Simulating Electric Field Distribution in Tumor Cells Undergoing Mitosis

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Motivation and Introduction

Cancer is a global cause of fatalities-many treatments are underway.
Main Focus-Electrical Tumor Treating Fields

- electric pulses through cells
- lethal when cell is dividing

Advantages:

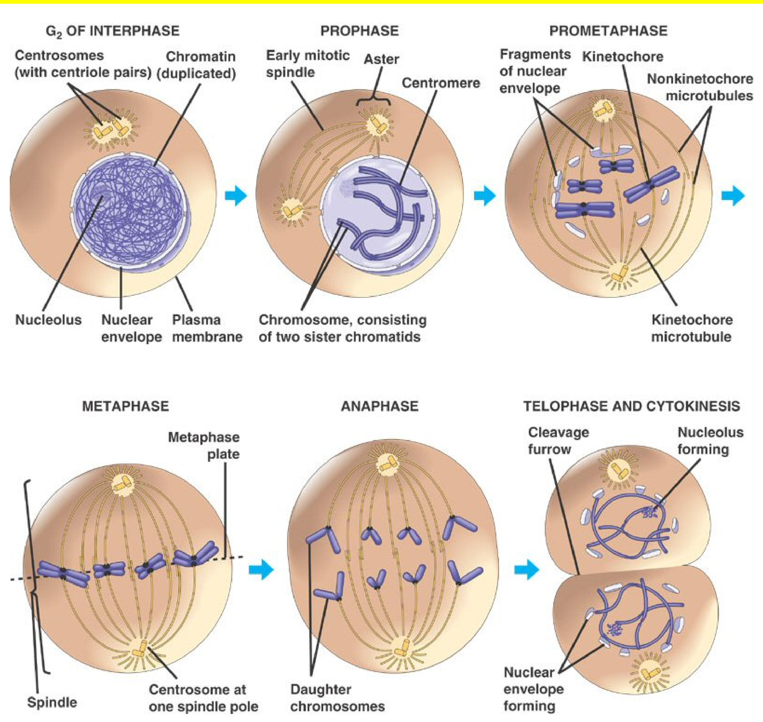
- Minimal side-effects
- Evidence of effectiveness
- Targets tumor

Motivation-to gain understanding how electrical field is distributed in cancer cells in various phases of mitosis

Research Objectives

-Use COMSOL Multiphysics software to model electric field distribution of a cancer cell at stages of cell separation (mitosis) when applying pulsed electric potential at certain time duration

Mitosis



http://fhs-bio-wiki.pbworks.com/w/page/12145788/Mitosis

One cell divides into 2 daughter cells

Stages:

1. Interphase
2. Prophase
3. Metaphase
4. Anaphase
5. Telophase/Cytokinesis

Figure 1 (left): Process of mitosis

Built Model of Metaphase in COMSOL

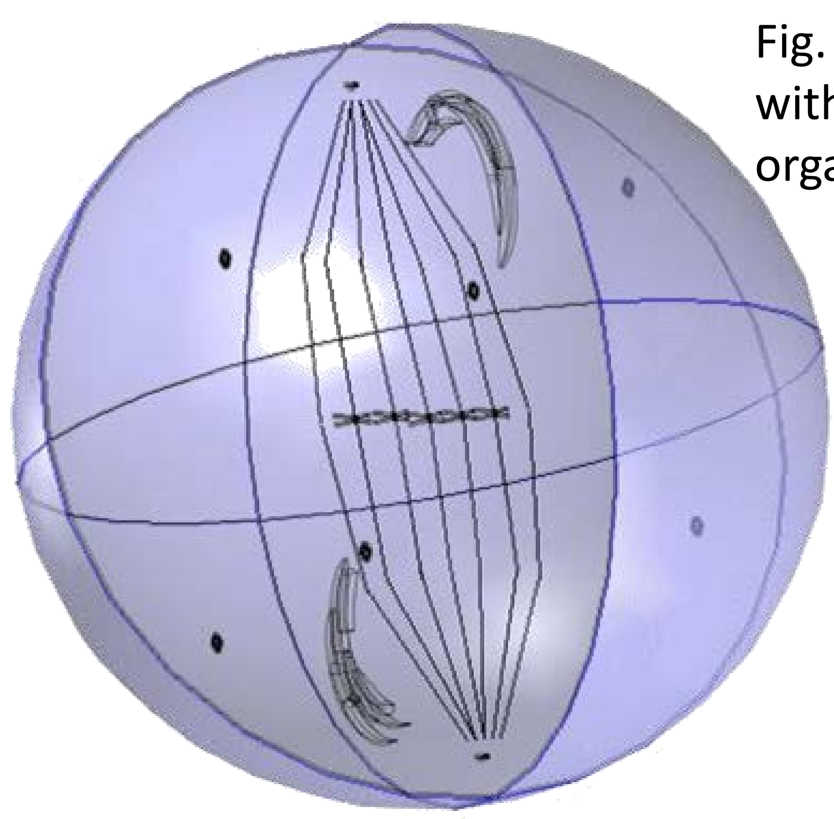


Fig. 2: Complete drawing with cell membrane and organelles

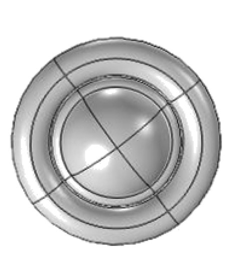


Fig. 3a: Mitochondria Representation: Inner Compartment, Inner Membrane, Outer Membrane

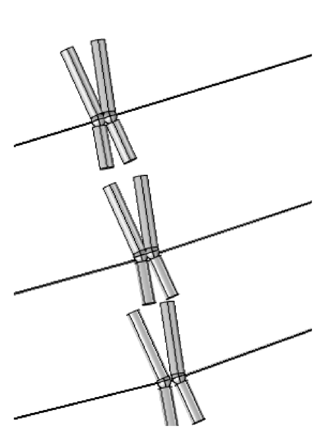


Fig. 3b: Chromosomes, Kinetochores, and Microtubules

Fig. 3c: Endoplasmic Reticulum[3]

Governing Equations/Boundary Conditions

Frequency-Transient Study: $\Delta J = Q_J$

$$J = (\sigma + j\omega\varepsilon_0\varepsilon_r)E + J_e$$

$$E = -\nabla V$$

Heat Transfer in Solids Module:

$$\rho C_p \frac{\partial T}{\partial t} + \rho C_p u \cdot \nabla T = \nabla \cdot (\mathrm{k}\nabla T) + Q + Q_{ted}$$

Thermal Insulation Parameter:

$$-n \cdot q = 0$$

Electromagnetic Heat Source:

$$\rho C_p \frac{\partial T}{\partial t} + \rho C_p u \cdot \nabla T = \nabla \cdot (\mathrm{k}\nabla T) + Q_e$$

Non-viscous heating source = $Q_e = Q_{rh} + Q_{ml}$

Resistive Heat Loss = $Q_{rh} = \frac{1}{2} Re(J \cdot E^*)$

Magnetic Losses = $Q_{ml} = \frac{1}{2} Re(i\omega B \cdot H^*)$

Boundary Electromagnetic Heat Source:

$$-n \cdot (-k\nabla T) = Q_b$$

Parameters and Specifications

Model	3D
Physics:	Electrostatics/Heat Transfer in Solids
Study:	Frequency-Transient
Mesh:	Coarse
Electric Potential/Time Duration	60V/60ns[1]
Model Cell Radius [um]	22.5
Density [kg/m^3]	993.25
Heat Capacity [J/kg*K]	4178
Thermal Conductivity [W/m*K]	0.604[4]
Conductivity of Cytoplasm [S/m]	0.48[2]
Relative Permittivity of Cytoplasm	60.0[2]

Mesh for Computation

Complex due to large and tiny domains with intricate element sizes around edges and faces

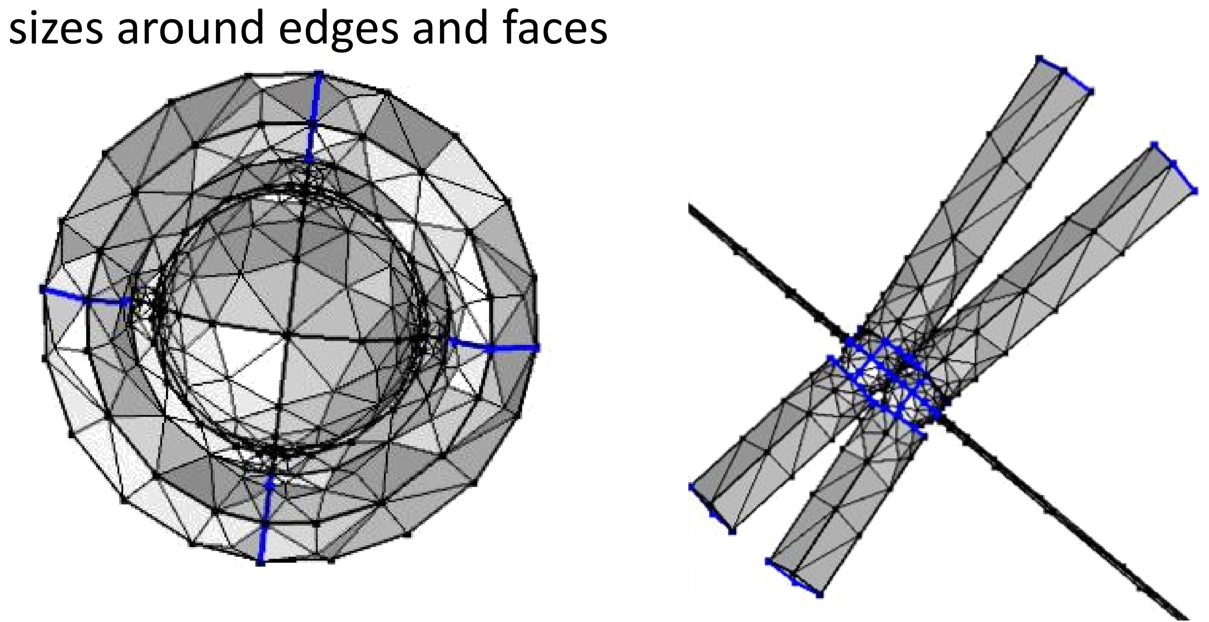


Figure 4 (above): Intricate mesh around mitochondria (left) and chromosome (right)

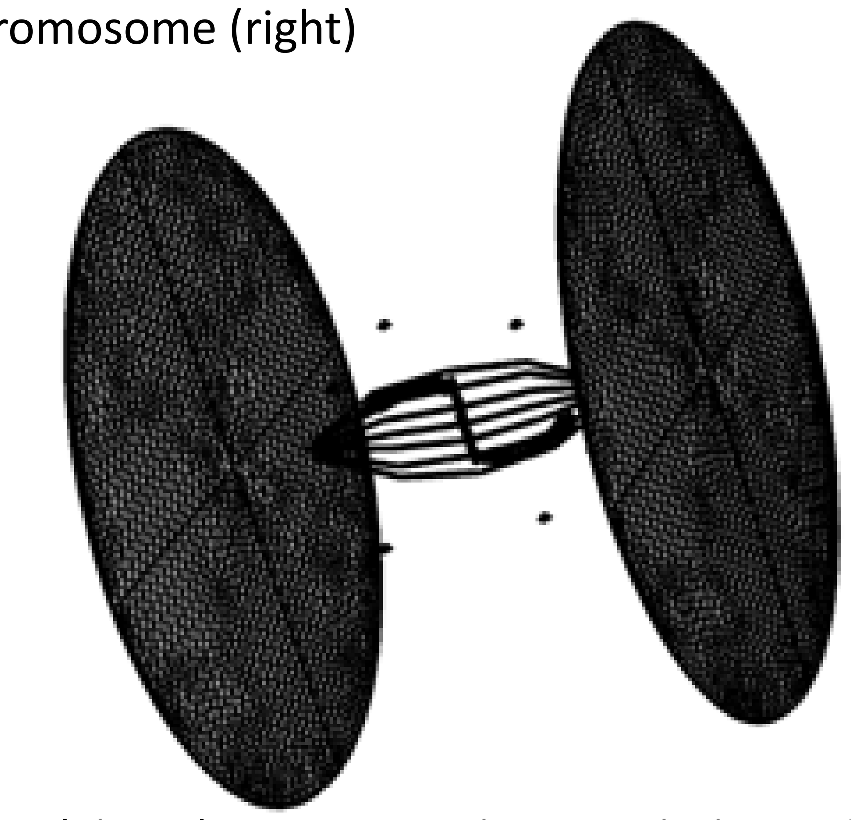


Figure 5 (above): Coarse mesh over whole model with copper electrodes

Discussion

- Complications with obtaining and understanding solution
- Difficulty with material properties being accounted for in model
- Electric Potential at 60V; Ground at 0V shown briefly during time duration with color scale.
- Hoped to obtain plot with electric field distributions at various times

Future Work

- Troubleshoot mesh and computation
- Obtain visual plots of how dielectric properties are affected by electric field
- Test various sizes and placement of electrodes around cell at different stages of mitosis
- Model cell in Anaphase, Cytokinesis, and Prophase

Acknowledgements and References

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