Robustness of tissue growth to cell mechanics

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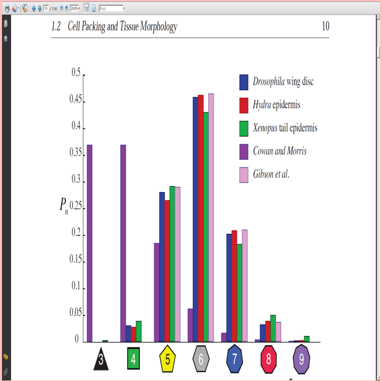
Tissue growth: cells as polygons, tissues as networks

Different kind of tissues



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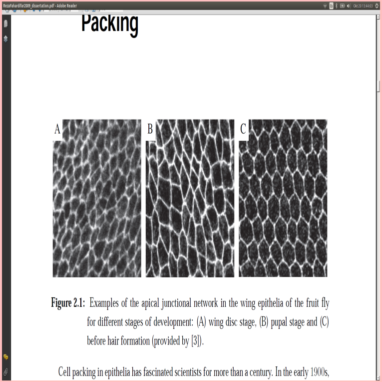
- Different cells *shapes* distributions are related to **different kind** of tissues[1].

Developmental stages of tissues


Packing

A B C

Figure 2.1: Examples of the apical junctional network in the wing epithelia of the fruit fly for different stages of development: (A) wing disc stage, (B) pupal stage and (C) before hair formation (provided by [3]).

Cell packing in epithelia has fascinated scientists for more than a century. In the early 1900s,

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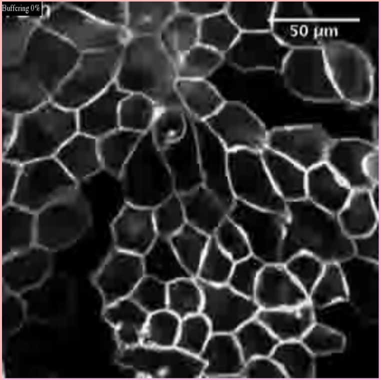
- Different cells *shapes* distributions are related to different **developmental stages** of a same tissue[2].

Tissue, cells, Edges, and Vertices



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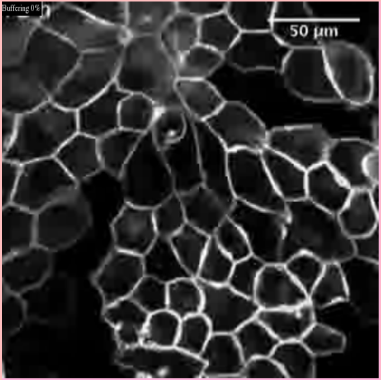
1. Tissue as a network of cells.

Tissue, cells, Edges, and Vertices



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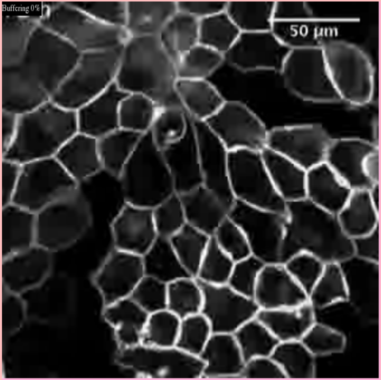

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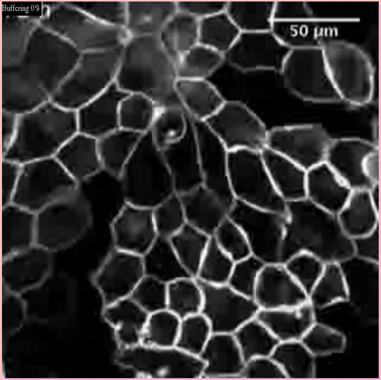
2. Cells as polygons.
3. Each 2 Cells share 1 Edge.

Tissue, cells, Edges, and Vertices



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1. Tissue as a network of cells.
2. Cells as polygons.
3. Each 2 Cells share 1 Edge.
4. Each Edge is composed by 2 Vertices.

Edge's Line Tension

Include figure of a cell from Farhadifar

- Edge's Line tension (Λ) is associated to Edge's length.

Cell's Contractility

Include figure of a cell from Farhadifar

- Cell's Contractility (Γ) is associated to Cell's Perimeter.

Cell's Elasticity

Include figure of a cell from Farhadifar

- Cell's Elasticity (K) is associated to Cell's Area.

Force Balance Energy Function

$$F = \sum_\alpha \frac{K_\alpha}{2}(A_\alpha - A_\alpha^{(0)})^2 \; + \; \sum_{(i,j)} \Lambda_{ij} L_{ij} \; + \; \sum_\alpha \frac{\Gamma_\alpha}{2} L_\alpha^2$$

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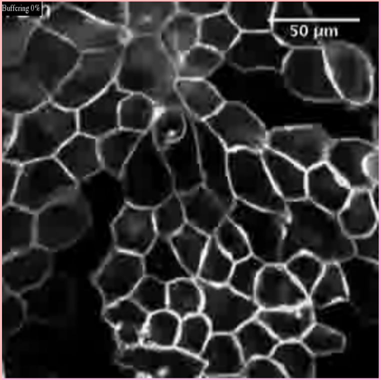
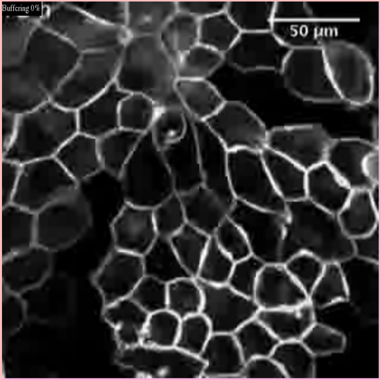


We keep the physical properties of the cells fixed during the simulation. So, in order to satisfy the **Minimal Energy's Assumption** theh positions of the vertices need to change.

Preferred Cell's Area $A_\alpha^{(0)}$

$$F = \sum_\alpha \frac{K_\alpha}{2}(A_\alpha - A_\alpha^{(0)})^2 \; + \; \sum_{(i,j)} \Lambda_{ij} L_{ij} \; + \; \sum_\alpha \frac{\Gamma_\alpha}{2} L_\alpha^2$$



$A_\alpha^{(0)}$ is the preferred area of cell α which is related to the volume, V_α and height, h_α of the cell: $A_\alpha^{(0)} = \frac{V_\alpha}{h_\alpha}$

Sequence of Events

1. **Relaxation** (Vertices change their position to guarantee the force balance equal to zero).

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2. **Cell Proliferation** (cells growth and cells division).

Relaxation

1. Vertices change their position to guarantee the force balance equal to zero.

Relaxation

1. The position of the vertices is defined by a *Verlet Function*[**?**] in which the accelleration is defined by the total force on the junctions of the tissue $(r(t+\Delta t) = 2r(t) - r(t-\Delta t) + a(t)\Delta t^2)$.

Relaxation

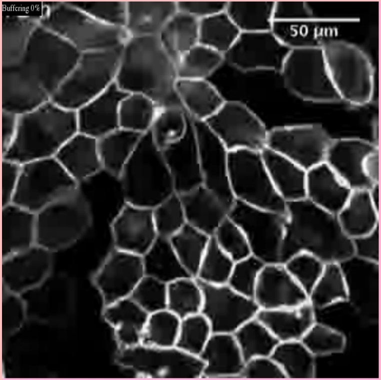
1. Once the force is zero, the accelleration of the *Verlet Function* is also zero, and so the position of the vertices don't change from time step t to $t + \Delta t$.

Relaxation

1. Relaxation is finished once the length of the tissue remains *steady* (the position of its vertices don't change) along 100 time steps ($\frac{sd(\sum_\alpha L_\alpha)}{\sum_\alpha L_\alpha} \approx 0$).

Regularness of the tissue

We define ***regularness*** as a dimensionless measure to say how regular the cells of a tissue are.



1. Regularness is defined as: $Reg = \frac{sd(L_{ij}}{L_{ij}}$ over all the edges.

Thank you!

- SystemsX Initiative.
- ***EpiphysX*** members: Andreas Wagner (UZH), Aziza Merzouki, Orestis Malaspinas, Bastien Chopard, Aurélien Roux, Michel Milinkovitch, Marcos Gonzalez-Gaitan (UNIGE)
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