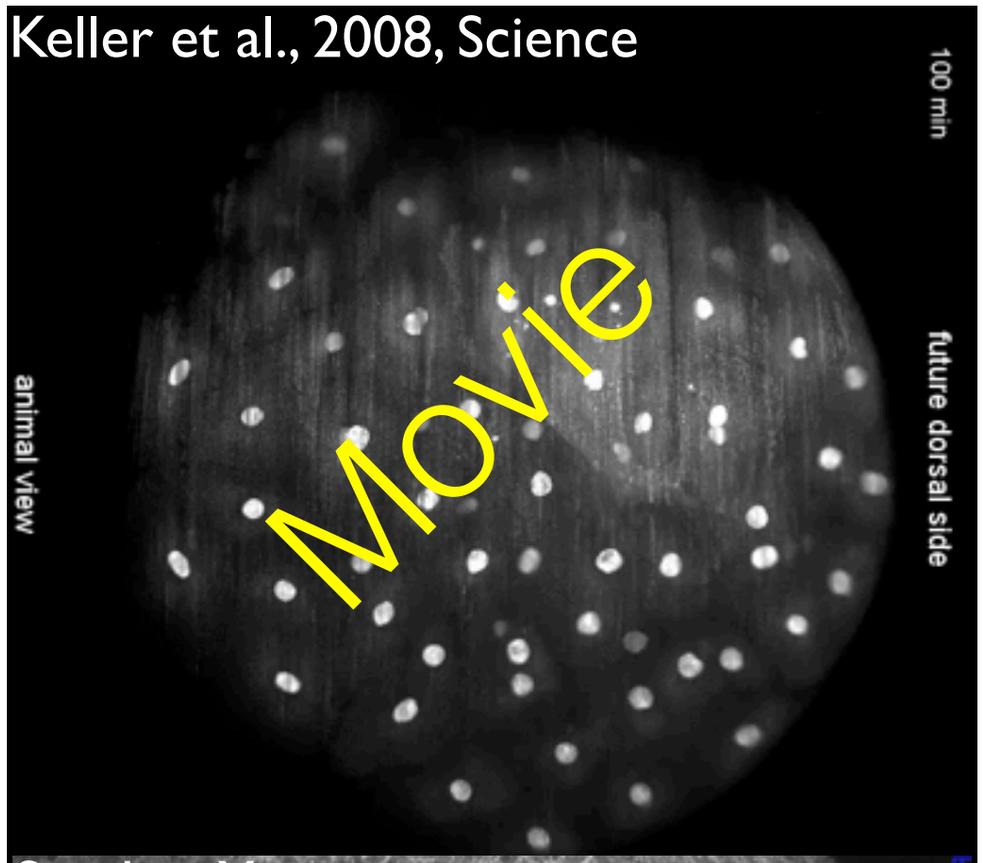
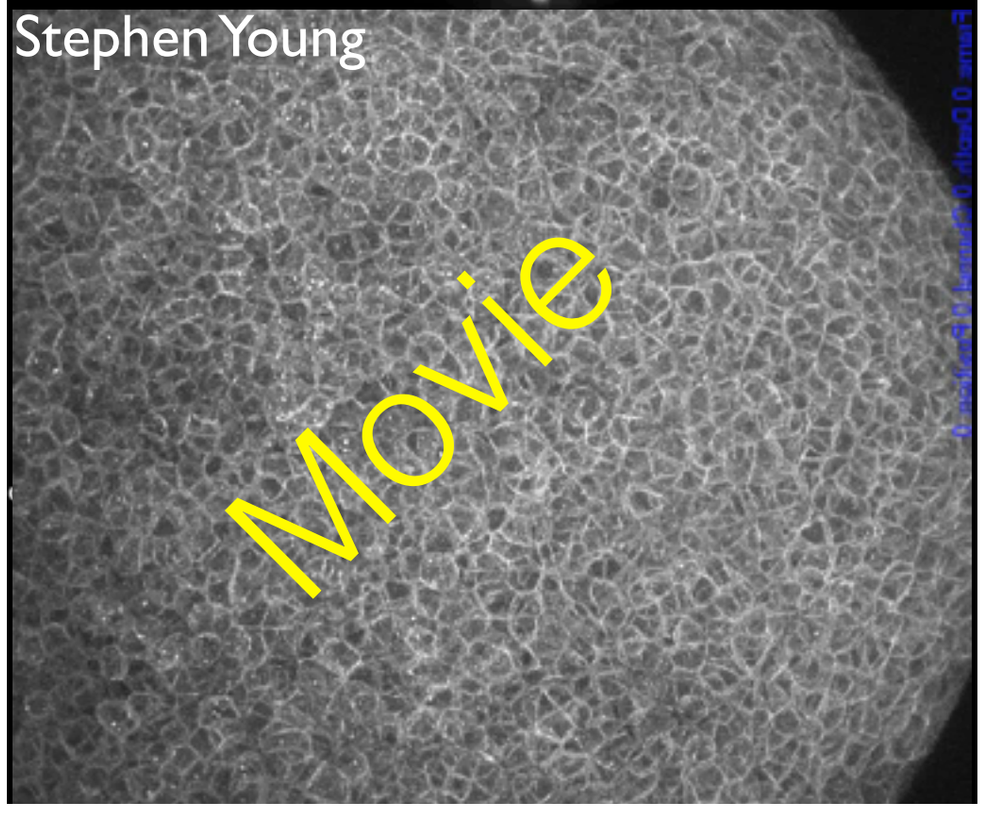
# Big data solutions to dynamic imaging

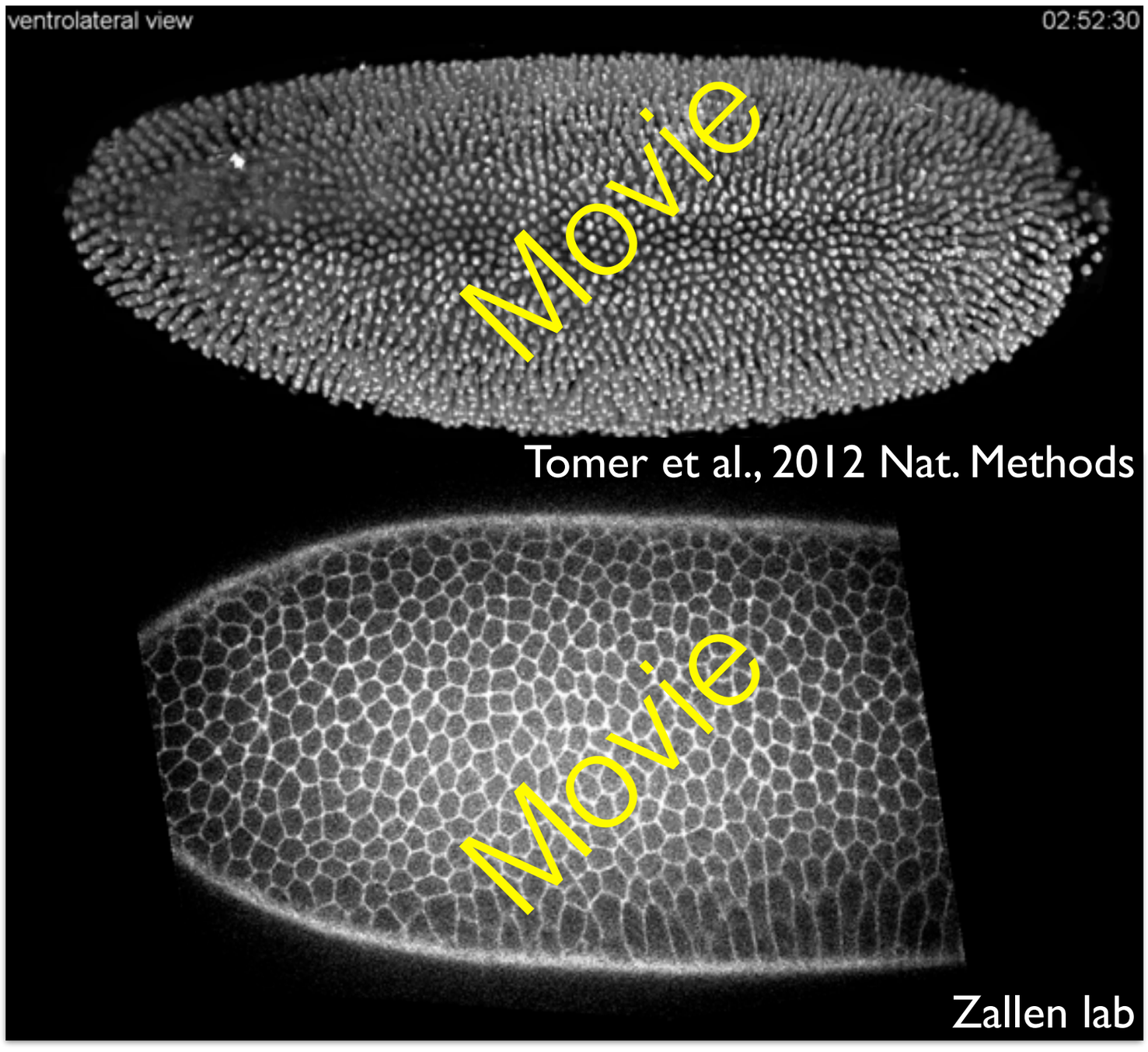
Keller et al., 2008, Science



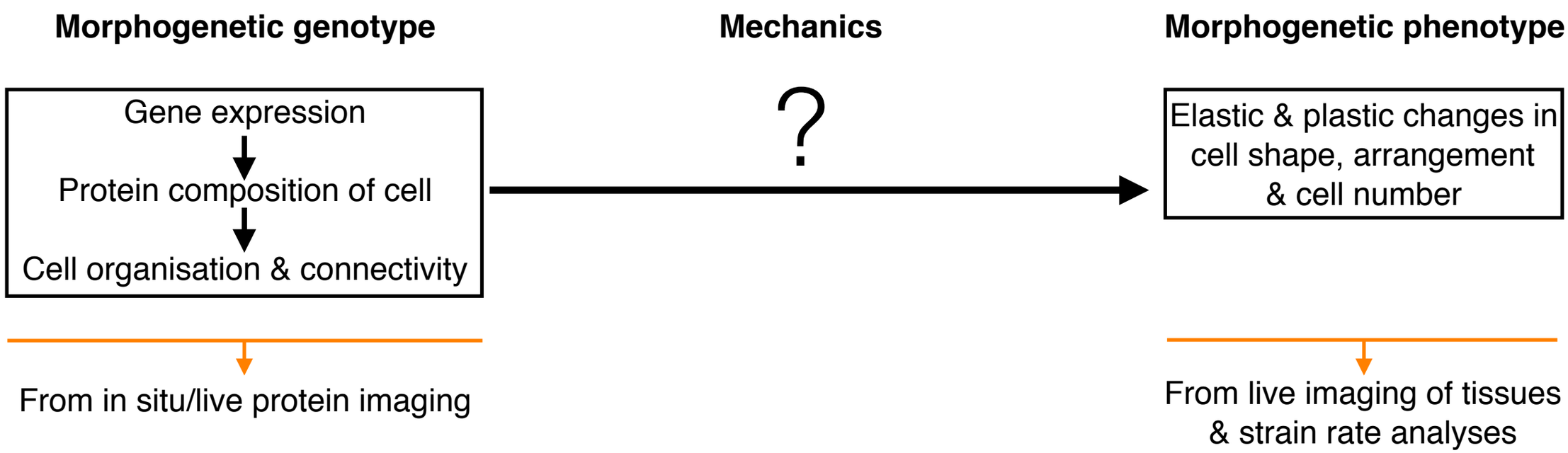

Stephen Young




Guy Blanchard



# Mechanics




Normal development…

Cancer!

Biomaterials etc.

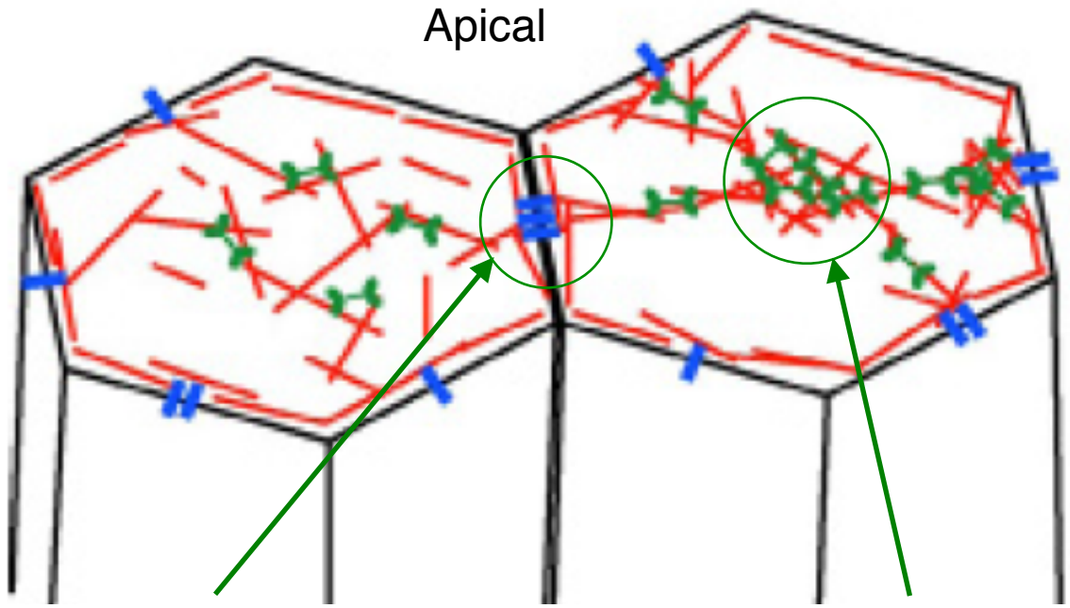
LETTER

doi:10.1038/nature14329

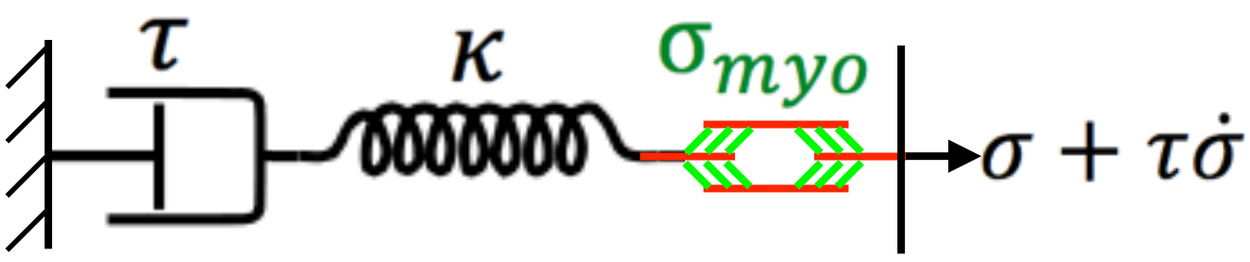
## Mechanical induction of the tumorigenic β-catenin pathway by tumour growth pressure

María Elena Fernández-Sánchez[1]*, Sandrine Barbier[1]*, Joanne Whitehead[1], Gaëlle Béalle[2], Aude Michel[2], Heldmuth Latorre-Ossa[3], Colette Rey[4], Laura Fouassier[4], Audrey Claperon[4], Laura Brullé[5], Elodie Girard[6], Nicolas Servant[6], Thomas Rio-Frio[7], Hélène Marie[8], Sylviane Lesieur[8], Chantal Housset[4], Jean-Luc Gennisson[3], Mickaël Tanter[3], Christine Ménager[2], Silvia Fre[9], Sylvie Robine[10] & Emmanuel Farge[1]

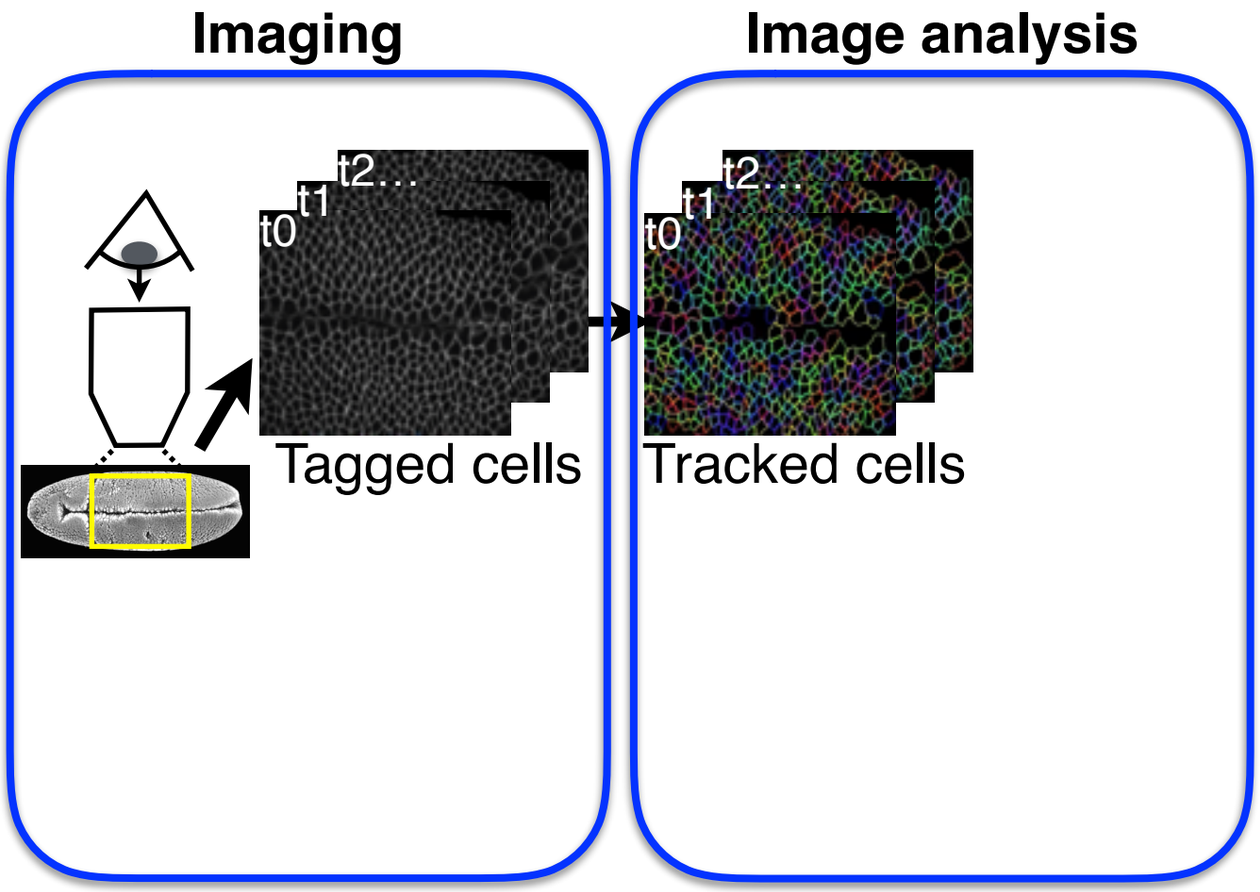
# Actomyosin cortex




$$\sigma + \tau\dot{\sigma} - 2\tau\,\kappa\,\dot{\epsilon} = \sigma_{myo}$$



# Dynamic imaging analysis pipeline

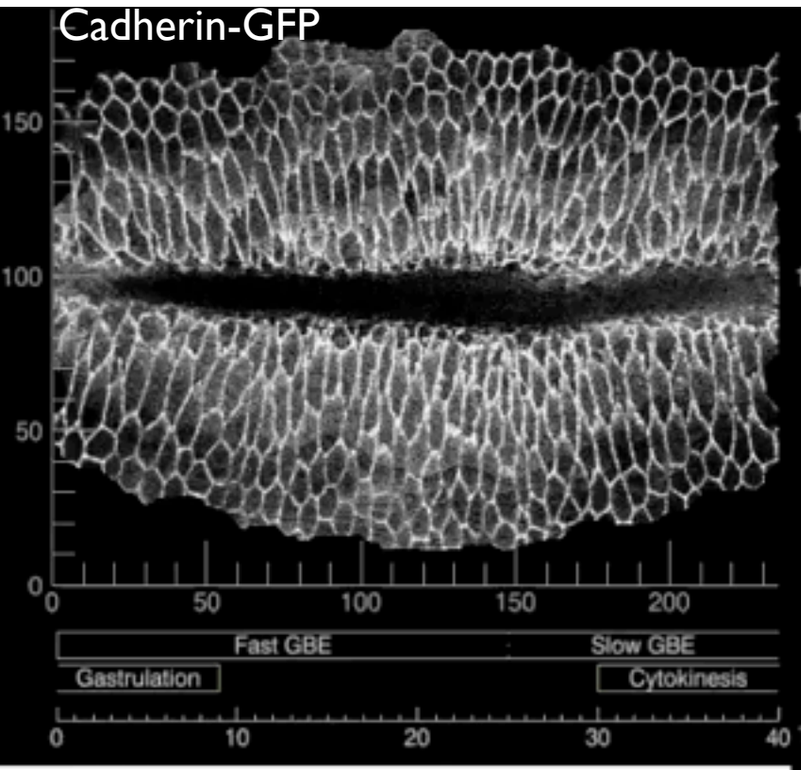


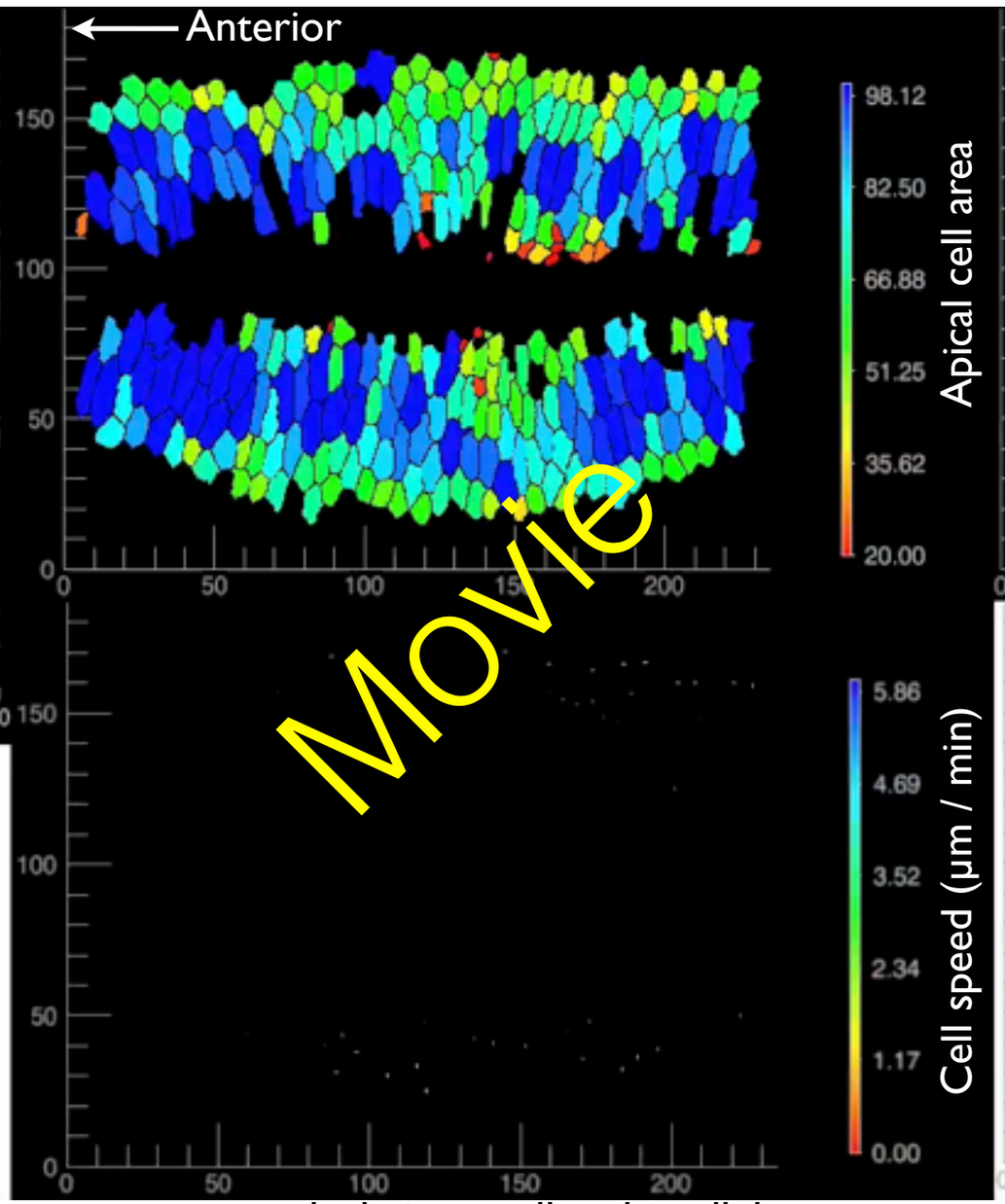
# Automated cell shape tracking

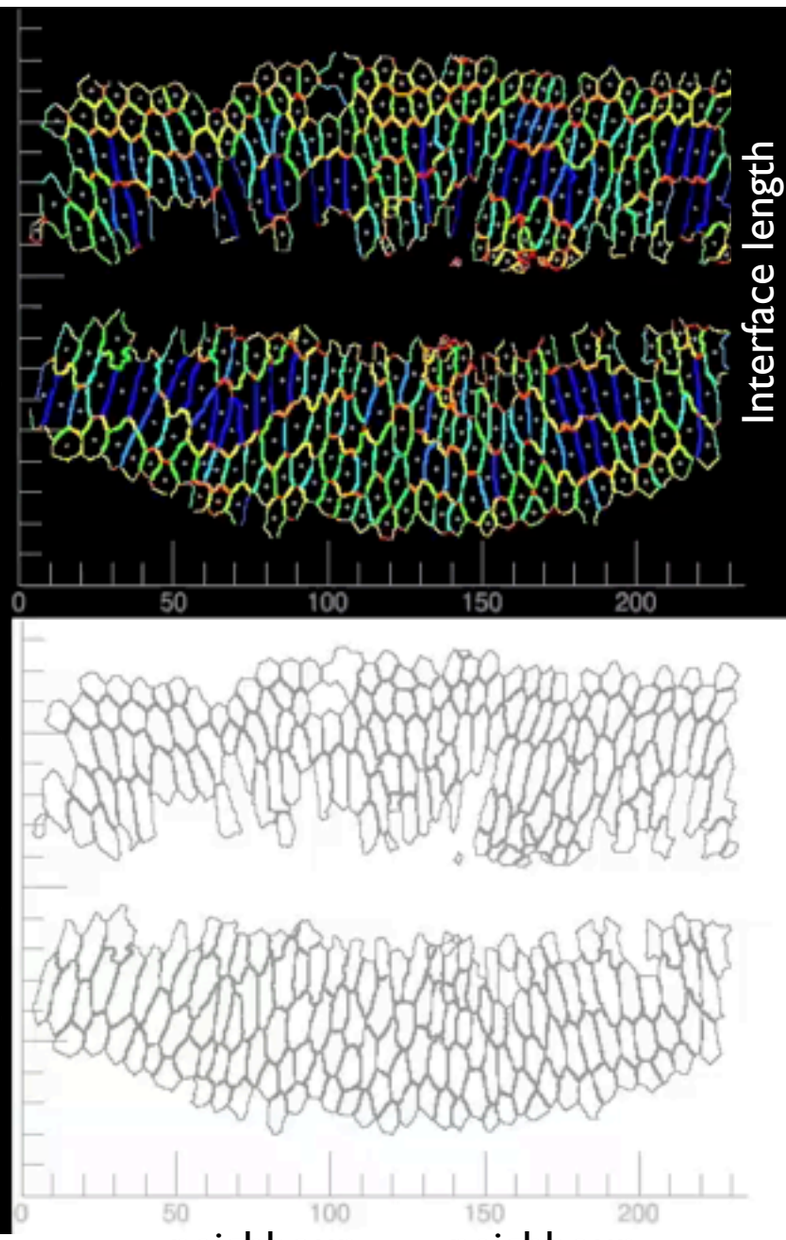
Raw movies
(ventral view of *Drosophila* germ-band, with Lucy Butler & Benedicte Sanson)

Cell properties & dynamics
(location, movement, area/volume, best-fit ellipsoid, elongation ratio...)

Cell-cell interface properties & dynamics
(length, orientation, vertex angles, neighbour connectivity...)

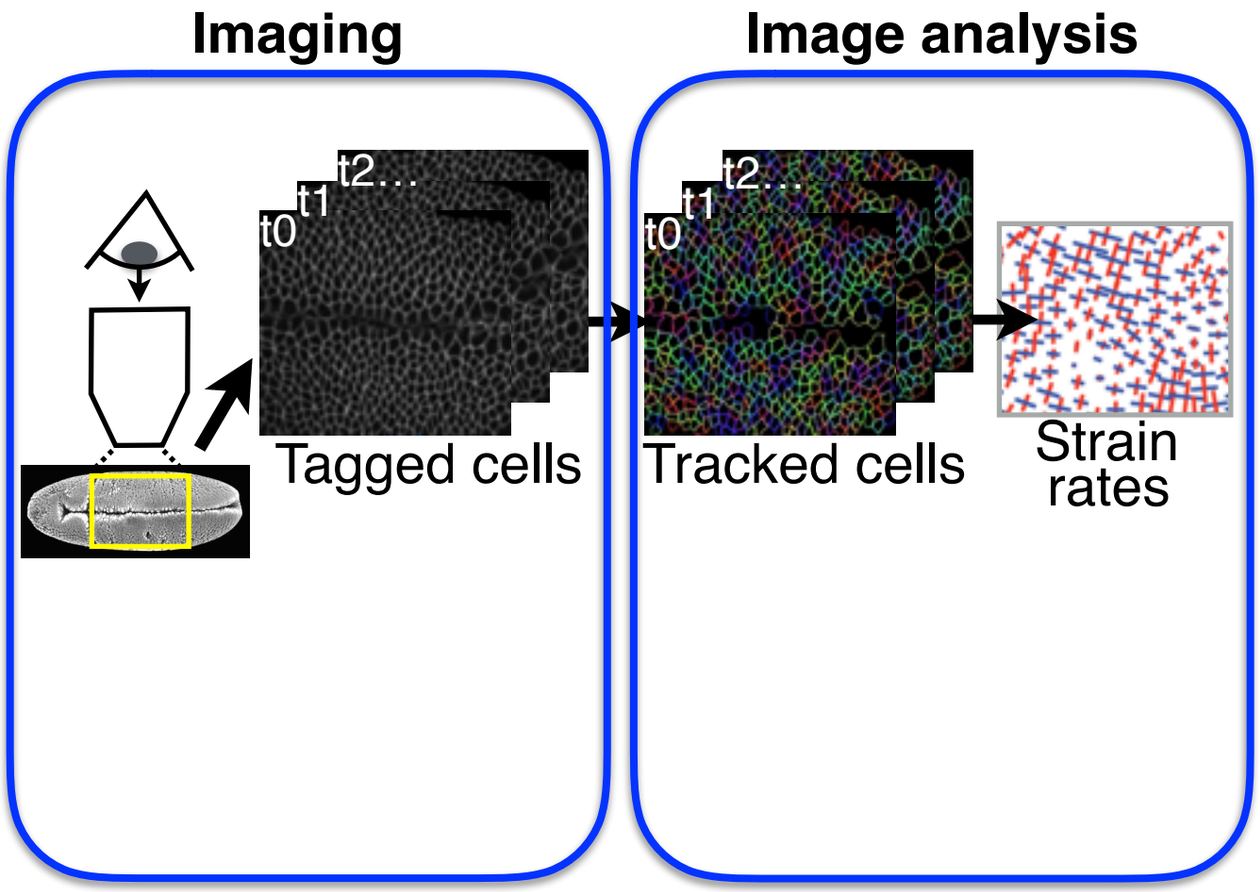


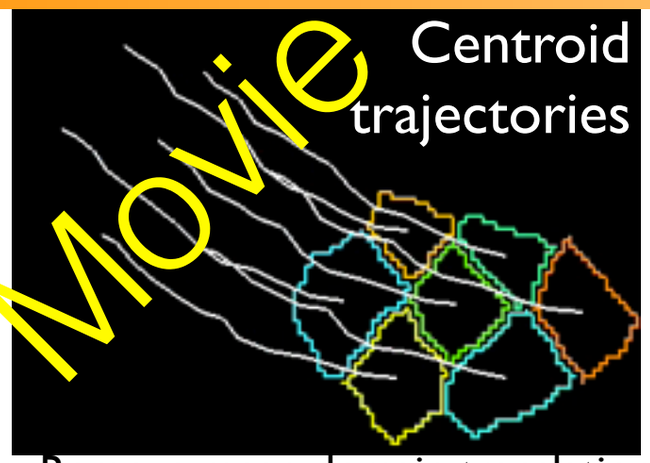




...to calculating small multi-cellular domain deformation rates

# Dynamic imaging analysis pipeline



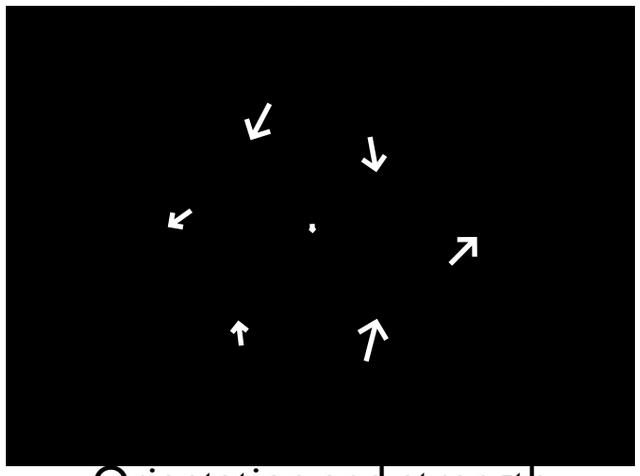
# Tissue tectonics




Remove mean domain translation

↓

Relative cell movements



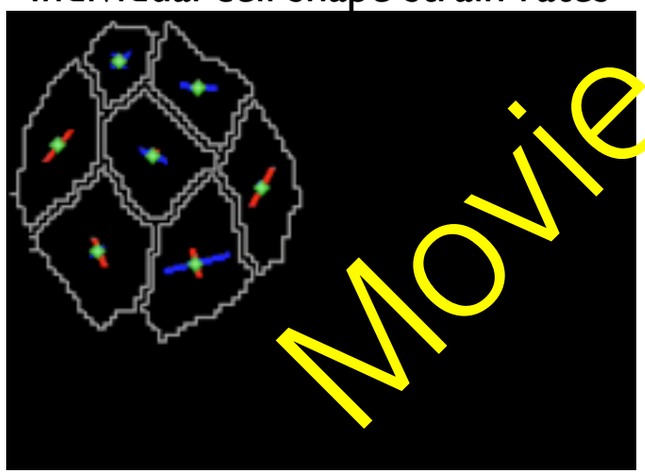
Orientation and strength of greatest deformation

↓


Differentiate w.r.t. time

↓

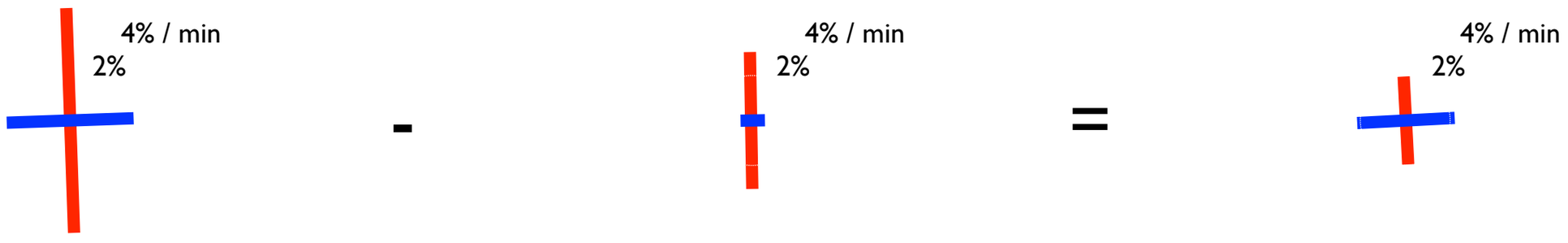
Individual cell shape strain rates




Domain average

↓

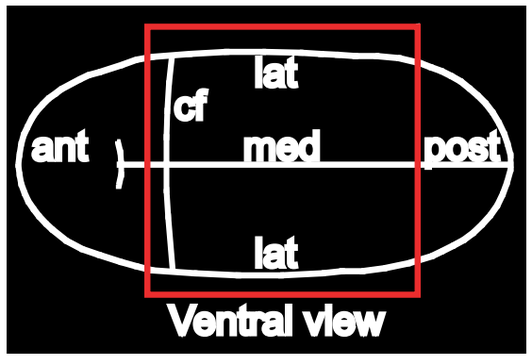
Size change
- expansion
- contraction




| Tissue (total) strain rate | - | Cell shape strain rate | = | Intercalation strain rate |
|---|---|---|---|---|

Blanchard, Kabla, … Mahadevan & Adams (2009) *Nat. Methods*

# Small domain strain rates



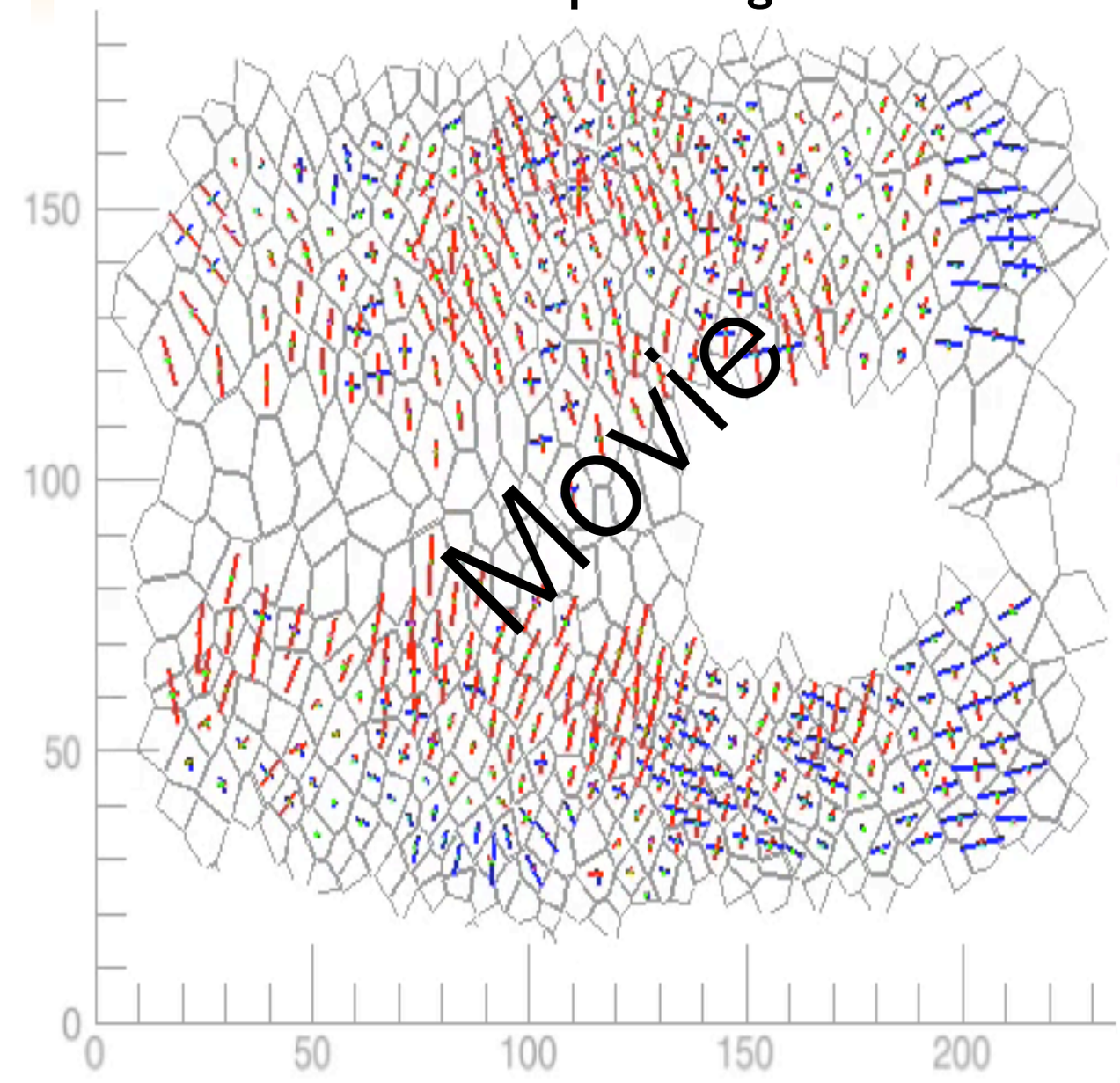

Extension rate

0.04 (pp/min)

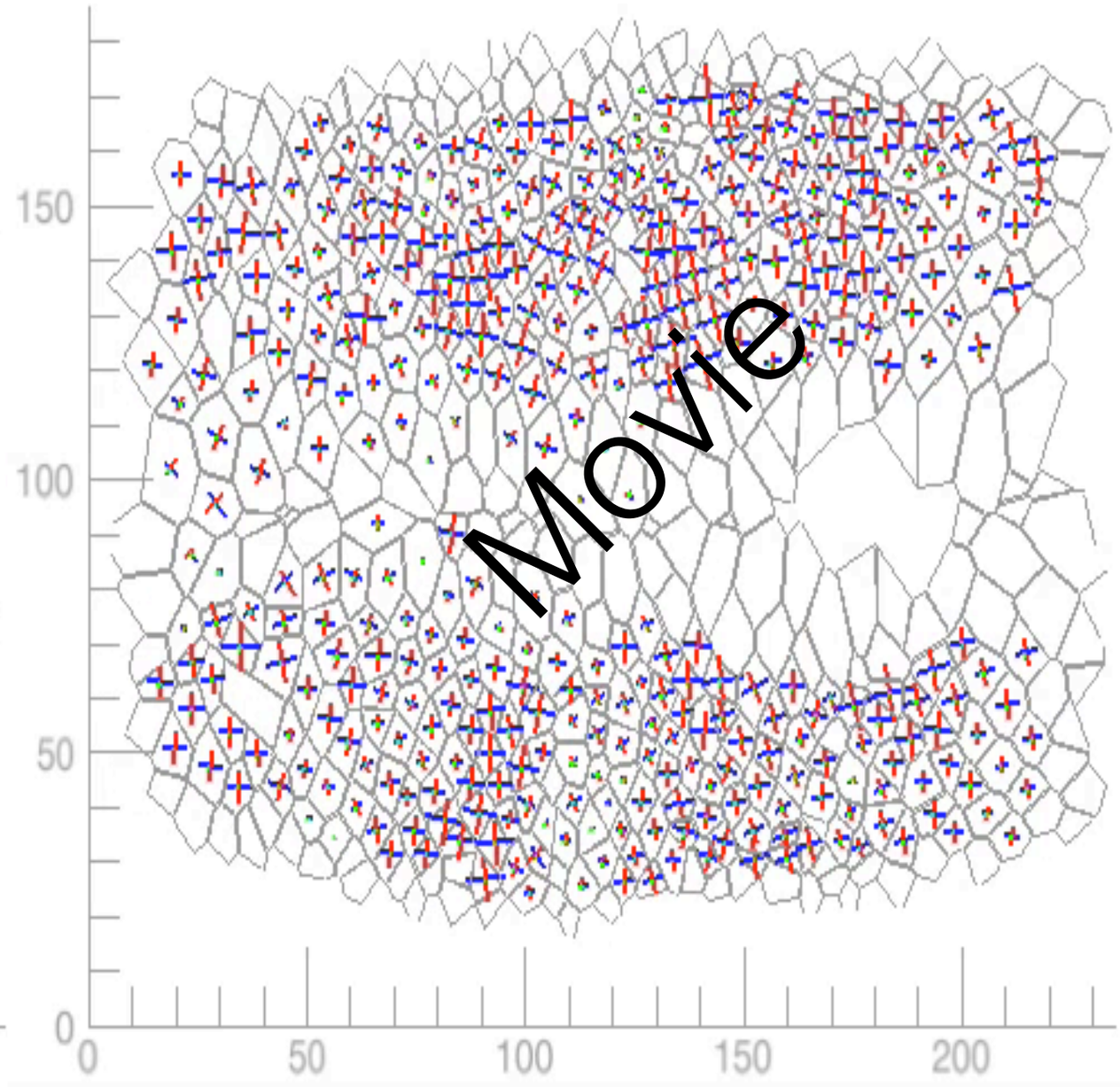
Convergence rate

-0.04 (pp/min)

## Cell shape change

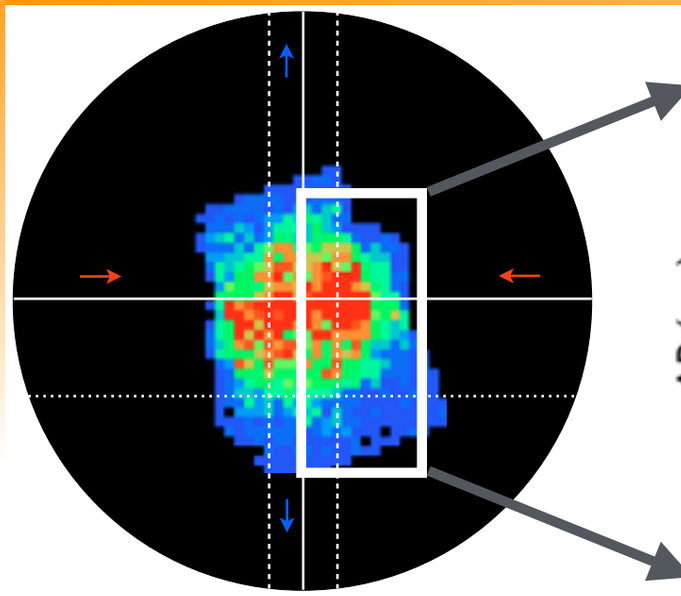


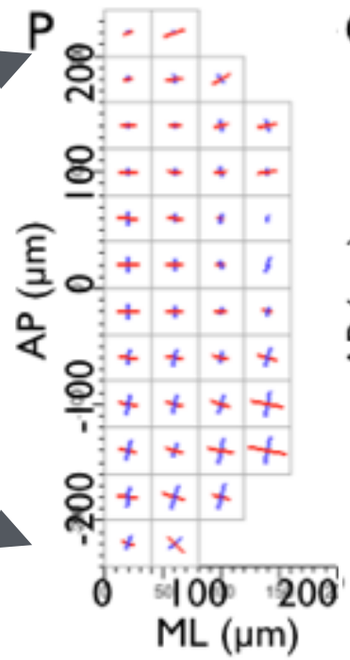

## Cell intercalation

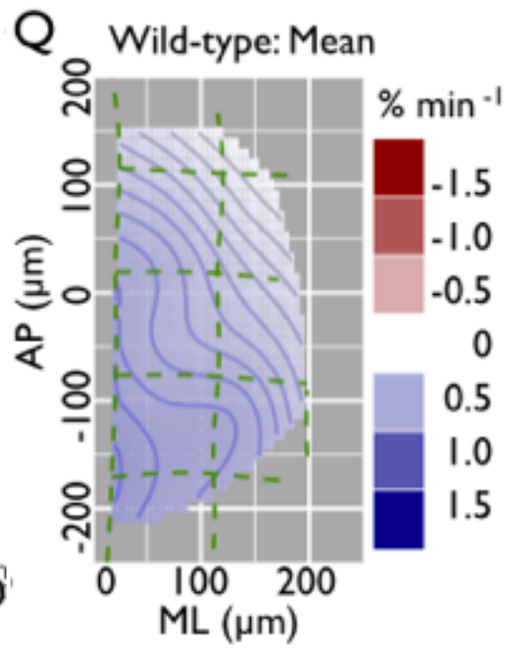


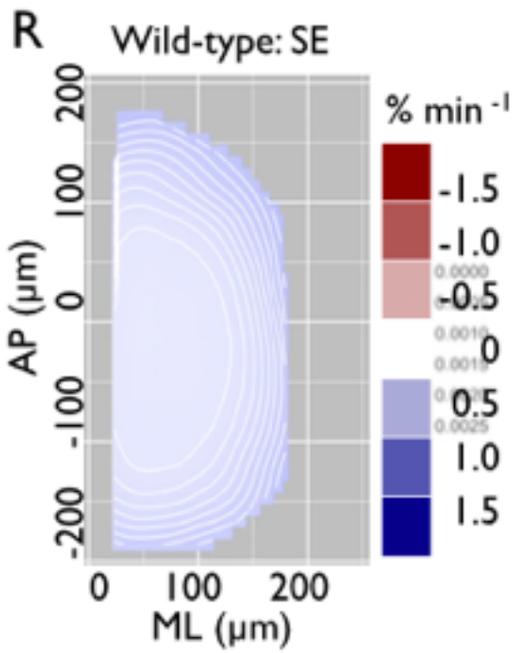

Blanchard, Kabla, … Mahadevan & Adams, 2009, *Nat. Methods*

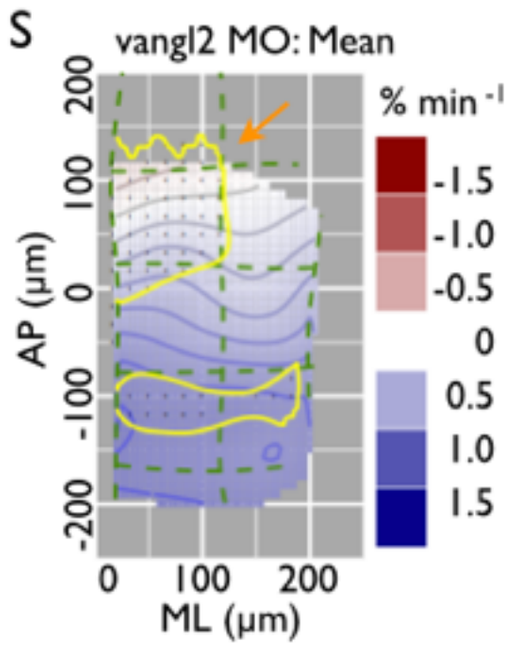
# 3D morphogenetic maps (GAMMs)

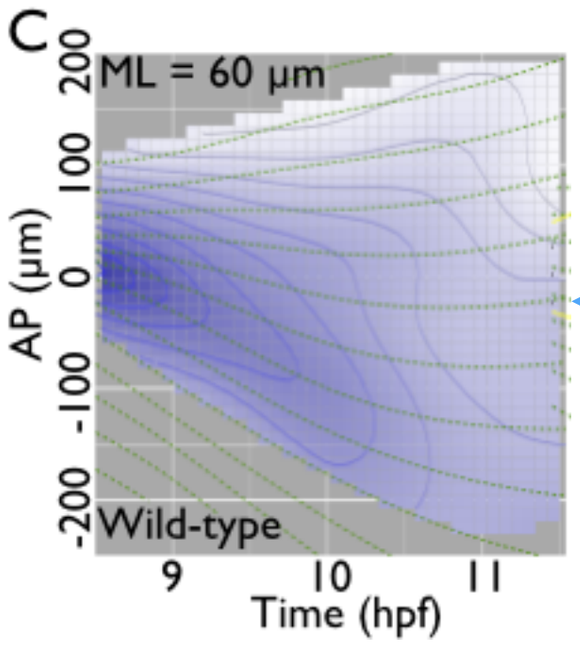


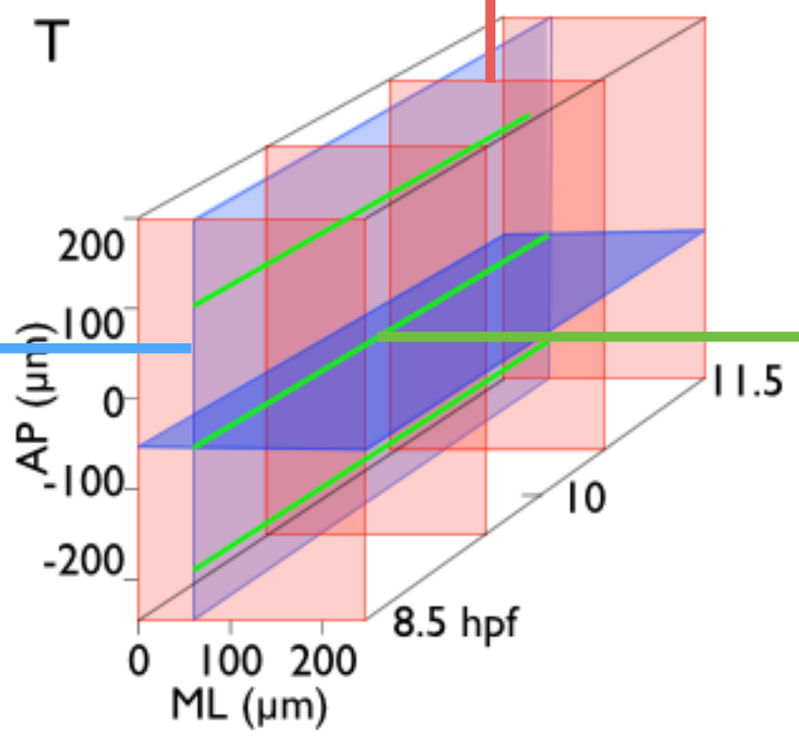


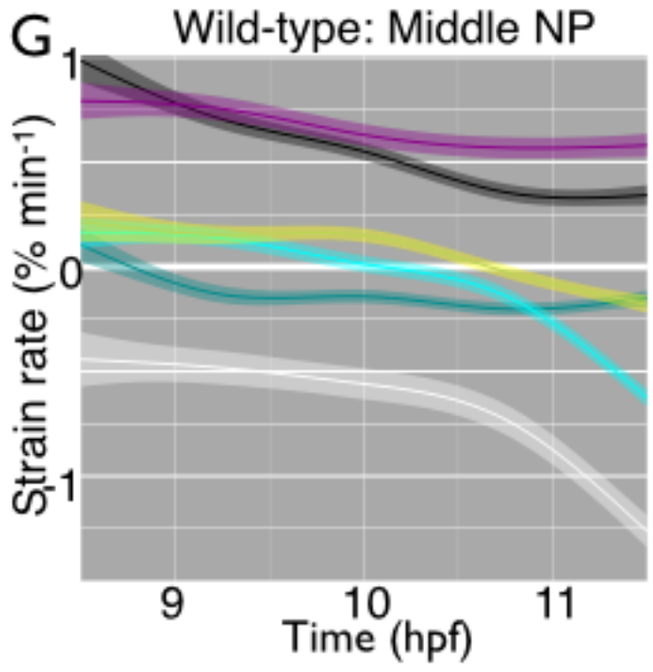



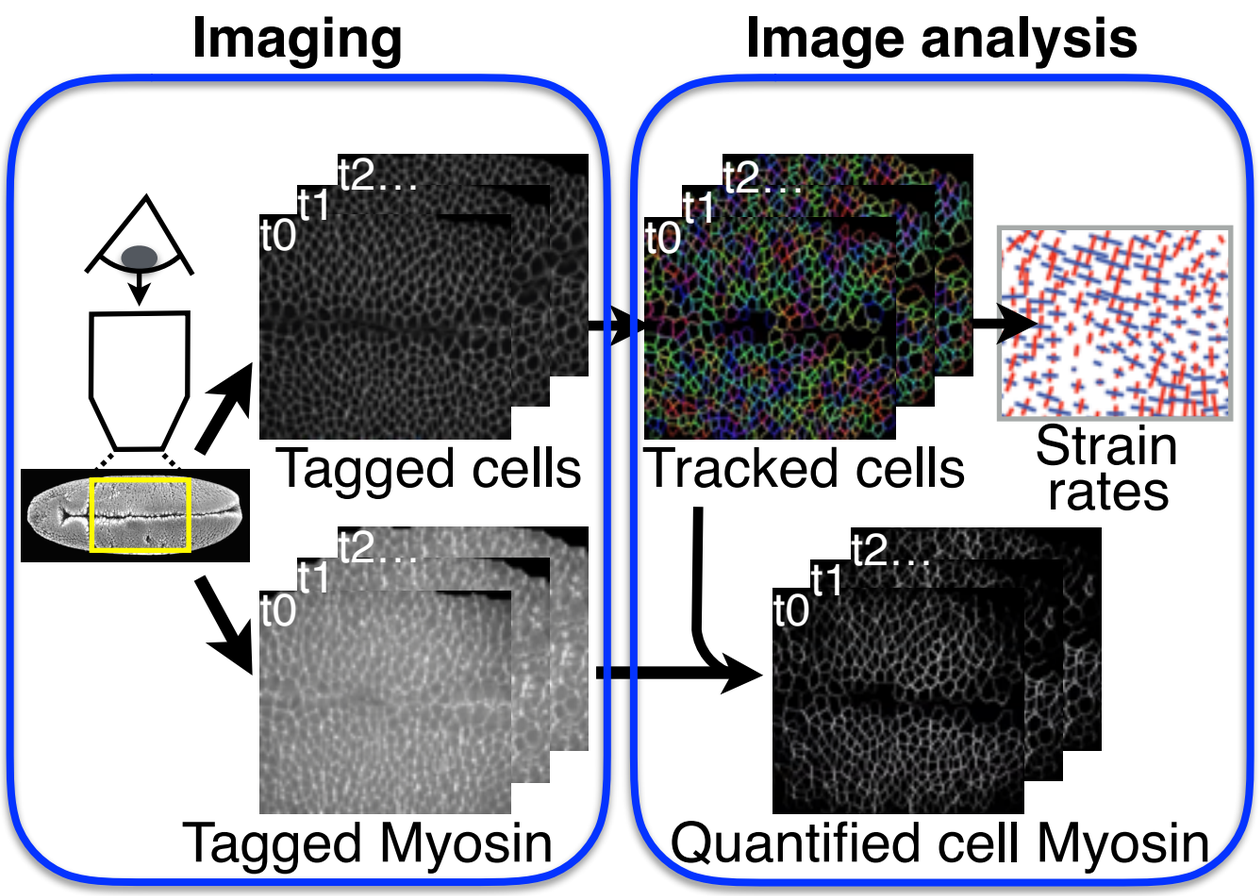




Blanchard*, Schultz*, Kabla & Adams

# Dynamic imaging analysis pipeline



# Dual-labelled *Drosophila* embryos

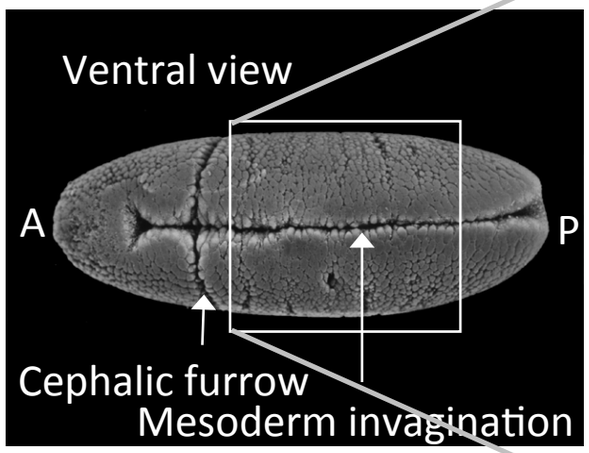
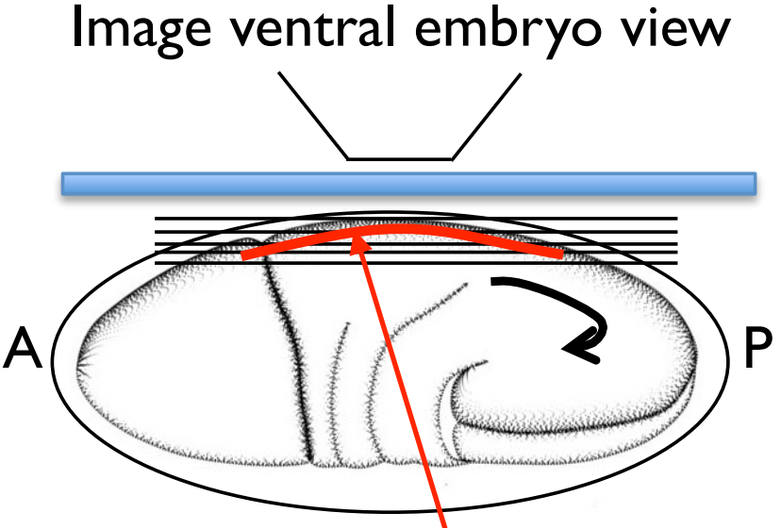


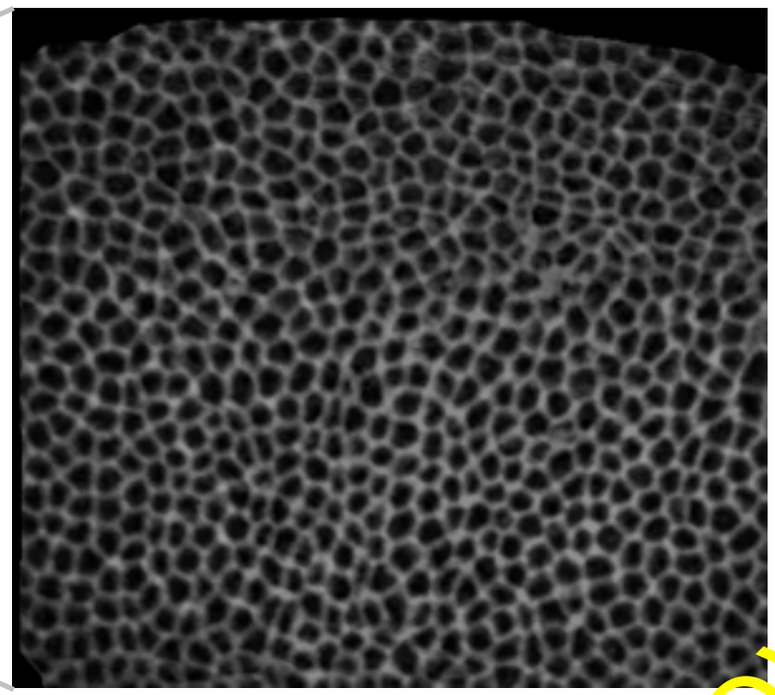

Image ventral embryo view

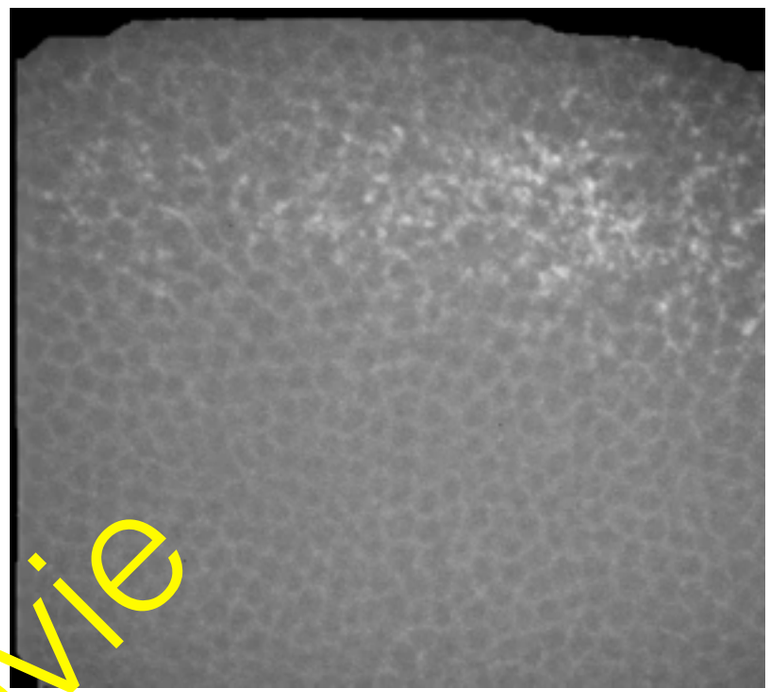


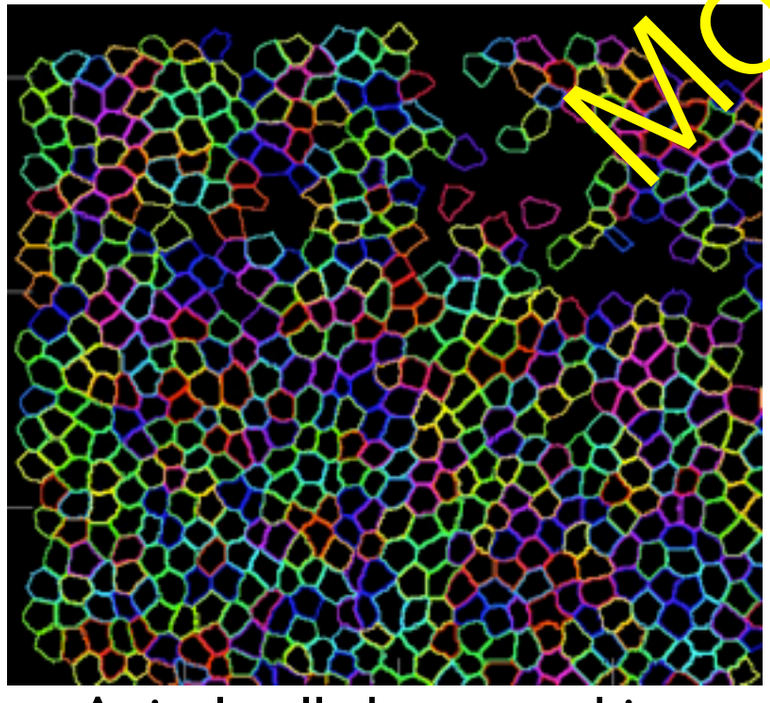

Use curved plane through Adherens Junctions

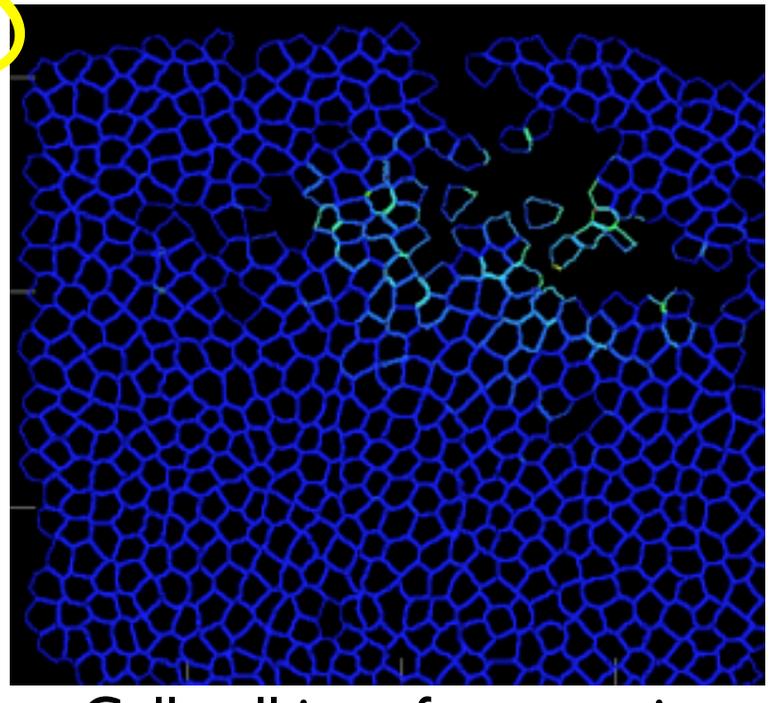
Cell membranes (Gap43-Cherry)

Myosin (Sqh-GFP)









Fluorescence legend

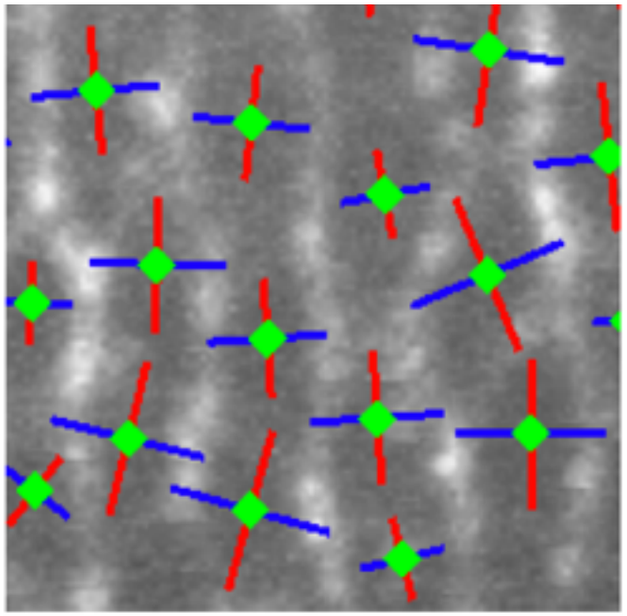
Apical cell shape tracking (random cell colours)

Cell-cell interface myosin fluorescence intensity

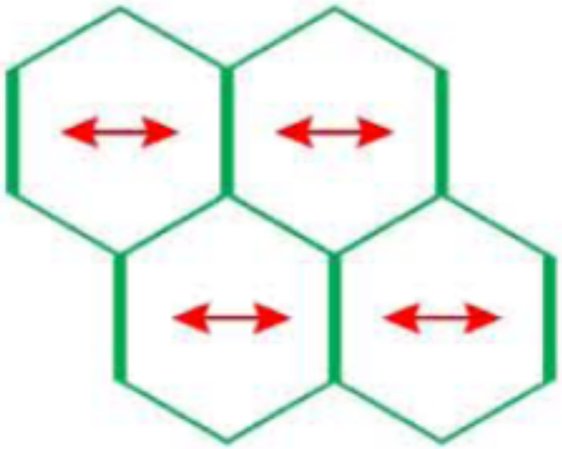
Tetley*, Blanchard*, Fletcher, Adams & Sanson

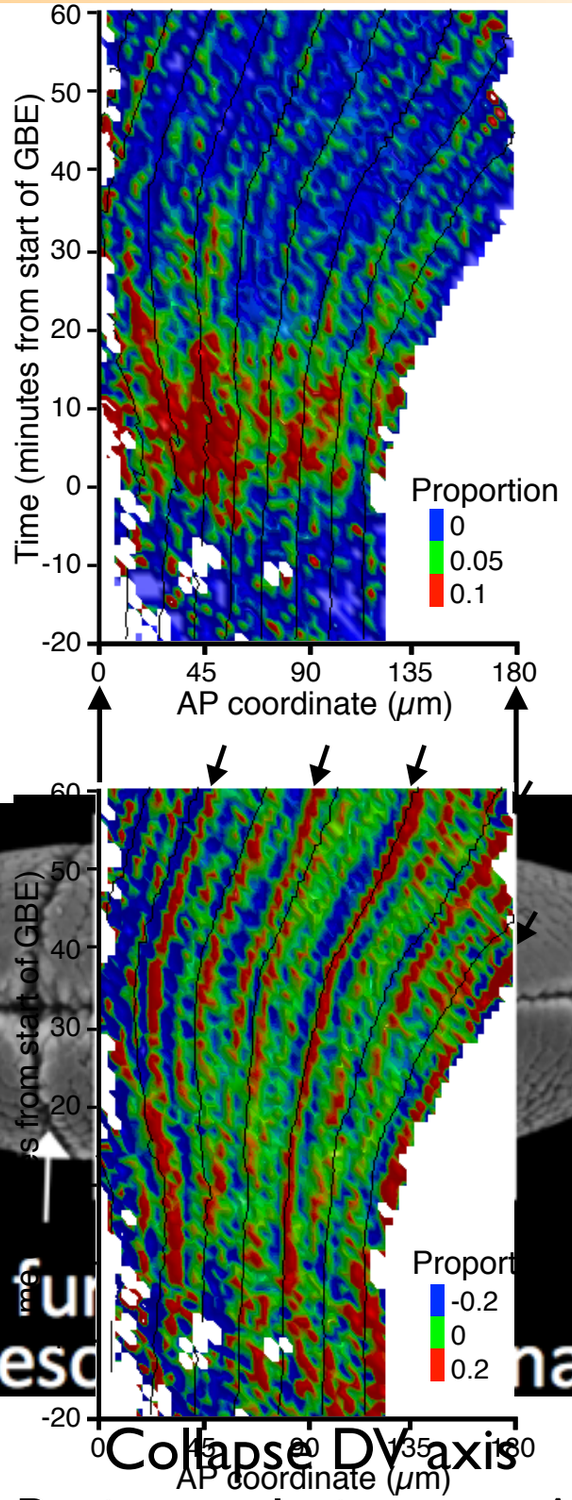
x6 WT embryos

# Myosin polarity patterns across AP axis

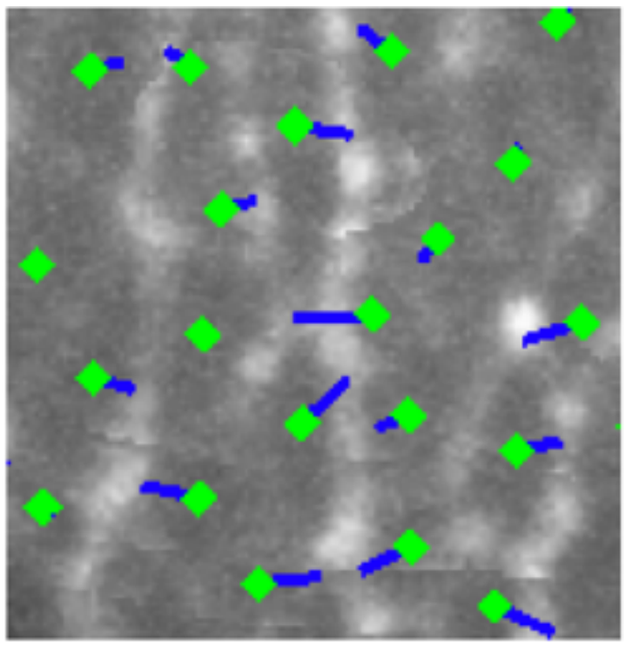


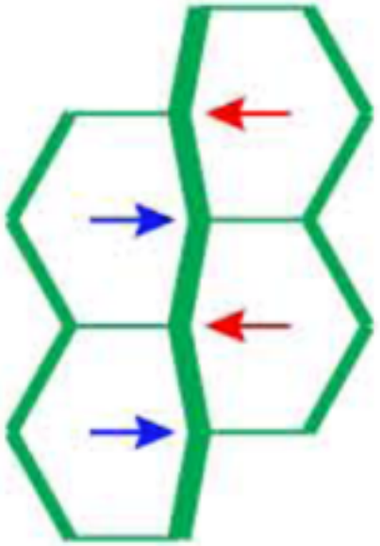
**Bidirectional polarity**






**Unidirectional polarity**





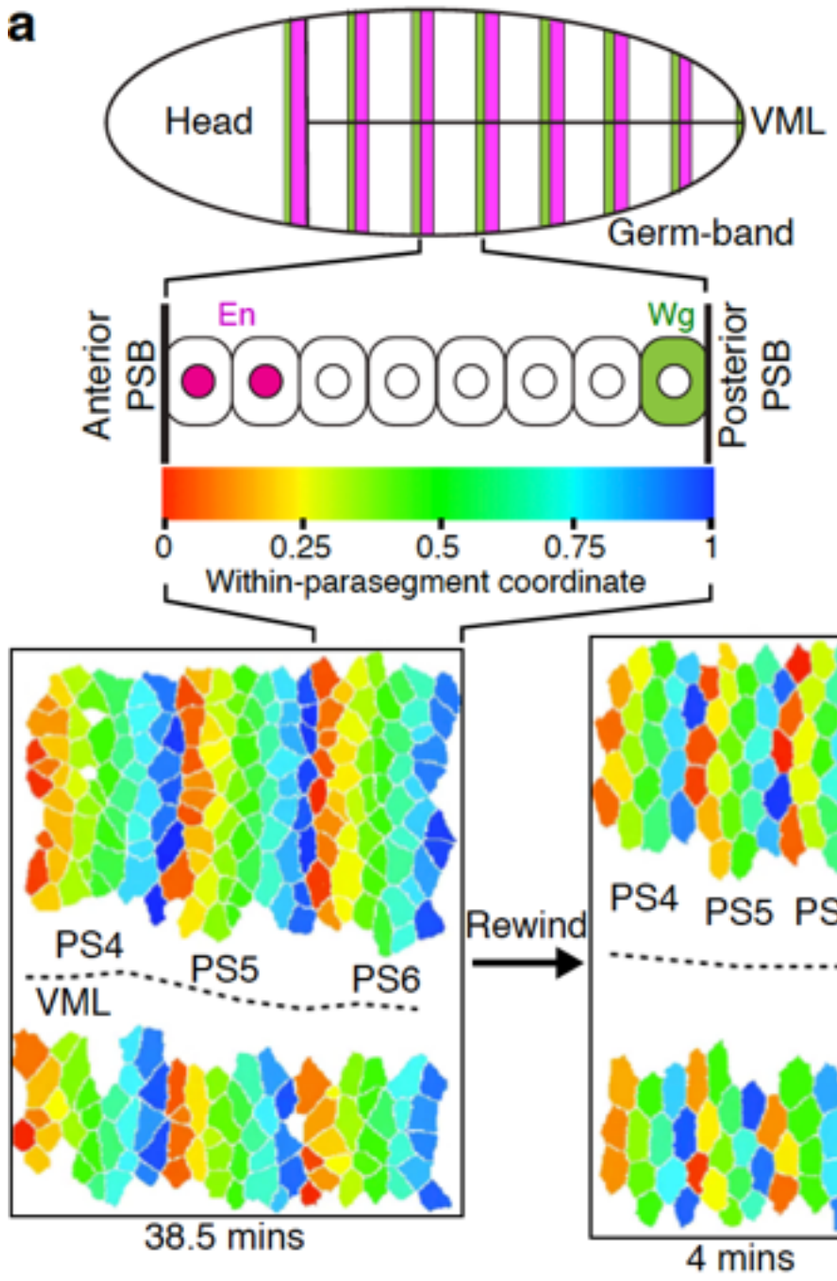


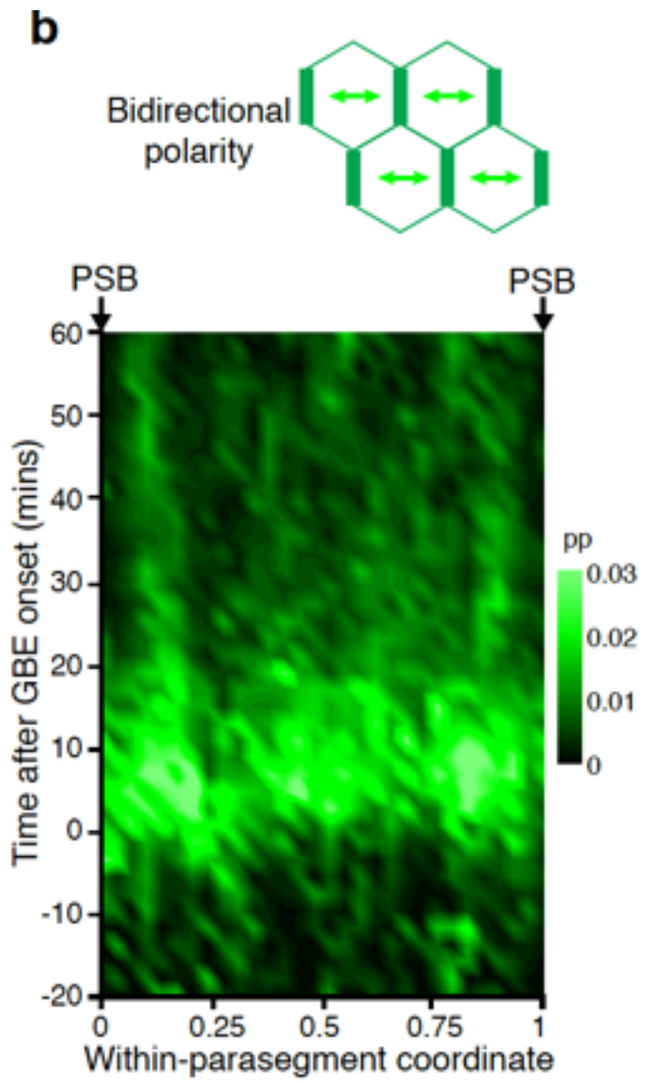

Collapse DV axis

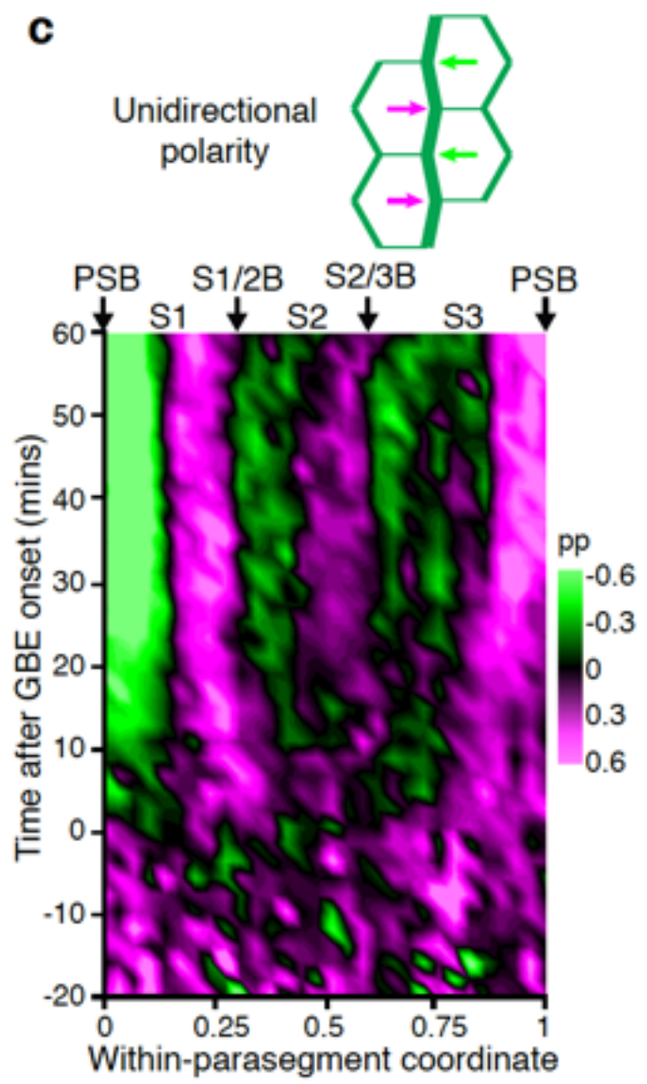
Project polarity onto AP

Single embryos. To find stereotypical behaviour want **standardised AP axis coordinate system.**

# Within-parasegment patterns



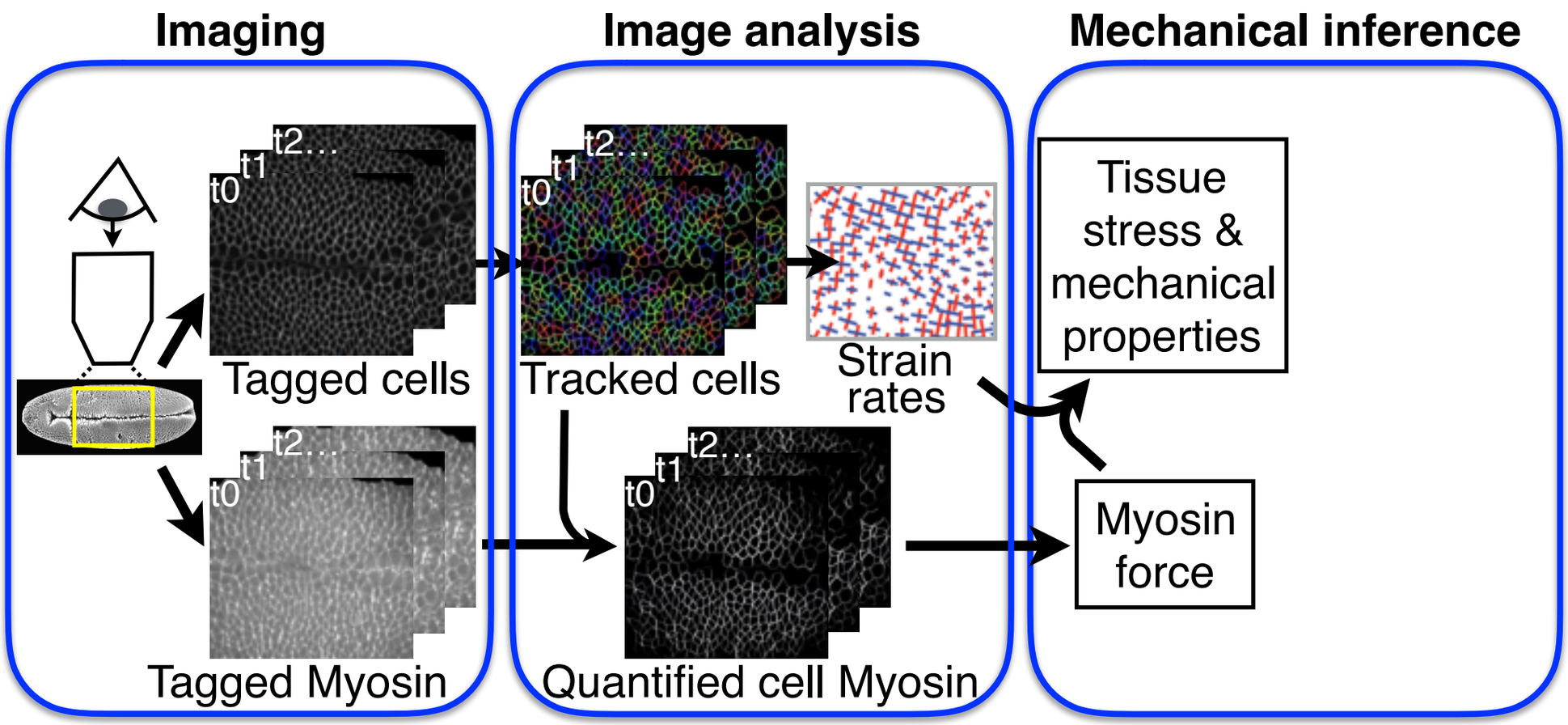




6 embryos, 3-4 parasegments each

**Stereotypical within-parasegmental 'cable' locations**

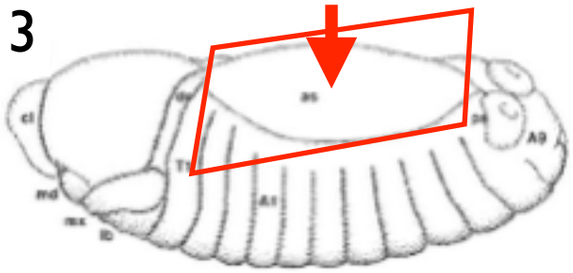
Tetley*, Blanchard*, Fletcher, Adams & Sanson

# Dynamic imaging analysis pipeline

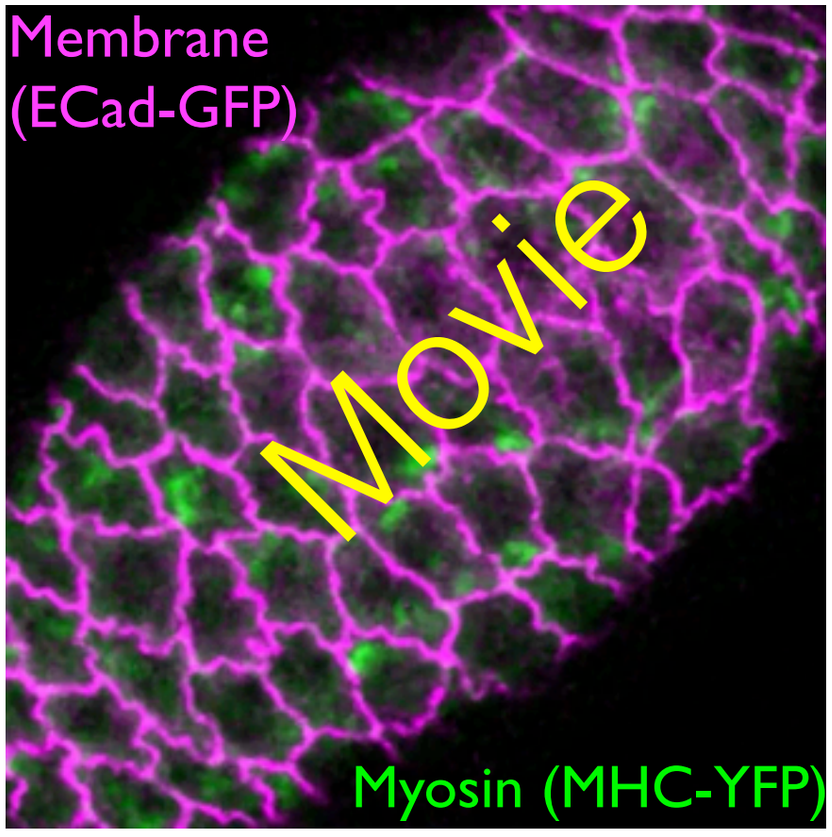


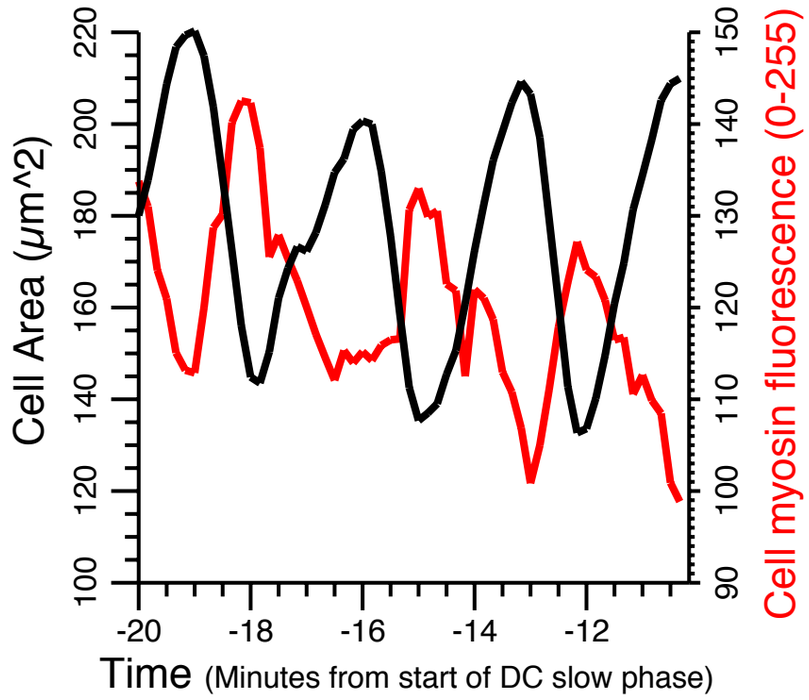
# Myosin motors drive morphogenetic contraction

stage 13

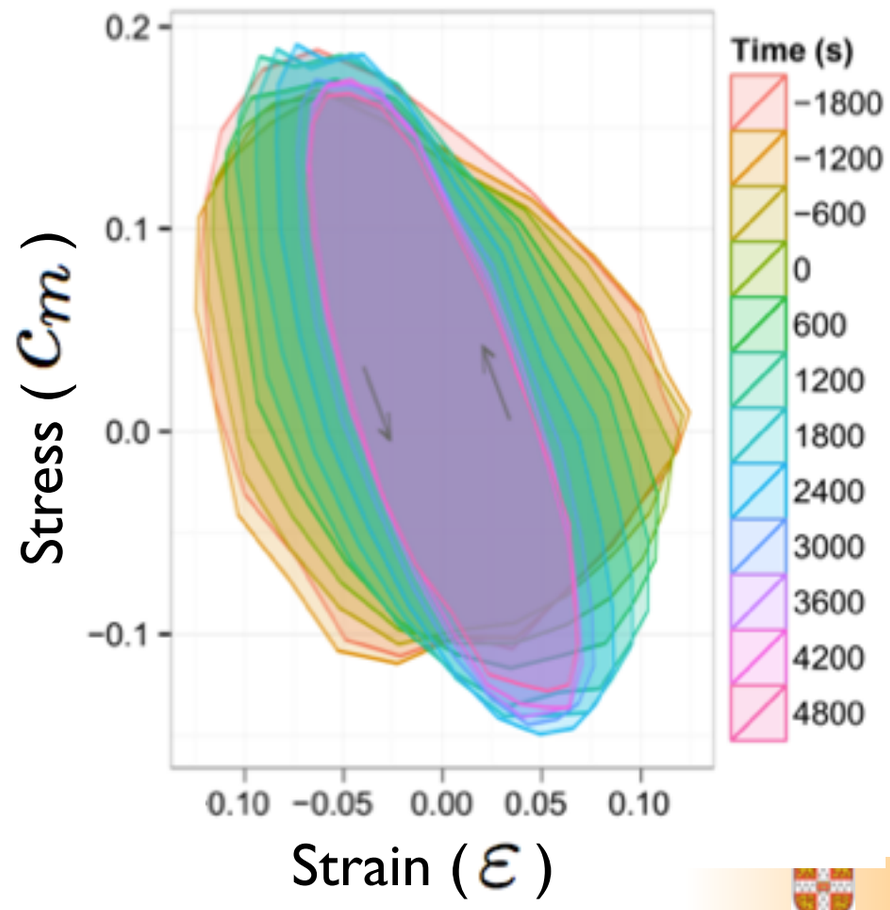


Dorsal view of amnioserosa




$$\sigma + \tau_R \dot{\sigma} = \bar{\tau} \kappa c_m + \tau_R \kappa \dot{\varepsilon}$$




Machado et al., 2015, BMC Biol.

# Emergent physical properties

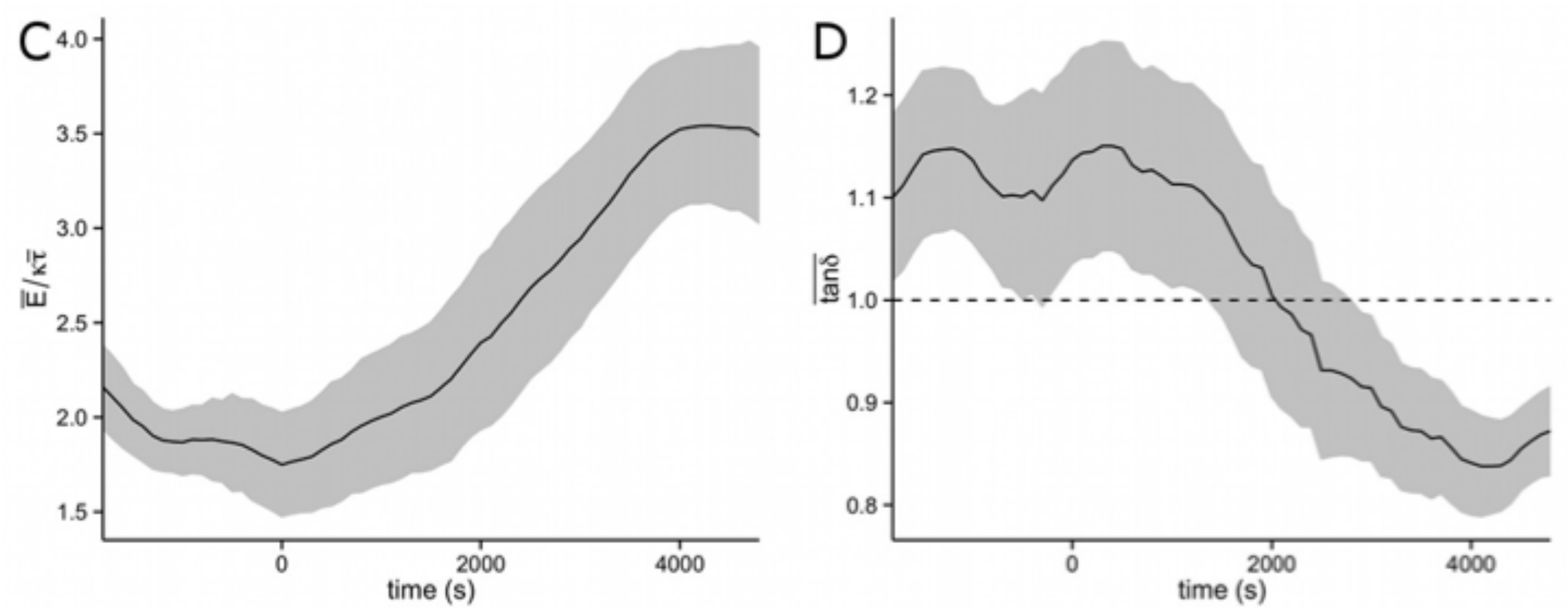
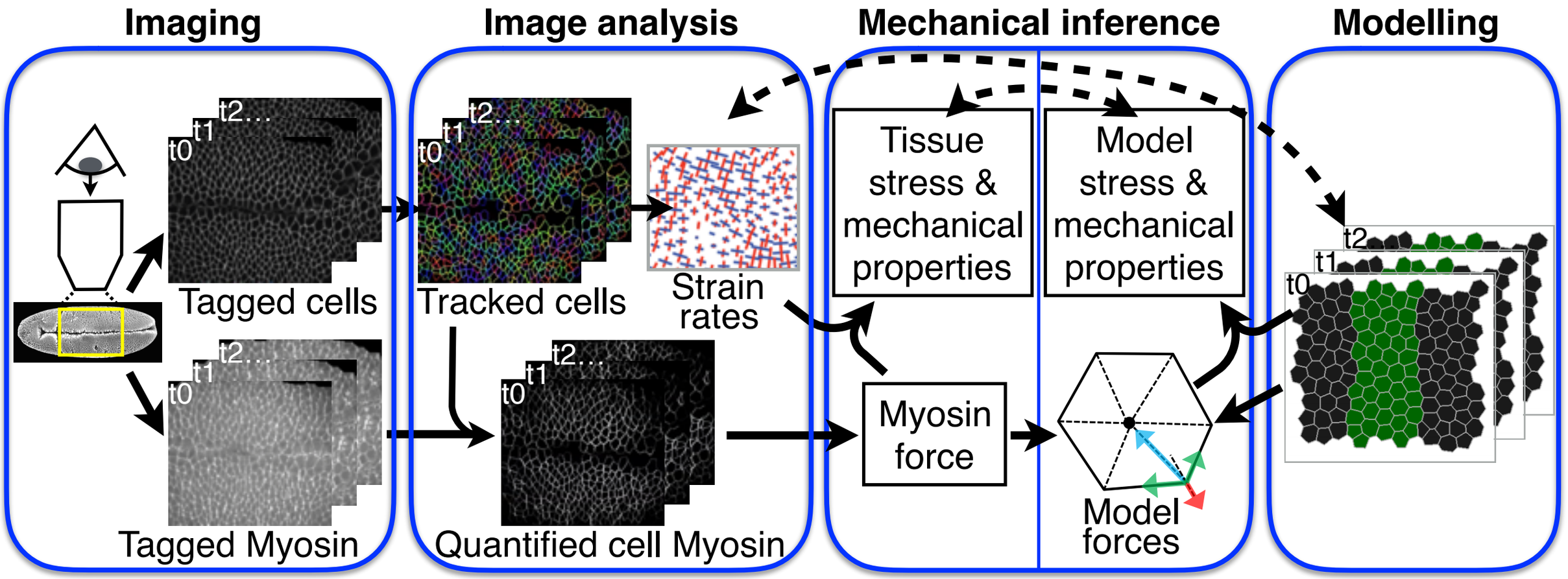



**Table 1 Cell stiffness and estimates of stress and viscosity evolution between slow (stage 13, t $\simeq$ 1000s) and fast (stage 14, t $\simeq$ 4000s) phases of DC ($\pm$ SE).**

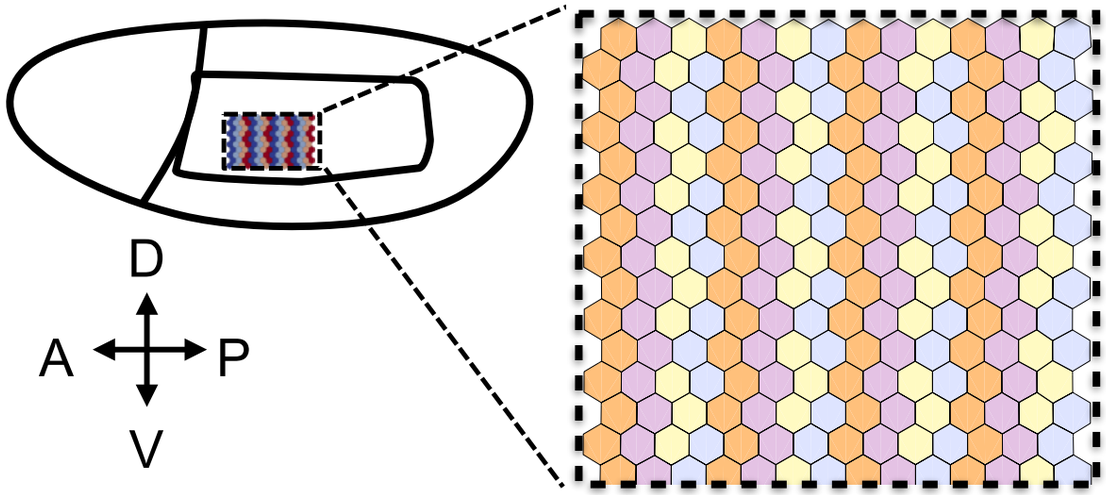
| Cell site | Relative stiffness $E_{14}/E_{13}$ | Relative stress $\sigma_{14}/\sigma_{13}$ | Relative viscosity $\eta_{14}/\eta_{13}$ |
|---|---|---|---|
| medial | $1.76 \pm 0.27$ | $3.99 \pm 1.34$ | $2.17 \pm 0.80$ |

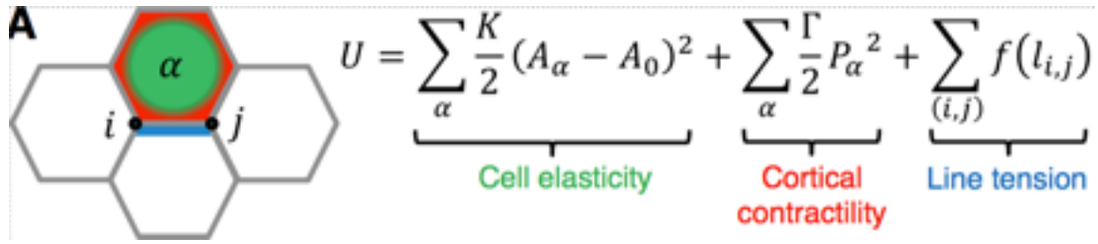
Machado et al., 2015, BMC Biol.

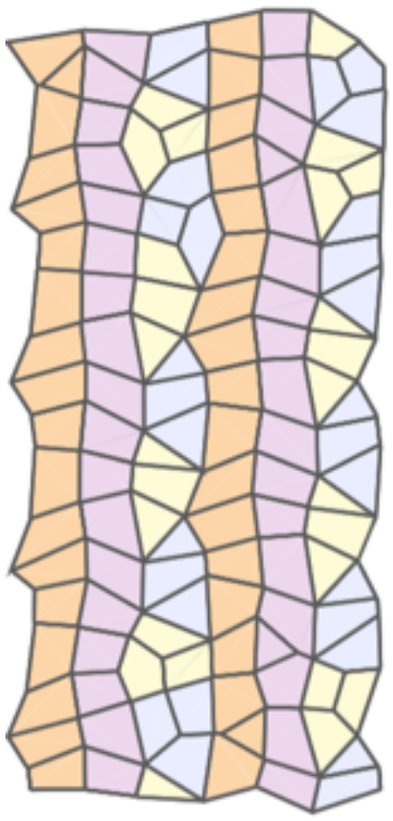
# Dynamic imaging analysis pipeline

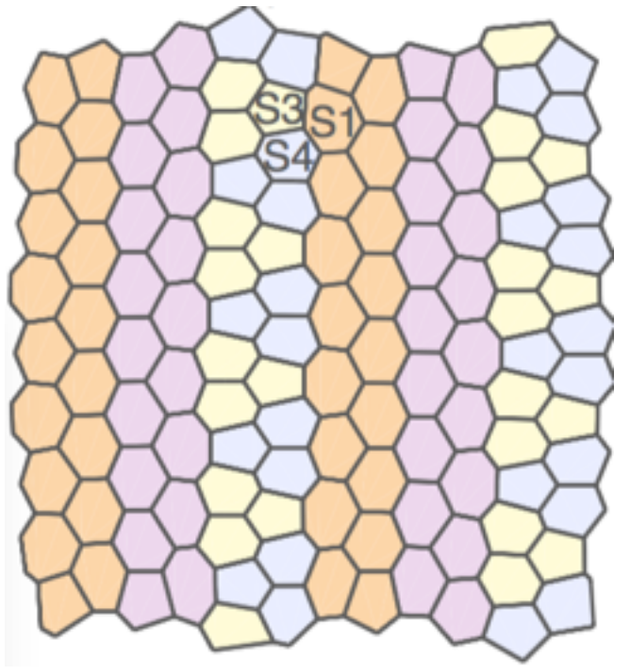


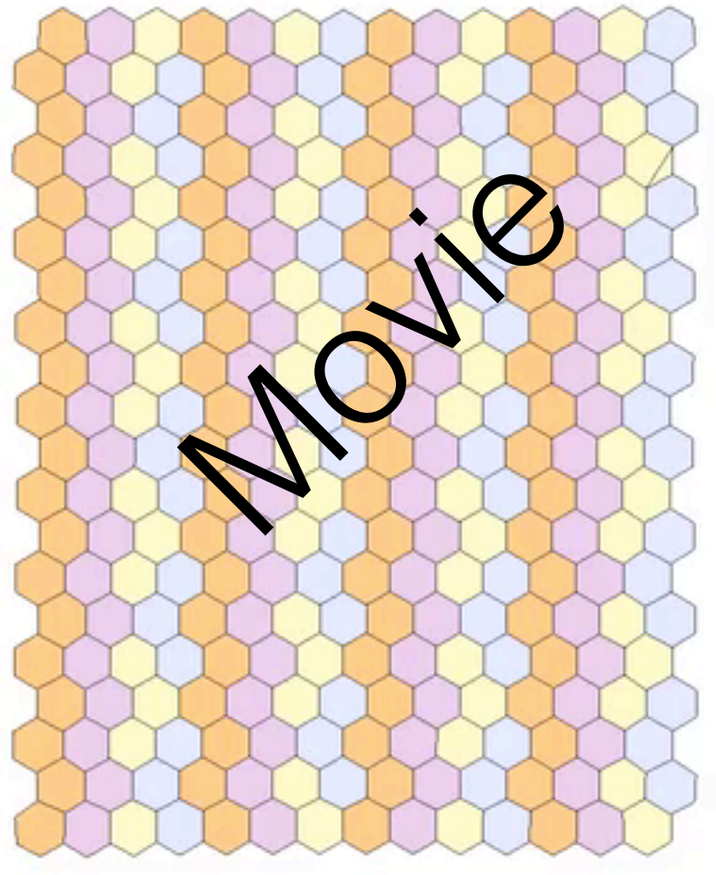
# Vertex-based (mechanical?) simulation



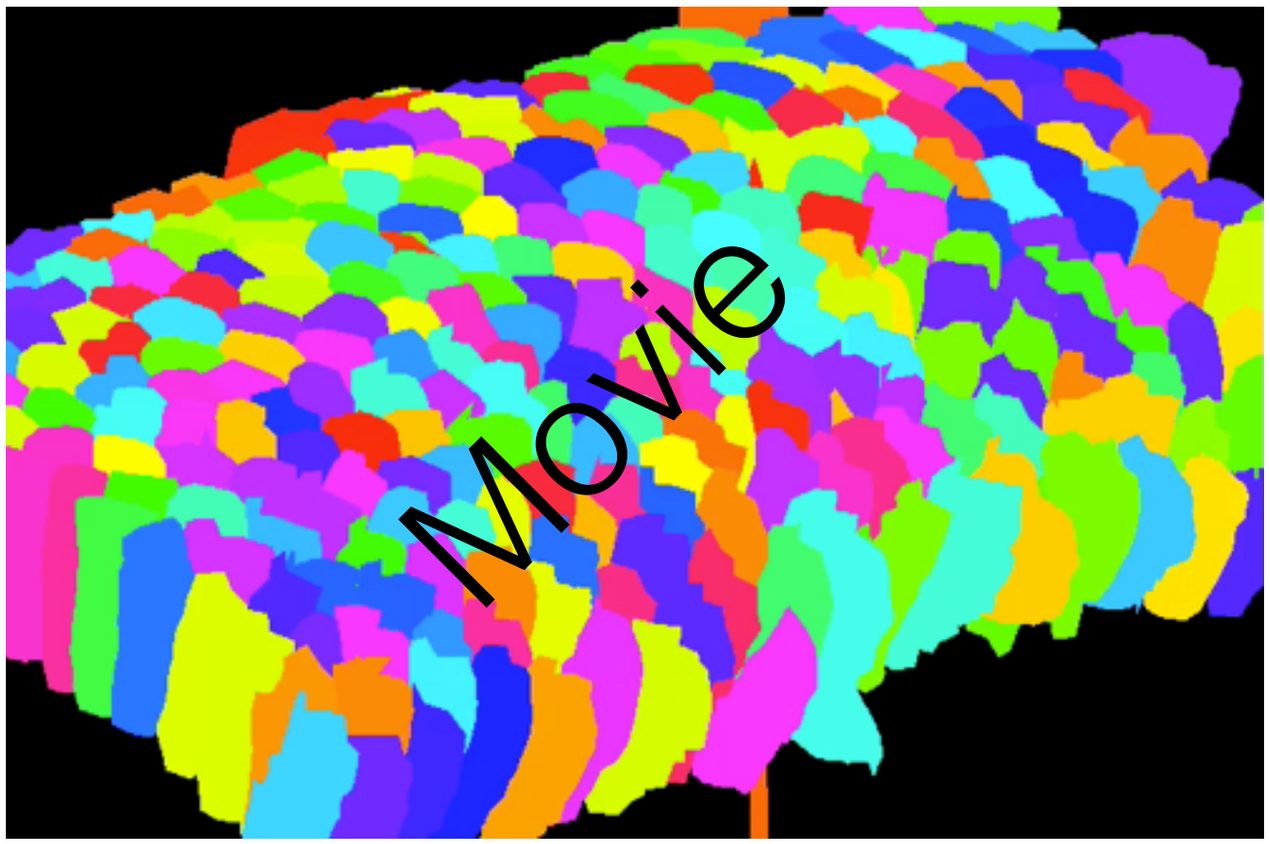



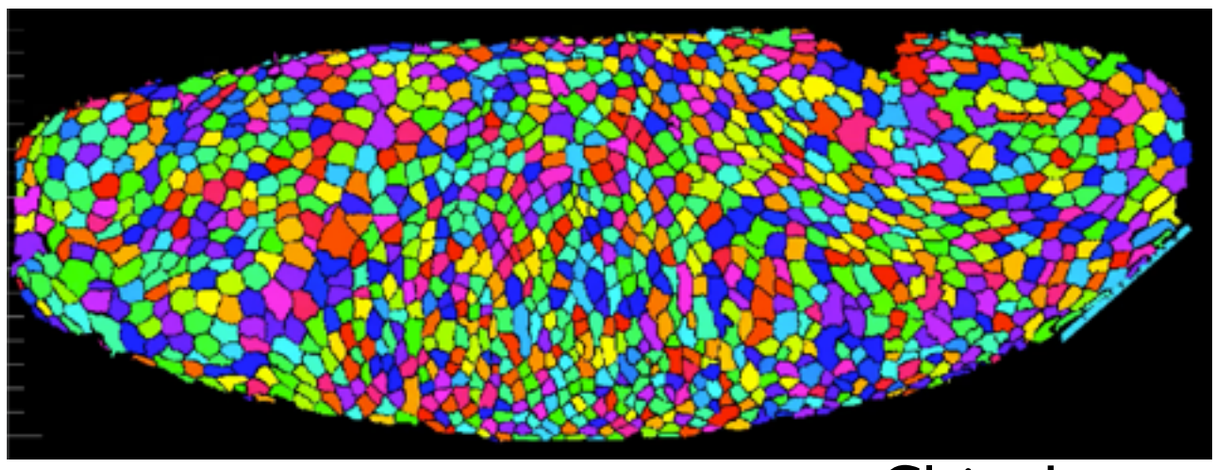


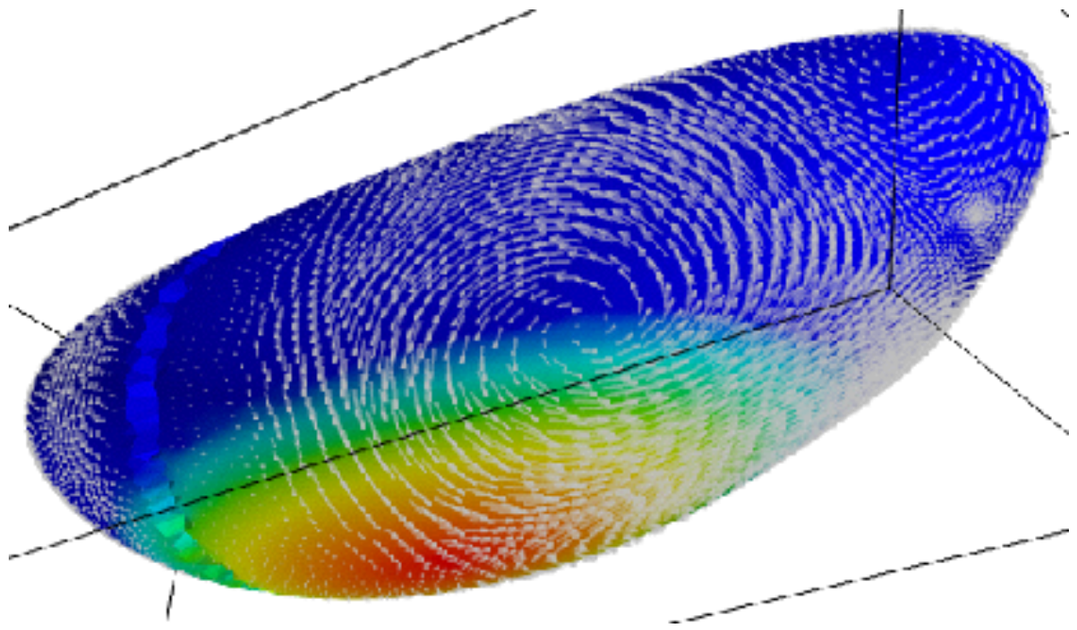

Chaste modelling platform https://chaste.cs.ox.ac.uk, Alex Fletcher (University of Sheffield)

# 3D and *in toto* tracking & modelling



Claire Lye



Jocelyn Etienne, Grenoble


Interface surface area (µm^2)

140

85

30

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