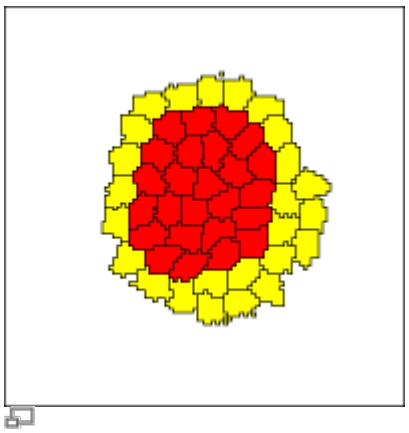
Cellular Potts models

Differential Adhesion: cell sorting in two dimensions



Yellow cells engulf the red cells as a result of differential adhesion

Introduction

This model shows the original cellular Potts model (a.k.a. Glazier-Graner model) of cell sorting based on the Steinberg's differential adhesion hypothesis.

Model description

Two `CellTypes` are defined, each of which has a `VolumeConstraint` specifying the cell's target area/volume. In the `CPM` element, the `MetropolisKinetics` can be configured and the `Interaction` energies between cell types are specified.

Although cells can be initialized as single points using e.g. the `InitCircle` plugin, in this example, the `Nodes` of each `Cell` in the `CellPopulations` are given explicitly. In fact, these `Populations` are restored results of a previous simulation.

The simulation shows two populations of spatially resolved cells that initially organized in a mosaic fashion. Through differential adhesion, the motile cells sort out and re-organize into an distribution in which one cell type engulfes the other.

Snapshots of the simulation are saved to files named [Title][Time].xml.gz. These files containing intermediate and result states can be opened and used as initial conditions for new simulations. Remember to change `StartTime` and `StopTime` accordingly.

Model

h CellSorting_2D.xml |h

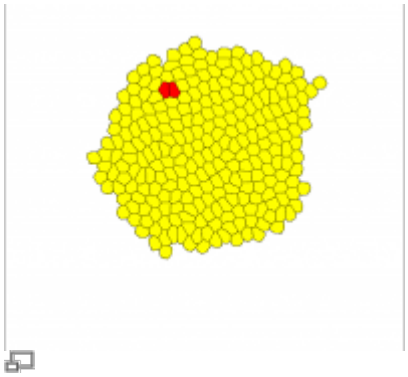
```
extern>http://imc.zih.tu-dresden.de/morpheus/examples/CPM/CellSorting_2D.xml
```

In Morpheus GUI: `File → Examples → CPM → CellSorting_2D.xml`

Reference

Graner F, Glazier J. Simulation of Biological Cell Sorting Using a Two-Dimensional Extended Potts Model. *Phys. Rev. Lett.* 69 (13): 2013–2016, 1992.

Proliferation in two dimensions



Growing cell population

Introduction

This model show a simulation of a growing cell population, using the cellular Potts model.

Model description

This model specifies `CellType` which has a `VolumeConstraint` and a `Proliferation` plugin.

In the `Proliferation` plugin, the `Conditions` for a cell to divide are given. Here, each cell that has more than 90% of the target volume has a small probability to divide. Once a division has taken place, the `Equation` defined in the `Triggers` elements are triggered.

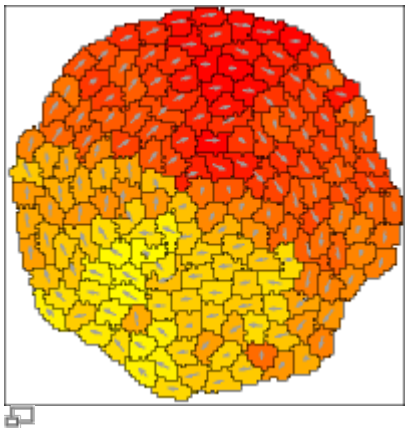
Model

h Proliferation_2D.xml |h

```
extern>http://imc.zih.tu-dresden.de/morpheus/examples/CPM/Proliferation_2D.xml
```

In Morpheus GUI: `File → Examples → CPM → Proliferation_2D.xml`

Persistence



Persistence of individual cells causes self-organized collective motion

Introduction

This example shows self-organized collective motion of cells as a result of persistence ('cellular inertia'). A similar model has recently been used in (Czirok et al., 2013).

Description

The model uses the `Persistence` plugin that causes cells to prefer to move in their current direction. The direction is stored in a `PropertyVector` that is used to plot the color and arrows in `Gnuplotter`.

The model is simulated in a circular domain with constant boundary conditinos, which can be set up in `Lattice / Domain / Circle`. The value for the constant boundary is specified in `CPM / BoundaryValue`.

Try it!

- Change the boundary conditions from circular=constant to x/y=periodic and observe the resulting collective motion.
- Change the `decay-time` of `Persistence` (specifying the 'memory').

Model

h Persistence_2D.xml |h

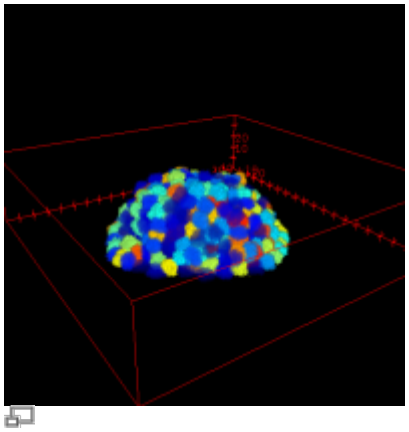
```
extern>http://imc.zih.tu-dresden.de/morpheus/examples/CPM/Persistence_2D.xml
```

In Morpheus GUI: `File → Examples → CPM → Persistence_2D.xml`

Reference

Czirók A, Varga K, Mehes E, Szabo A, Collective cell streams in epithelial monolayers depend on cell adhesion. *New J. Phys.* 15 075006, 2013.

Proliferation in three dimensions



Cell population grown from single initial cell

Intror uction

This model show a CPM simulation of a growing cell population in 3D.

Model description

This model specifies `CellType` which has a `VolumeConstraint` and a `Proliferation` plugin. In the `Proliferation` plugin, the `Conditions` for a cell to divide are given. Here, each cell that has more than 90% of the target volume has a small probability to divide. Once a division has taken place, the `Equation` defined in the `Triggers` elements are triggered.

In this model, two `medium` cell types have been defined. One of these (called matrix) is used to represent a matrix with higher adhesivity. This is done by (1) defining the 'matrix' cell type as a `BoundaryCondition` of the -z boundary in the `CPM` and (2) providing lower contact energy for cell-matrix interaction than for cell-medium interactions.

The simulation is visualized using the `TiffPlotter` that saves TIFF image stacks that can be loaded by image analysis software such as Fiji and displayed using Fiji's 3D Viewer plugin.

Model

h Proliferation_3D.xml |h

```
extern>http://imc.zih.tu-dresden.de/morpheus/examples/CPM/Proliferation_3D.xml
```

In Morpheus GUI: `File → Examples → CPM → Proliferation_3D.xml`