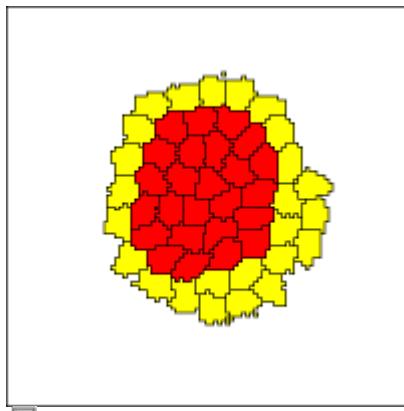


## Cellular Potts models

### Differential Adhesion: cell sorting in two dimensions



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



Video

#### 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 a distribution in which one cell type engulfs 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
```

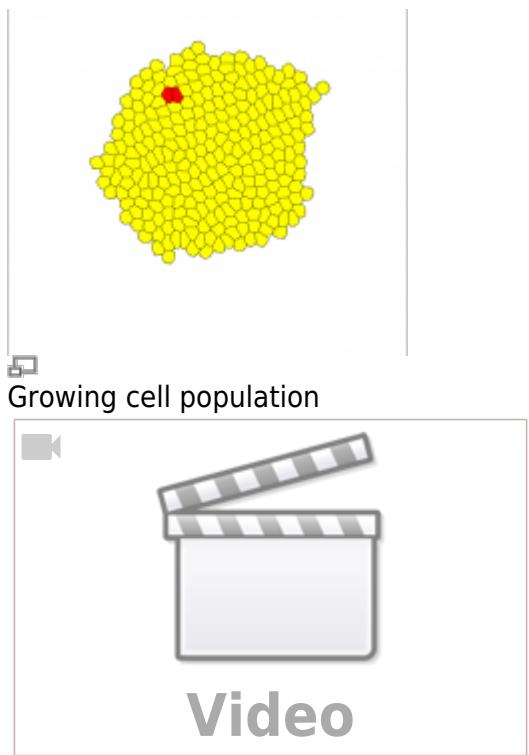
In Morpheus GUI: Examples → CPM → CellSorting\_2D.xml

## 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.

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## Proliferation in two dimensions



## Introduction

This model shows 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

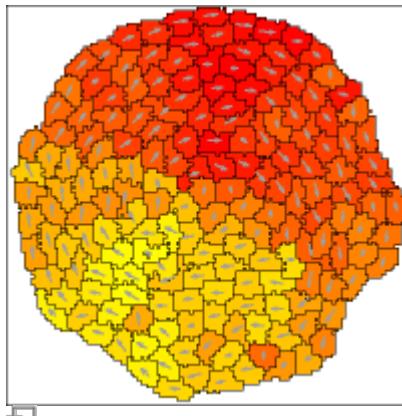
h Proliferation\_2D.xml |h

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

In Morpheus GUI: 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

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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 conditions, 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
```

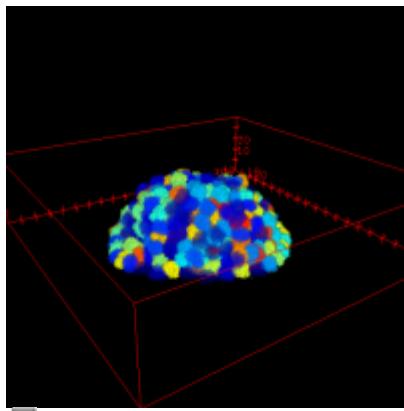
In Morpheus GUI: Examples → CPM → Persistence\_2D.xml

## Reference

Czirók A, Varga K, Mehés E, Szabó A, [Collective cell streams in epithelial monolayers depend on cell adhesion](#). *New J. Phys.* 15 075006, 2013.

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## Proliferation in three dimensions



Cell population grown from single initial cell



## Introduction

This model shows 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: Examples → CPM → `Proliferation_3D.xml`

---

## Run and Tumble

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Modeling cell movements as a Levy walk



## Introduction

This example models a single cell that moves according to a Levy walk: a random walk with occasional occurrence of long straight walks.

## Model description

The model defines a CPM cell that has two properties:

- A `PropertyVector` that gives the direction of movement and
- A `Property` that defines the time when this direction of movement is changed.

The change in direction is using a `VectorRule`. In this case, it specifies a new random direction for each of the 3 x,y,z coordinates separately: `move_dir = sin(angle), cos(angle), 0` where `angle = rand_uni(0, 2*pi)`.

This is calculated with an `Event`. Upon triggering, this sets the new direction and a waiting time until the next change of direction. To model a superdiffusive Levy walk, this waiting time is chosen from an exponential distribution: `change_time = time + 20 * rand_gamma(0.5, 5)`

Finally, the cell is made to move in the chosen direction using `DirectedMotion` that takes the `PropertyVector` as input.

## Model

h RunAndTumble.xml |h

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

In Morpheus GUI: Examples → CPM → RunAndTumble.xml

## Stem cells in the intestinal crypt

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Asymmetric cell division and changing cell type



### Introduction

This illustrative example shows the emergence of clonal populations from stem cells in intestinal crypt

### Model description

- Asymmetric cell division - Conditionally changing cell types - Loading domain from image - PopulationReporter

### Model

h Crypt.xml |h

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

In Morpheus GUI: Examples → CPM → Crypt.xml

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Last update: **16:09 11.11.2014**

