MODELLING IN BIOMEDICINE

ECTS: 6

COORDINATOR: Ester Aurora Torrente Orihuela (esteraurora.torrente@uc3m.es)

UNIVERSITY WHERE THE COORDINATOR IS: UC3M

HAVE YOU GIVEN PERMISSION TO RECORD YOUR CLASSES? NO

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LECTURER 2: E. Aurora Torrente Orihuela (esteraurora.torrente@uc3m.es)

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LECTURER 3: Luis L. Bonilla (luis.bonilla@uc3m.es)

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HAVE YOU GIVEN PERMISSION TO RECORD YOUR CLASSES? NO

SUBJECT CONTENTS

1. Introduction.

2. Mechanotransduction. Cell structures involved in cellular mechanics. Stochastic models in the mechanics of cell structures. Cell rheology. Mathematical models of the mechanics of an isolated cell. Description of experimental techniques used to characterize cellular rheology and the forces exerted by/on cells. Tissue mechanics: continuous models. Model components: density, velocity, stresses, polarization and concentration of molecules involved in cell movement. Summary of experimental results from the literature. Numerical resolution of models based on PDEs. Tissue mechanics: discrete models. Vicsek model and its application to the mechanics of a biological tissue. Recent models derived from Vicsek. Comparison with continuous models. Numerical implementation and statistical processing of results.

3. Angiogenesis: blood vessel formation induced by growth factors. Endothelial cell differentiation: branching, extension, and anastomosis. Capillary movement following gradients of continuous fields: chemotaxis and haptotaxis. Blood circulation. Stochastic models using birth-and-death processes and stochastic differential equations. Numerical resolution. Laws of large numbers and derivation of a deterministic description through partial differential equations. Numerical resolution. Hybrid models. Cellular Potts models and Monte Carlo methods: durotaxis and Notch signals between cells.

4. Linear models for gene expression data. Detection of genes linked to cancer. Variance analysis: ANOVA table and parameter contrasts. Simple factorial designs. factorial designs with interaction.

METHODOLOGY

1) Lecture sessions: these classes are dedicated to the presentation of the course content.

2) Formulation, analysis and resolution of problems and exercises related to the theoretical contents.

Classes will be given online (videoconference).

LANGUAGE USED IN CLASS: It will be adapted according to the students' needs.

IS IT COMPULSORY TO ATTEND CLASS? Videoconference.

BIBLIOGRAPHY

Cell migration

1. M. Basan, J. Prost, J.-F. Joanny y J. Elgeti, Dissipative particle dynamics simulations for biological tissues: rheology and competition. Phys. Biol. 8, 026014 (2011).

2. M. Basan, J. Elgeti, E. Hannezo, W.-J. Rappel y H. Levine, Alignment of cellular motility forces with tissue flow as a mechanism for efficient wound healing. PNAS 110, 2452-2459 (2013).

3. B.A. Camley y W.-J. Rappel, Velocity alignment leads to high persistence in confined cells. Phys. Rev. E 89, 062705 (2014).

4. A. Habbal, H. Barelli y G. Malandain. Assessing the ability of the 2D Fisher-KPP equation to model cell-sheet wound closure. Mathematical Biosciences 252, 45-49 (2014).

5. M. Poujade, E. Grasland-Mongrain, A. Hertzog, J. Jouanneau, P. Chavrier, B. Ladoux, A.Buguin y P.Silberzan, Collective migration of an epithelial monolayer in response to a model wound..PNAS, 104 15988-15993 (2007)

6. N. Sepúlveda, L. Petitjean, O. Cochet, E. Graslad-Mongrain, P. Silberzan y V. Hakim. Collective cell motion in an epithelial sheet can be quantitatively described by a stochastic interacting particle model. PLOS Computational Biology 9 (2013).

7. X. Trepat, M.R. Wasserman, T.E. Angelini, E. Millet, D. A. Weitz, J.P. Butler y J.J. Fredberg. Physical forces during collective cell migration. Nature Physics 5, 426-430 (2009).

8. T. E. Angelini, E. Hannezo, X. Trepat, M. Marquez, J. J. Fredberg y D.A. Weitz. Glasslike dynamics of collective cell migration. PNAS. 108, 4714-4719 (2011)

Angiogénesis

1. T. Adair y J.-P. Montani, Angiogenesis. Morgan & Claypool Life Sciences, San Rafael CA 2010. Web site: http://www.ncbi.nlm.nih.gov/books/NBK53242/

2. E.A. Logsdon, S.D. Finley, A.S. Popel y F.M. Gabhann, A systems biology view of blood vessel growth and remodelling. J. Cellular Molec. Medicine 18, 1491-1508 (2014).

3. L.L. Bonilla, V. Capasso, M. Álvaro y M. Carretero, Hybrid modeling of tumor-induced angiogenesis. Phys. Rev. E 90, 062716 (2014).

4. P. Carmeliet y R.K. Jain, Molecular mechanisms and clinical applications of angiogenesis. Nature 473, 298-307 (2011).

5. V. Capasso y D. Morale, Stochastic modelling of tumour-induced angiogenesis. J. Math. Biol. 58, 219-233 (2009).

6. M. Fruttiger, Development of the retinal vasculature. Angiogenesis 10, 77-88 (2007).

7. P. Carmeliet, Angiogenesis in life, disease and medicine. Nature 438, 932-936 (2005).

Métodos estocásticos numéricos

1. C.W. Gardiner, Stochastic methods. A handbook for the natural and social sciences. 4ª ed. Springer, Berlín 2010.

2. P.E. Kloeden, E. Platen y H. Schurz, Numerical solution of stochastic differential equations through computer experiments. Springer, Berlín, 1994.

3. A. Shirinifard, J.A. Glazier, M. Swat, J.S. Gens, F. Family, Y. Jiang y H.E. Grossniklaus, Adhesion Failures Determine the Pattern of Choroidal Neovascularization in the Eye: A Computer Simulation Study. PLOS Comput. Biol. 8(5), e1002440 (2012)

4. M.H. Swat, G.L. Thomas, J.M. Belmonte, A. Shirinifard, D. Hmeljak y J.A. Glazier, Multi-Scale Modeling of Tissues Using CompuCell3D. Methods Cell Biol. 110, 325-366 (2012).

Análisis de la Varianza

1. H. Causton, J. Quackenbush y A. Brazma. Microarray Gene Expression Data Analysis: A Beginner's Guide. Blackwell publishing, 2003.

2. W.G. Cochran y G.M. Cox M. Experimental designs. New York: Wiley, 1992.

3. A. Torrente, M. Lukk, V. Xue, H. Parkinson, J. Rung y A. Brazma. Identification of cáncer related genes using a comprehensive map of human gene expression. PLOS One, 11(6), e0157484 (2016).

Useful links

http://www.angio.org/

http://www.compucell3d.org/

SKILLS

General:

CG1: To have knowledge that provides a basis or opportunity for originality in developing and / or applying ideas, often within a research context, knowing how to translate industrial needs in terms of R & D in the field of industrial mathematics.

CG4: To have the ability to communicate the findings to specialist and non-specialist audiences in a clear and unambiguous way.

CG5: To have the appropriate learning skills to enable them to continue studying in a way that will be largely self-directed or autonomous, and also to be able to successfully undertake doctoral studies.

Specific:

CE2: To model specific ingredients and make appropriate simplifications in the model to facilitate their numerical treatment, maintaining the degree of accuracy, according to previous requirements.
CE3: To determine if a model of a process is well made and well mathematically formulated from a physical standpoint.

CE5: To be able to validate and interpret the results, comparing them with visualizations, experimental measurements and functional requirements of the physical engineering system.

Numerical specialization:

CM1: To be able to extract, using different analytical techniques, both qualitative and quantitative models.

CM2: To know how to model elements and complex systems leading to formulate well-posed problems.

WILL YOU BE USING A VIRTUAL PLATFORM? NO

WILL YOU BE USING ANY SPECIFIC SOFTWARE? NO

CRITERIA FOR THE 1ST ASSESSMENT OPPORTUNITY

Final project and/or public presentation of this project, both of them correctly done (skills CG1, CG4, CG5, CE2, CE3, CE5, CM1, and CM2 will be evaluated).

CRITERIA FOR THE 2ND ASSESSMENT OPPORTUNITY

The same as for the first opportunity.
