TRICHOME PATTERN FORMATION:
COMPUTATIONAL EXPLORATION OF THE ROBUSTNESS AND MECHANISTIC INFLUENCES OF THE TURING MECHANISM

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Introduction

Trichome Phenotypes

Fig. 1: Col-0 wildtype and three patterning mutants. Leaf three is depicted exemplarily.

Model system

- **2D point pattern** - Easily observable model
- **Different patterning proteins** and their **functions identified**
- Not essential proteins

Reaction-Diffusion System

$$\partial\tau[GL1]_j = \sigma_0 - \lambda_0\,[GL1]_j + \beta_-[AC]_j - \beta_0[GL1]_j[GL3]_j$$
$$\partial\tau[GL3]_j = \sigma_1 - \lambda_1\,[GL3]_j + \beta_-[AC]_j - \beta_0[GL1]_j[GL3]_j - \beta_1[GL3]_j[TRY]_j + \alpha_1[AC]_j^2$$
$$\partial\tau[TRY]_j = \sigma_2 - \lambda_2[TRY]_j \qquad\qquad\qquad - \beta_1[GL3]_j[TRY]_j + \alpha_2[AC]_j^2 + \delta\langle[TRY]_j\rangle$$
$$\partial\tau[AC]_j = \qquad - \lambda_3\,[AC]_j - \beta_-[AC]_j + \beta_0[GL1]_j[GL3]_j$$

Fig. 3: System of discretized and coupled ordinary differential equations describing the time evolution of GL1, GL3, TRY and the active complex (AC). Where <[TRY]> defines the passive transport of TRY.

Exploring interaction networks

- Using **reaction-diffusion principles** to model and simulate protein interactions - Turing mechanism
- Investigating how different proteins might interact to form phenotype
- Reproducing **genotype-phenotype relationships**
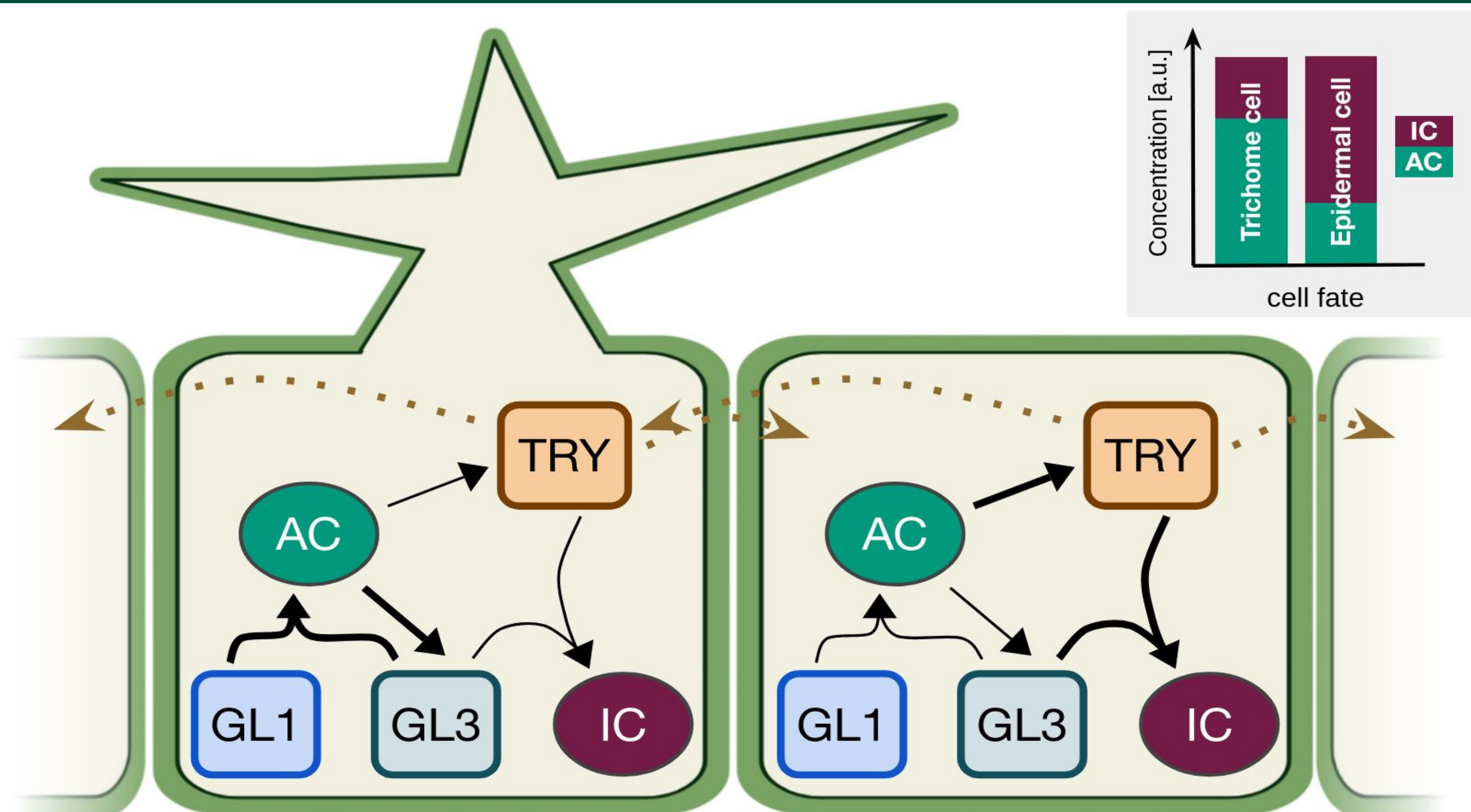
Schematic Trichome Model

Fig. 2: An Activation-Inhibition-Model for Trichome Patterning in Arabidopsis. With GL1 and GL3 forming an Activation-Complex (AC) activating GL3 and TRY. With GL3 and TRY forming an Inhibition-Complex (IC). AC/IC ratio determines cell fate.

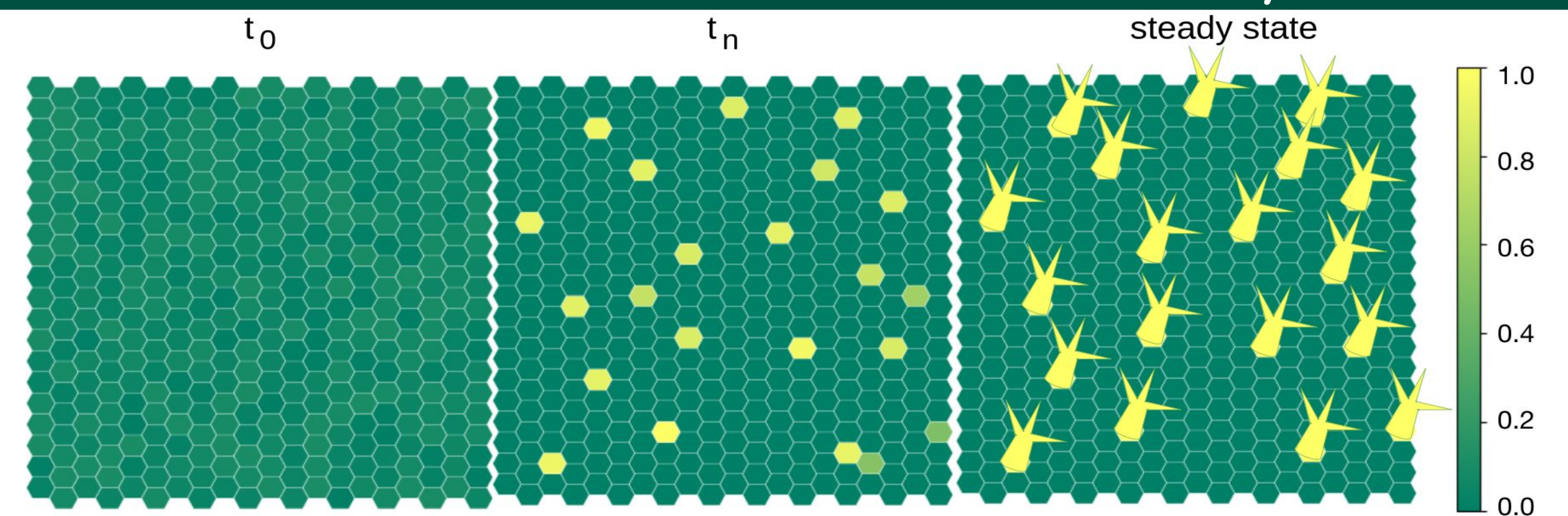### Numerical Results for the Reaction-Diffusion System

Fig. 4: Visualization of the numerical integration of the reaction-diffusion system. Cells are assumed to be organized on a hexagonal grid. Shown are initial homogeneous (left), intermediate (middle) and steady (right) states. The colors indicate the concentration of AC, which has been normalized to a value between 0 and 1.
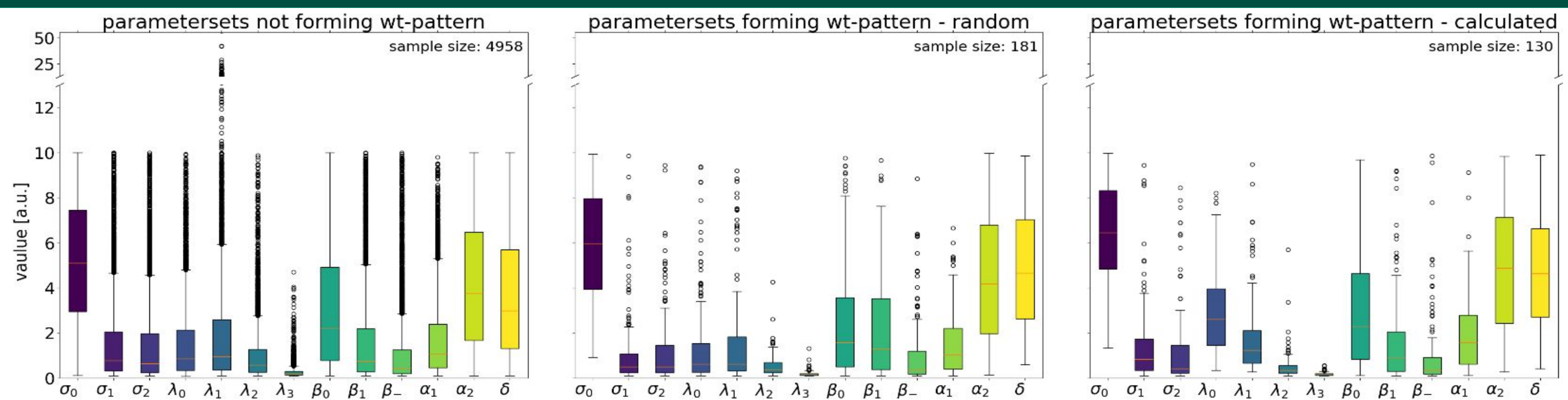
Parameter Space Analysis of Bulk Data

Fig. 5: Distribution of parameters in Turing space (parameter-sets that can form patterns according to Turing mechanism). Parameters in Turing space without wild-type pattern (left), parameters with wild-type pattern (centre and right), of which randomly drawn (centre) and calculated from stabilization data (right).

Further Research Questions

- How do the **mechanical interactions** influence the pattern?
- How do **different cell shapes** affect the resulting pattern?
- How does the **tissue grow** after the pattern has stabilized?
- Which processes drive **intercalation** the initial pattern has formed?

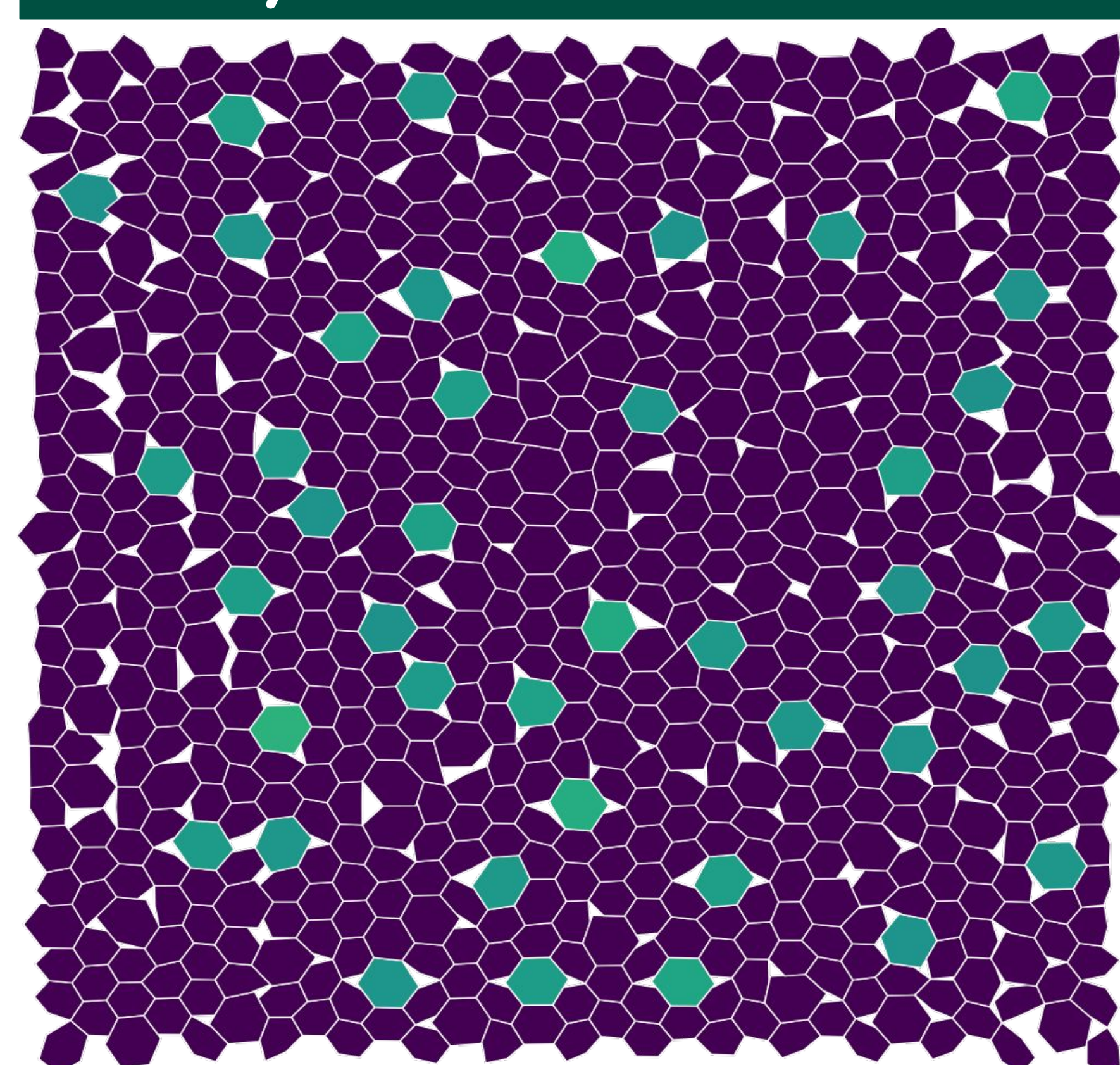➔ **Need dynamic and flexible model**

Dynamic Simulation

Fig. 6: Freely motile vertex-shaped cell model with Reaction Diffusion System between adjacent cells.
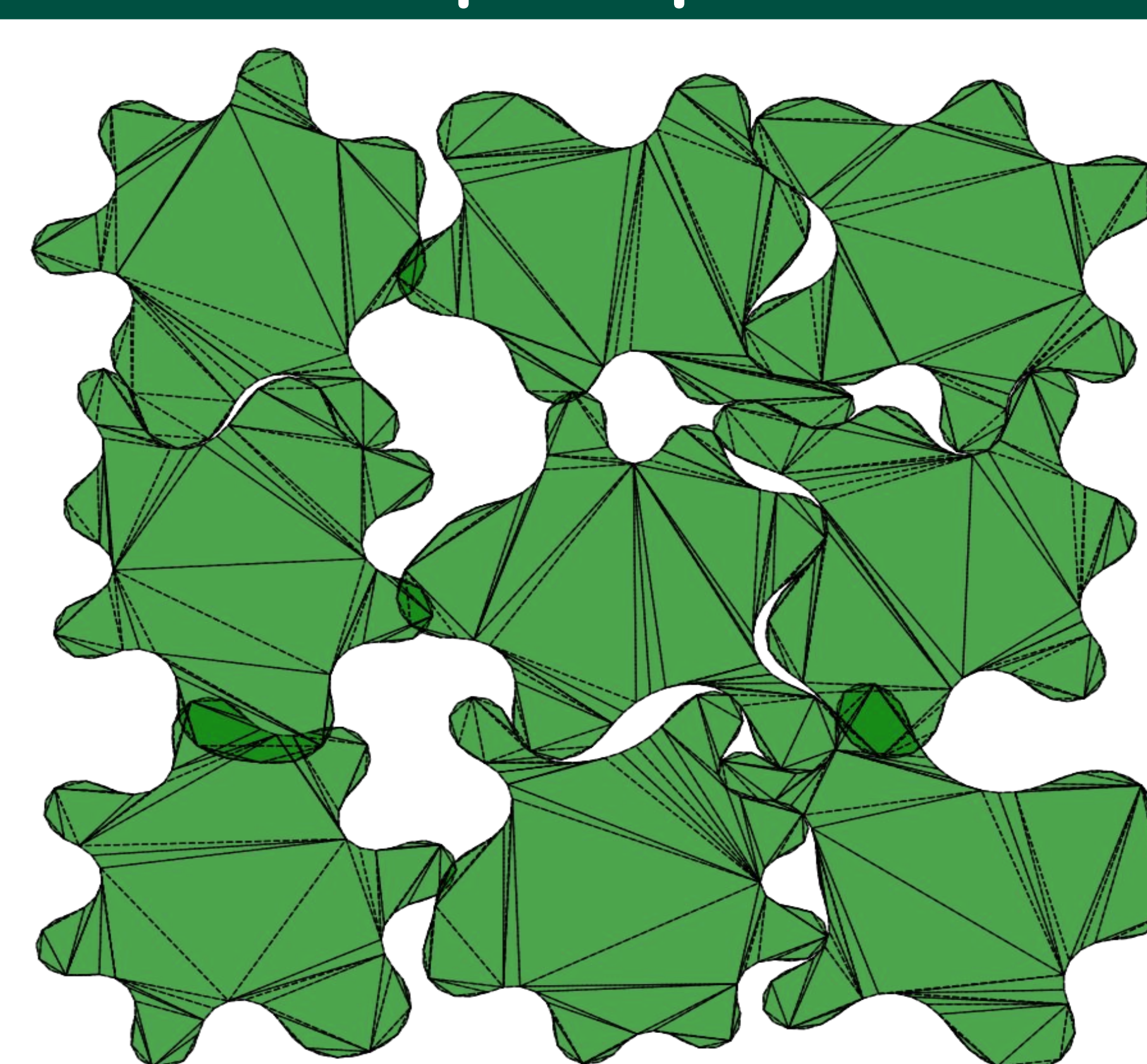
Puzzle-Shaped Epidermal Cells

Fig 7: Experimental model of Puzzle-shaped epidermal cells, modeled by triangulated multi-vertex agents.

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- Agent-Based Model (ABM)
- Treat cells individually
- Mechanistic rules
- Low-parametric
- Flexible in Model design
- Greater variability of cell shapes

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