

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

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## 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
- typical models for biochemistry/systems biology use hill kinetics:



$$\dot{A} = \frac{\theta^n}{\theta^n + B^n} A$$

### 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:

$$\begin{aligned} \dot{A}_1 &= \frac{\theta^n}{\theta^n + A_2^n} - A_1 \\ \dot{A}_2 &= \frac{\theta^n}{\theta^n + A_1^n} - A_2 \end{aligned}$$

- this system is bistable for certain parameter ranges, if the students are advanced they might find this out themselves
- bistable e.g. for  $\theta=0.1$ ,  $n=4$ ,
- 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

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