Engineering Distinguished Lecture Series

Engineering for the Body: Reproducing body functions

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Reproducing/Understanding Body Functions

Using Nanomaterials for Cardiovascular Applications

Significance:
• Approximately every 25 seconds, an American will have a coronary event, and approximately every minute, someone will die of one.
• The total direct and indirect cost of CVD and stroke in the United States for 2010 was estimated at $503.2 billion.

Purpose:
• Use if Nanomaterials to create a system enhance cardio-cell growth.

Designing a System to Understand Cancer Metastasis

Significance:
• Approximately 13.7 million Americans with a history of cancer were alive on January 1, 2012
• About 1,660,290 new cancer cases are expected to be diagnosed in 2013.

Purpose:
• Creating a new assay system to look at cancer metastasis.


Nanomaterials for Cardiovascular Applications

- During a **heart attack**, the cardiac muscle is deprived from blood which leads to the **destruction of cardiomyocytes** (cardiac contractile muscle cells).

- Heart tissue cannot regenerate and the scar left after a heart attack remains a **non-contractile dead zone**.

- The scarred cardiac muscle results in heart failure for millions of heart attack survivors worldwide.
CNFs with a 200nm diameter were sonicated in 20mL of chloroform at 20W for 30 min.

PLGA (50:50) was dissolved in 15 ml of THF in a water-mediated bath sonicator for 30 minutes below 30°C.

Add CNFs and PLGA at the following percentage ratios [PLGA:CNFs (wt:wt), 100:0, 75:25, 50:50, 25:75, 0:100].

Vacuum dried for 48 hrs

Ultra-sonicated at 2W

Placed on glass disc
Increase in Stem Cell growth and Cardiomyocyte direction

Data = mean +/- SEM; N = 3; * p < 0.05
Reproducing Cell Migration

- Cancer cells can migrate through both individual and collective cell-migration strategies. Moreover, diffusional instability mechanisms can induce the separation of single or clustered cells from a tumorous body/object and then immigrate towards a source of nutrients and thus invade wider areas and tissues.
- Understanding tissue-independent cell migration = Understanding cancer cell metastasis.

Utilizing digital volume correlation (DVC) algorithm to track motions of sub-volumes within 3-D images obtained using fluorescence confocal microscopy. Displacement—strain calculations—tractions—forces.

A pure chemoattractant linear concentration gradient in a 3D collagen gel sample was generated by diffusion while the addition of fluorescence beads were dispersed, for the first time, to measure cell forces generated during migration. Measure neutrophil 3D displacement during migration.

Movie captured using an Apo LWD 40x WI S DIC N2 objective, with a numeric aperture = 1.15, a refractive index = 1.33 and a Z-step = 0.05 um. All images were rendered in NIS-Elements program. dt = 2 min.
Cell Mechanics: Cell Migration

3D rendition of cell and collagen from collagen-cell interaction experiment. Image was captured using an Apo LWD 40x WI S DIC N2 objective, with a NA = 1.15, a refractive index = 1.33 and a Z-step = 0.05 um. Image were rendered in NIS-Elements program.

Cell migrating towards gradient. Movies captured using an Apo LWD 40x WI S DIC N2 objective, with a numeric aperture = 1.15, a refractive index = 1.33 and a Z-step = 0.05 um. All images were rendered in NIS-Element program.

dt = 2 min
Using images from experiments and DVC code we are able to load into computer programs and see how the cell displaces into surroundings in 3D. Images calculated in MATLAB and rendered in TecPlot. \( dt = 2 \text{ min.} \)

Using images from diffusion and cell experiments, we were able to solve the diffusion equation and find the specific concentration at a particular point in time. We can now alter \( dx, dy, dz, dt, \) and \( dc \) and find what the cell is feeling. Images calculated in MATLAB and rendered in TecPlot. \( dt = 2 \text{ min.} \)
Cell Mechanics: Pushing or Pulling?

Experimental computer rendition of neutrophil migration showing cell displacement and specific cell surface concentration. Images calculated in MATLAB and rendered in TecPlot. \( dt = 2 \) min.

Experimental computer rendition of neutrophil migration showing cell movement and principle strains. Calculated in MATLAB and rendered in TecPlot. \( dt = 2 \) min.
## Conclusion

### Cardiovascular Nanomaterial

- Surface Material is conductive
- Cardiomyocyte stem cells can proliferation on surface and have specific biomarkers to the myocardium

**Questions:**

- Toxicity (Both cell and nanomaterial)?

### Migration Assay

- Pure-chemotactic system
- Measure and investigate neutrophil migration with 6 variables
  - $dt$, $dx$, $dy$, $dz$, collagen density, chemical concentration.
- Obtain 5 outcomes
  - Specific concentration on cell surface ($dx$, $dy$, $dz$, $dt$), migration direction and speed, displacements, forces and strains.

**Questions:**

- How is cell doing this?
## Acknowledgements

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<thead>
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