Modelling in Biomedicine

ECTS: 6

COORDINATOR: Jesús Salas Martínez (jesus.salas@u3m.es)

UNIVERSITY WHERE THE COORDINATOR IS: UC3M

HAVE YOU GIVEN PERMISSION TO RECORD YOUR CLASSES? NO

LECTURER 1: Antonio Lasanta Becerra (antonio.lasanta@uc3m.es)

UNIVERSITY WHERE THE LECTURER 1 IS: UC3M

HAVE YOU GIVEN PERMISSION TO RECORD YOUR CLASSES? NO

LECTURER 2: Javier Rodríguez Rodríguez (javier.rodriguez@uc3m.es)

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HAVE YOU GIVEN PERMISSION TO RECORD YOUR CLASSES? NO

LECTURER 3: Ester Aurora Torrente Orihuela (esteraurora.torrente@uc3m.es)

UNIVERSITY WHERE THE LECTURER 3 IS: UC3M

HAVE YOU GIVEN PERMISSION TO RECORD YOUR CLASSES? NO

LECTURER 4:

UNIVERSITY WHERE THE LECTURER 4 IS:

HAVE YOU GIVEN PERMISSION TO RECORD YOUR CLASSES?

SUBJECT CONTENTS

1. Introduction.

2. Migration of epithelial cells and application to tissue engineering. Cell proliferation, control factors. Measurements of cell velocity and density in two-dimensional tissues by using imaging techniques. Mechanisms of collective motion, quorum sensing. Mathematical models. Numerical solutions: results, validation and interpretation. Validation using experimental results.

3. Angiogenesis: formation of blood vessels induced by growth factors. Differentiation of epithelial cells: branching, extension and anastomosis. Chemotaxis and haptotaxis. Blood circulation. Stochastic models using birth and death processes and stochastic differential equations. Numerical solutions. Law of large numbers and derivation of deterministic PDE equations. Numerical solutions. Hybrid models. Cellular Potts models and Monte Carlo methods.

4. Retinal vascularization. Angiogenesis and postnatal vascularization in mice, prenatal vascularization in primates. Retinopathy of prematurity. Mathematical models. Numerical solution.

METHODOLOGY

1) Lectures.

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

We will use the videoconference system.

LANGUAGE USED IN CLASS: Adapted to the audience.

IS IT COMPULSORY TO ATTEND CLASS? Videoconference.

BIBLIOGRAPHY

Cell migration

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

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2. M. Basan, J. Elgeti, E. Hannezo, W.-J. Rappel, and 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 and W.-J. Rappel, Velocity alignment leads to high persistence in confined cells. Phys. Rev. E **89**, 062705 (2014).

4. A. Habbal, H. Barelli, and 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, and 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, and 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, and 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, and D.A. Weitz. Glass-like dynamics of collective cell migration. *PNAS*. **108**, 4714-4719 (2011)

Angiogenesis

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

2. E.A. Logsdon, S.D. Finley, A.S. Popel, and 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, and M. Carretero, Hybrid modeling of tumor-induced angiogenesis. Phys. Rev. E **90**, 062716 (2014).

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

5. V. Capasso and 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).

8. R.F. Gariano and T.W. Gardner, Retinal angiogenesis in development and disease. Nature **438**, 960-966 (2005).

Numerical stochastic methods

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

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

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

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

Useful links

http://www.angio.org/

http://www.compucell3d.org/

SKILLS

Basic:

CG1: To have knowledge that provide 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 mathematics Industrial.

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.

Modelling 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 well-posed formulated 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.