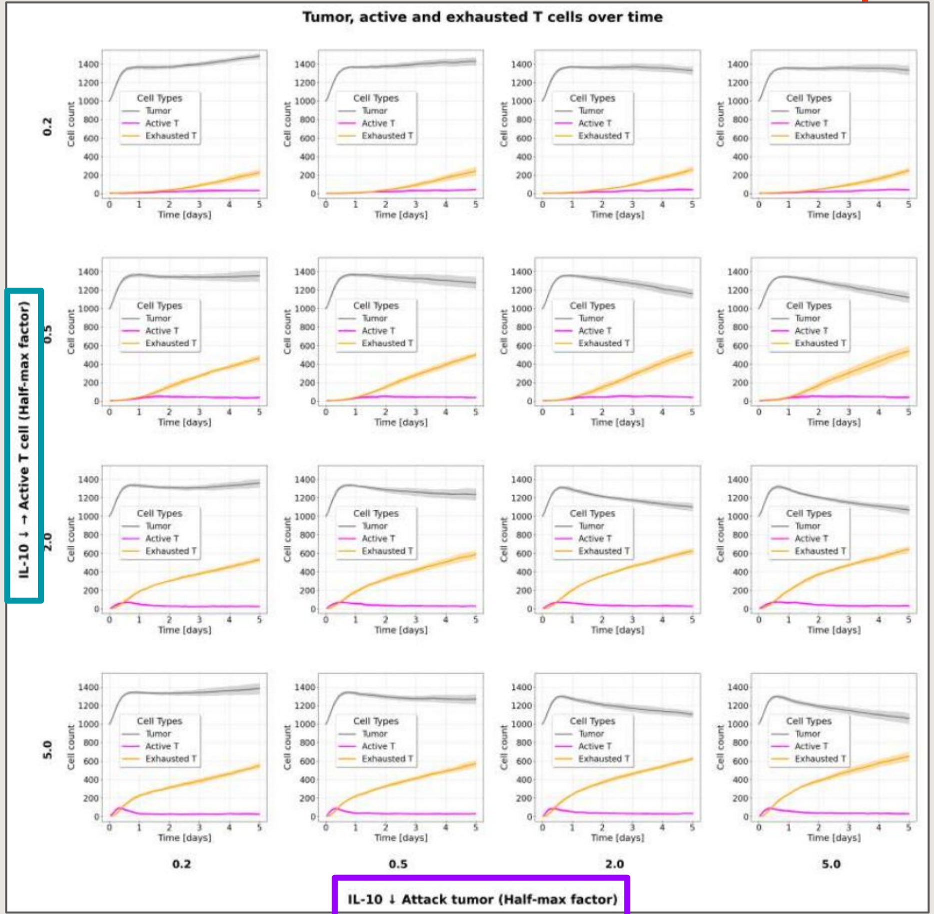


Johnson *et.al.* model

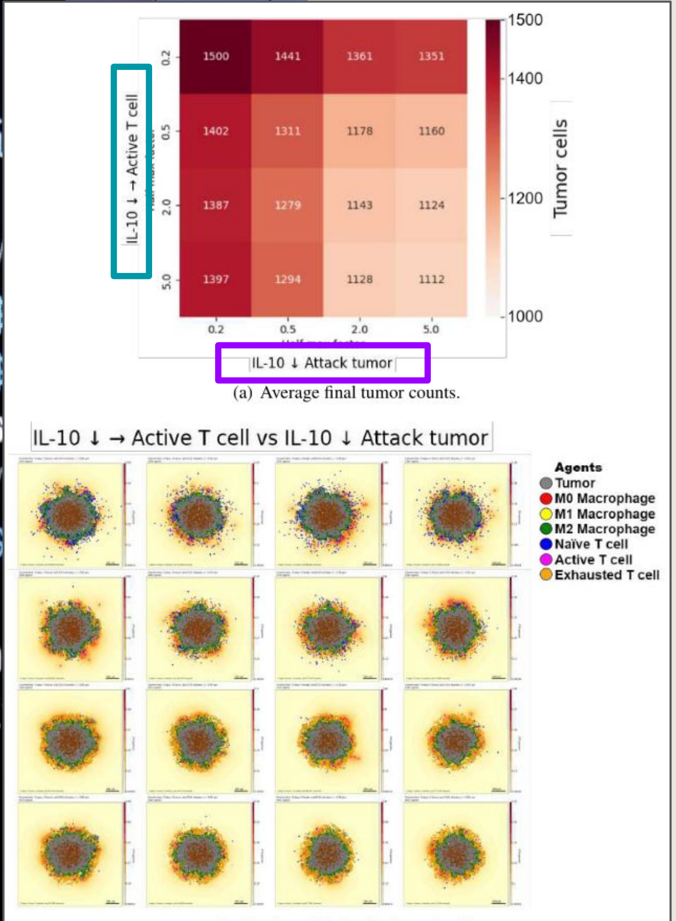
Eduardo Rodolfo Rodriguez Gallegos, **Master Thesis (in progress/almost finished)**, Instituto Nacional de Astrofísica, Óptica y Electrónica, jointly supervised with Gustavo Rodríguez Gómez, *Off-Lattice Parallel Algorithm for Tumor Immunosurveillance Based on Cess-Finley Model*

Colin G. Cess and Stacey D. Finley, Multi-scale modeling of macrophage - T cell interactions within the tumor microenvironment, PLOS Computational Biology, 2020, https://doi.org/10.1371/journal.pcbi.1008519
Johnson, Jeanette A.I. et. al. Digitize your Biology! Modeling multicellular systems through interpretable cell behavior, bioRxiv, Cold Spring Harbor Laboratory, 2023, https://doi.org/10.1101/2023.09.17.557982

#	Cell Type	Signal	Effect on Behavior (↑promotion, ↓inhibition)
1	Tumor cell	Pressure	↓ Cycle entry
2	Tumor cell	Oxygen	↑ Cycle entry
3	Tumor cell	Oxygen	↓ Necrosis
4	Tumor cell	Damage	↑ Apoptosis
5	Tumor cell	Dead cell	↑ Debris secretion
6	M0 macrophage	Dead cell contact	↓ Migration speed
7*	M0 macrophage	Dead cell contact	↑ Polarization to M1 macrophage
8*	M0 macrophage	IFN-γ	↑ Polarization to M1 macrophage
9*	M0 macrophage	IL-10	↑ Polarization to M2 macrophage
10*	M0 macrophage	IL-4	↑ Polarization to M2 macrophage
11	M0 macrophage	Dead cell	↑ Debris secretion
12	M1 macrophage	Dead cell contact	↓ Migration speed
13	M1 macrophage	Tumor contact	↓ Migration speed
14	M1 macrophage	Oxygen	↓ Re-polarization to M2 macrophage
15*	M1 macrophage	IL-4	↑ Re-polarization to M2 macrophage
16	M1 macrophage	Dead cell	↑ Debris secretion
17	M2 macrophage	Dead cell contact	↓ Migration speed
18	M2 macrophage	Tumor contact	↓ Migration speed
19	M2 macrophage	Dead cell	↑ Debris secretion
20*	M2 macrophage	IFN-γ	↑ Re-polarization to M1 macrophage
21*	Naive T cell	IL-10	↓ Differentiation to Active T cell
22*	Naive T cell	IFN-γ	↑ Differentiation to Active T cell
23	Naive T cell	Dead cell	↑ Debris secretion
24	Naive T cell	Tumor contact	↓ Migration speed
25*	Active T cell	IL-10	↓ Tumor killing
26	Active T cell	IL-10	↓ Migration speed
27	Active T cell	Tumor contact	↓ Migration speed
28	Active T cell	IFN-γ	↑ Cycle entry
29*	Active T cell	IL-10	↑ Differentiation to exhausted T cell
30	Active T cell	Dead cell	↑ Debris secretion
31	Exhausted T cell	Dead cell	↑ Debris secretion

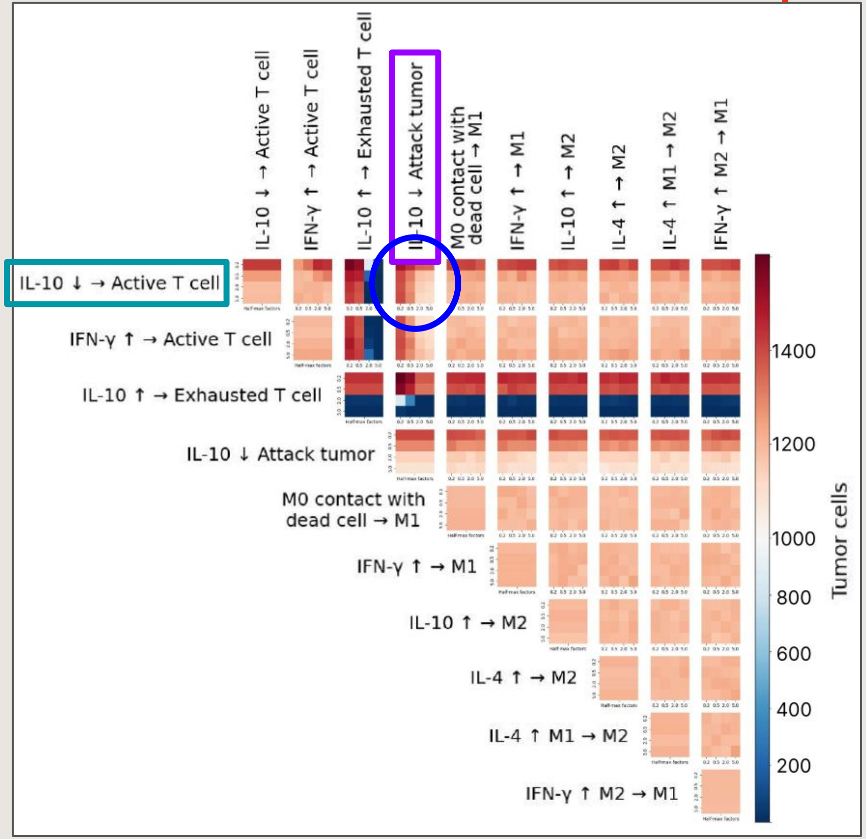


Rodríguez-Gallegos, E. R. Pérez-Sansalvador, J. C. Rodríguez-Gómez, G. and Pomares-Hernández, S. E., **(2025)** An off-lattice parallel algorithm for tumour immunosurveillance based on Cess-Finley model, *2025 IEEE International Autumn Meeting on Power, Electronics and Computing (ROPEC 2025)*, Ixtapa, Mexico, **to be published.**

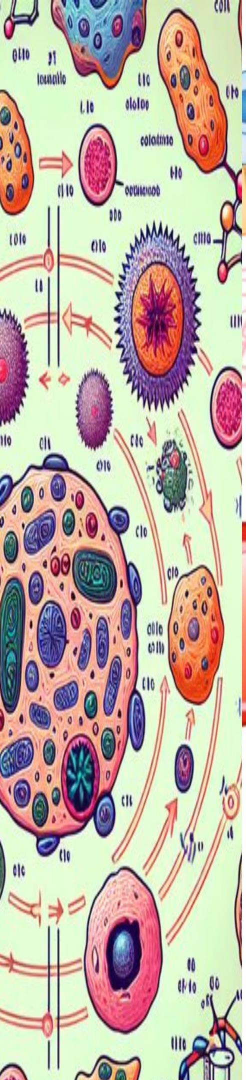


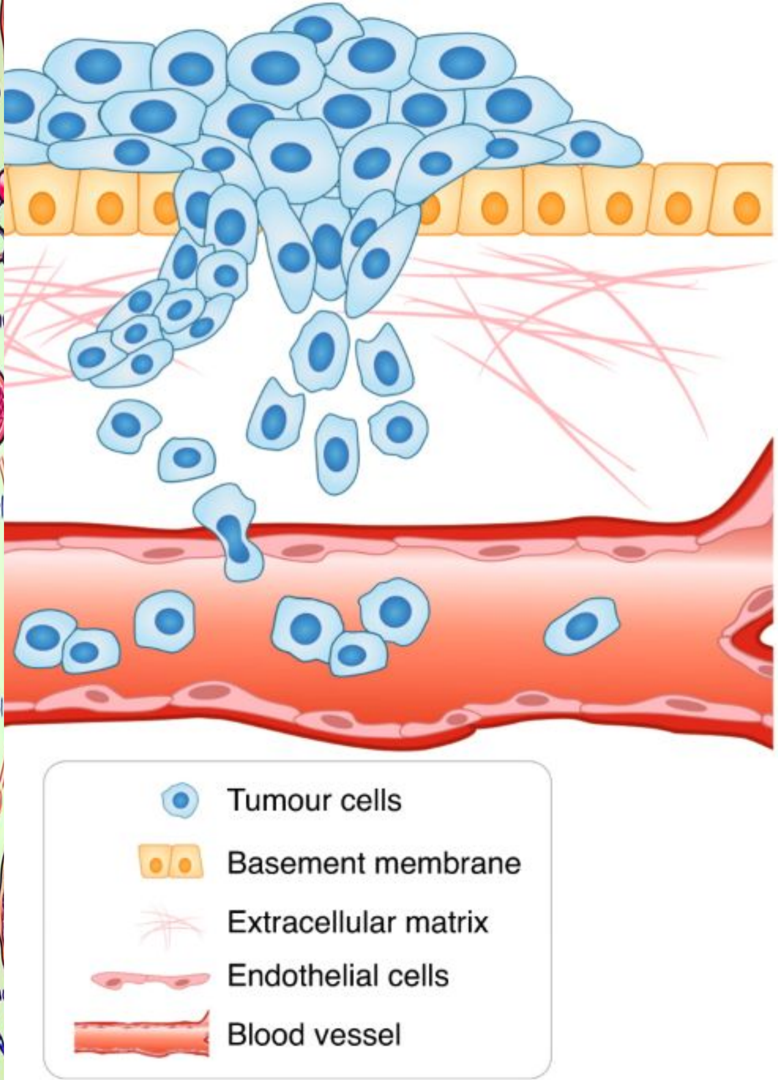
(a) Average final tumor counts.

(b) Final spatial distribution of cells.



Rodríguez-Gallegos, E. R. Pérez-Sansalvador, J. C. Rodríguez-Gómez, G. and Pomares-Hernández, S. E., **(2025)** An off-lattice parallel algorithm for tumour immunosurveillance based on Cess-Finley model, *2025 IEEE International Autumn Meeting on Power, Electronics and Computing (ROPEC 2025)*, Ixtapa, Mexico, **to be published.**





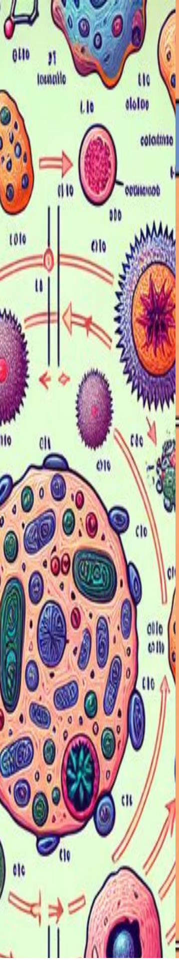
Cancer cells evolve and may migrate (metastasis)

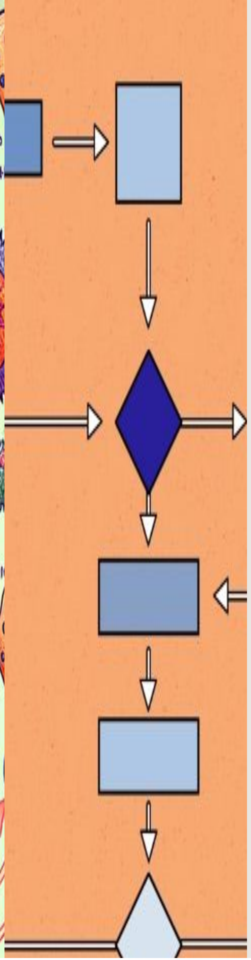
How do we capture other elements in the microenvironment?

How do we capture the displacement of cancer cells in the environment?

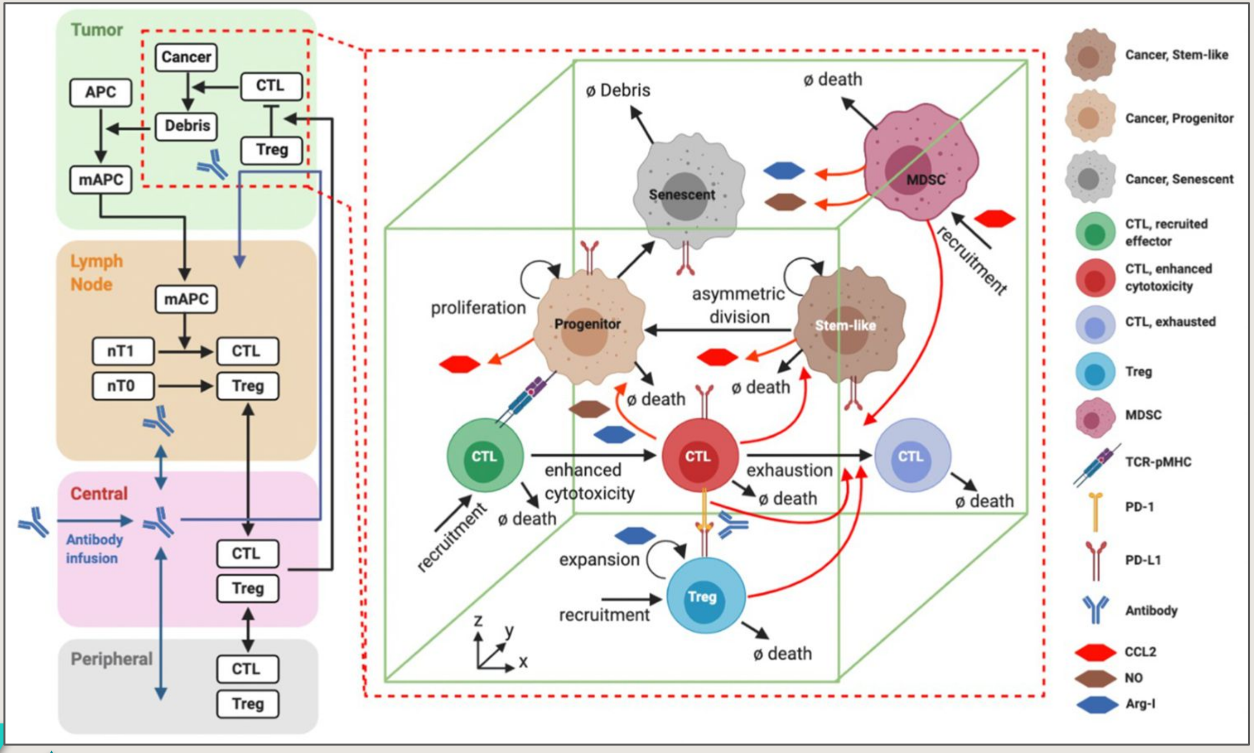
Could we apply deep learning to discover **migration patterns**?

Could we apply deep learning techniques to **reduce simulation computational costs**?



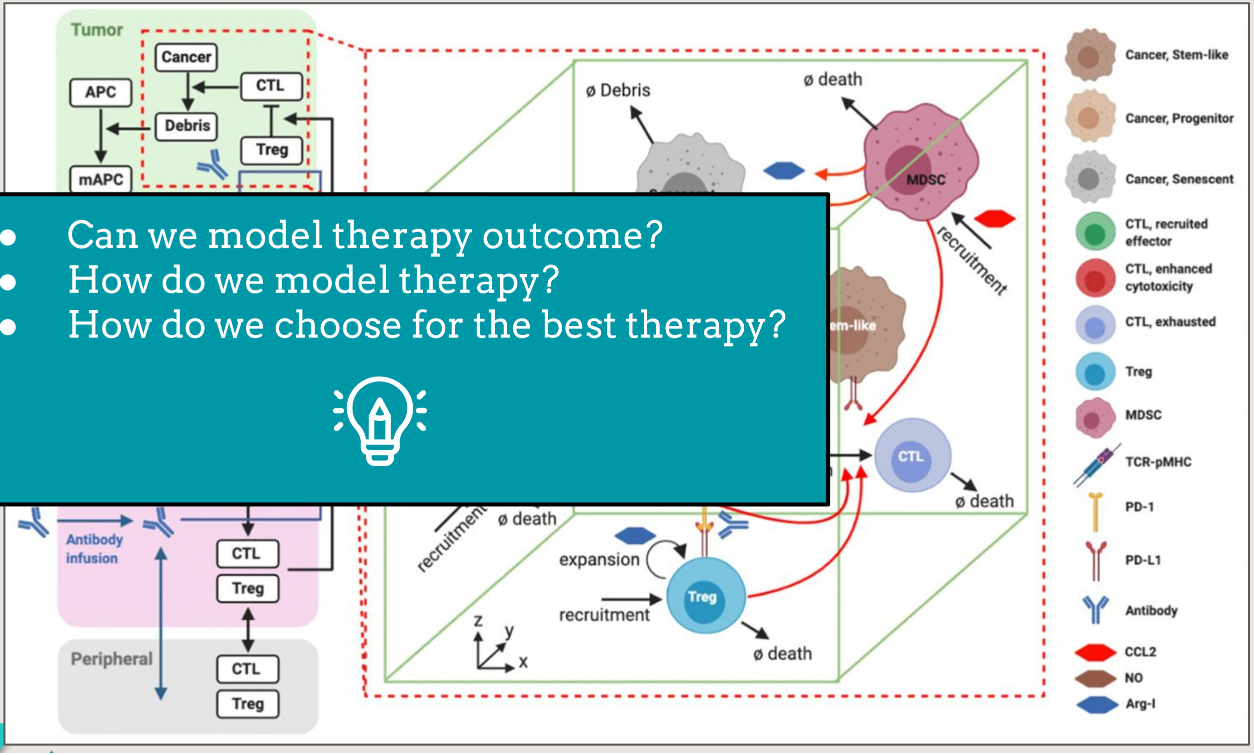


What about more complex models?



Picture from Ruiz-Martinez A, Gong C, Wang H, Sové RJ, Mi H, et al. (2022) Simulations of tumor growth and response to immunotherapy by coupling a spatial agent-based model with a whole-patient quantitative systems pharmacology model. PLOS Computational Biology 18(7) https://doi.org/10.1371/journal.pcbi.1010254

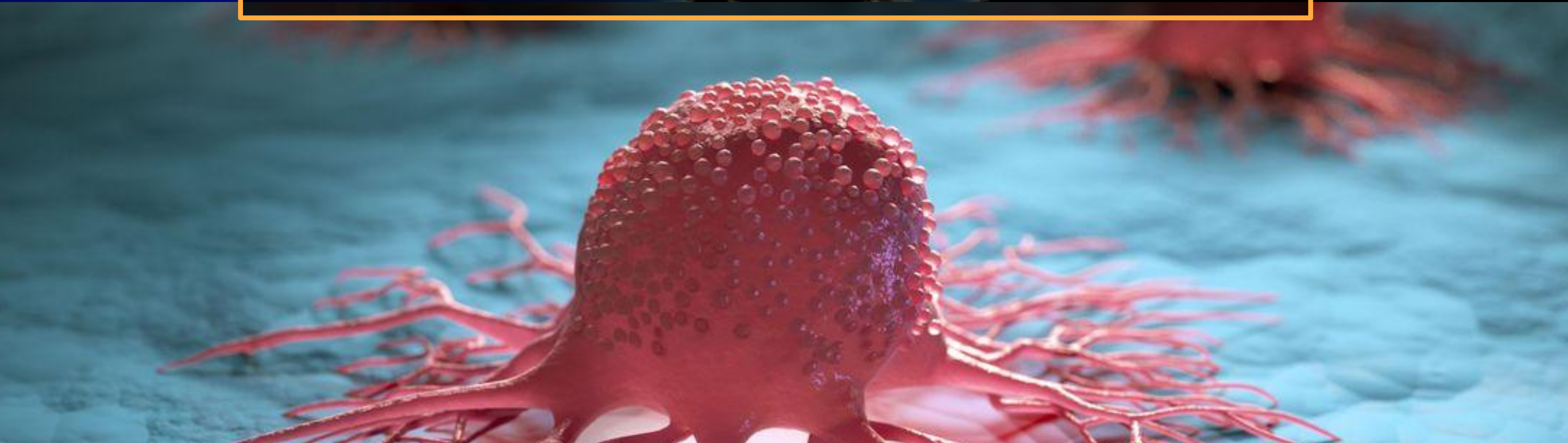
What about more complex models?

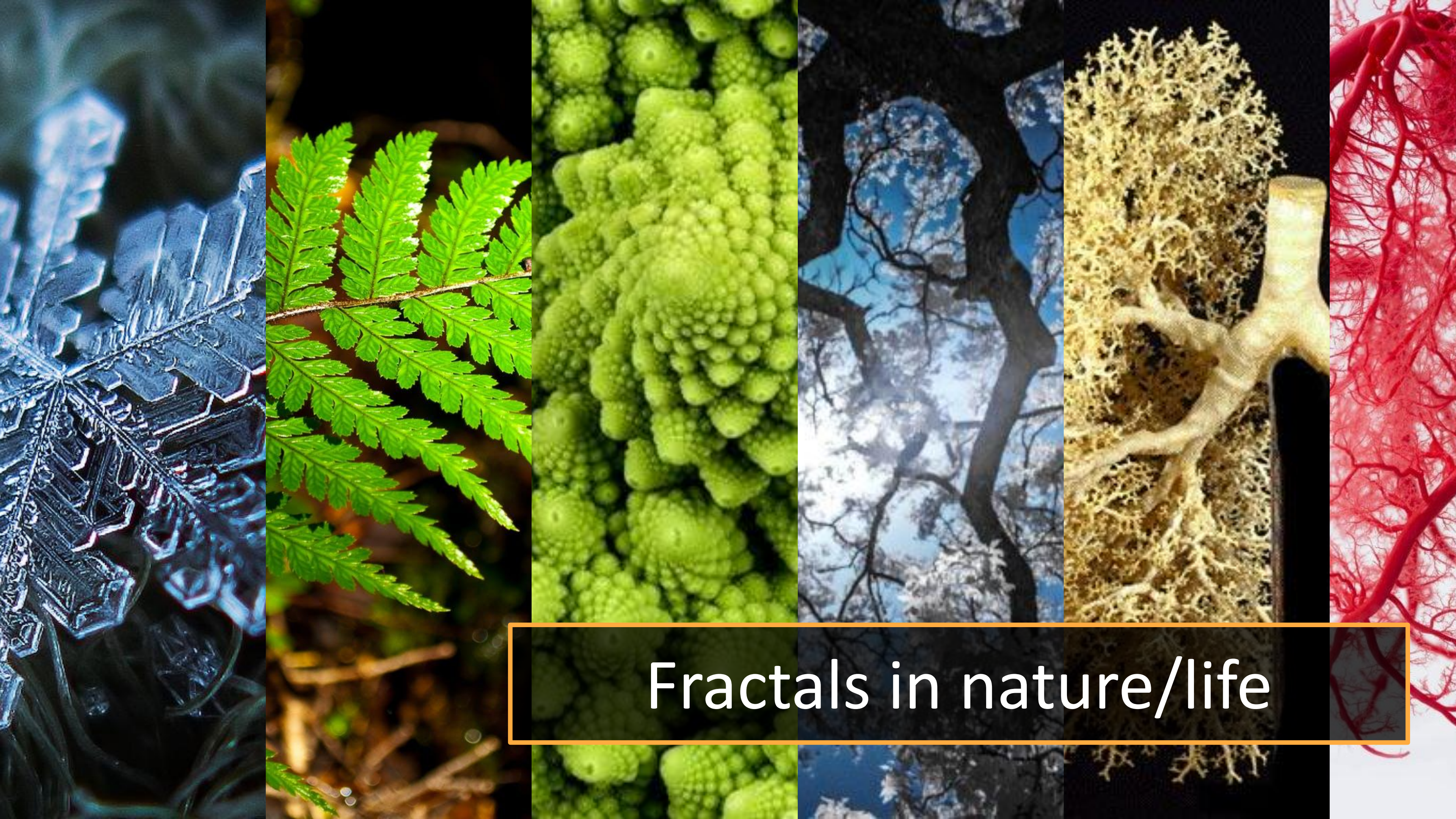


- Can we model therapy outcome?
- How do we model therapy?
- How do we choose for the best therapy?

Picture from Ruiz-Martinez A, Gong C, Wang H, Sové RJ, Mi H, et al. (2022) Simulations of tumor growth and response to immunotherapy by coupling a spatial agent-based model with a whole-patient quantitative systems pharmacology model. PLOS Computational Biology 18(7) https://doi.org/10.1371/journal.pcbi.1010254

Fractals and Cancer

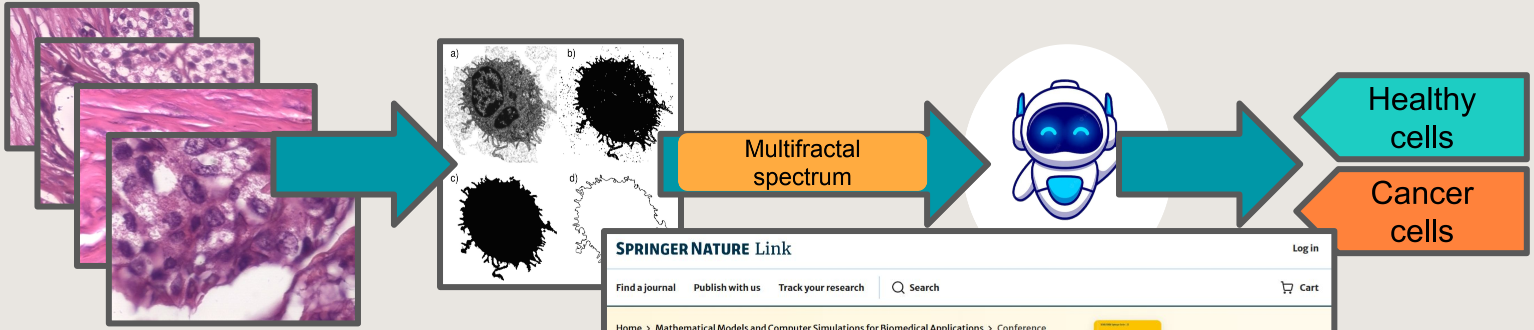



Fractals in nature/life

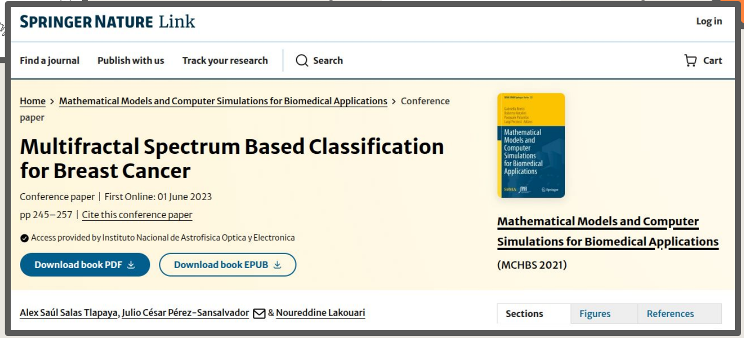
Fractal and multifractal spectrum as cells features

Alex Saul Salas Tlapaya, **Master Thesis**, Instituto Nacional de Astrofísica, Óptica y Electrónica, jointly supervised with Noureddine Lakouari, Multifractal dimension for breast cancer cells identification, **2023**.

Tlapaya, A.S.S., Pérez-Sansalvador, J.C., Lakouari, N. Multifractal Spectrum Based Classification for Breast Cancer. In: Bretti, G., Natalini, R., Palumbo, P., Preziosi, L. (eds) *Mathematical Models and Computer Simulations for Biomedical Applications*. MCHBS 2021. SEMA SIMAI Springer Series, vol 33. Springer, Cham. **2023** https://doi.org/10.1007/978-3-031-35715-2_9



*from BreakHis dataset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Multifractal Spectrum Based Classification for Breast Cancer

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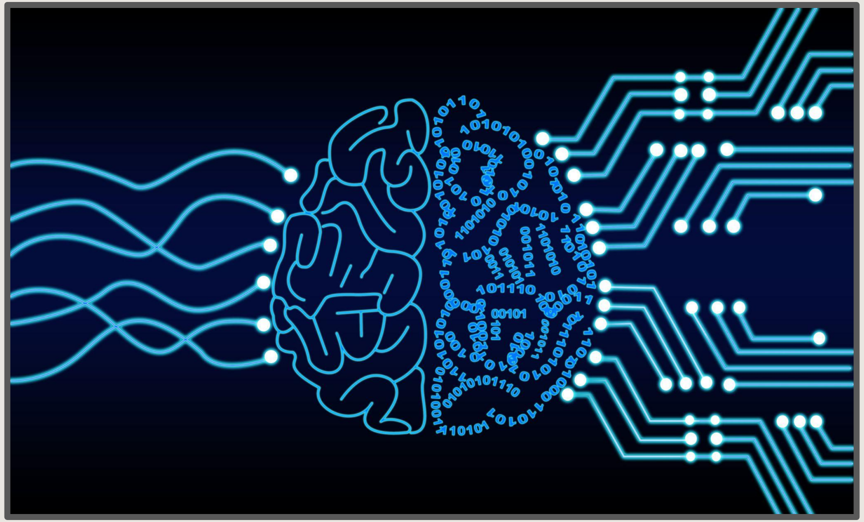
Mathematical Models and Computer Simulations for Biomedical Applications

(MCHBS 2021)

Alex Saúl Salas Tlapaya, Julio César Pérez-Sansalvador & Noureddine Lakouari

Sections Figures References

How to improve current results?



Additional image processing

- Cell segmentation
- Cell counting

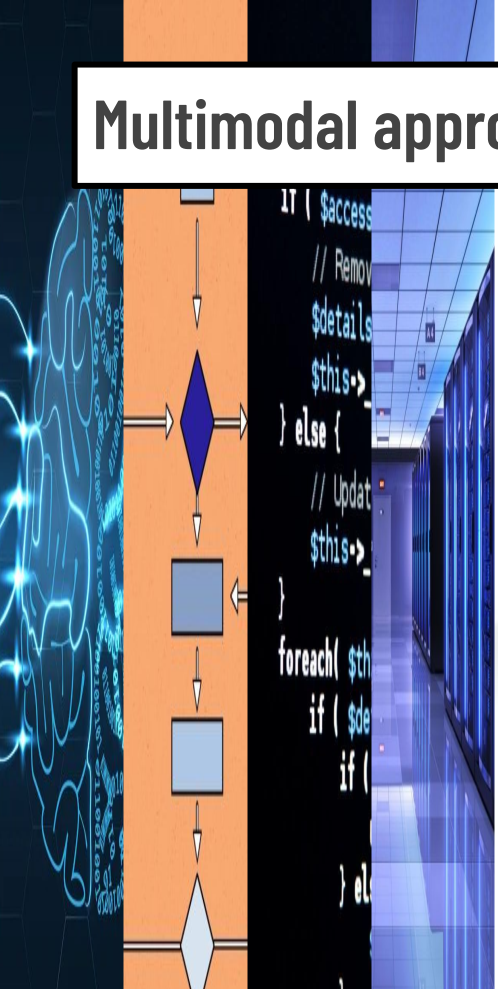
Single cell identification

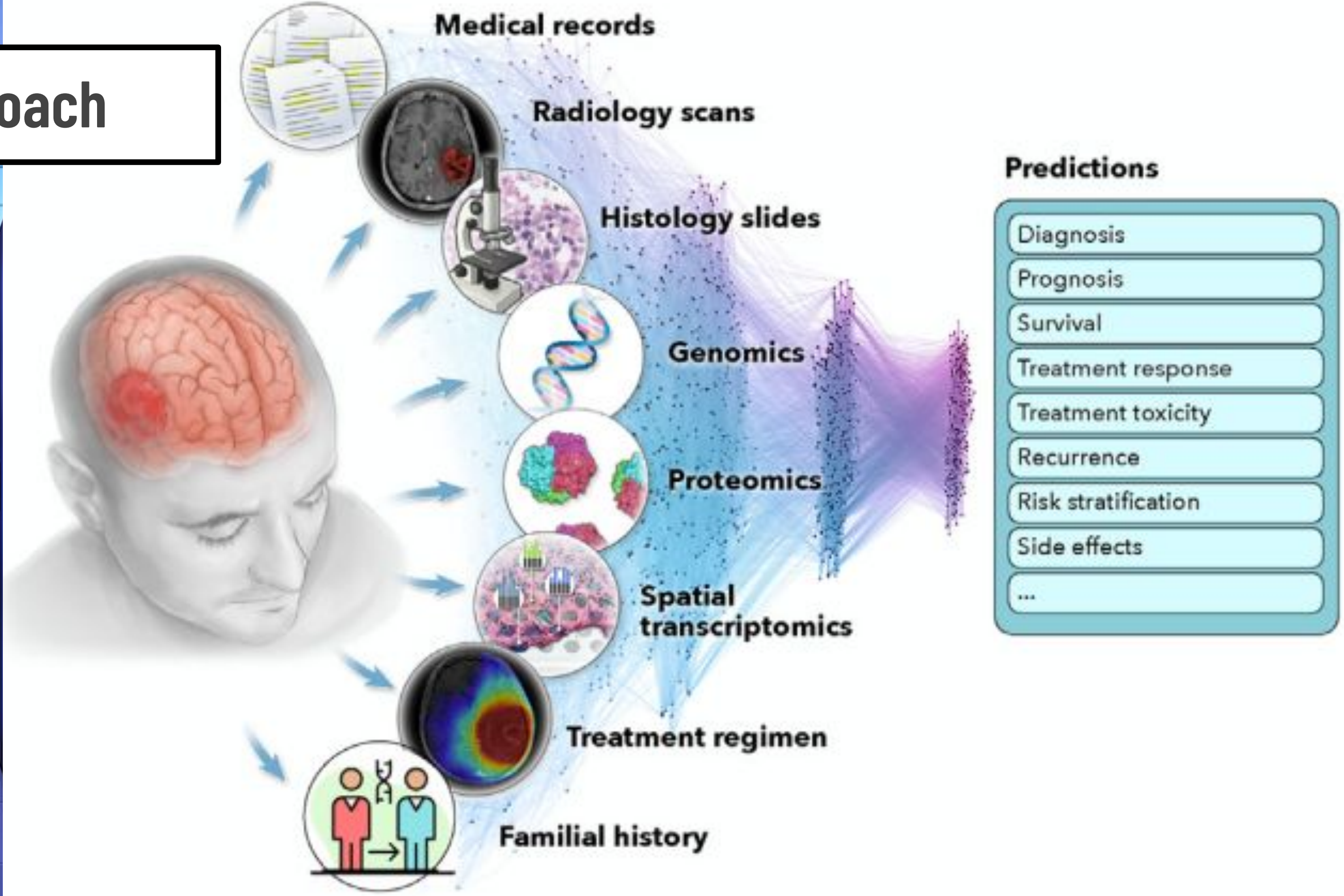
Application of deep learning techniques

Does it work with other types of cancer cells?

Does it helps for disease grading and staging?

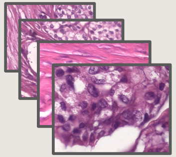
Multimodal approach



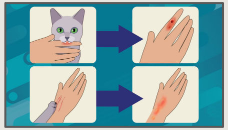


Figures from Lipkova, Jana *et. al.*, Artificial intelligence for multimodal data integration in oncology, *Cancer Cell*, Elsevier 40 (10), pp. 1535-6108, 2022.
https://doi.org/10.1016/j.ccell.2022.09.012

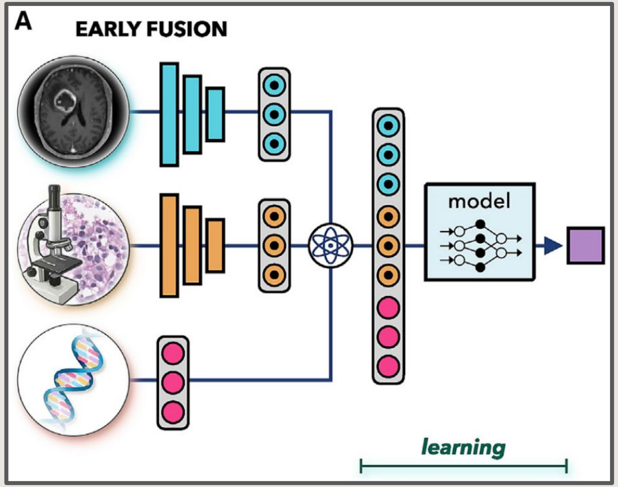
Multimodal approach

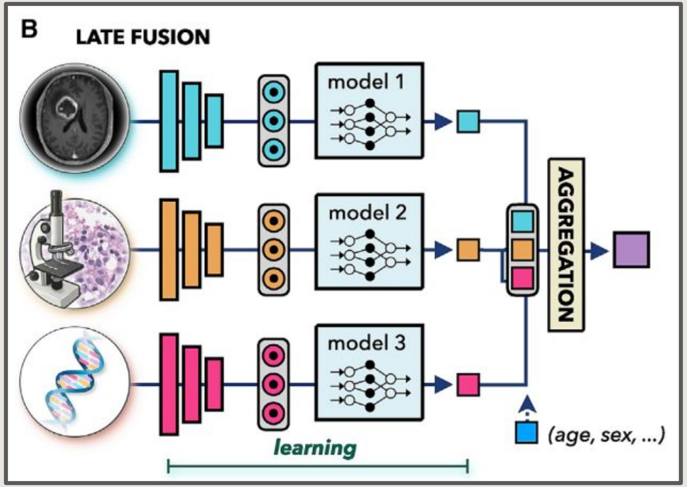


Alejandro Méndez Calvario, **Doctoral Thesis (in progress)**, Instituto Nacional de Astrofísica, Óptica y Electrónica, jointly supervised with Noureddine Lakouari, *Multimodal based identification of DLBCL*



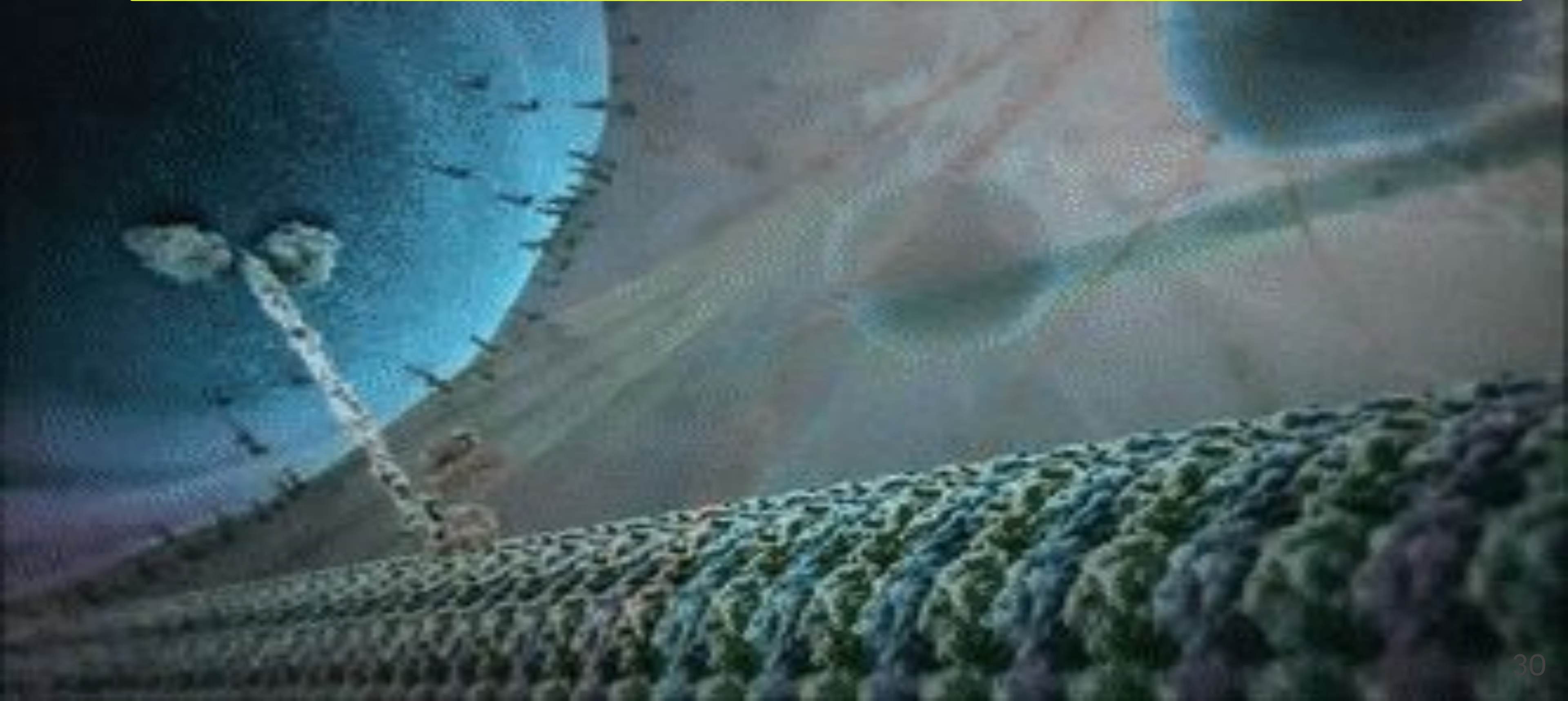
Vania Déborah Vázquez Palacios, **Doctoral thesis (in progress)**, Instituto Nacional de Astrofísica, Óptica y Electrónica, jointly supervised with Humberto Pérez Espinosa, *Deep learning for the identification of under-the-skin lesions caused by fungus*

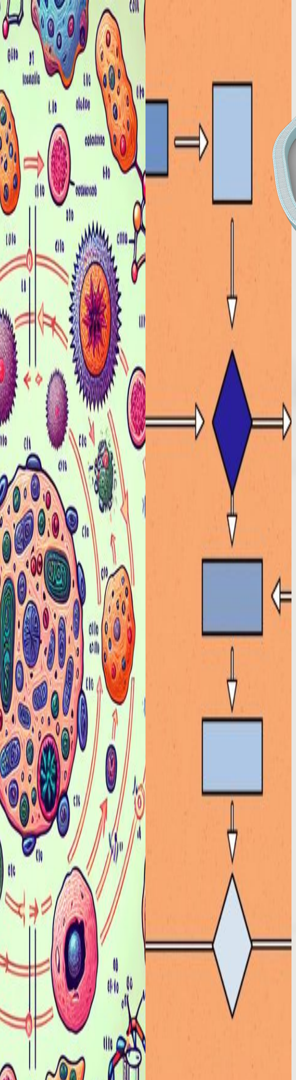


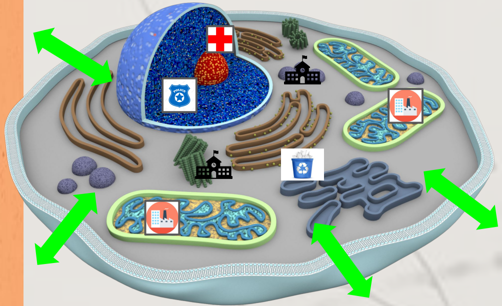


Figures from Lipkova, Jana *et. al.*, Artificial intelligence for multimodal data integration in oncology, *Cancer Cell*, Elsevier 40 (10), pp. 1535-6108, 2022.
https://doi.org/10.1016/j.ccell.2022.09.012

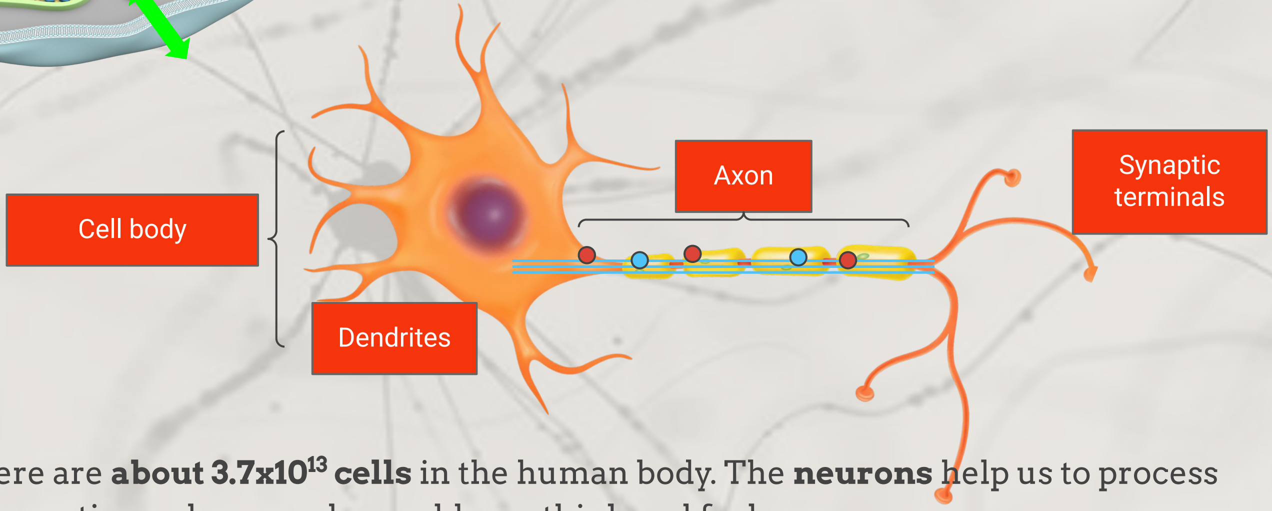
Molecular motors







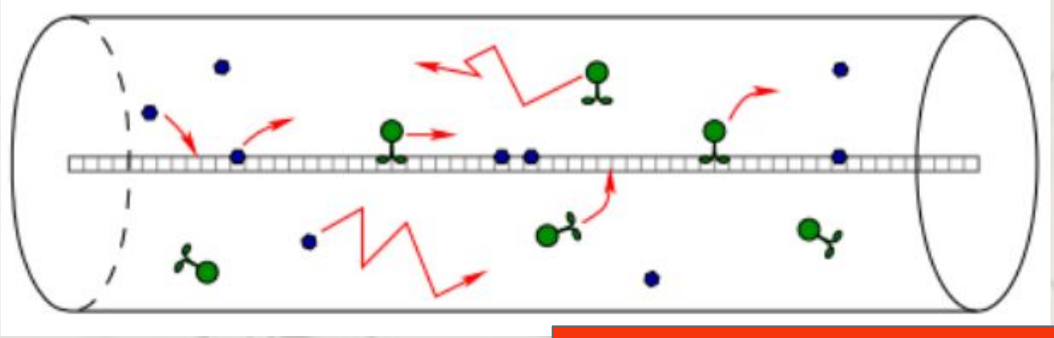
Molecular motors dynamics



There are **about 3.7x10^{13} cells** in the human body. The **neurons** help us to process information, solve complex problems, think and feel.

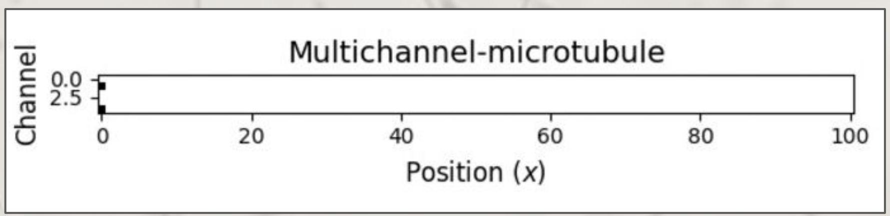
The neurons require molecular motors **to transport proteins along the axon** through the synaptic terminals. The flow of these proteins on the axon is strongly related with neurological disorders such as Alzheimer's disease.

Molecular motors dynamics



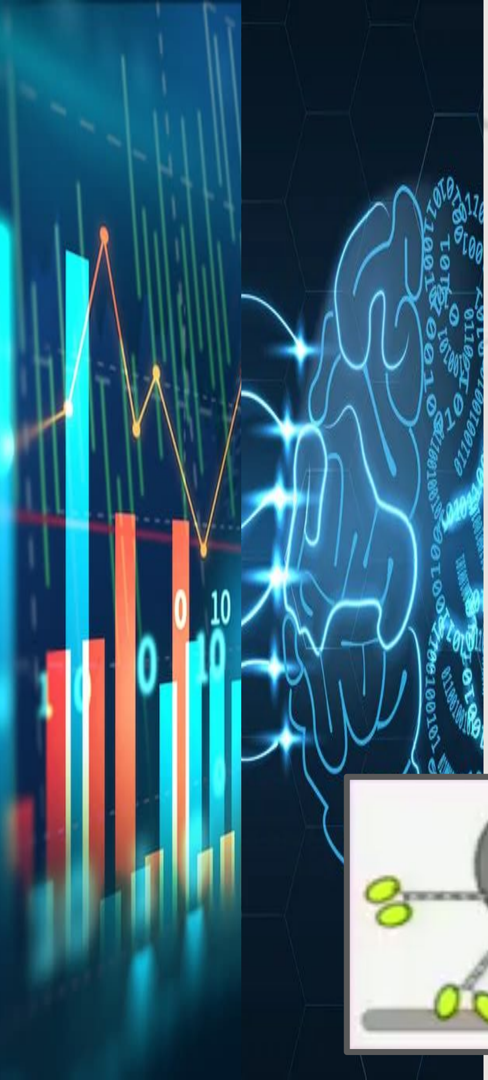
Axon and microtubule

Alejandro Méndez Calvario, **Master Thesis**, Instituto Nacional de Astrofísica, Óptica y Electrónica, jointly supervised with Noureddine Lakouari, Simulation of the effect of the tau-protein on the axonal-intracellular traffic dynamic, **2023**.



mTASEP - LK model

https://github.com/tachidok/scicellxx



Molecular motors dynamics

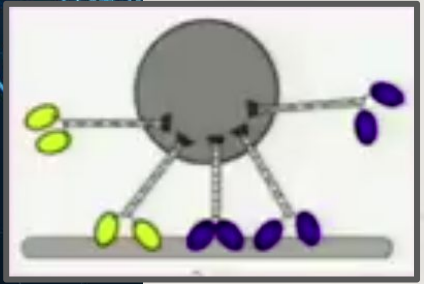
How do we **model the transport of proteins in a dynamic cytoskeleton**?

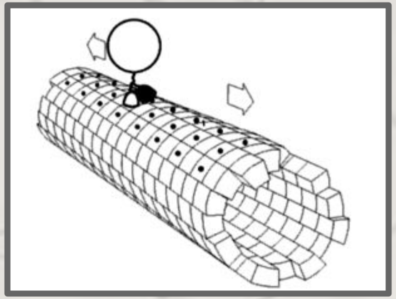
How do these molecular motors **interact**?

What are the effects of these transport on the generation of neurological disorders?

Tania del Valle García, **Master Thesis**, Instituto Nacional de Astrofísica, Óptica y Electrónica, jointly supervised with Noureddine Lakouari and Rubén Vázquez Roque (BUAP), Alzheimer's characterisation based on AI predictions on intracellular axonal dynamics, **2025**.

https://github.com/tachidok/scicellxx



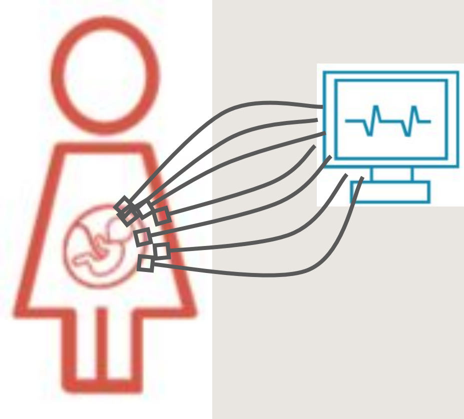


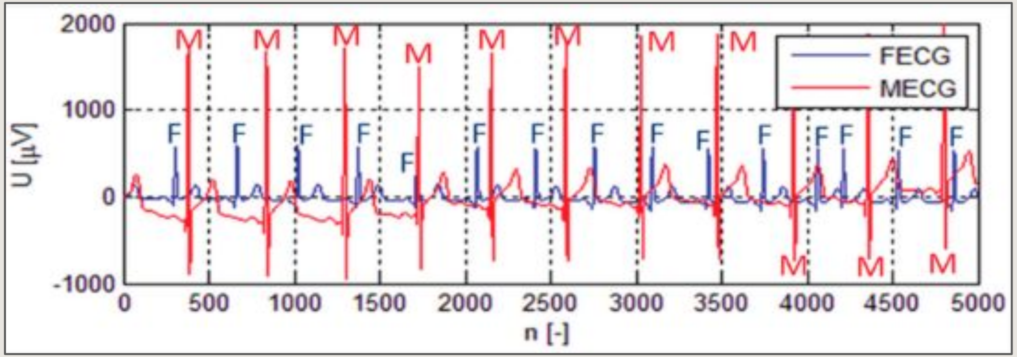
SciCell++

Fetal health monitoring

Identification of fetal heart rate disorders

The **NI-FECG** signal contains the fetal ECG and the mother ECG signals



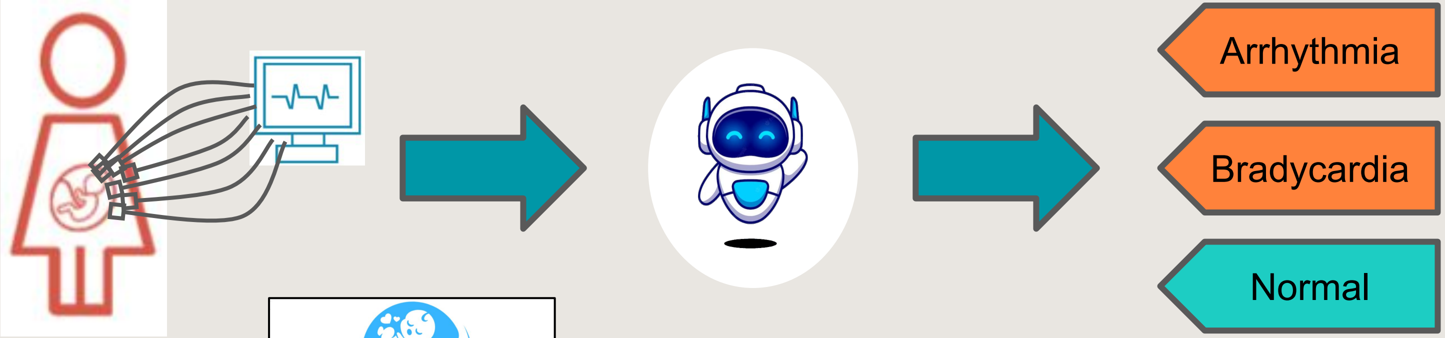


- Process the signal using specialised signal processing methods
- Use deep learning to identify patterns and fetal heart rate disorders

Figure from Aggarwal, G.; Wei, Y. Non-Invasive Fetal Electrocardiogram Monitoring Techniques: Potential and Future Research Opportunities in Smart Textiles. *Signals* 2021, *2*, 392-412. https://doi.org/10.3390/signals2030025

Identification of fetal heart rate disorders

Socrates Romero Reyes, **Master Thesis**, Instituto Nacional de Astrofísica, Óptica y Electrónica, *Machine learning for the identification of arrhythmias in NI-FECG signals*, **2023**
Socrates Romero Reyes, **Doctoral Thesis**, Instituto Nacional de Astrofísica, Óptica y Electrónica, *Multimodal based identification of arrhythmias in NI-FECG signals*



HEART BEATING


Heart beating: una aplicación para el diagnóstico prenatal inteligente
Julio César Pérez Sansalvador, Arelly Ornelas Vargas, Alejandro Barreiro Valdez, Kernel Enrique Prieto Moren, Socrates Romero Reyes

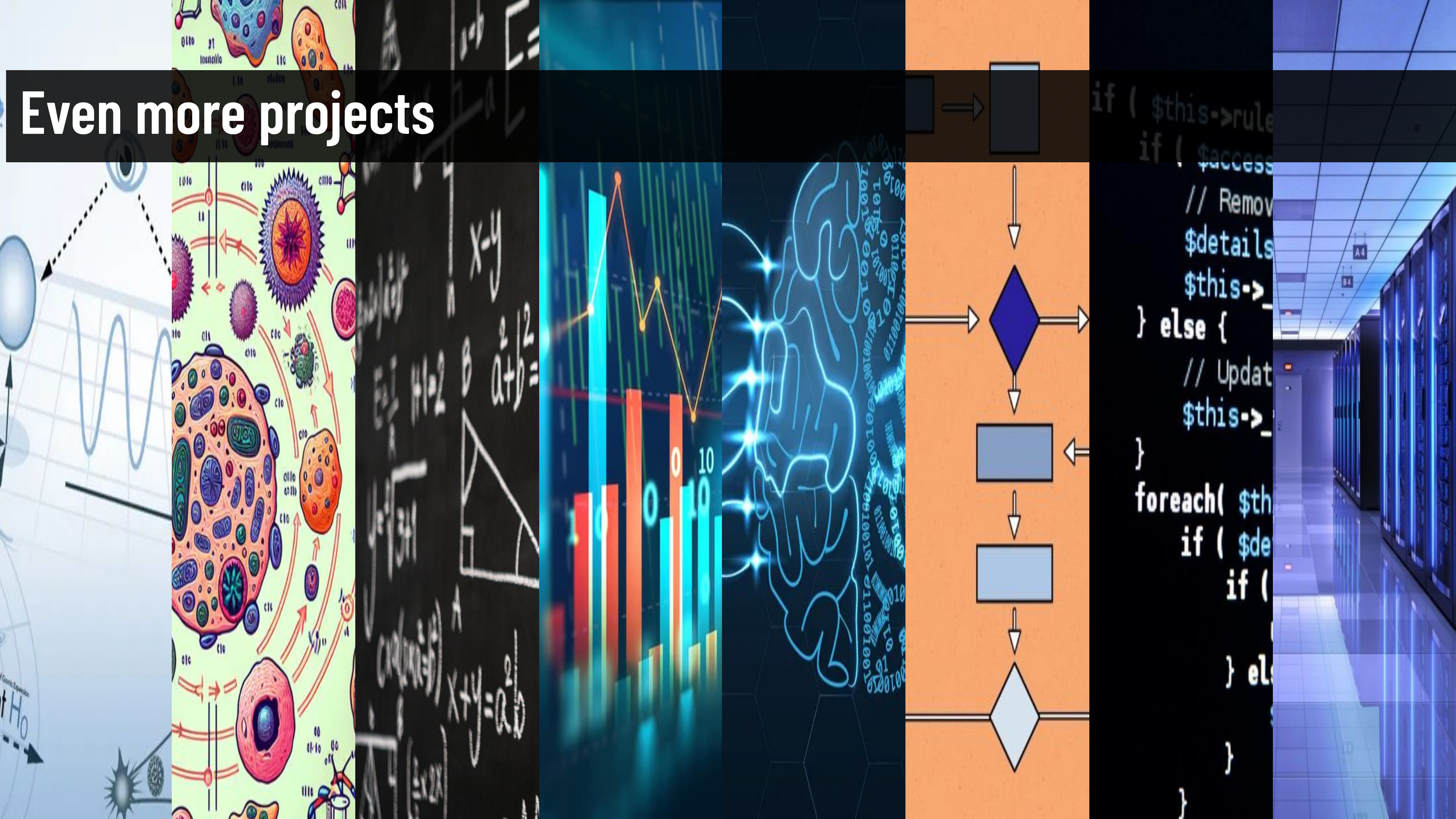
TiES Revista de Tecnología e Innovación en Educación Superior
www.ties.unam.mx

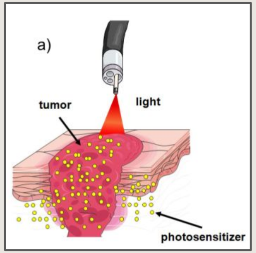
Heart beating: una aplicación para el diagnóstico prenatal inteligente

Identificación del ritmo cardíaco de la madre y del feto en señales NI-FECG, proyecto de investigación en la "Convocatoria 2022-Proyectos de investigación en Inteligencia Artificial en el Espacio de Innovación **UNAM-HUAWEI**", líder del proyecto Dr. Julio César Pérez Sansalvador, **2022**.

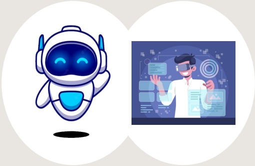
HUAWEI

Even more projects

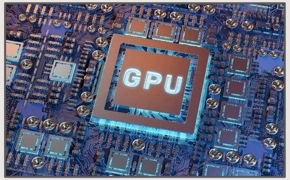




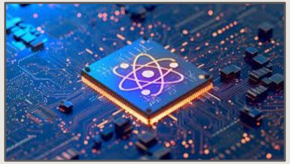
Elvis Anyel García Cortés, **Doctoral thesis (in progress)**, Instituto Nacional de Astrofísica, Óptica y Electrónica, jointly supervised with Teresita Spezzia Mazzocco, *Diffusion processes in photodynamic therapy of biological tissue: a theoretical-experimental study*



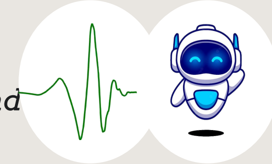
Julián A. Díaz Ayón, **Doctoral thesis (in progress)**, Instituto Nacional de Astrofísica, Óptica y Electrónica, jointly supervised with Saúl Zapotecas Martínez, *Investment portfolio optimization: a many objective approach*



Jehiel Lopez Grande, **Master thesis (in progress)**, Instituto Nacional de Astrofísica, Óptica y Electrónica, jointly supervised with René A. Cumplido Parra and Ignacio Algredo Badillo, *Hardware acceleration of continuous cellular automata through parallel computing on GPUs*



Freddy Alejandro Chaurra Gutierrez, **Doctoral thesis,** Instituto Nacional de Astrofísica, Óptica y Electrónica, jointly supervised with Claudia Feregrino Uribe and Gustavo Rodríguez Gómez, *Quantum approach to the integer wavelet transform and its application to quantum lossless compression*, **2024.**



What would be good you already know?

Maths
Modeling, Linear Algebra, Calculus, **PDEs**, **ODEs** and **Statistics**

Scientific Computing
Algorithms design, simulation, parallel computing

Computing skills
Object-Oriented programming, **C++**, C, **Python**, **Matlab**, Machine Learning, **abstraction and decomposition**.

Biological maths
Mathematical models for biological processes (cell growth, chemical processes)

CONTACT

Julio César Pérez Sansalvador

OFFICE	Computer Science Department - 8316/2111
PHONE	2663100 Ext. 8316/2111
WEB PAGE	https://ccc.inaoep.mx/~jcp.sansalvador/
EMAIL	jcp.sansalvador@inaoep.mx

Thank you