

## **Report on NRP Nonlinear Dynamics and Complex Systems Group – September 2007 - June 2008**

**Director:** Prof. Celso Grebogi, School of Natural and Computing Sciences, UoA

**Deputy Director:** Prof Mark Chaplain, Department of Mathematics, UoD

### **Research Project Areas:**

1. *The dynamics of in-stenting restenosis process.* Project initially funded by MRC (£104,075). Grant holders: Prof. Celso Grebogi and Prof. Nuala Booth. The work involves Dr. Gyorgy Karolyi (Senior Researcher), Dr. Alessandro de Moura (Lecturer), Mrs. Adriane Schelin (Postgraduate student) and Benjamin Biemond (visiting student).
2. *Ion and solute homeostasis in enteric bacteria.* Project funded by BBSRC involving institutions in Germany, Spain and The Netherlands (UoA share: £1,122,006). Grant holders: Prof. Ian Booth, Prof. Celso Grebogi, Dr. Alessandro Moura and Dr. Samantha Booth. Pos-doctoral fellow, Dr. Morgiane Richard, and postgraduate students, Camila Almeida and Ksenia Guseva, have been hired to work on the project.
3. *Combinatorial responses of fungal pathogens to their human hosts: an integrative systems biology approach.* Project funded by BBSRC under Systems Approaches to Biological Research (SABR) involving University of Aberdeen and Imperial College London (UoA share: £3,182,717). Grant holders: Prof. Al Brown, Prof. Celso Grebogi, Prof. Neil Gow, Dr. Alessandro Moura, Dr. Marco Thiel, Dr. Mamen Romano, Dr. George Coghill. We are in the processing of hiring post-doctoral fellows and postgraduate students.
4. *Fundamentals of Complexity.* Project funded by the College for Physical Sciences, UoA. It involves Prof. Celso Grebogi, Dr. Alessandro Moura, Dr. Marco Thiel, Prof. Geoffrey Robinson, and postgraduate student Christian Rodrigues.
5. *Stochastic modelling of translation.* Project funded by SULSA (Dr. Mamen Romano) and EPSRC Academic Fellowship (Dr. Marco Thiel) awarded to Prof. Celso Grebogi (£105,000). A BBSRC bid on the topic will be submitted shortly.
6. *Modelling the influence of cell wall on mechanosensitive ion channels.* Project involving Prof Celso Grebogi, Dr. Marco Thiel (EPSRC Academic Fellow) and Dr. Mamen Romano (SULSA Lecturer).
7. *Complex Networks in the Hippocampus.* Proposal to be submitted to the Wellcome Trust shortly.

### **Course Development:**

We have developed and launched two new Master Degree Courses to start next autumn. One of the courses emphasises general modelling and the other emphasises modelling of biological systems. We are inviting application.

### **Outreach:**

1. Organization of a major *International Conference on Chaos and Nonlinear Dynamics: Advances and Perspectives* ([www.abdn.ac.uk/dynamics07](http://www.abdn.ac.uk/dynamics07)) was held at UoA on 17-21 September 2007 with 150 participants. It brought over 50 invited speakers, the people responsible for the development of nonlinear dynamics in the last 30 years.
2. Co-organization of the *Second International Recurrence Plot Workshop* on 10-12 September, Siena. It was largely based on our work on data-based modelling of dynamical systems.
3. Co-organization of the *Tenth Experimental Chaos Conference* on 3-6 June 2008, Catania. Our experimental and modelling work is being featured at this traditional event.
4. We are currently involved in collaborative work with researchers of various institutions in UK, Germany, Spain, Brazil, Hungary, The Netherlands, Japan, Italy, Norway, and the United States.
5. The two complete issues of the Philosophical Transactions A of the Royal Society on *Experimental Chaos* edited by us have been published (Vol. 386, numbers 1864 and 1865).
6. Editing of a Springer-Verlag book on the *Advances and Perspectives of Dynamics*, involving top workers in the field, which should appear in print in 2008.
7. Editing of a special issue of the *International Journal of Bifurcations and Chaos on Multistability in Dynamical Systems*, which will appear in print in November 2008.
8. Editing a special issue of the *European Physics Journal on the Fundamentals of Dynamics*, to appear in print in 2008.
9. Editing a Theme Issue of the *Philosophical Transactions A of the Royal Society on Experimental Chaos*, to appear in print in 2009.

### **Long Term Plans:**

We are building, with the support of NRP a leading UK group in nonlinear and complex systems. It is part of this plan to create, with the full support of the College of Physical Sciences, UoA, the **Institute for Complex Systems and Mathematical Biology**. This Institute will house the researchers working on basic theory, theoretical implications of nonlinear and complex dynamics in science and technology, and modelling of experimental research. We are also directly involved with SUPA and SULSA. In fact, Dr. Mamen Romano was hired as a SULSA Lecturer.

### **NRP Studentships:**

Miss Vivi Andasari, joint postgraduate student of Profs. Mark Chaplain (UoD) and Celso Grebogi (UoA) started this Fall working on "Multi-scale mathematical modelling of cell migration and adhesion processes- the effect of non-local interaction terms on the spatio-temporal dynamics".

### **Exemplar Project:**

An exemplar NRP project involving the University of Dundee (Prof. Mark Chaplain) and UoA (Prof Celso Grebogi) is on the *mathematical modelling of cancer invasion: the role of adhesion*.

Unravelling the processes involved in cell migration through tissue is of utmost importance for the understanding of many biological and pathological processes. In recent years increasingly complex models of cell migration through tissue have appeared in the research literature. The models are largely all based on the assumption that cells move in a directed manner in response to chemotactic and/or haptotactic cues. This directed movement, however, is facilitated by the binding and unbinding of cell surface molecules to other cells and the cell matrix, leading to cell-cell and cell-matrix adhesion, respectively. The adhesion molecules are transmembrane proteins: cadherins in cell-cell adhesion and integrins in cell-matrix adhesion. The strength and number of such binding processes are mediated by chemical cues present in the cells microenvironment and subsequently lead to the observed cell movement due to chemotaxis and haptotaxis. So, on a more fundamental, yet still phenomenological, level cell movement is caused by cell-cell and cell-matrix adhesive properties modulated by the cells' microenvironment. In order to develop a more accurate model of cell migration, one should include non-local interaction terms in a PDE model accounting for both cell-cell and cell-matrix adhesion. Additionally, it would be desirable to model the actual receptor dynamics (cadherins and integrins) and couple this model with the PDE system, leading to a genuine multi-scale model of cell migration.

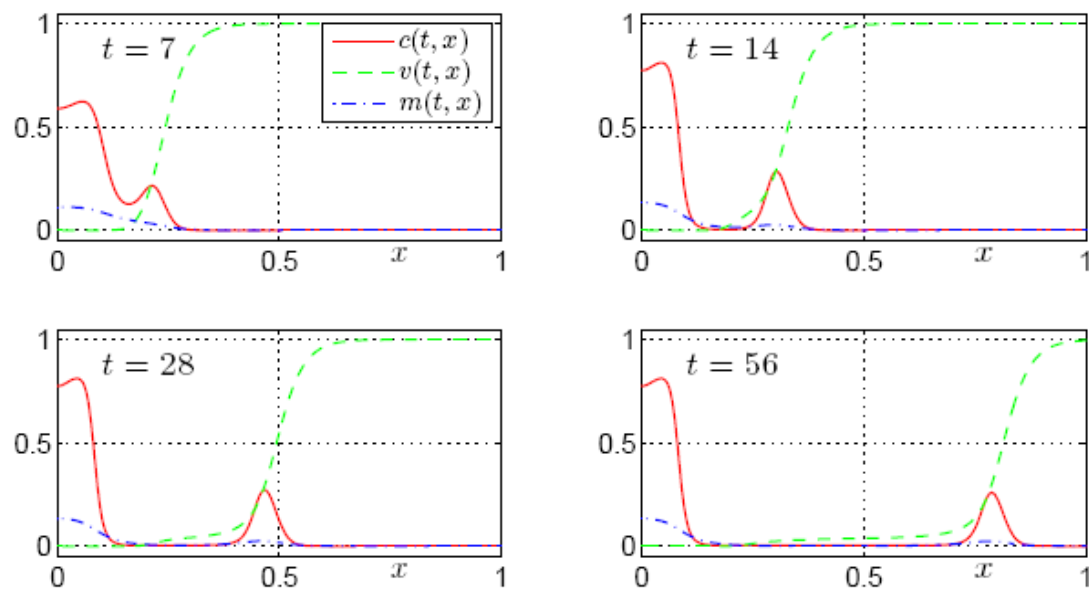


Figure 1: Plots showing the computational simulation results of a PDE model of cancer cell invasion of tissue. The red line denotes cancer cells, green denotes tissue/matrix and blue denotes matrix degrading enzyme. The plots show a fragment of the cancer cells breaking away from the initial mass and actively invading the tissue.

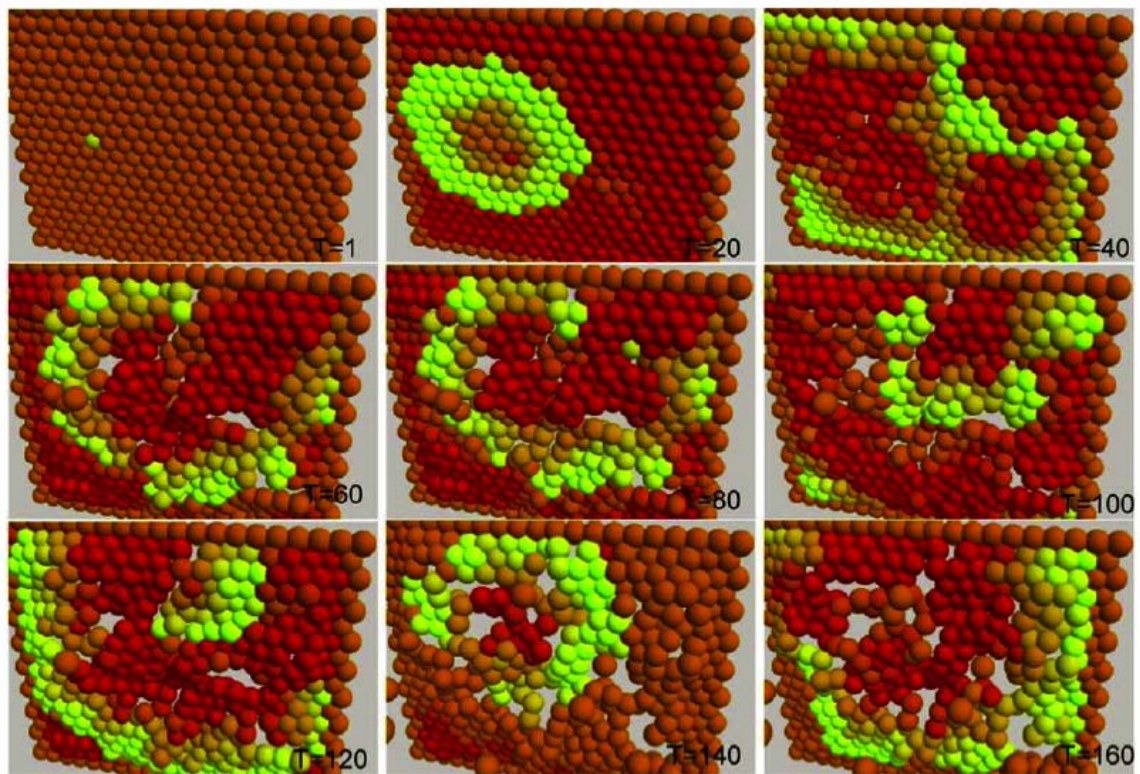


Figure 2: Plots showing the level of concentration of the adhesion molecule E-cadherin (in yellow) in a sheet of epithelial cells. The epithelial cells are connected via adhesion junctions. As the level of E-cadherin changes, so does the cell adhesion state, resulting in the break-up of the epithelial sheet.

Celso Grebogi and Mark Chaplain