

# Module 1: Delta-Notch (ODE systems, ODEs on a grid)

Author: Fabian Rost

## Aim

- learn about ODE models (dynamics in morpheus, steady states analytically)
- develop first models

## Description

### Basic ODEs

- get to know what students know about ODEs and adjust the module to the pre-knowledge
- give them very simple sketches of biomolecular models, which they should translate into ODEs, e.g.



- could be translated to the following ODEs:

$$\begin{aligned} \dot{A} &= k_1 \\ \dot{A} &= k_2 A \\ \dot{A} &= -k_3 A \\ \dot{A} &= k_4 - k_5 A \end{aligned}$$

- discuss those ODEs by
  - calculate steady state (do not calculate the stability, too complicated for biologists)
  - simulate in morpheus

### Delta-Notch

- then discuss the delta-notch sketch with two species
  - start with the Collier model
  - let them simplify the Collier model sketch (remove the delta or notch species)
  - let them develop an ODE for this system (they should be able to do so from the above examples)
  - they could come up with something like:

$$\begin{aligned} \dot{X}_1 &= c \frac{\theta^n}{\theta^n + X_2^n} - k X_1 \\ \dot{X}_2 &= c \frac{\theta^n}{\theta^n + X_1^n} - k X_2 \end{aligned}$$

- this system is bistable for certain parameter ranges, if the students are advanced they might find this out themselves

- bistable e.g. for  $\theta=0.5$ ,  $n=4$ ,  $c=k=1$
- if they have this system running in morpheus go spatial and let them simulate the system on a square and hexagonal grid
- then you could also move to shaped cpm cells or even moving cells
- students won't do so much on their own in this session, it is a lot teaching on ODEs (don't be theoretical here, not enough time!) and introducing morpheus

Paper:

- Joanne R. Collier, Nicholas A.M. Monk, Philip K. Maini, Julian H. Lewis, Pattern Formation by Lateral Inhibition with Feedback: a Mathematical Model of Delta-Notch Intercellular Signalling, Journal of Theoretical Biology, Volume 183, Issue 4, 21 December 1996, Pages 429-446, ISSN 0022-5193, <http://dx.doi.org/10.1006/jtbi.1996.0233>.

## Morpheus models

h ExponentialGrowth.xml |h

```
<?xml version='1.0' encoding='UTF-8'?>
<MorpheusModel version="3">
  <Description>
    <Details></Details>
    <Title></Title>
  </Description>
  <Space>
    <Lattice class="linear">
      <Neighborhood>
        <Order>1</Order>
      </Neighborhood>
      <Size symbol="size" value="100, 0, 0"/>
    </Lattice>
    <SpaceSymbol symbol="space"/>
  </Space>
  <Time>
    <StartTime value="0"/>
    <StopTime value="5"/>
    <TimeSymbol symbol="time"/>
  </Time>
  <Global>
    <Constant symbol="k1" value="1.0"/>
    <Variable symbol="A" value="1.0"/>
    <System solver="heun" time-step="0.01">
      <DiffEqn symbol-ref="A">
        <Expression>k1 * A</Expression>
      </DiffEqn>
    </System>
  </Global>
</MorpheusModel>
```

```
</Global>
<Analysis>
  <Logger time-step="0.01">
    <Input>
      <Symbol symbol-ref="A"/>
    </Input>
    <Output>
      <TextOutput/>
    </Output>
    <Plots>
      <Plot time-step="5">
        <Style style="points"/>
        <Terminal terminal="png"/>
        <X-axis>
          <Symbol symbol-ref="time"/>
        </X-axis>
        <Y-axis>
          <Symbol symbol-ref="A"/>
        </Y-axis>
      </Plot>
    </Plots>
  </Logger>
</Analysis>
</MorpheusModel>
```

From:  
<https://imc.zih.tu-dresden.de/wiki/morpheus/> - **Morpheus**

Permanent link:  
<https://imc.zih.tu-dresden.de/wiki/morpheus/doku.php?id=documentation:course:module1&rev=1510573338>

Last update: **12:42 13.11.2017**

