

KITP - Santa Barbara 2008

The Mechanics of Cell-cell Interactions

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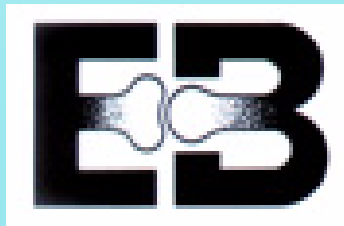
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CANADA

FUNDING: NSERC & HFSP

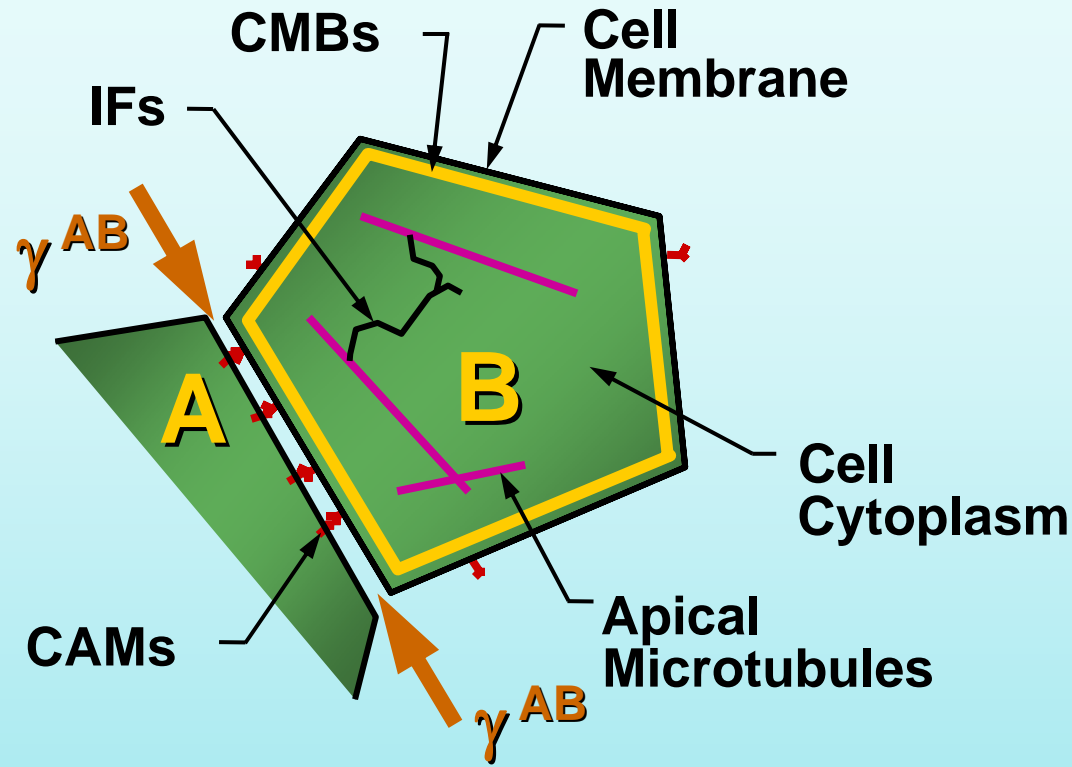


Outline:

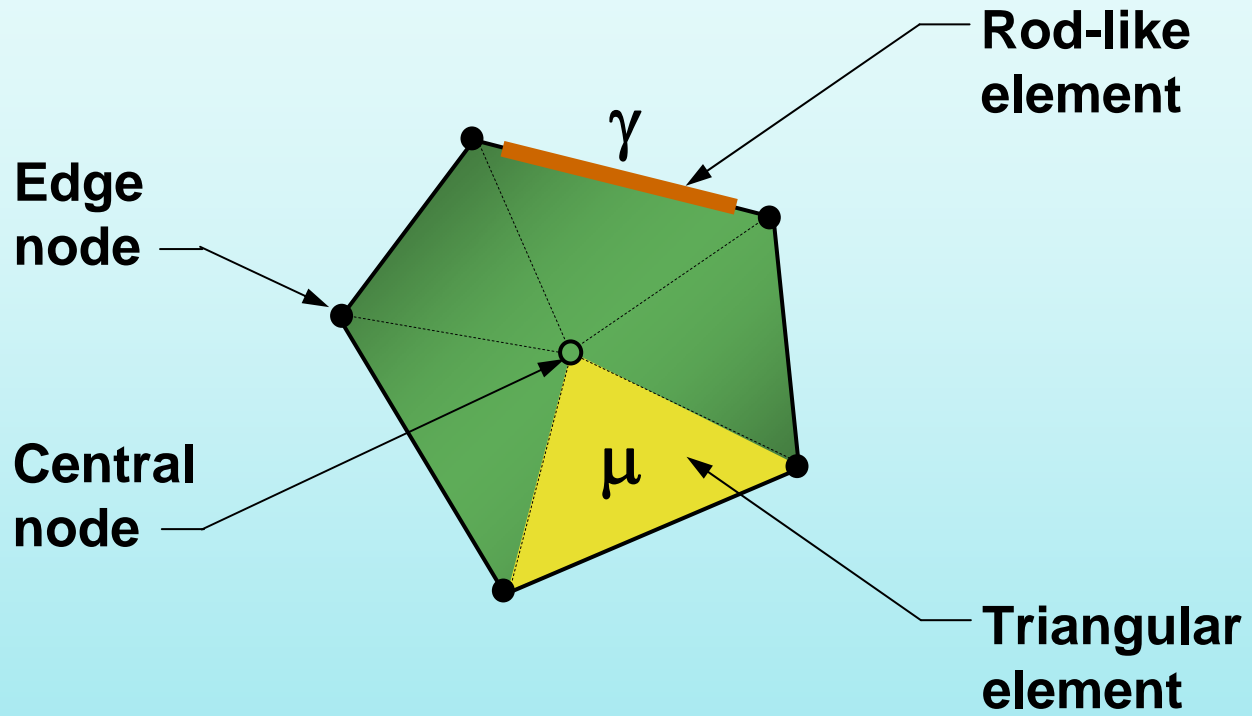
- *2D Modeling of Cell Mechanics*
- *2D vs 3D*
- *3D Neurulation Model*

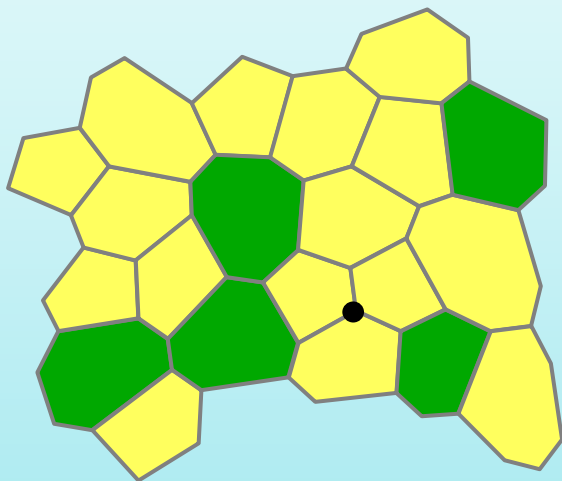


2D Modeling of Cell Mechanics



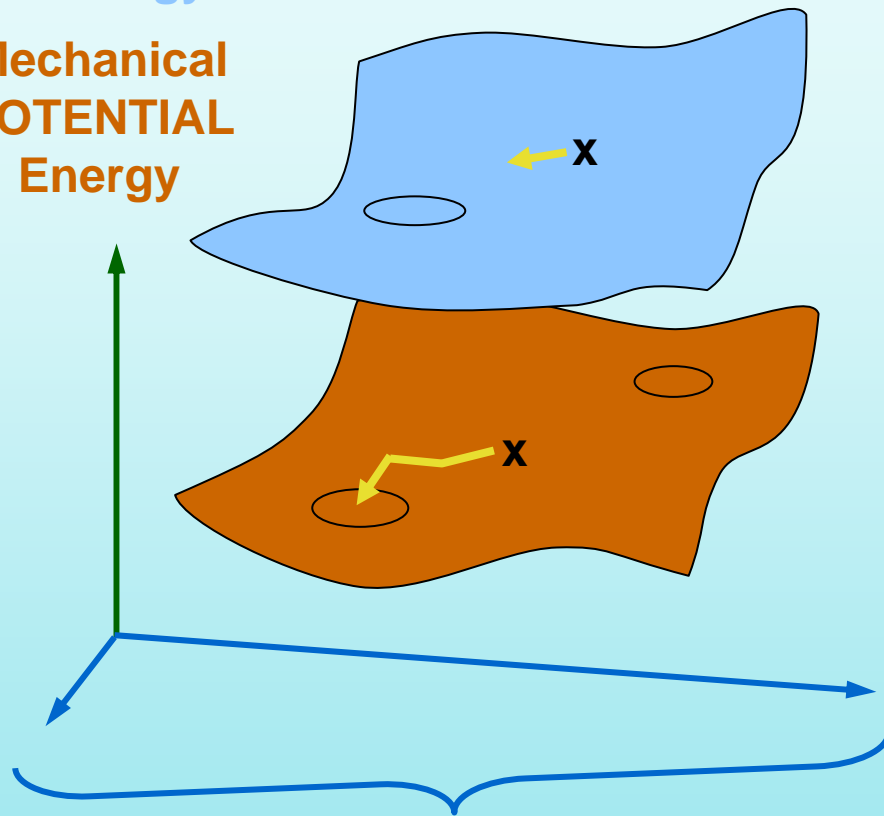
$$\gamma^{AB} = F_{MF}^A + F_{MF}^B + F_{Mem}^A + F_{Mem}^B + F_{Other}^{AB} - F_{Adh}^{AB}$$



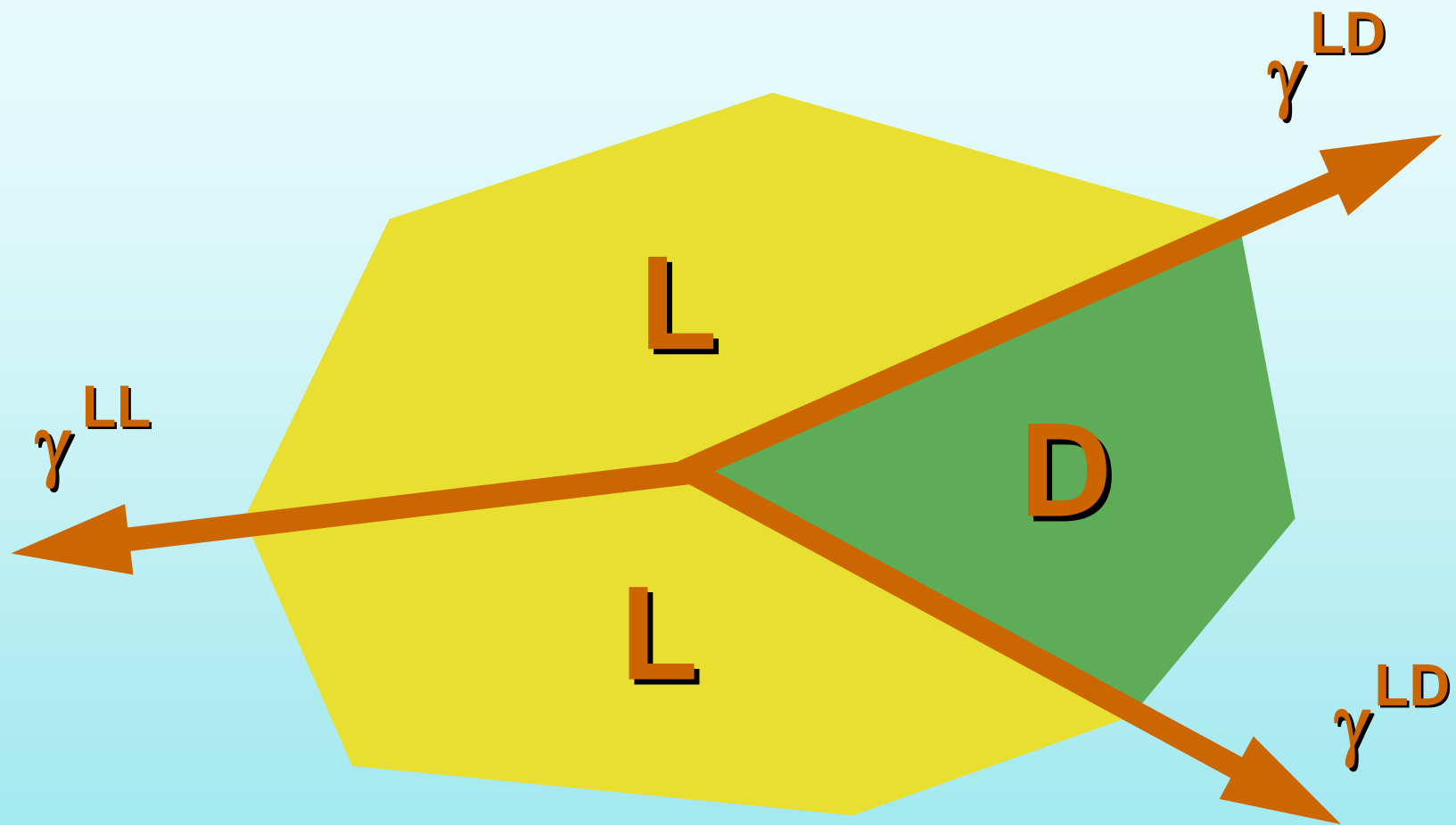


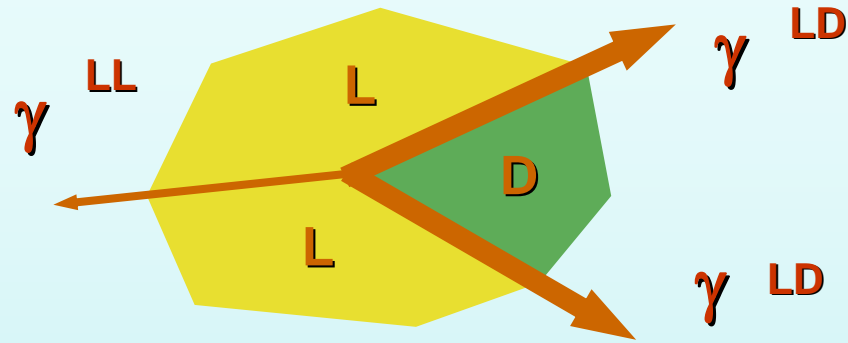
TOTAL System Energy

Mechanical POTENTIAL Energy



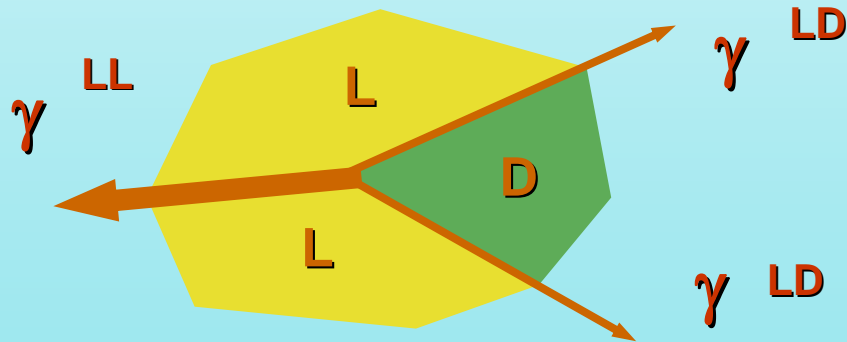
Nodal displacements





Sorting

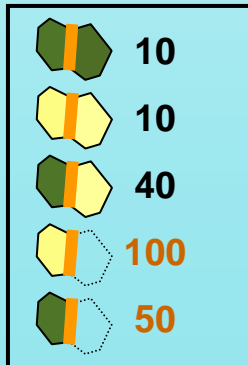
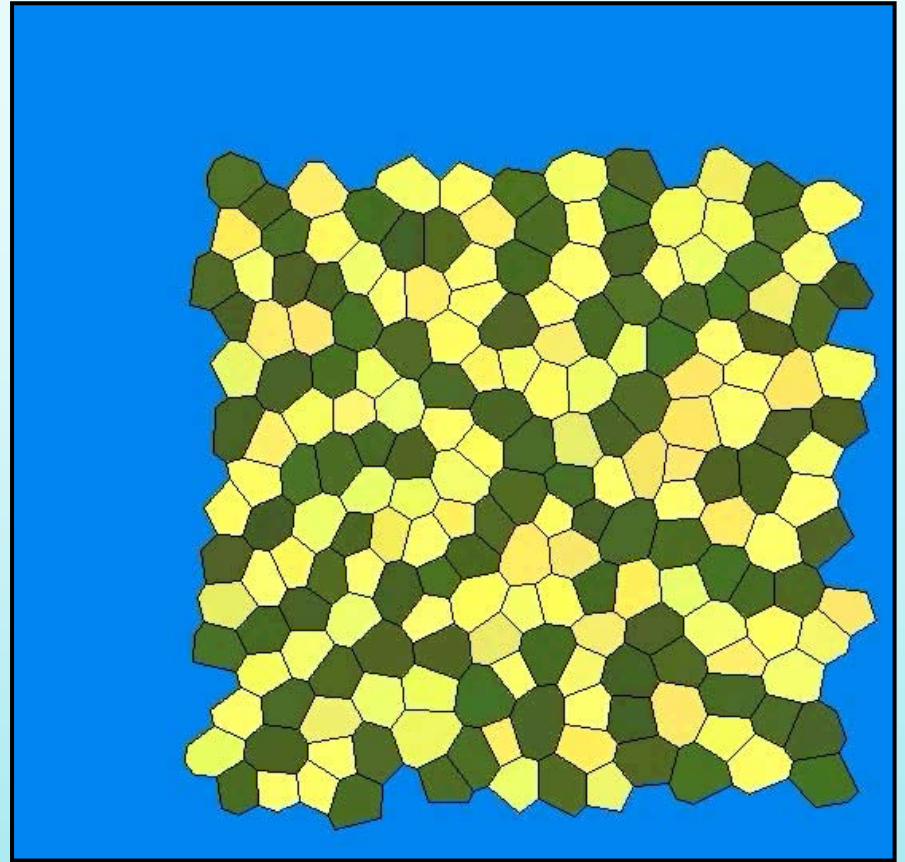
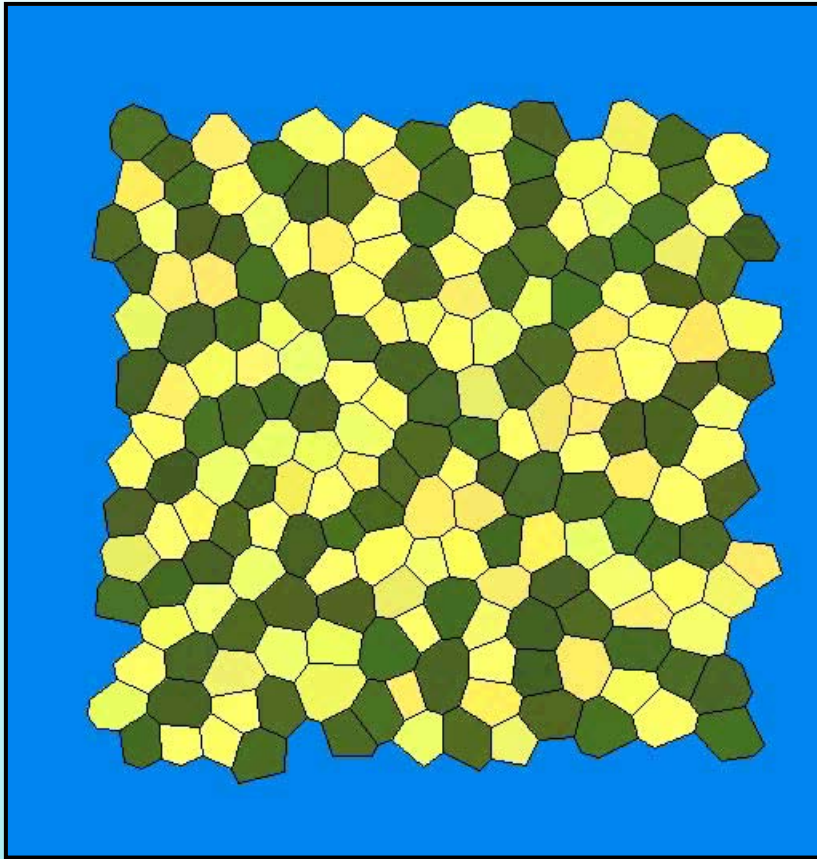
$$\gamma^{LD} > (\gamma^{DD} + \gamma^{LL})/2$$



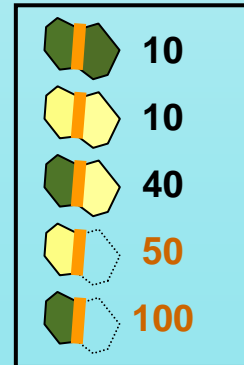
Mixing

$$\gamma^{LD} < \gamma^{LL} / 2 \quad \text{or} \quad \gamma^{LD} < \gamma^{DD} / 2$$

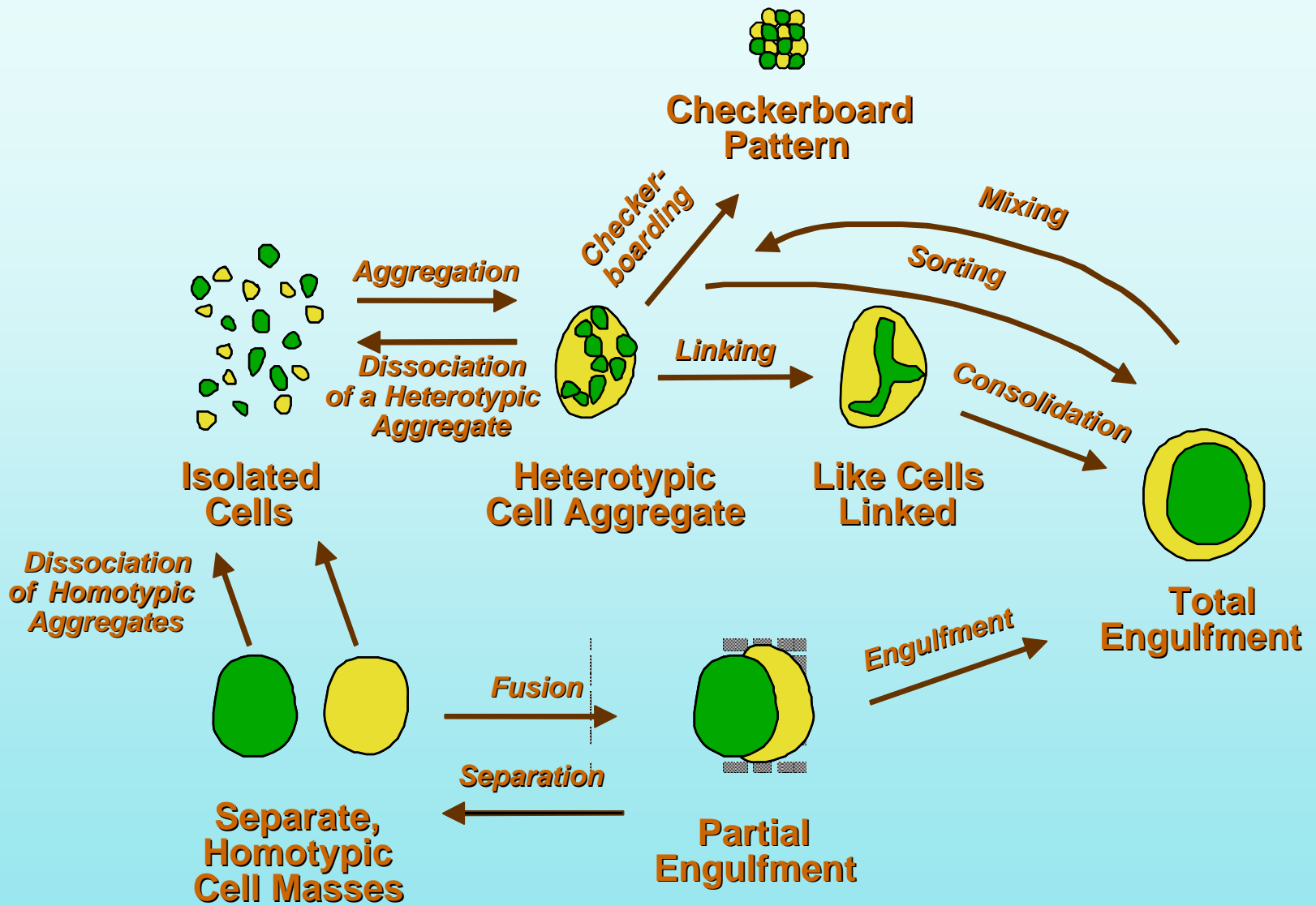
Engulfment and Sorting

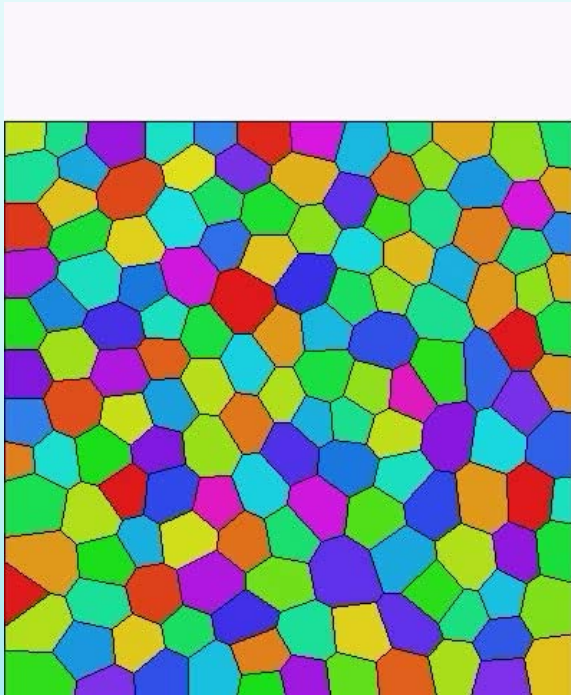


**Dark Engulfs
Light**

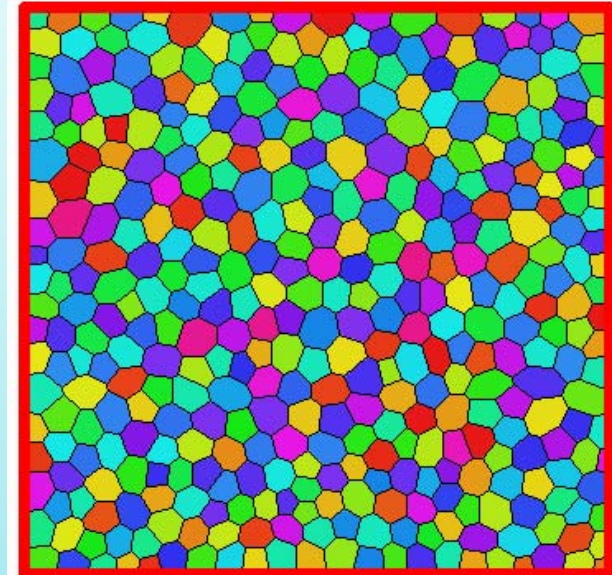


**Light Engulfs
Dark**



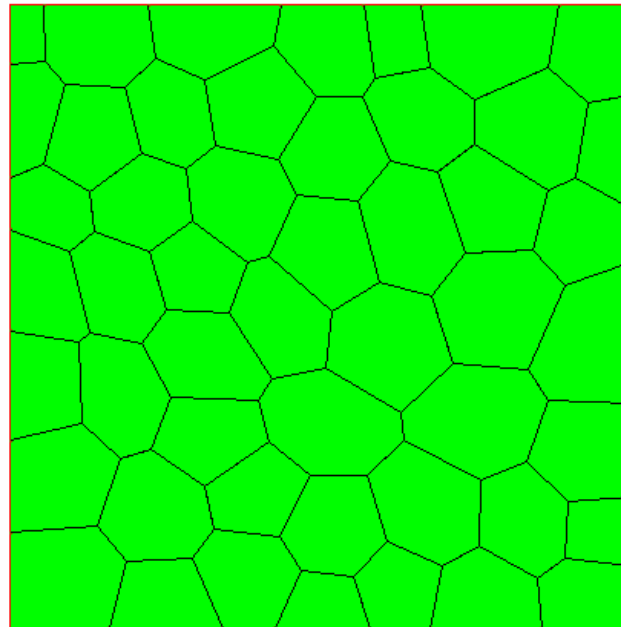
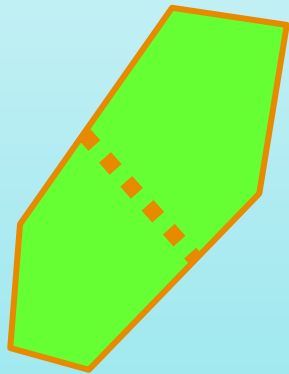


Lamellipodia-driven CE

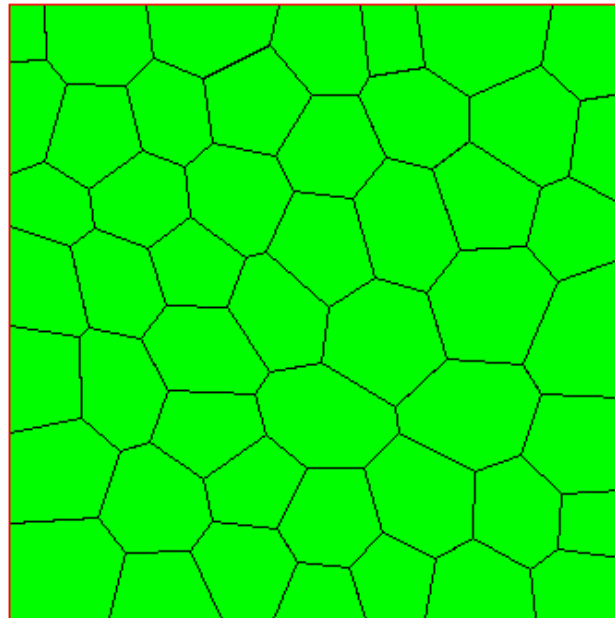
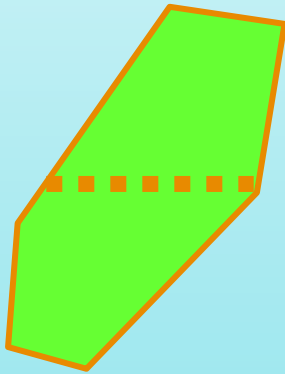


External loads

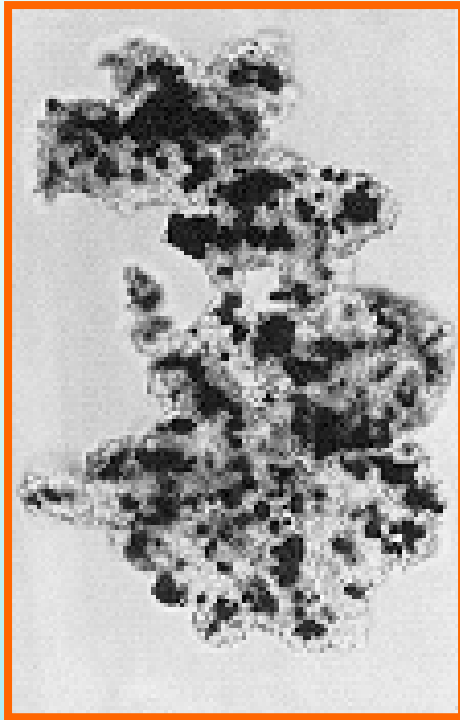
Mitotic plane
determined
by **cell** axis



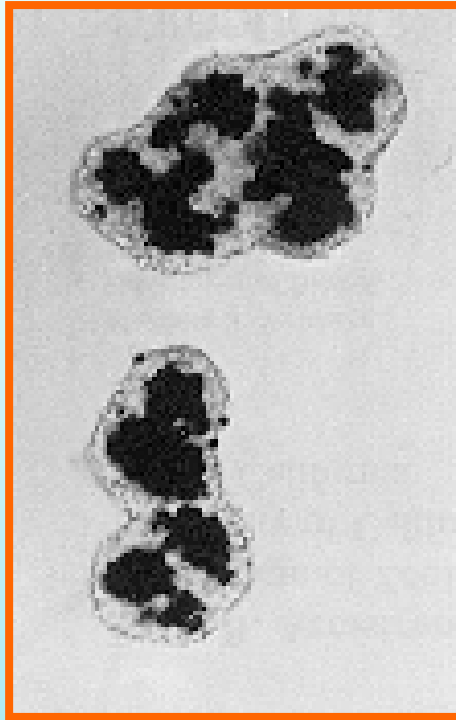
Mitotic plane
determined
by **global** axis



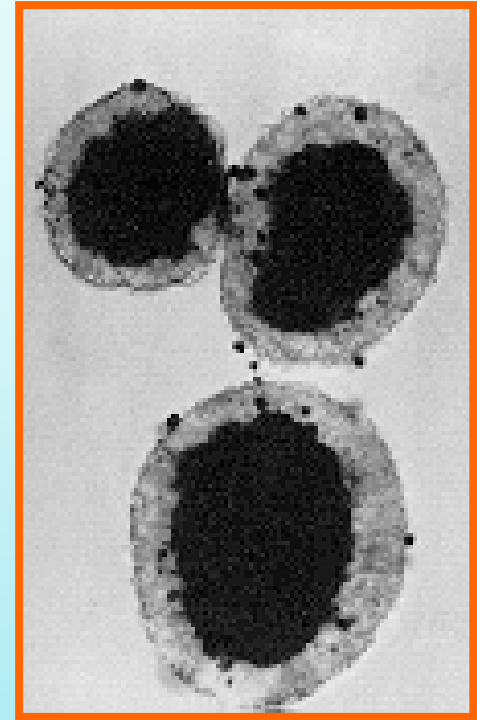
2D vs 3D



5 hours



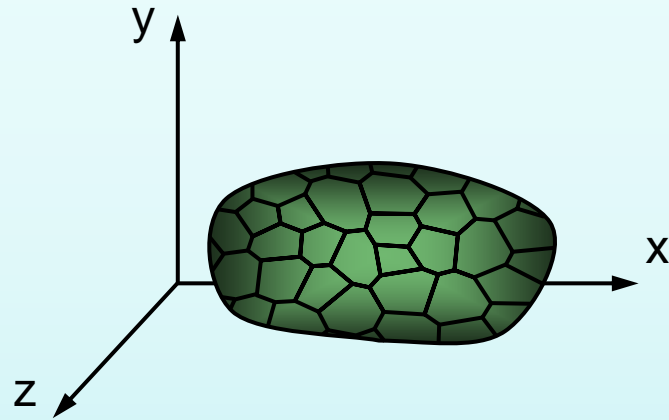
19 hours



2 days

**Chick Neural Retina (Light cells)
Pigmented Retina (Dark cells)**

(From P.B. Armstrong, 1989, *Crit. Rev. Biochem. Mol. Biol.*, Vol. 24, 119-149)

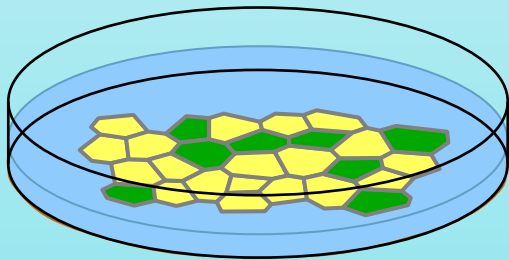


3D cell systems

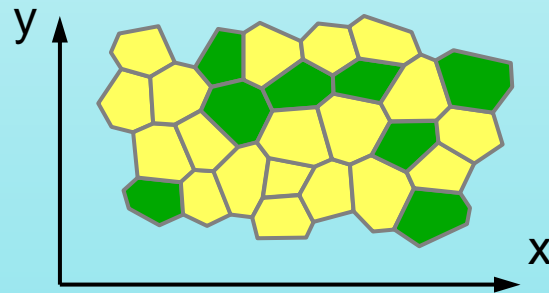
**Do NOT
behave
the same**



**Do NOT
behave
the same**



2D cell systems



2D models

Three, dimensionality-related differences:

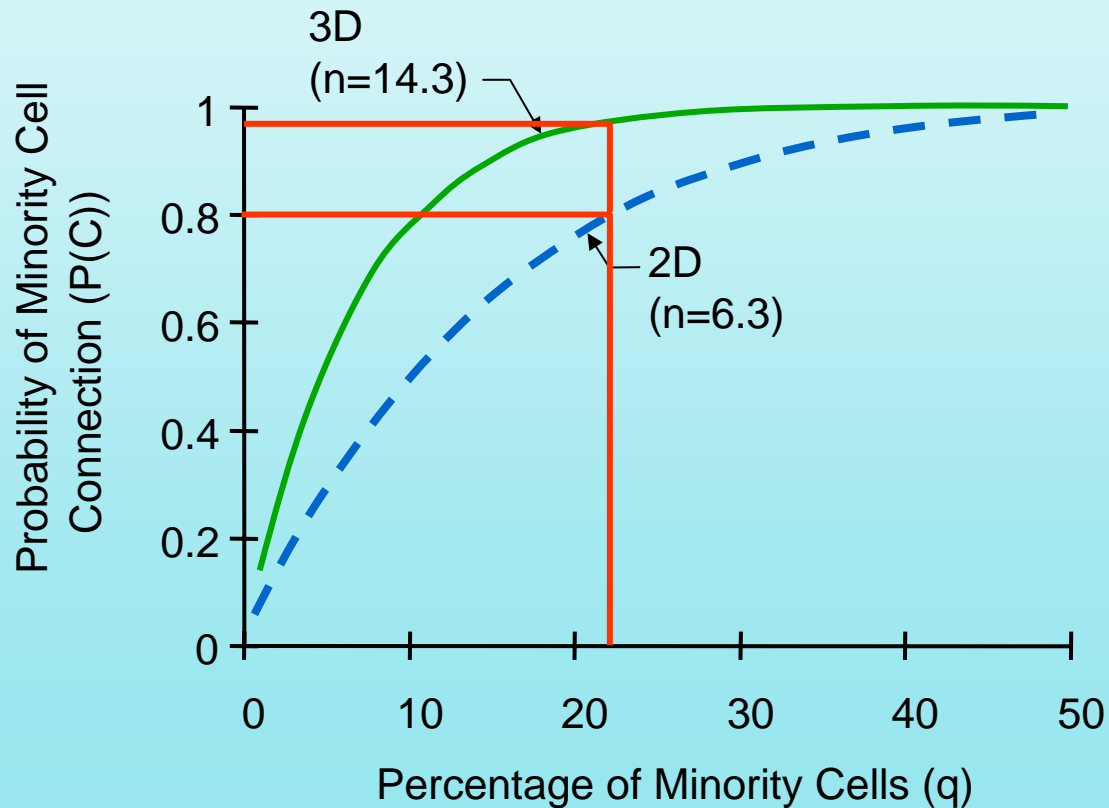
- *Initial number of neighbors*
- *Connection paths*
- *Rayleigh instability*

The probability of a minority cell being connected to cells of its own type is

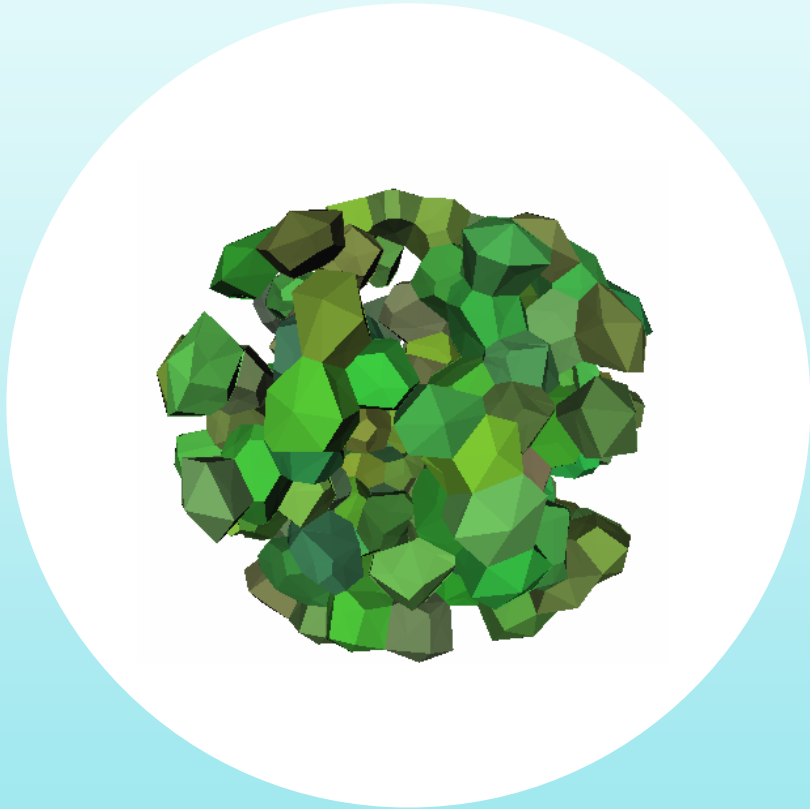
$$P(C) = 1 - (1-q)^n$$

q is the minority cell fraction

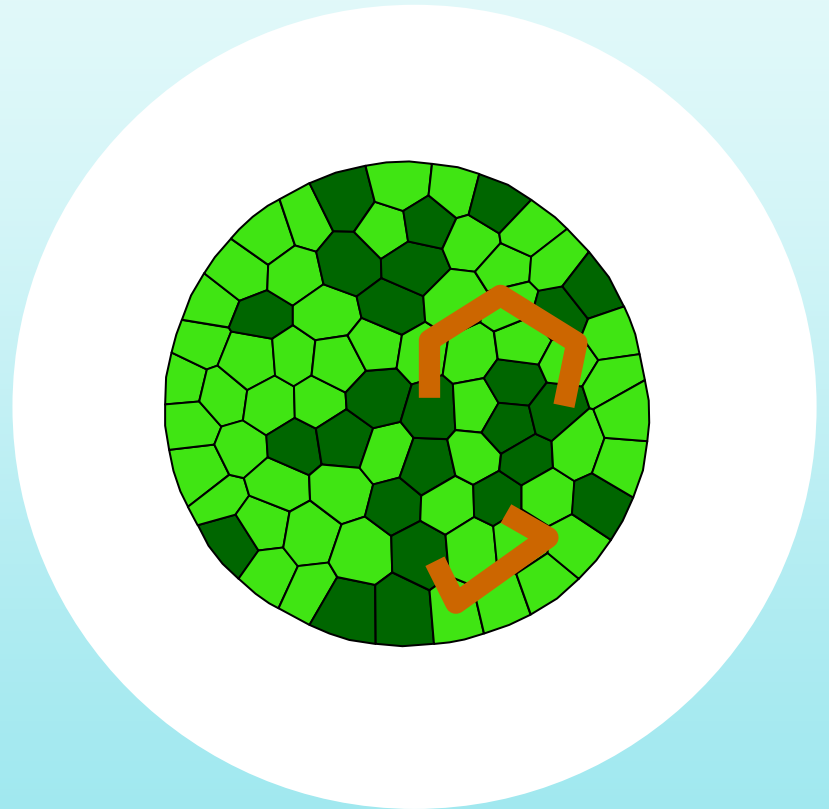
n is the number of neighbors it has



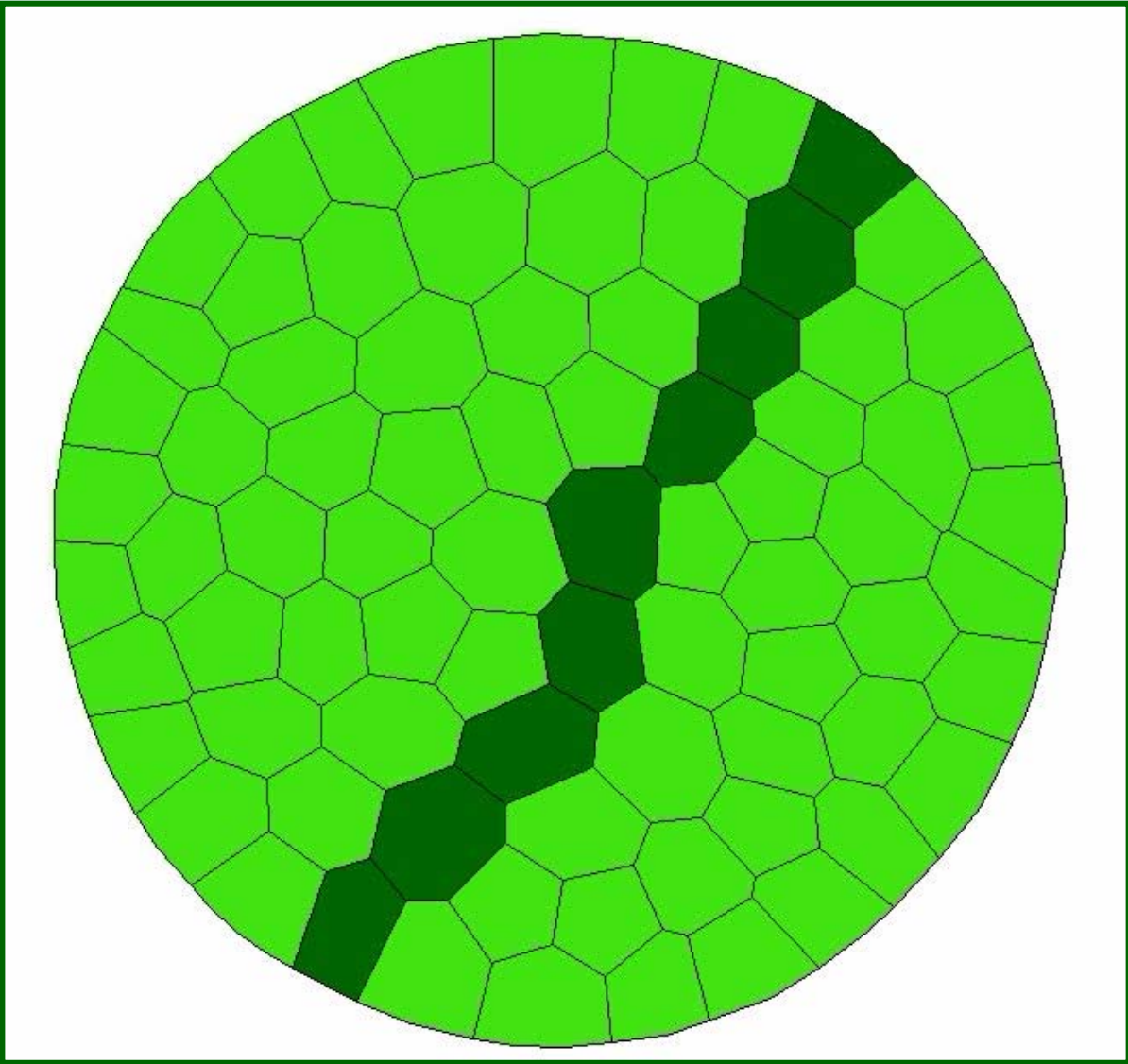
3D

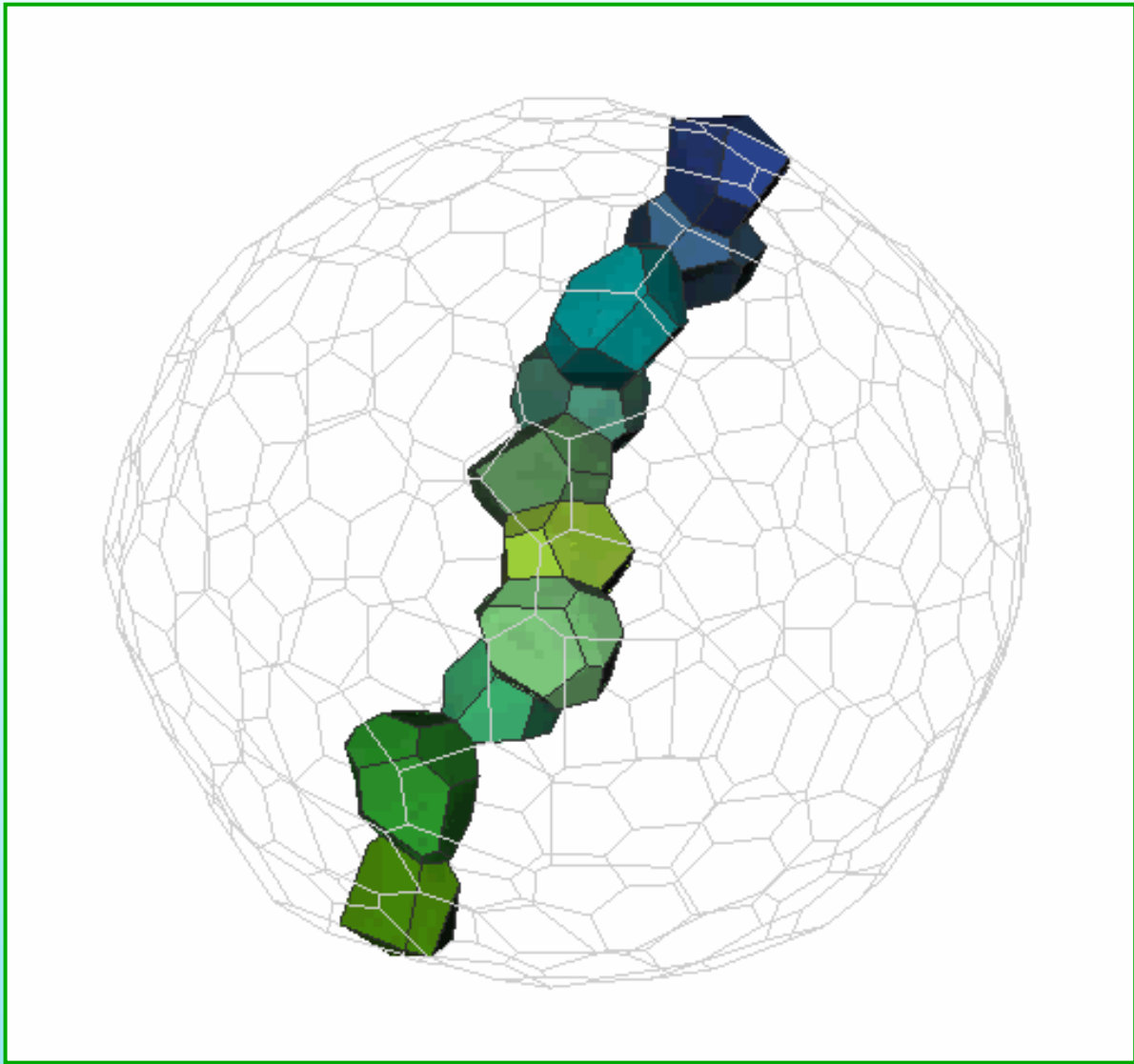


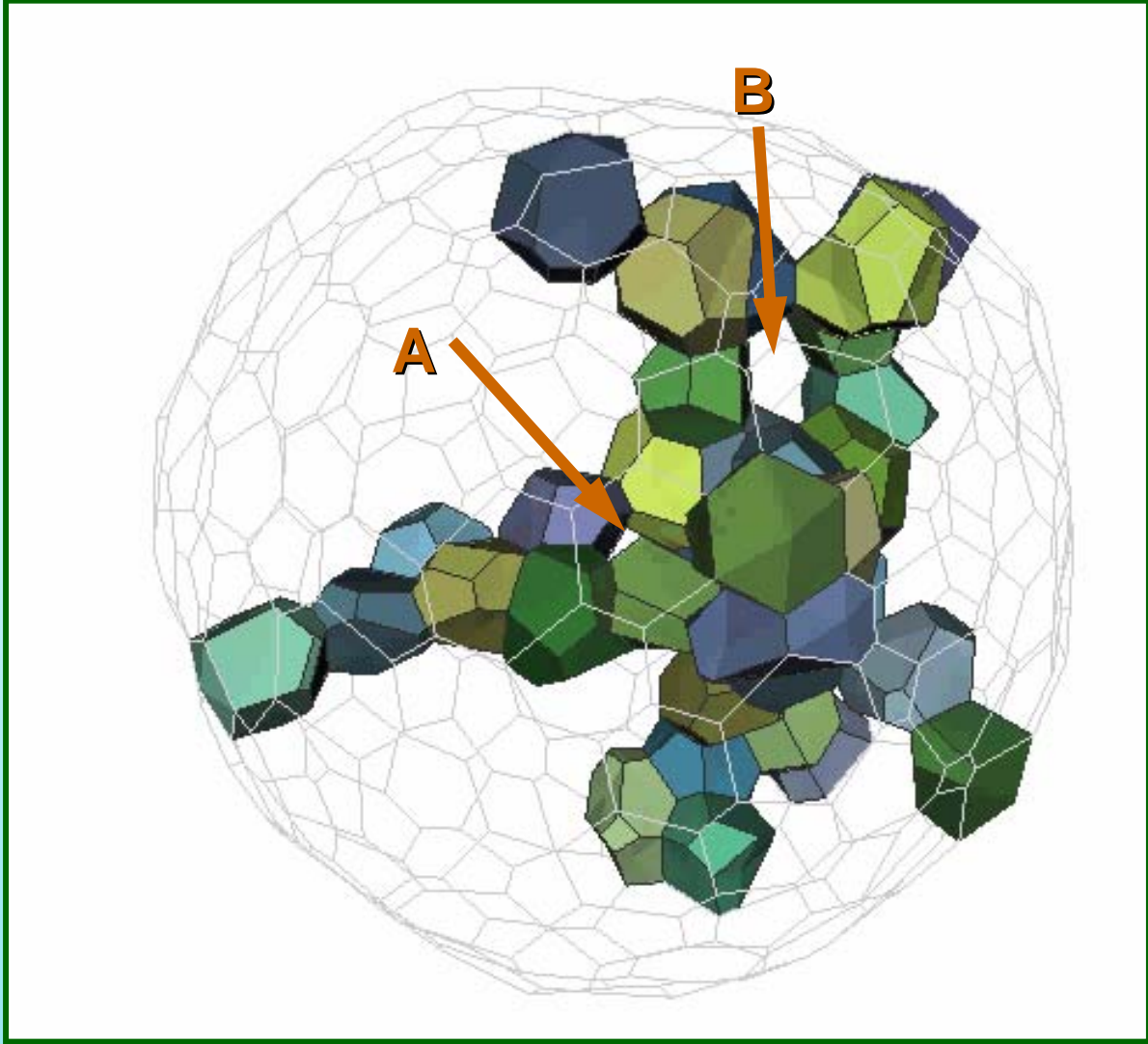
2D



q=30%

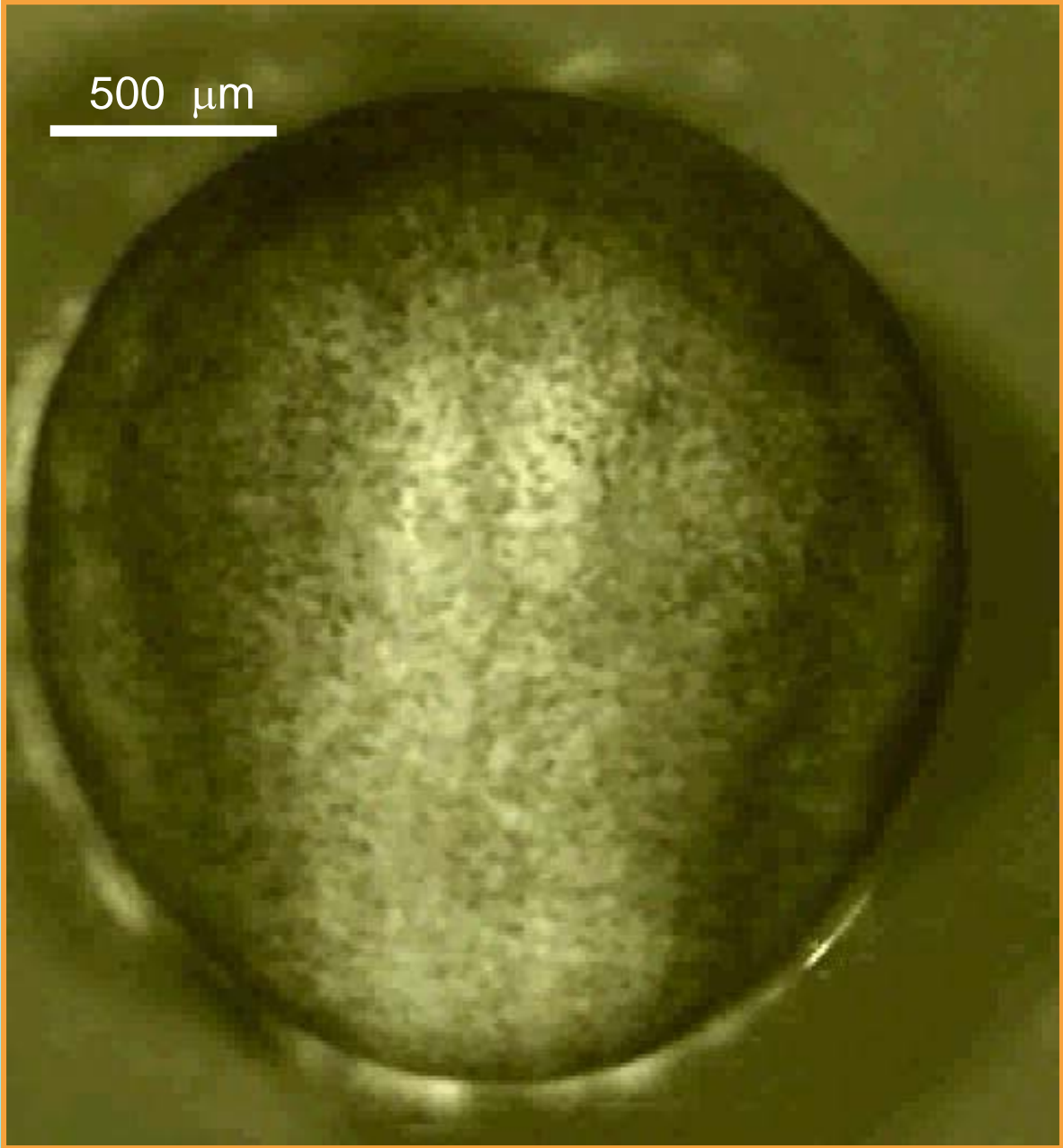
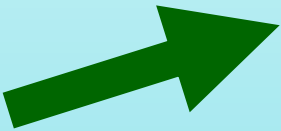






3D Neurulation Model

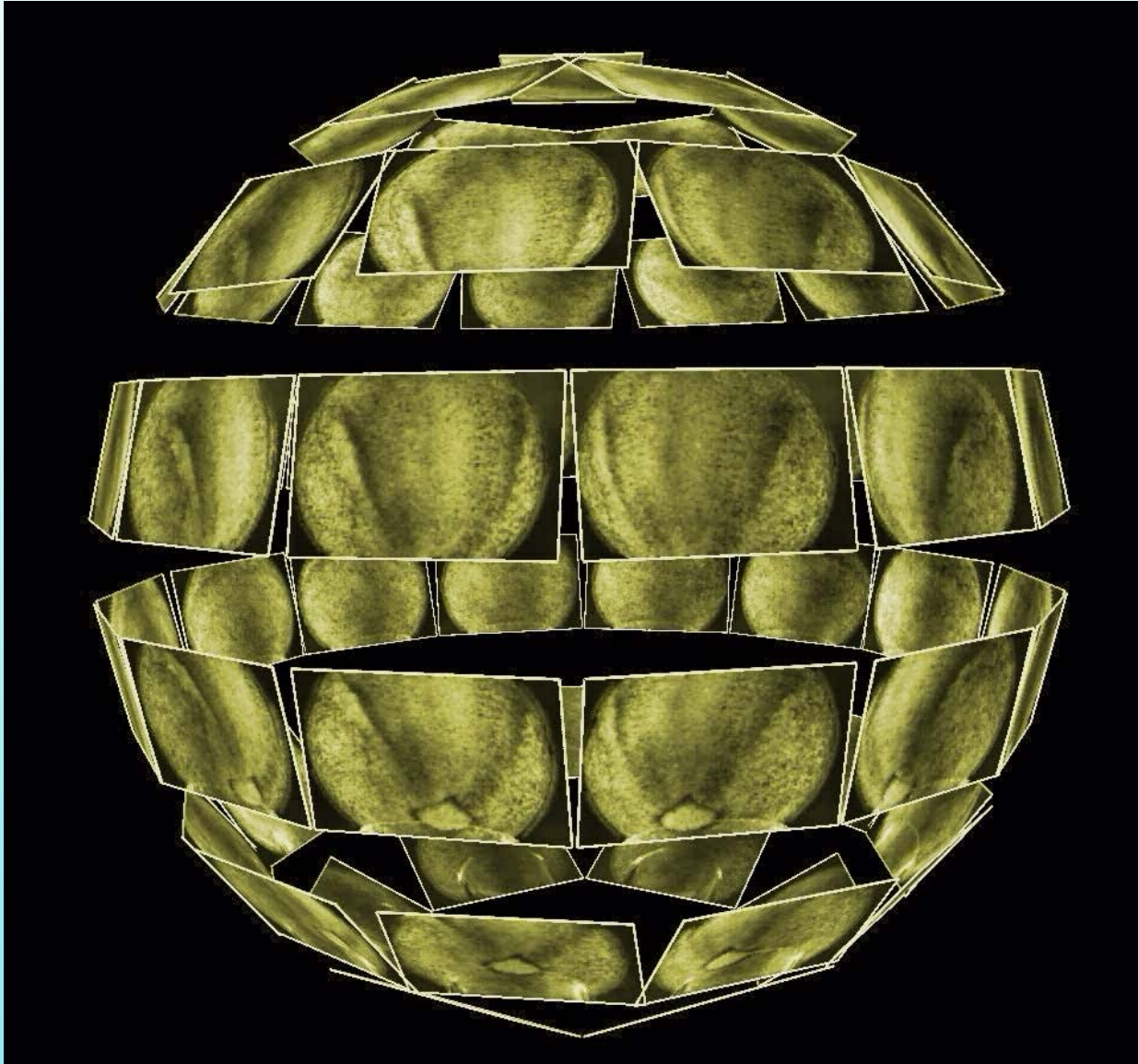
500 μm

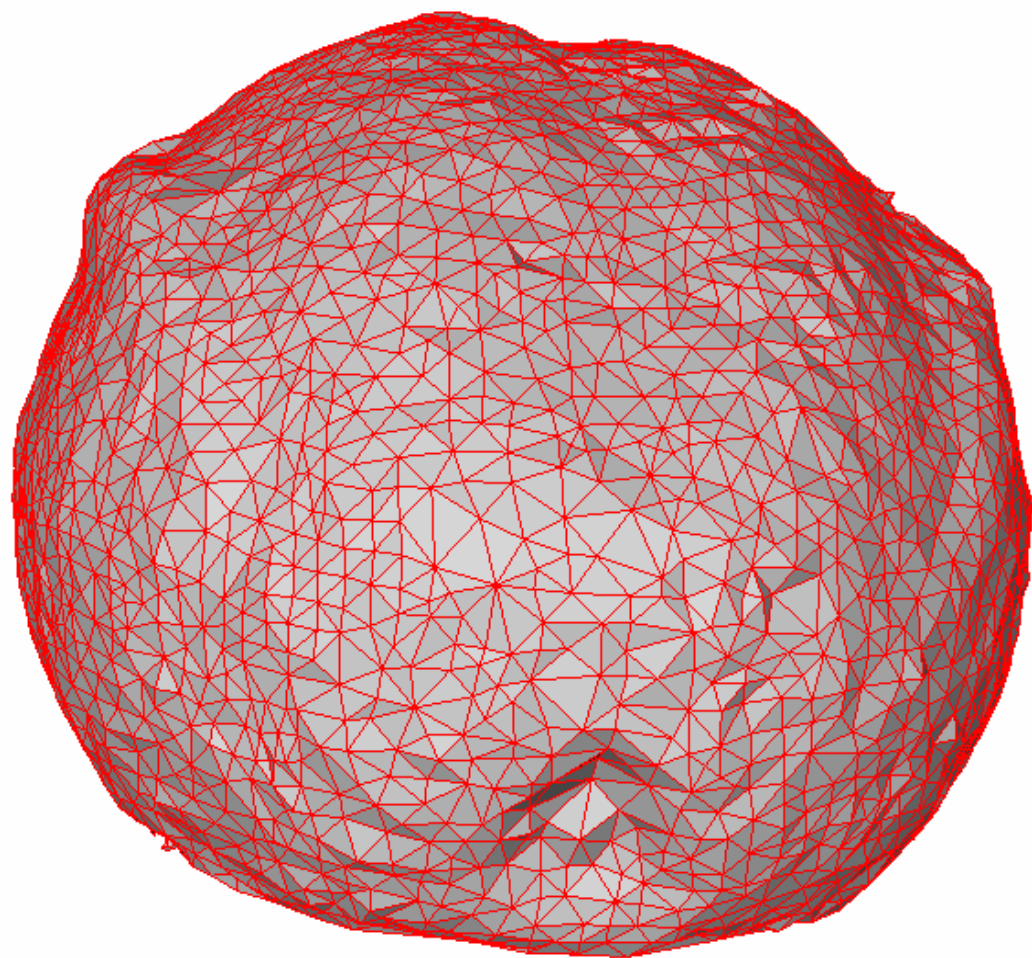


B072_T000_P013.0000.tif



Multi-view Time-lapse Movie

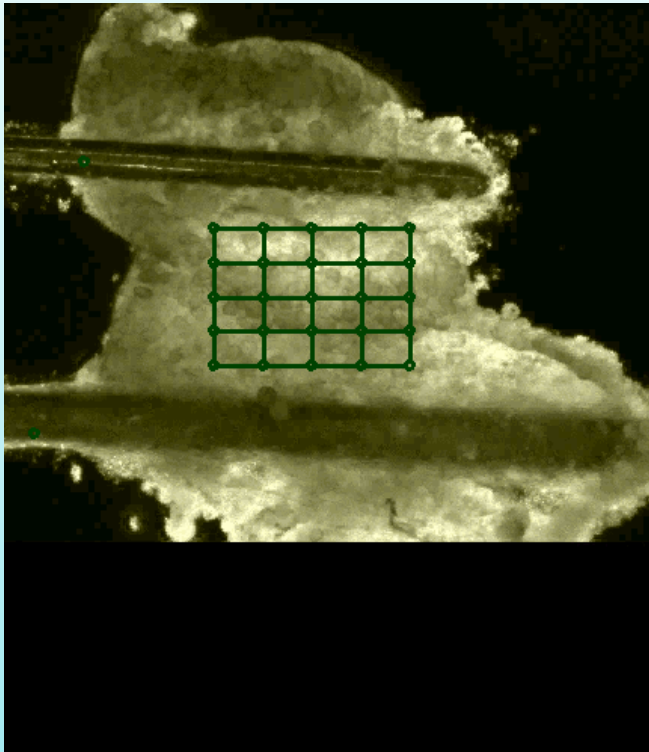




Top View

Side View

Bottom View



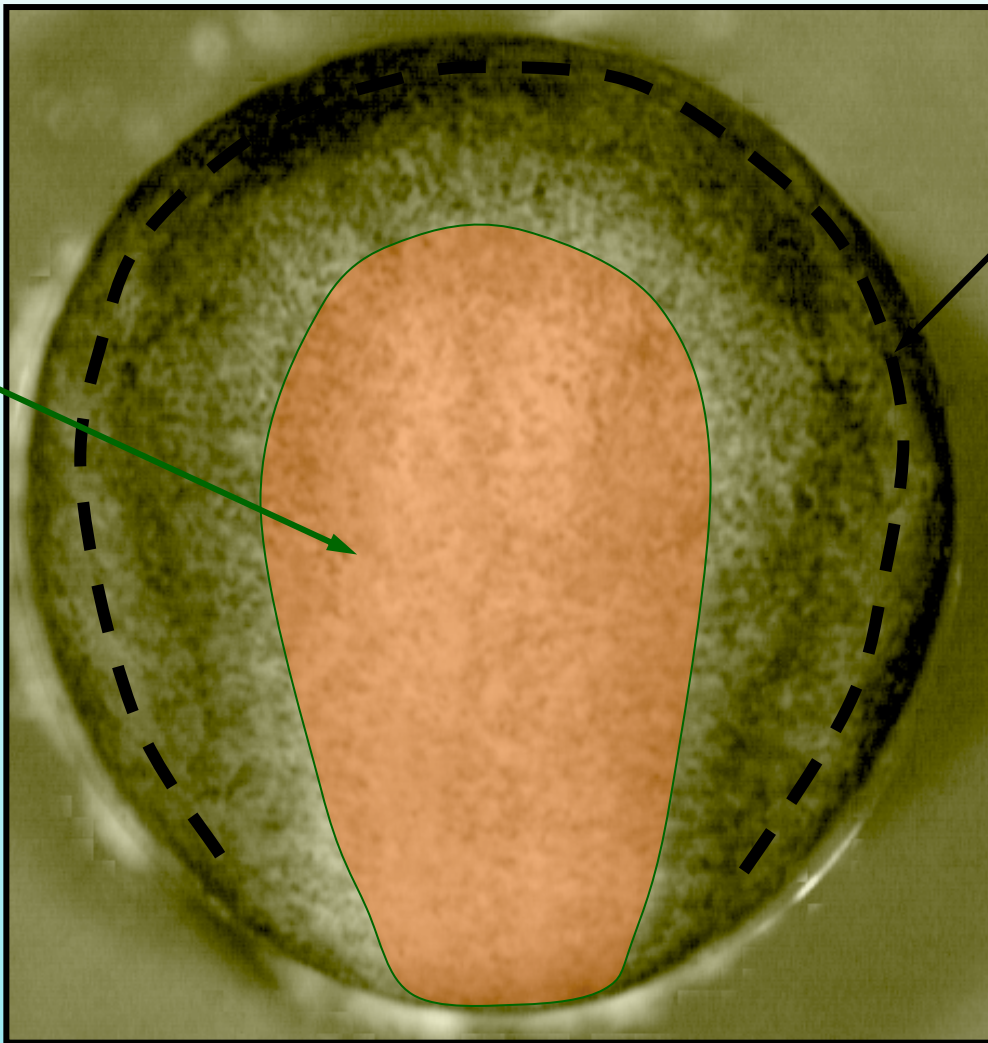
100 μ m

Chordin

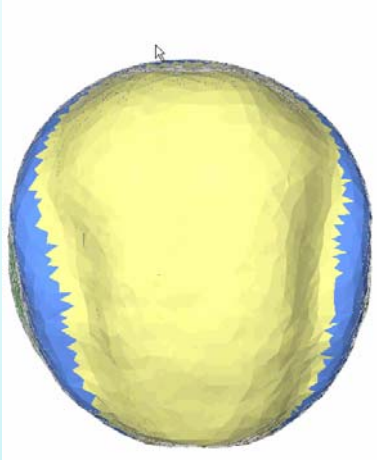
Xbra

PCP

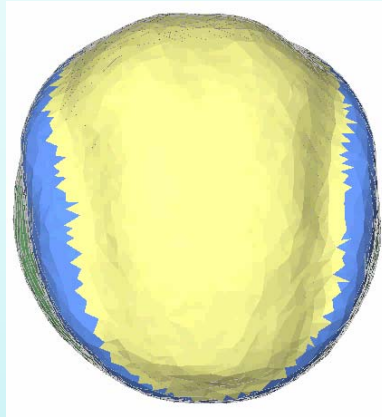
Wnt



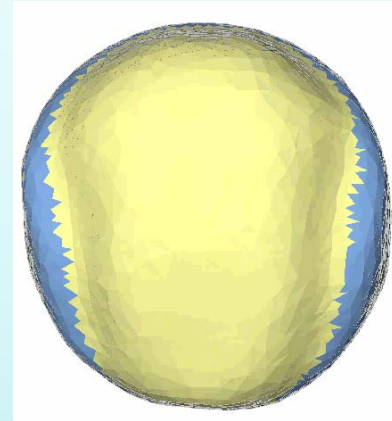
p190RhoGAP
Shroom



Normal



**CE Reduced
by 20%**



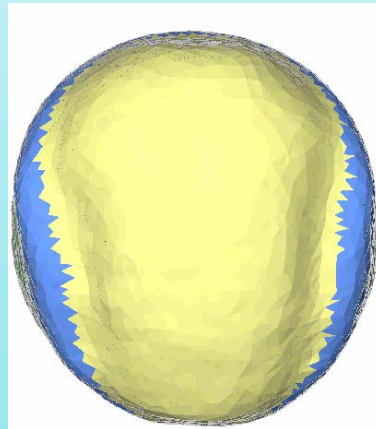
No CE



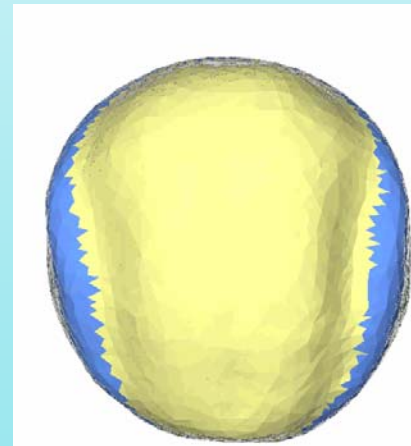
**Wallingford &
Harland 2002
Used with
permission.**



No Shroom



**Doubled NNE
Tension**



**Unilateral CE
Deficit**



***Parthipan Siva, Steve Leis, Xiaoguang Chen, Jim Veldhuis,
Caleb Horst, Denis Viens, Richard Benko
Jen Sweny, Fatima Kakal, Wayne Brodland, Robin Sambrook, Abby Li***

