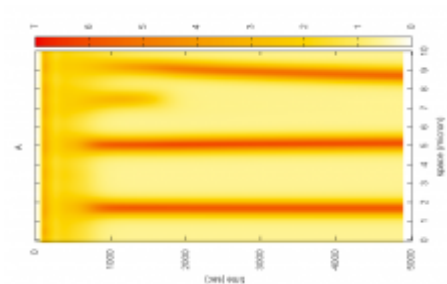


# Reaction-diffusion models

## 1D reaction-diffusion: Activator-Inhibitor



 Space-time plot of 1D reaction diffusion model.



### Introduction

The first example models a 1D activator-inhibitor model ([Meinhardt and Gierer, 1972](#)).

### Model description

This 1D PDE model uses a Lattice with linear structure and periodic boundary conditions.

The PDE defined two species called Layers: A (activator) and I (inhibitor) with resp. low and high Diffusion rates. The reaction part of the equations are defined in the System. Similar to ODE model, the System defines Constants and DiffEqns.

The results are recorded and visualized using the Logger and SpaceTimeLogger.

### Full model

h ActivatorInhibitor\_1D.xml |h

```
extern>http://imc.zih.tu-dresden.de/morpheus/examples/PDE/ActivatorInhibitor_1D.xml
```

In Morpheus GUI: File → Examples → PDE → ActivatorInhibitor\_1D.xml

## 2D reaction-diffusion: Activator-Inhibitor



 Stripe pattern generated by 2D Gierer-Meinhardt model



### Introduction

A 2D activator-inhibitor model ([Meinhardt and Gierer, 1972](#)).

### Description

This model uses a standard Lattice with square structure and periodic boundary conditions.

The PDE defined two species or Layers A (activator) and I (inhibitor) with resp. low and high Diffusion rates. The reaction part of the equations are defined in the System.

The results are visualized using the Gnuplotter.

### Full model

`h ActivatorInhibitor_2D.xml |h`

```
extern>http://imc.zih.tu-dresden.de/morpheus/examples/PDE/ActivatorInhibitor\_2D.xml
```

In Morpheus GUI: File → Examples → PDE → ActivatorInhibitor\_2D.xml

## Things to try

- Alter the level of saturation of the activator by changing kappa (for example, using a ParamSweep). By changing this parameter, the model can generate stripes, nets and spots.

## Domains: Reaction-diffusion in irregular domains



Spot pattern in Gierer-Meinhardt model with irregular domain



## Introduction

A 2D activator-inhibitor model ([Meinhardt and Gierer, 1972](#)), solved in a irregular domain that is load from file.

## Model description

This model uses an irregular Domain with constant boundary conditions. The domain is loaded from a TIFF image. See Space/Lattice/Domain.

## XML model

h ActivatorInhibitor\_Domain.xml |h

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

In Morpheus GUI: File → Examples → PDE → ActivatorInhibitor\_Domain.xml

---

## Spatial parameter sweep: Turing patterns



Spots and stripes appear under various conditions in linear Turing model



### Introduction

This model shows the pattern formation abilities of Turing's linear activator-inhibitor model ([Miyazawa et al., 2010](#)). It shows how to vary parameters as a function of space.

### Model description

Instead of fixed parameters defined as Constants, this model uses Functions for two parameters. The parameters C (activator production) and A (rate of auto-activation) as defined as Function of space and varied over the X- and Y-axes respectively. This requires the definition of a SpaceSymbol that can be used in expressions.

The results show the appearance of white spots (left), black spots (right) and labyrinthine patterns (middle).

### XML model

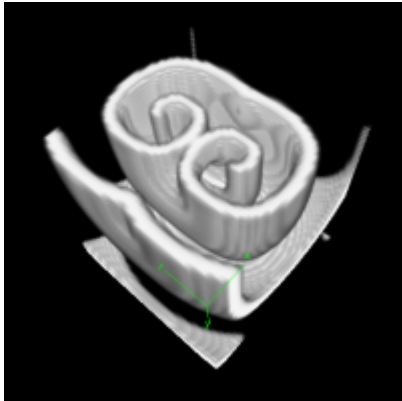
h TuringPatterns.xml |h

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

In Morpheus GUI: File → Examples → PDE → TuringPatterns.xml

---

## 3D reaction-diffusion: Excitable Media



Scroll wave appear in Barkley model of excitable media in 3D



### Introduction

This example uses the [Barkley model of excitable media](#), similar to the [Fitzhugh-Nagumo model](#) to show how to model and visualize reaction-diffusion models in 3D.

### Model description

This model defines a 3D cubic Lattice with noflux BoundaryConditions. Two Layers are defined for the two species: 'u' is the signal, and 'v' the refractoriness. As in the examples above, the DiffEqn as specified in the System in PDE. Nothing strange here.

To visualize the resulting scrolling waves in 3D, the TiffPlotter is used. This Analysis plugin writes TIFF image stacks that can be opened by image analysis software such as [Fiji/ImageJ](#). To import Morpheus TIFF images into Fiji, macros scripts are available that help you to create 3D (xyz), 4D (xyzt) or even 5D (xyzct) images and movies of your simulations.

Although unable to plot 3D, the GnuPlotter can still be helpful to plot a 2D slice. See [Analysis/Gnuplotter/PDE/slice](#).

## XML model

h ExcitableMedium\_3D.xml |h

```
extern>http://imc.zih.tu-dresden.de/morpheus/examples/PDE/ExcitableMedium_3D.xml
```

In Morpheus GUI: File → Examples → PDE → ExcitableMedium\_3D.xml

## Things to try

- Import resulting sequence of TIFF images in ImageJ or Fiji, and create 4D movie using ImageJ's 3D plugin:
  1. Open `u_v.tif` in ImageJ: File → Open.
  2. Create hyperstack: Image → Hyperstack → Convert to Hyperstack. Channels (c): 2, Slices (z): 50, Frames (t): 51, Display Mode: Composite.
  3. Display in 4D: Plugins → 3D Viewer. Use default parameters. Press OK.

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