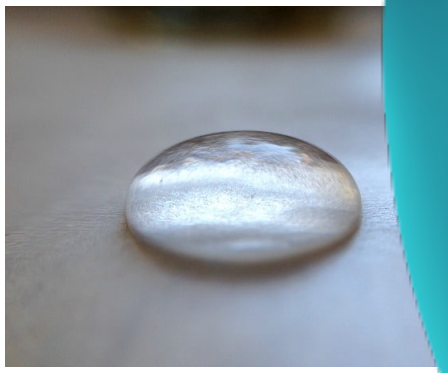
Des systèmes et matériaux (ré)actifs chez les plantes

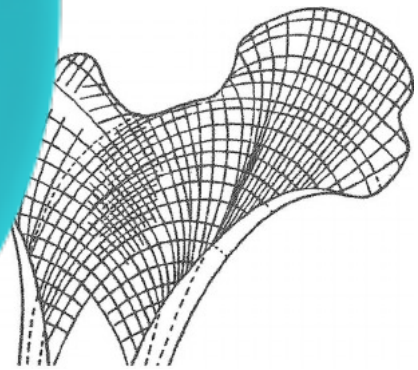
Olivier Hamant – ENS Lyon, France

The physics behind m question of scale

And for
pressurized objects?



Water droplet



Bones

Gravity

Surface tension

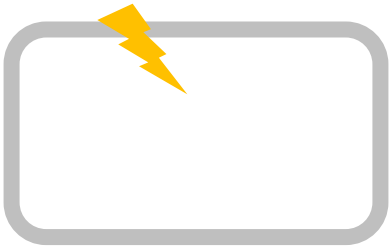
D'Arcy Thompson, *On growth and forms*

A hydroskeleton:
Plant tissues are pressurized (turgor pressure)

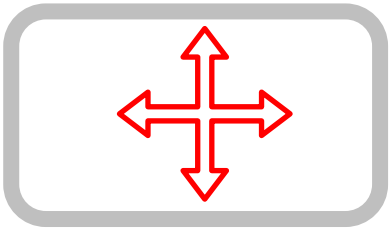
Plants as balloons

Vanessa McKeown

A feedback loop



Mechanical stress perception

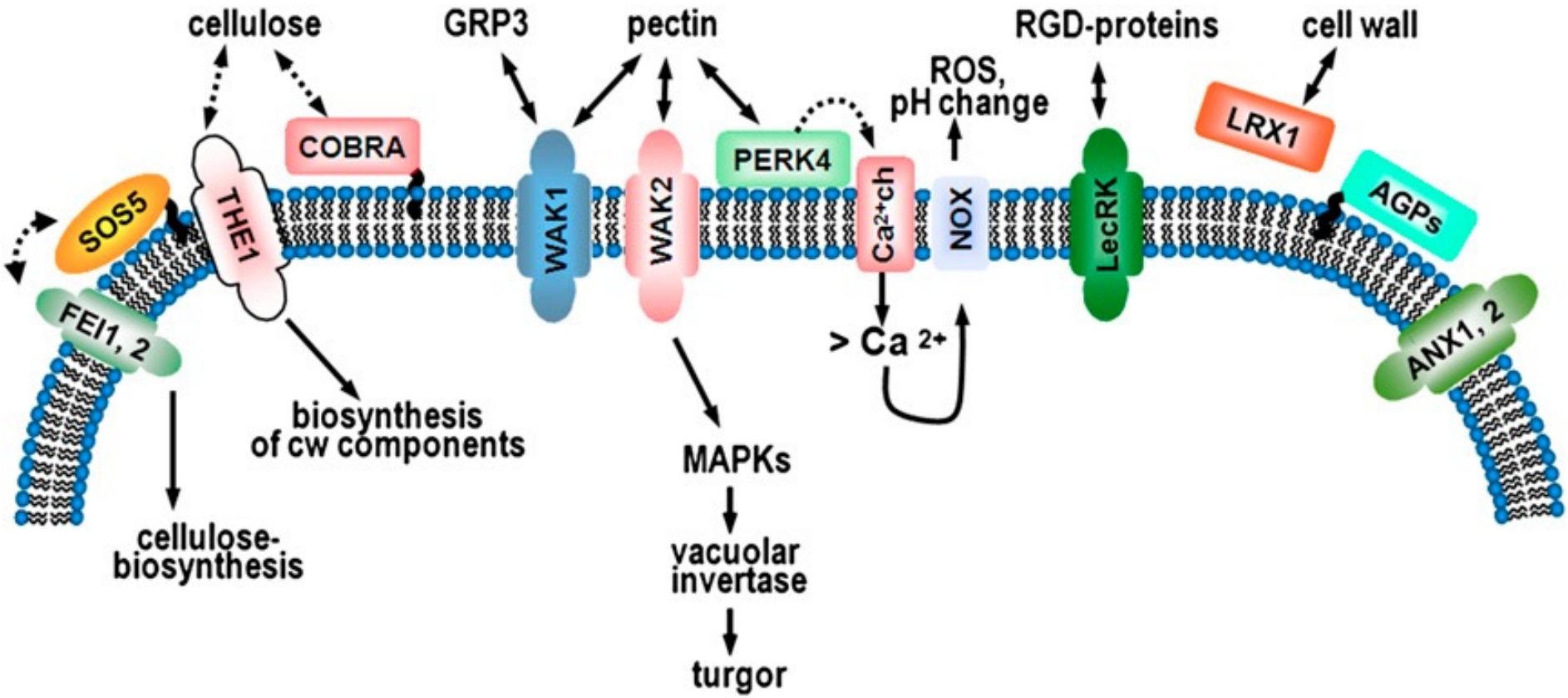


Cell response

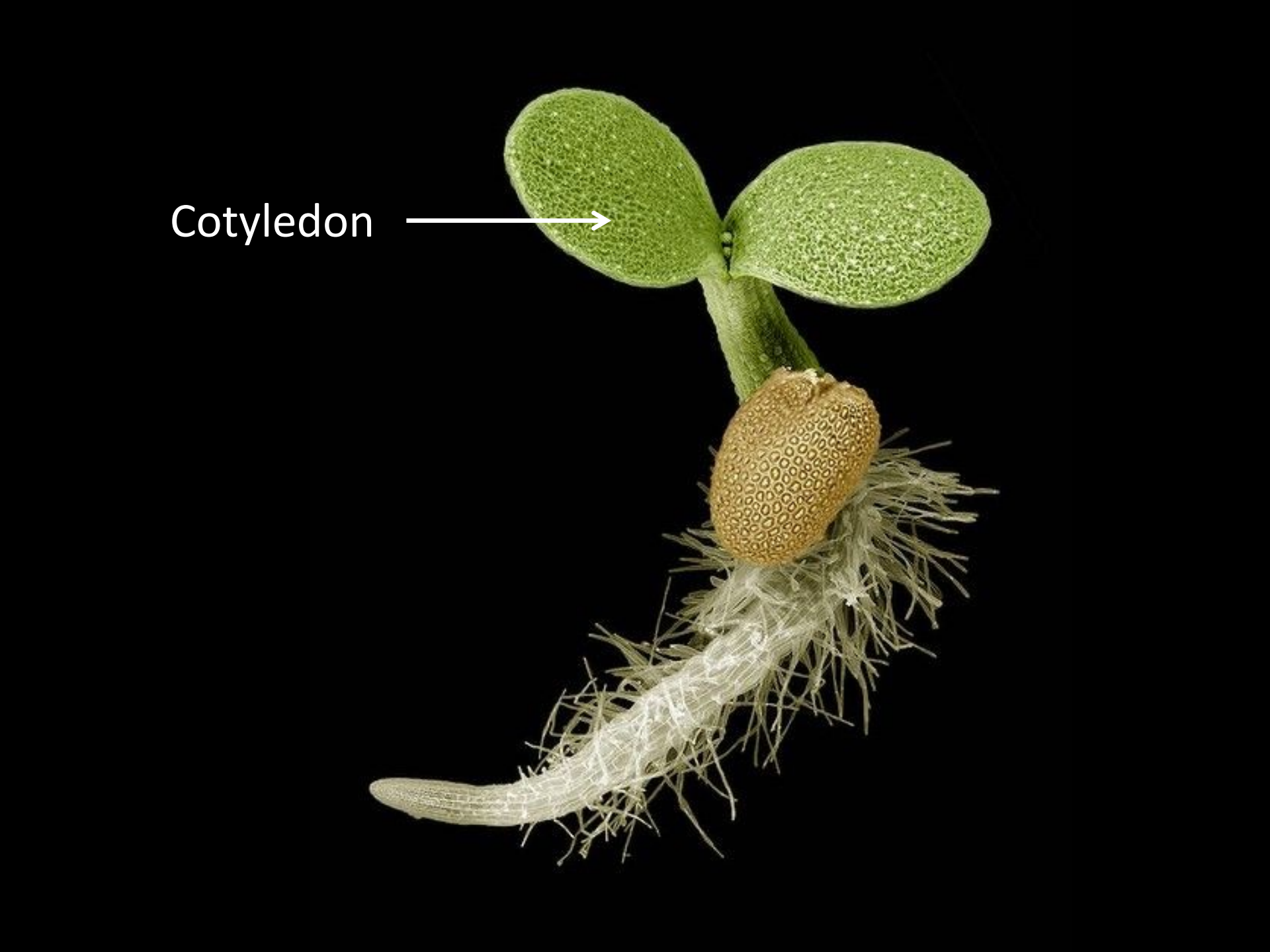
Cell wall reinforcement

Shape and growth

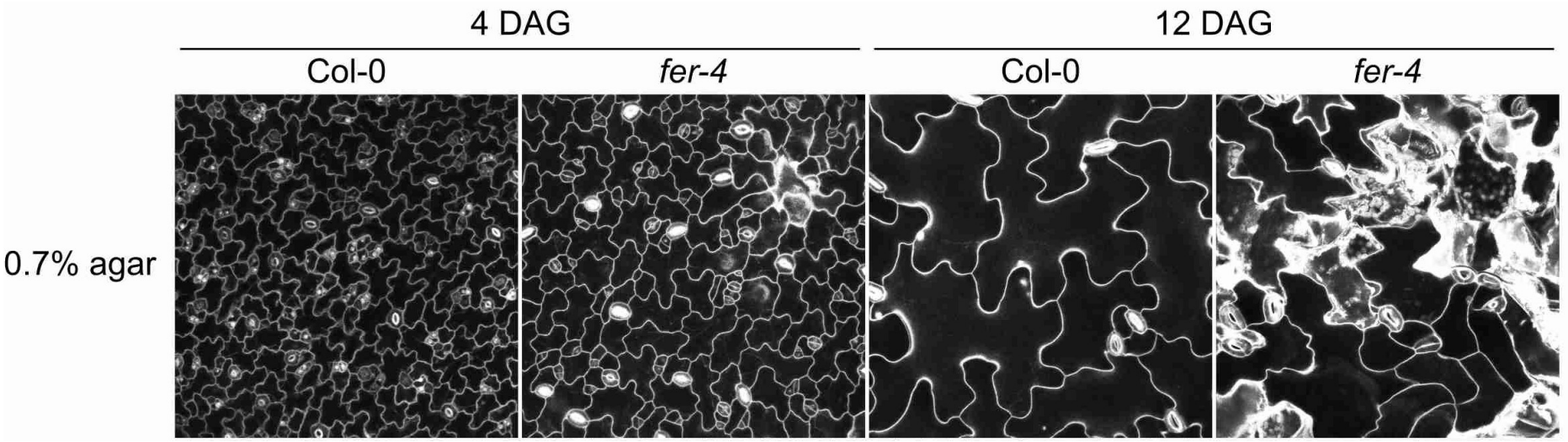
Mechanosensor screen



Ringli *et al.,* 2010 Plant Physiol.

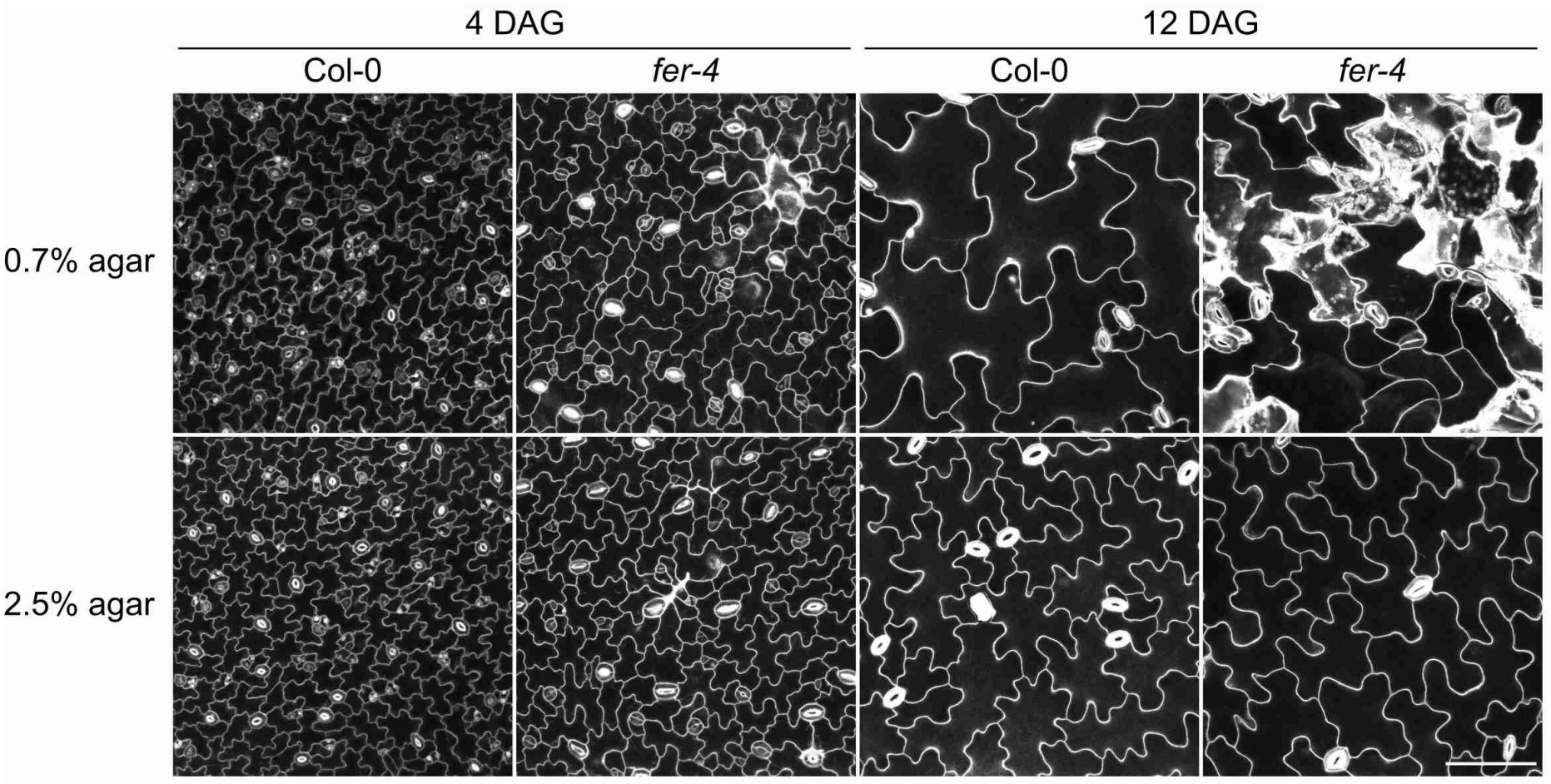

Cotyledon

Cell wall strength defects in *fer* cotyledons



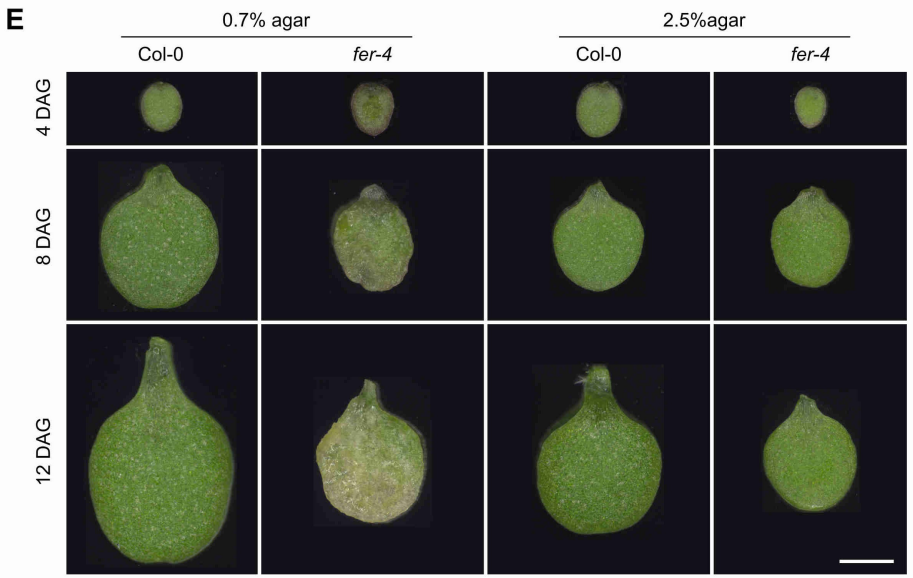
Malivert *et al.,* Plos Biol. *(in press)*

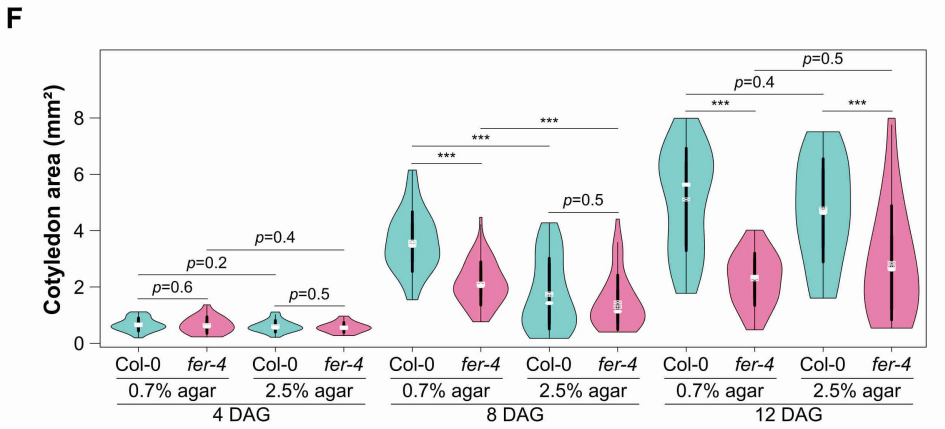
fer phenotype can be partially rescued on 2.5% agar



Malivert *et al.*, Plos Biol. *(in press)*

fer phenotype can be partially rescued on 2.5% agar





Malivert *et al.*, Plos Biol. *(in press)*

A feedback loop

FER

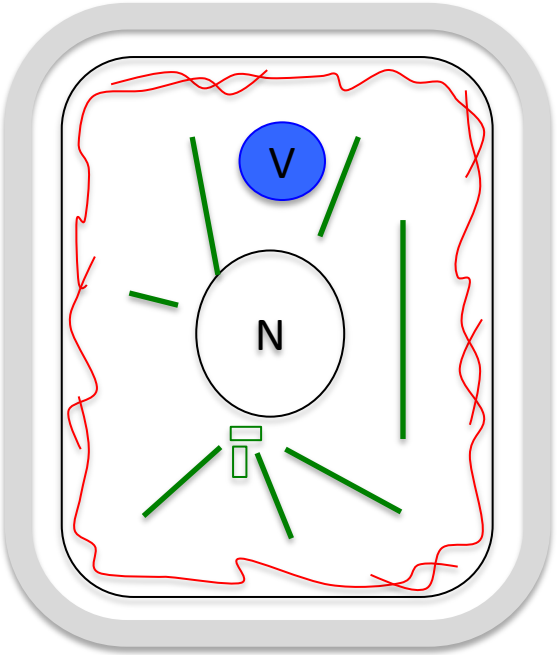
Mechanical stress perception

Cell response

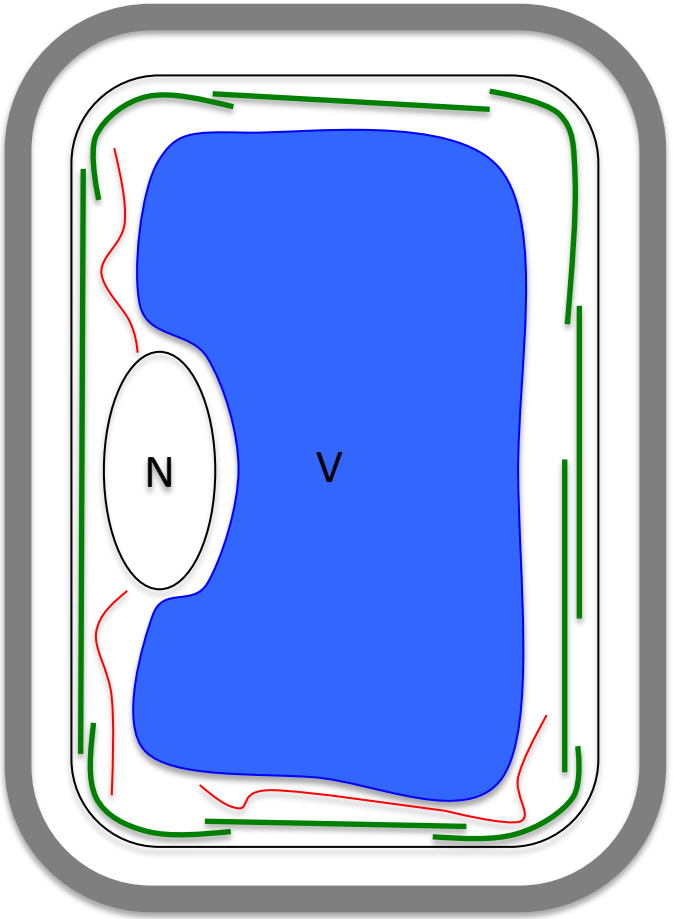
Cell wall reinforcement

Shape and growth

Animal cell



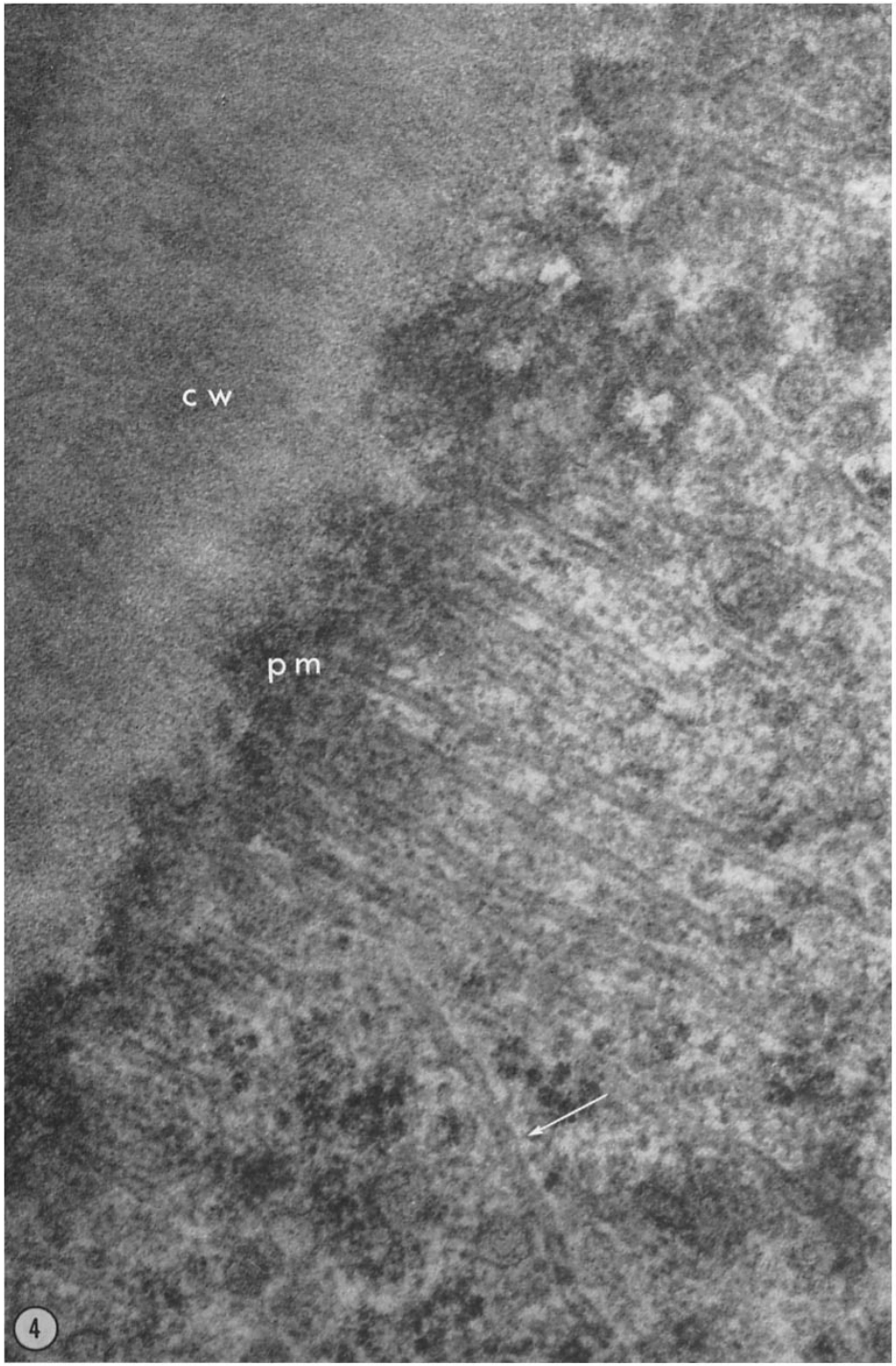
Plant cell



Extra Cellular Matrix

Actin

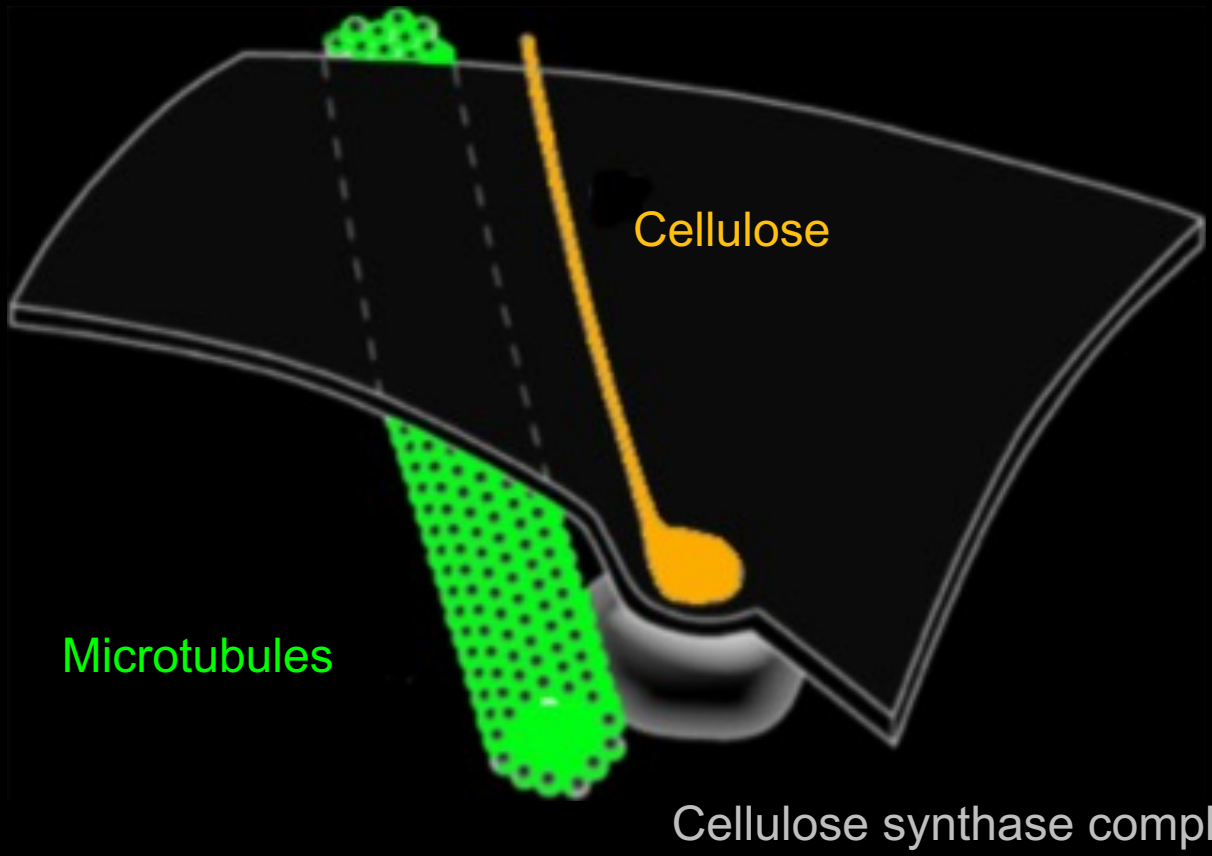
Microtubules



Microtubules were first observed in plant cells

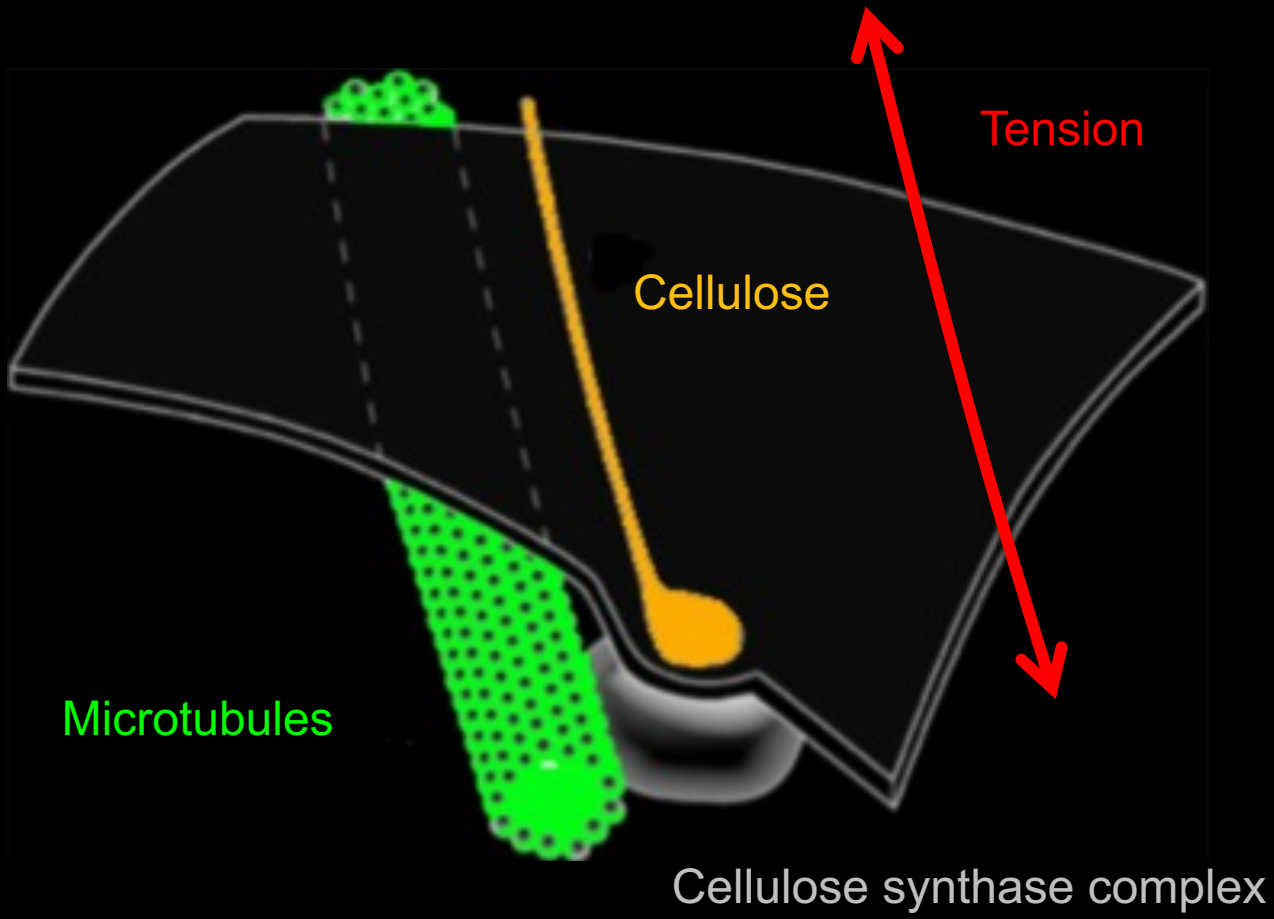
Ledbetter & Porter, JCB 1963

Cells resist turgor pressure through cellulose deposition in their walls

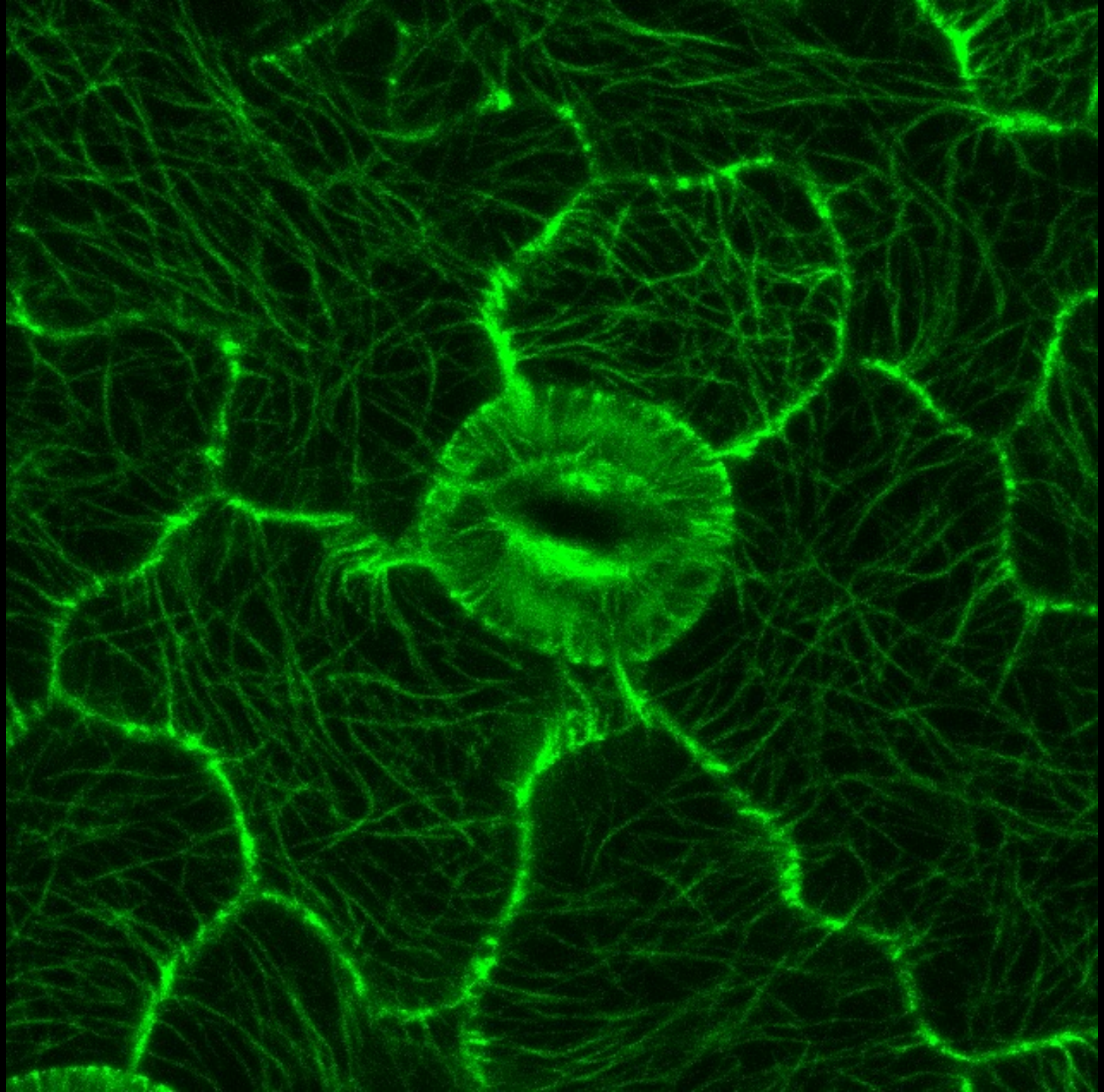


Green and King, 1966 Aust J Pl Sci.
Hejnowicz *et al.*, 2000 J Pl Growth Regul.
Hamant *et al.*, 2008 Science

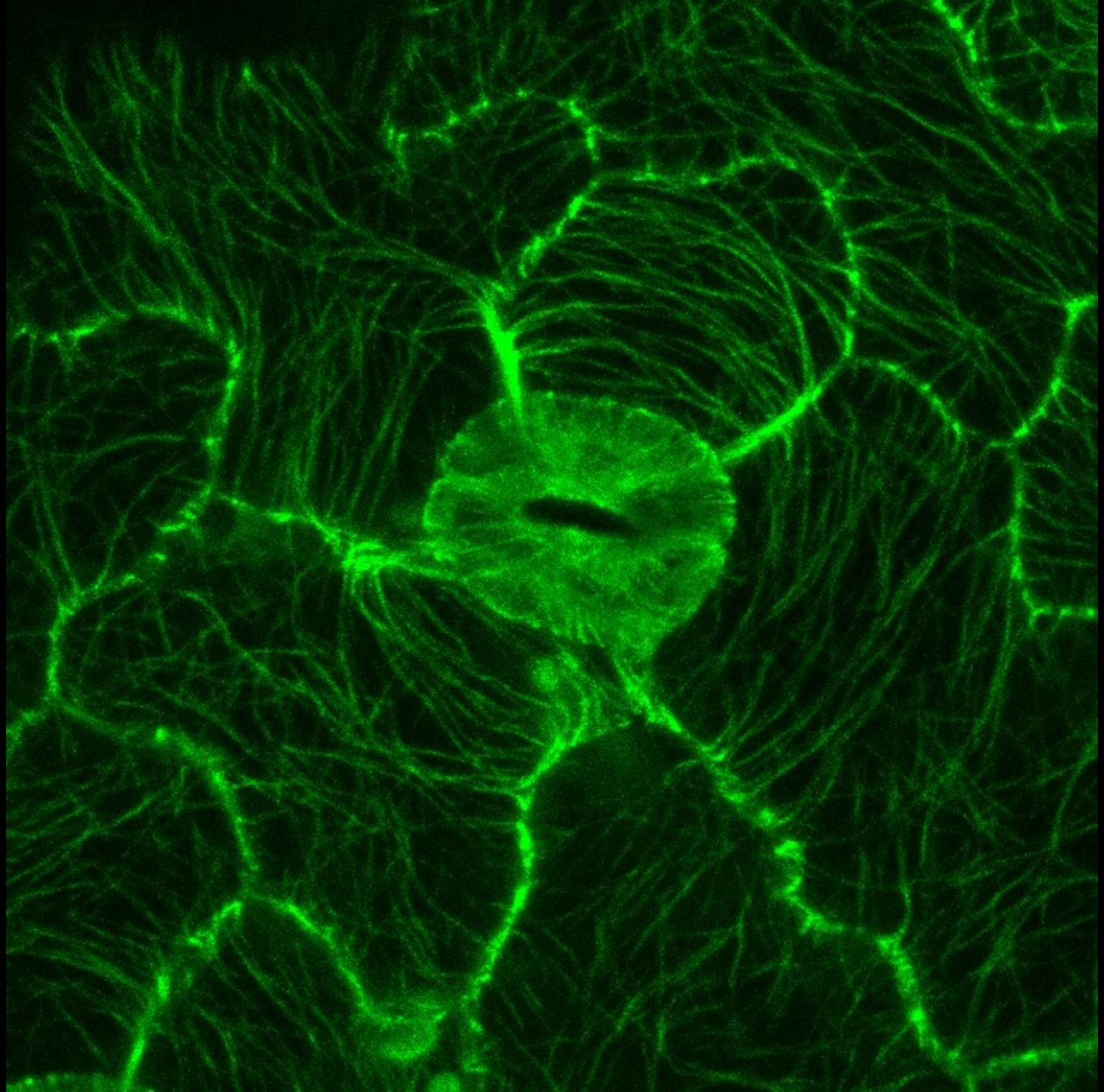
Cortical microtubules align with maximal tensile stress



Green and King, 1966 Aust J Pl Sci.
Hejnowicz *et al.*, 2000 J Pl Growth Regul.
Hamant *et al.*, 2008 Science

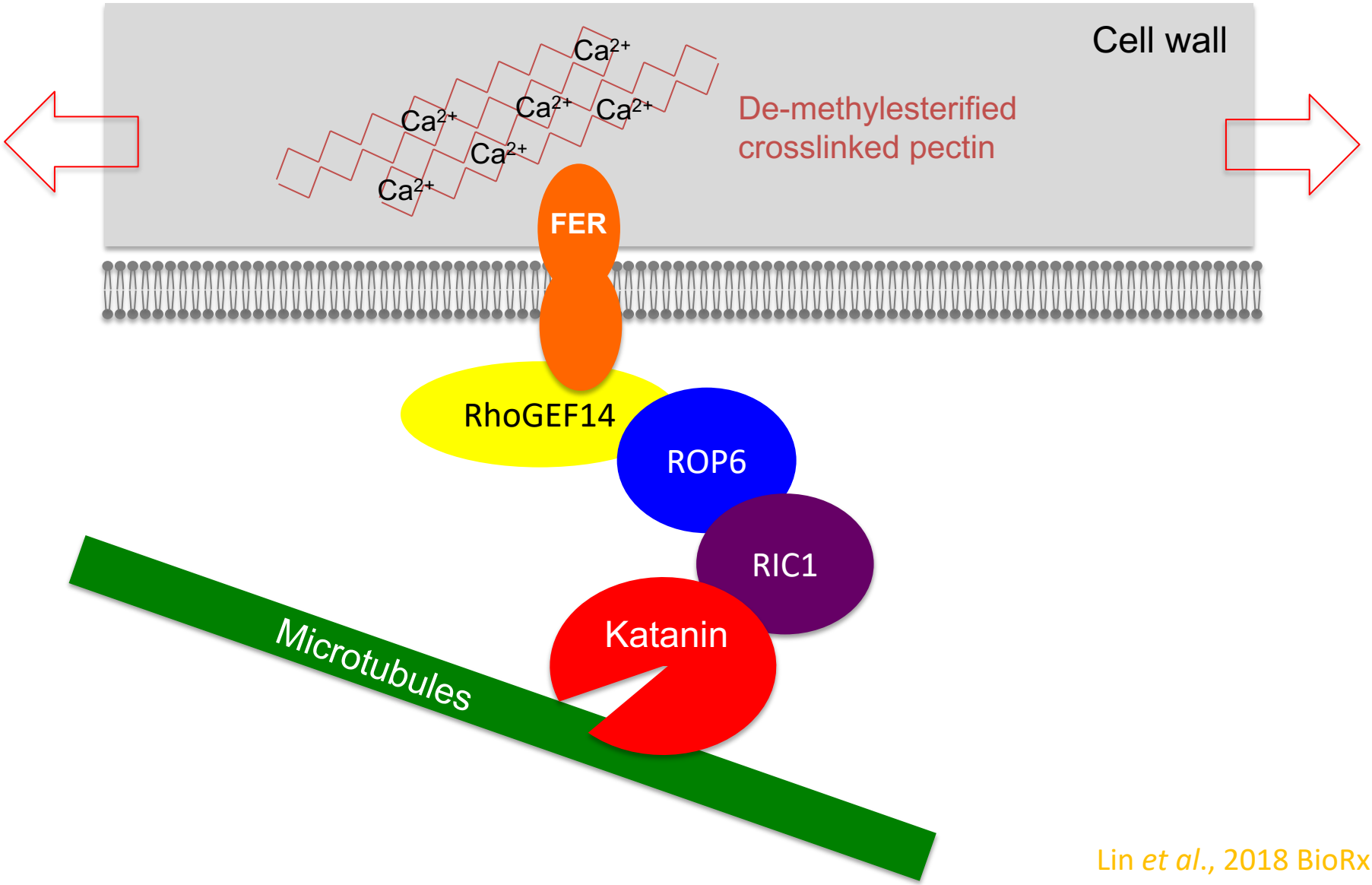


Unpub.



Unpub.

A contribution of FER to the MT response to stress?

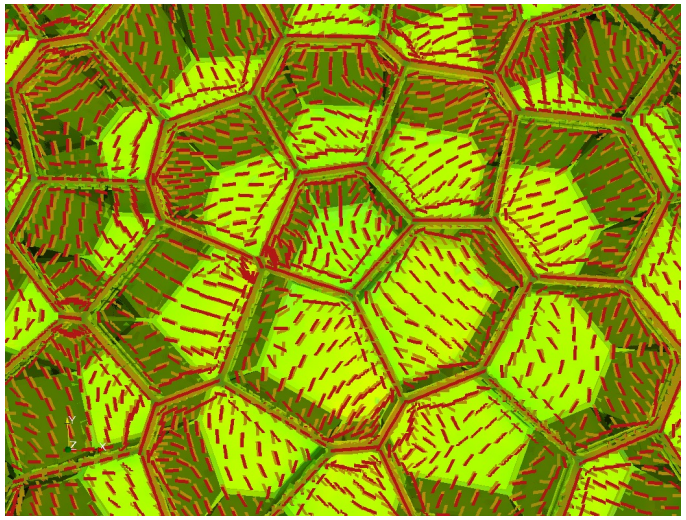


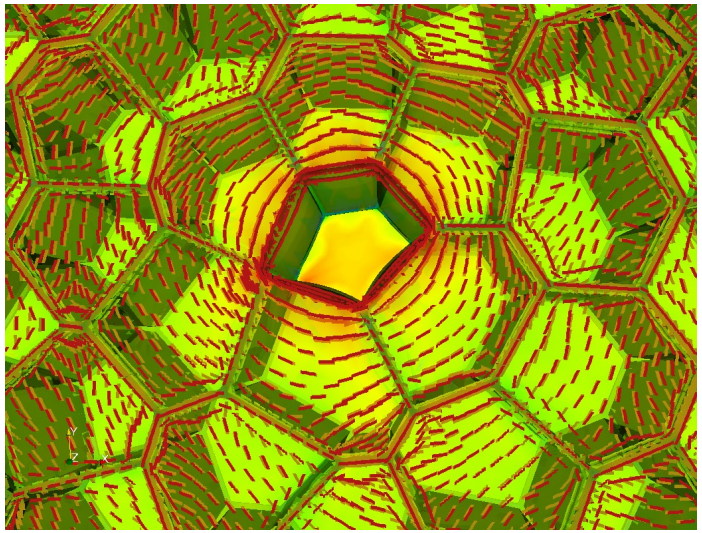
Lin *et al.*, 2018 BioRxiv

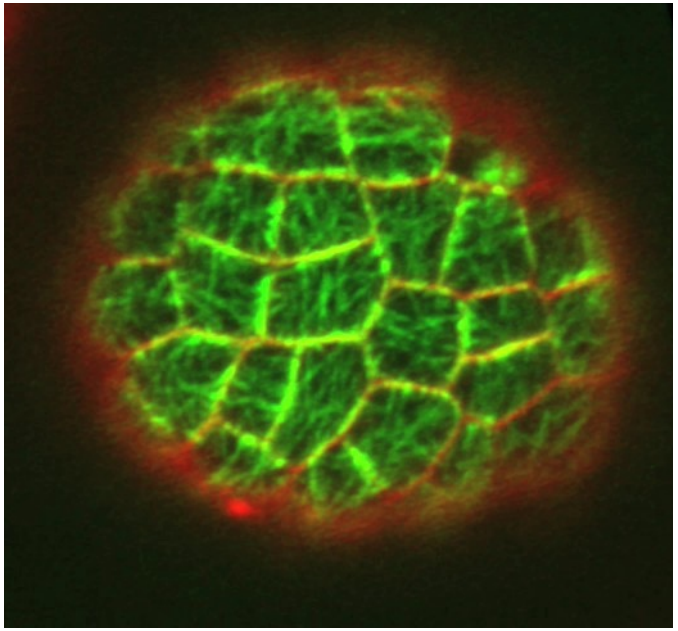
A classic test for the microtubule response to stress

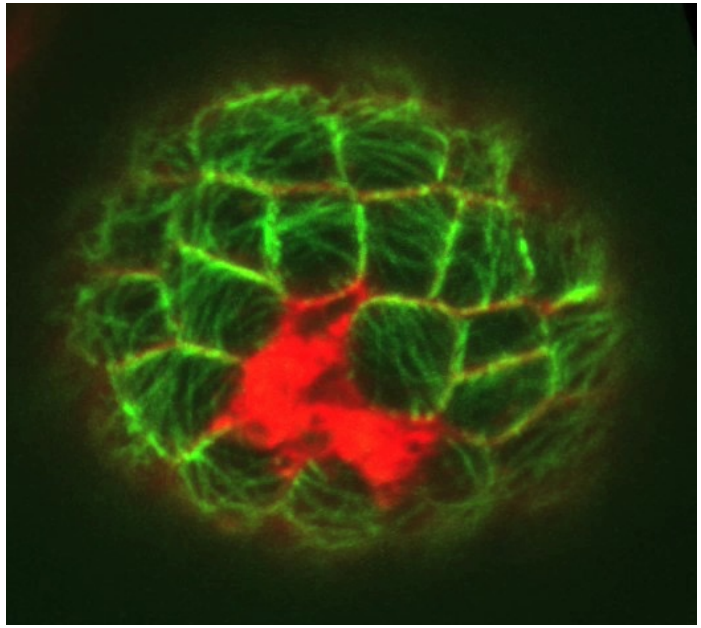
Before

After

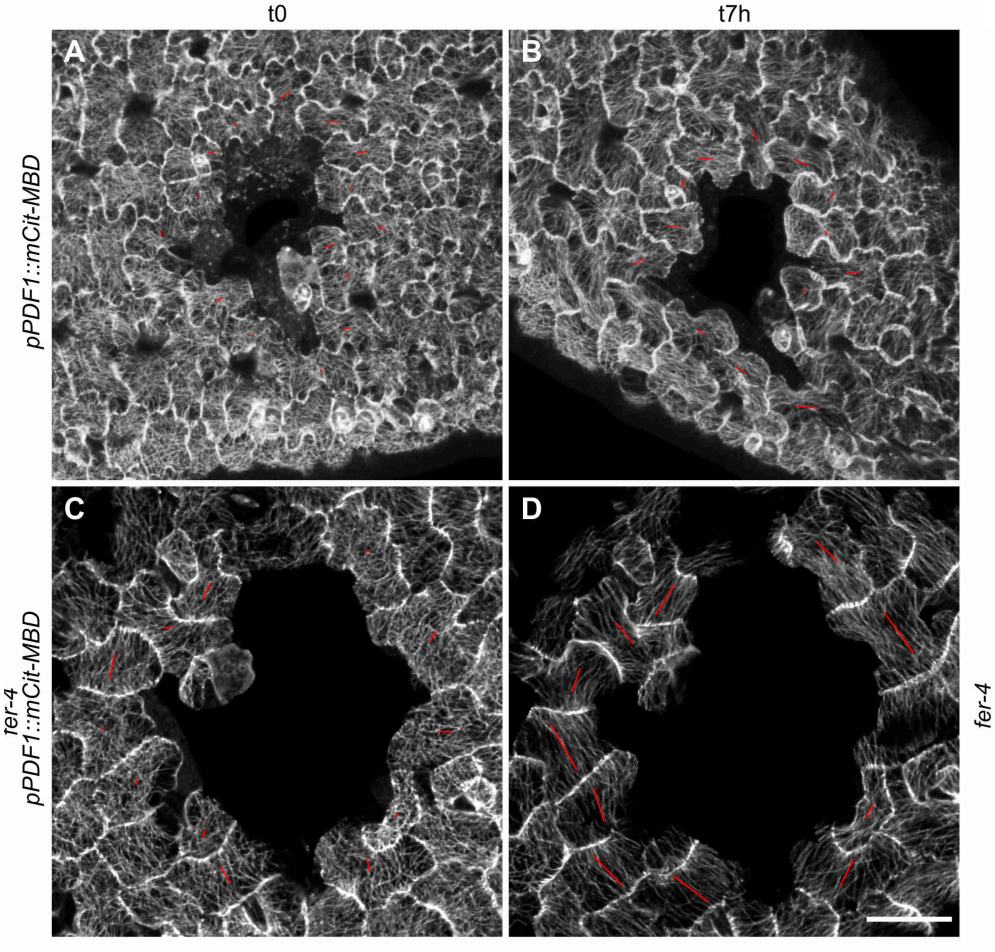


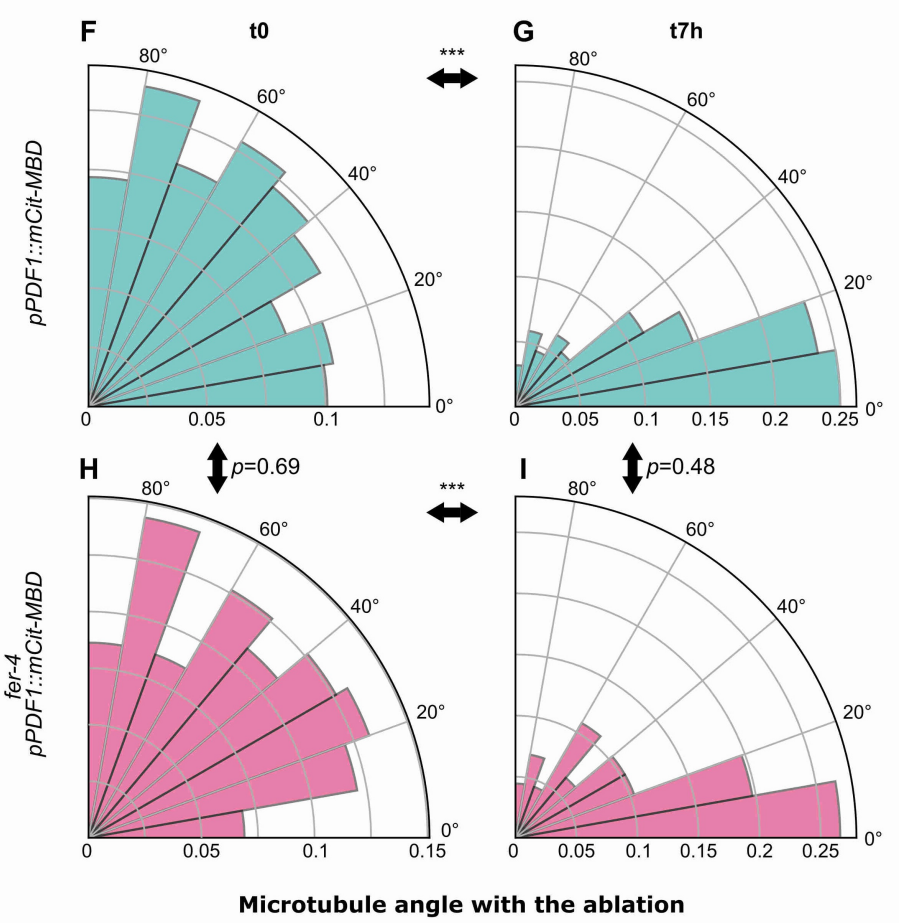






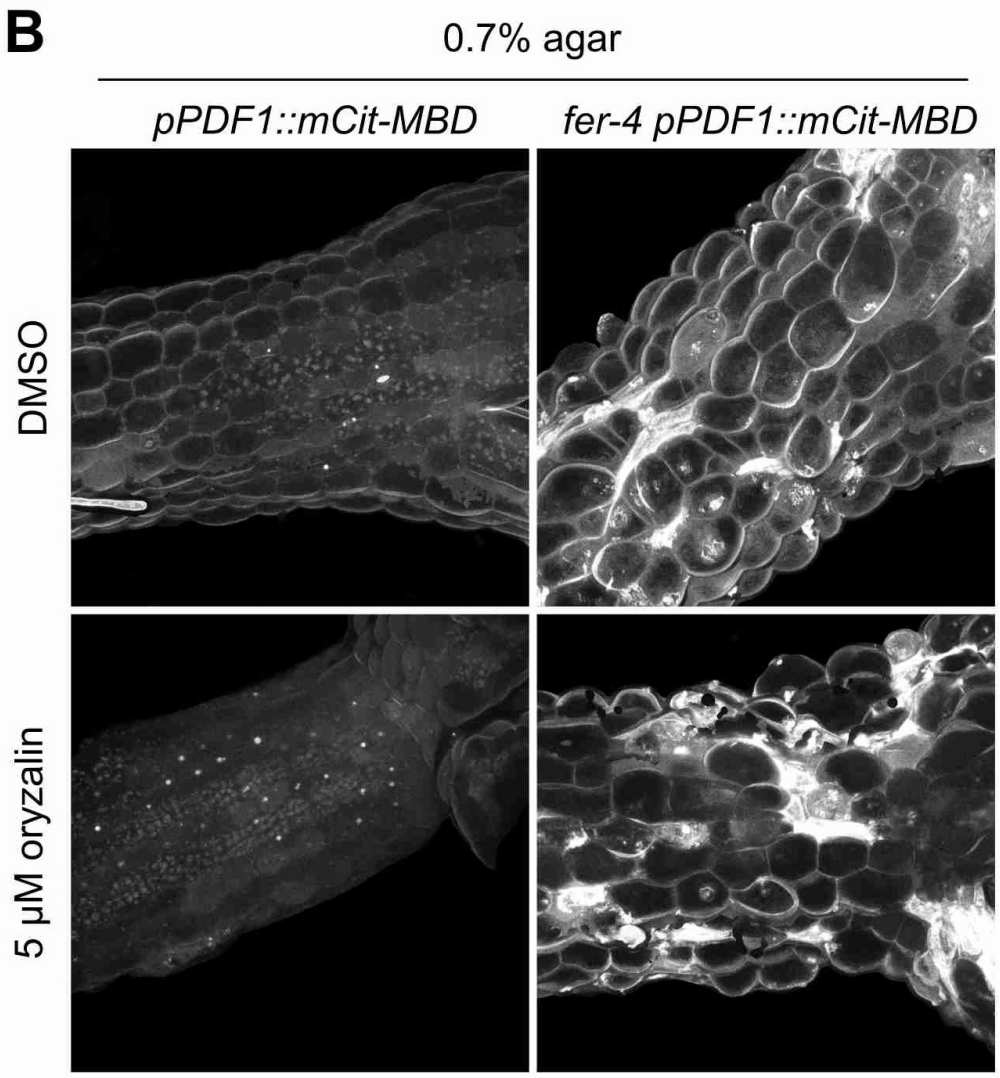
MTs reorient around ablation in *fer-4*

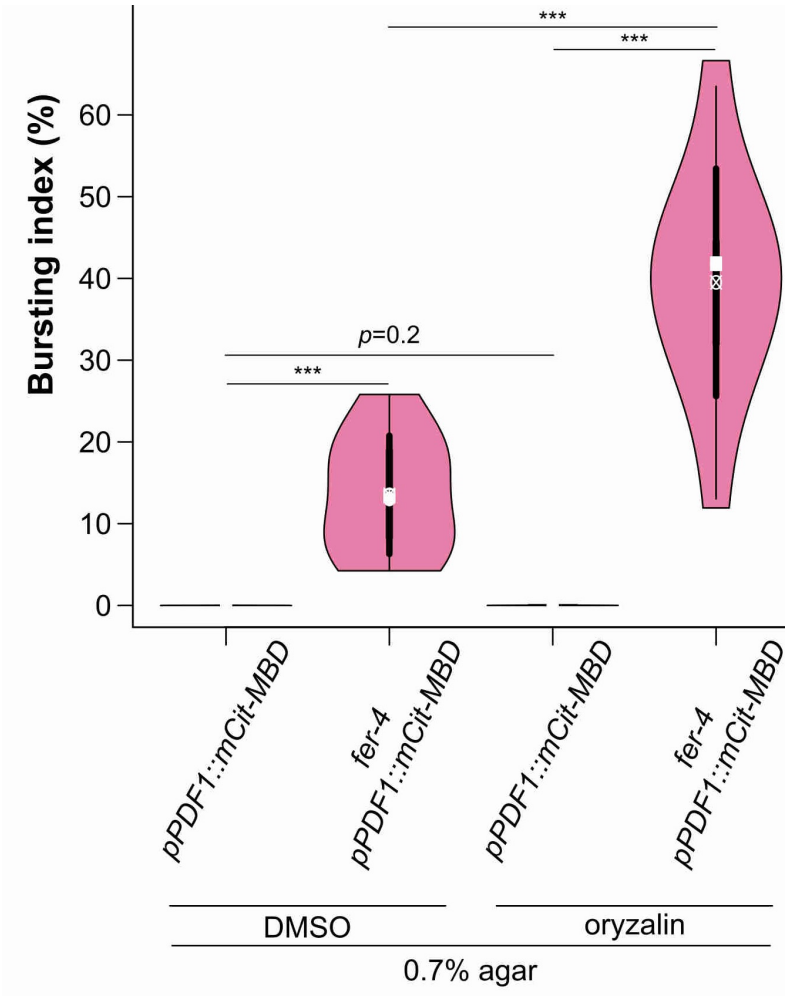




Malivert *et al.*, Plos Biol. *(in press)*

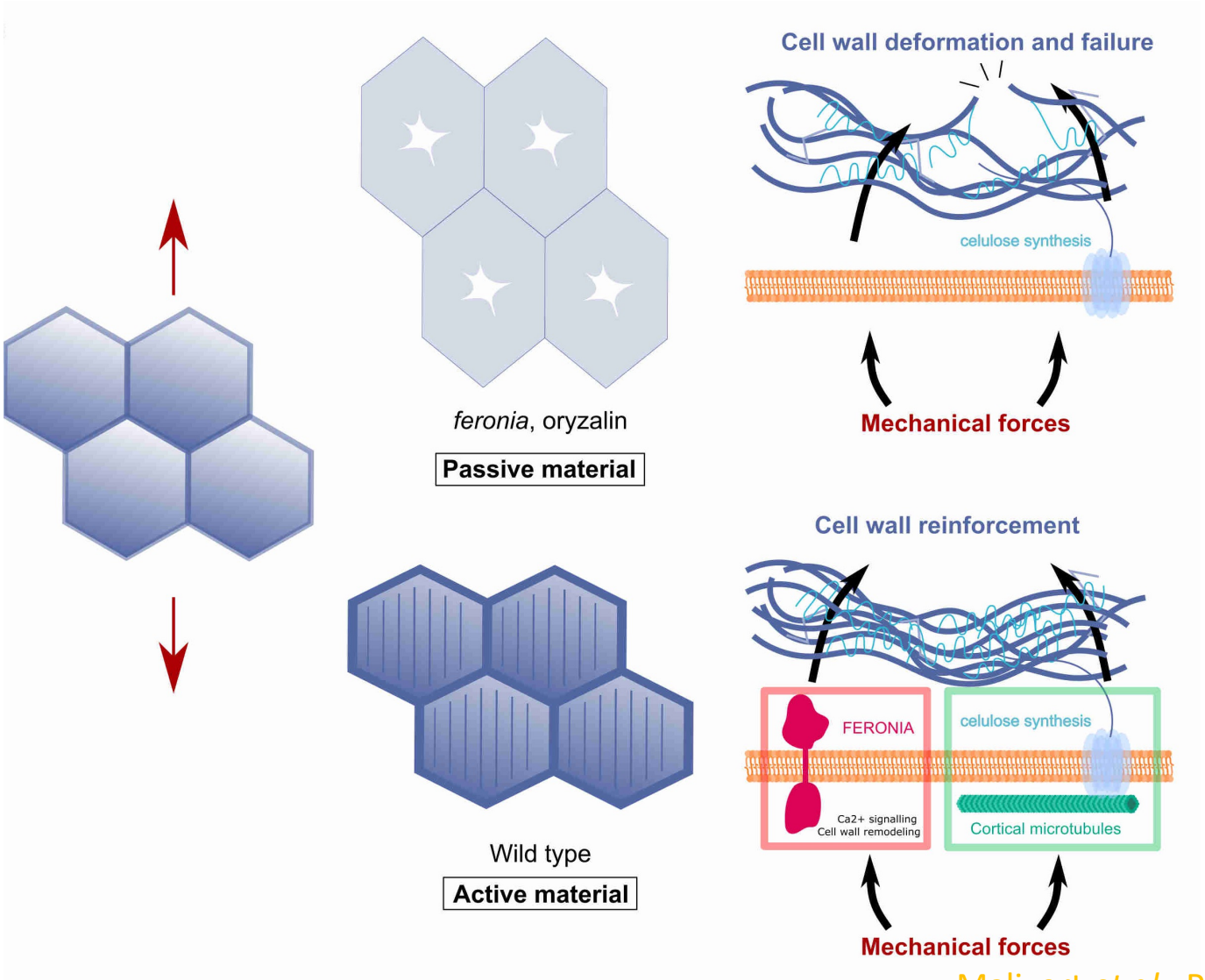
MTs and FER are two independent pathways behind the mechanical feedback in the shoot





Malivert *et al.*, Plos Biol. *(in press)*

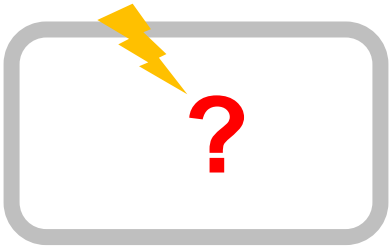
MTs and FER pathways independently turn plant tissues into active matter



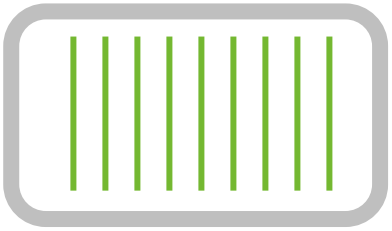
Malivert *et al.,* Plos Biol. *(in press)*

What mechanotransduction pathway upstream of MTs?

Shape and growth



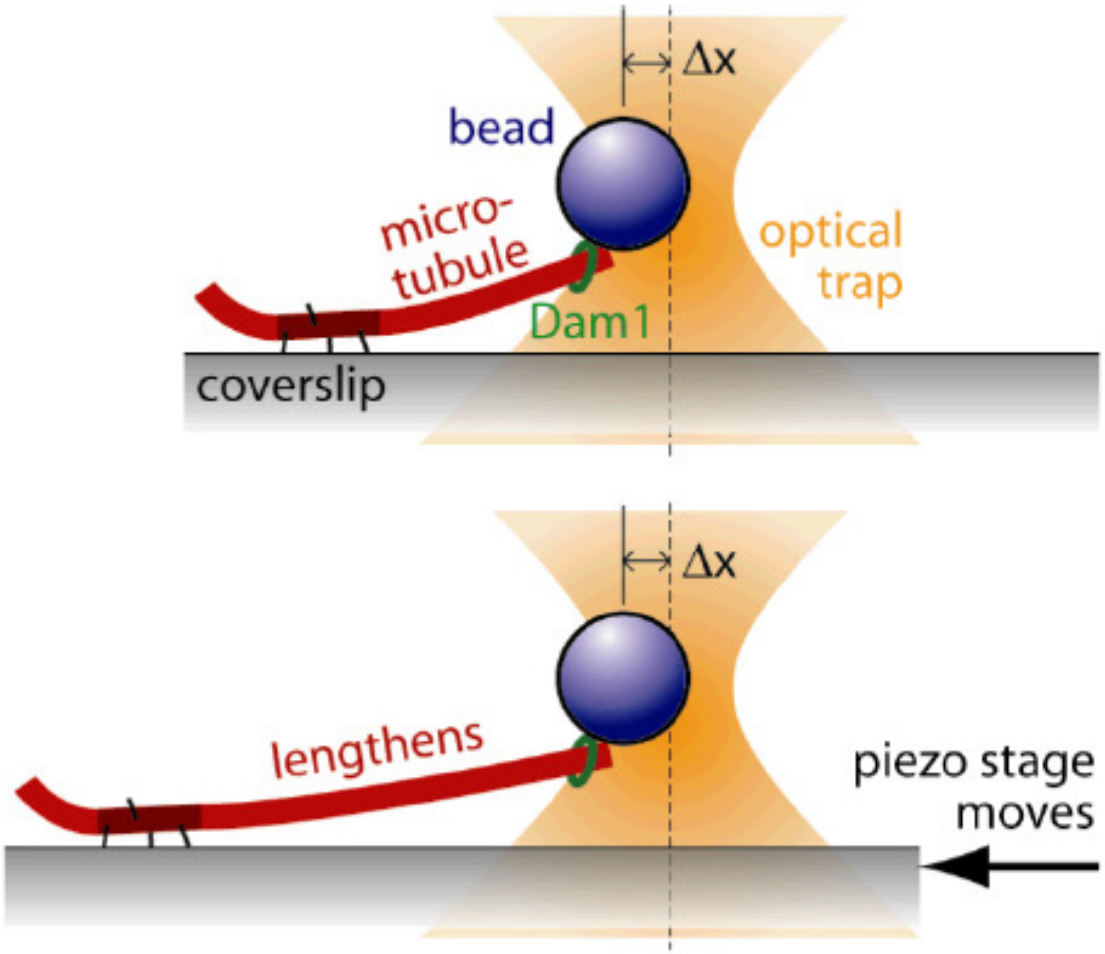
Mechanical stress perception?



Microtubule alignment

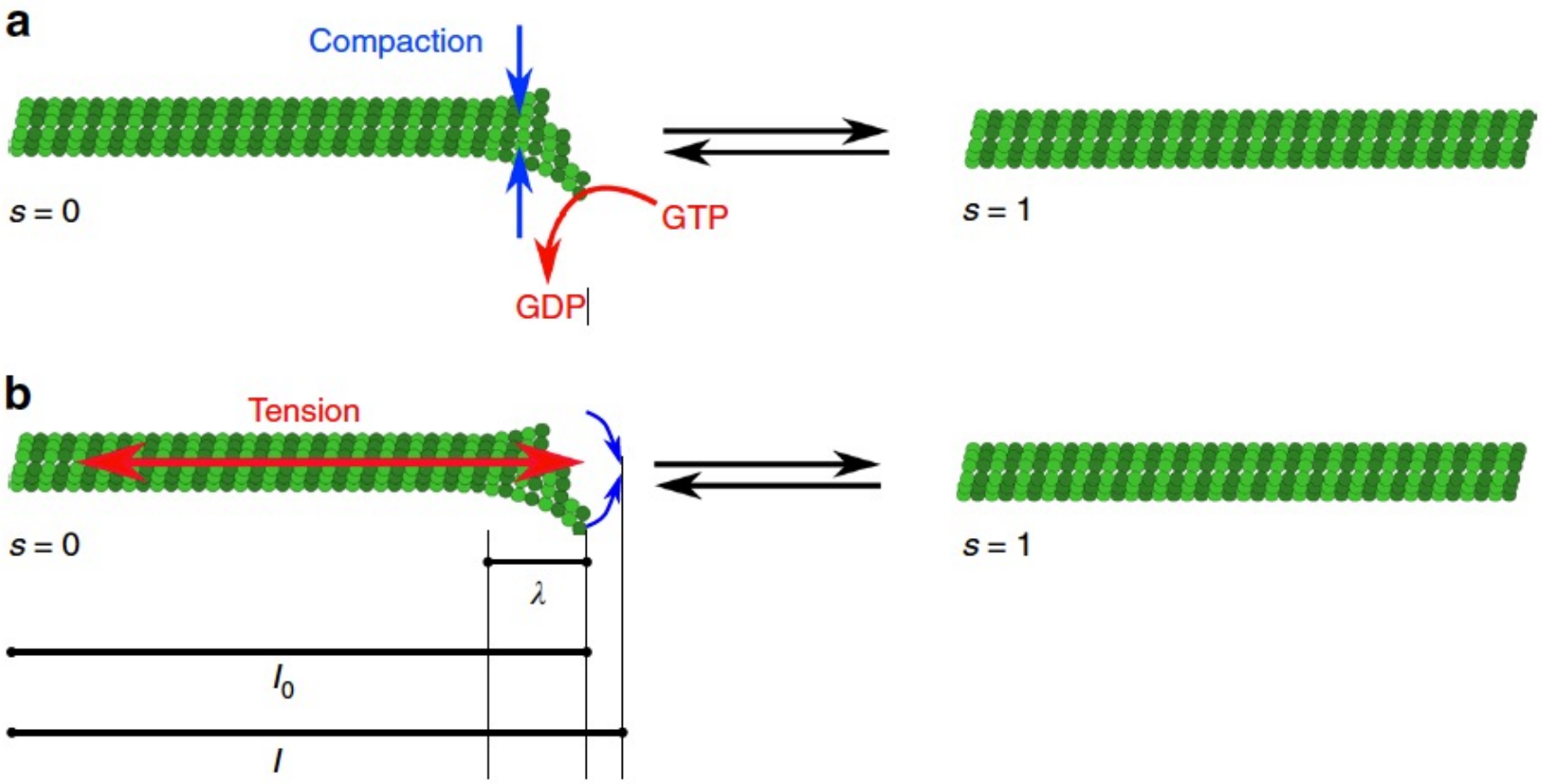
Cellulose deposition

An autonomous pathway?



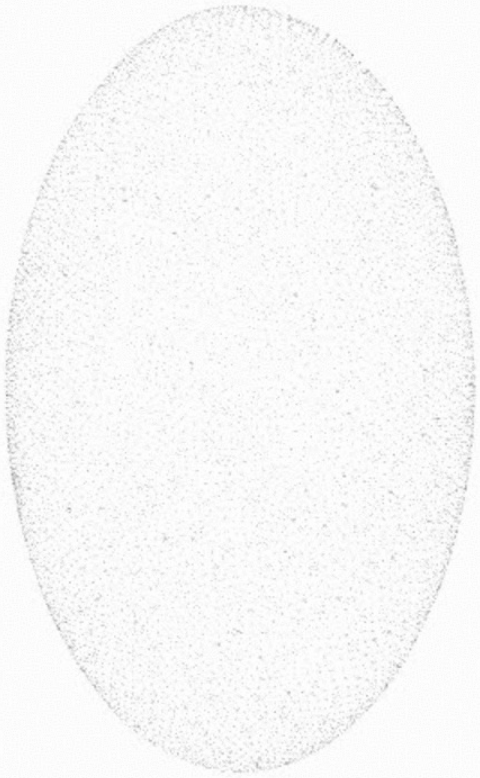
Franck *et al.,* 2009 Nat. Cell Biol.

Microtubules as tension sensors?



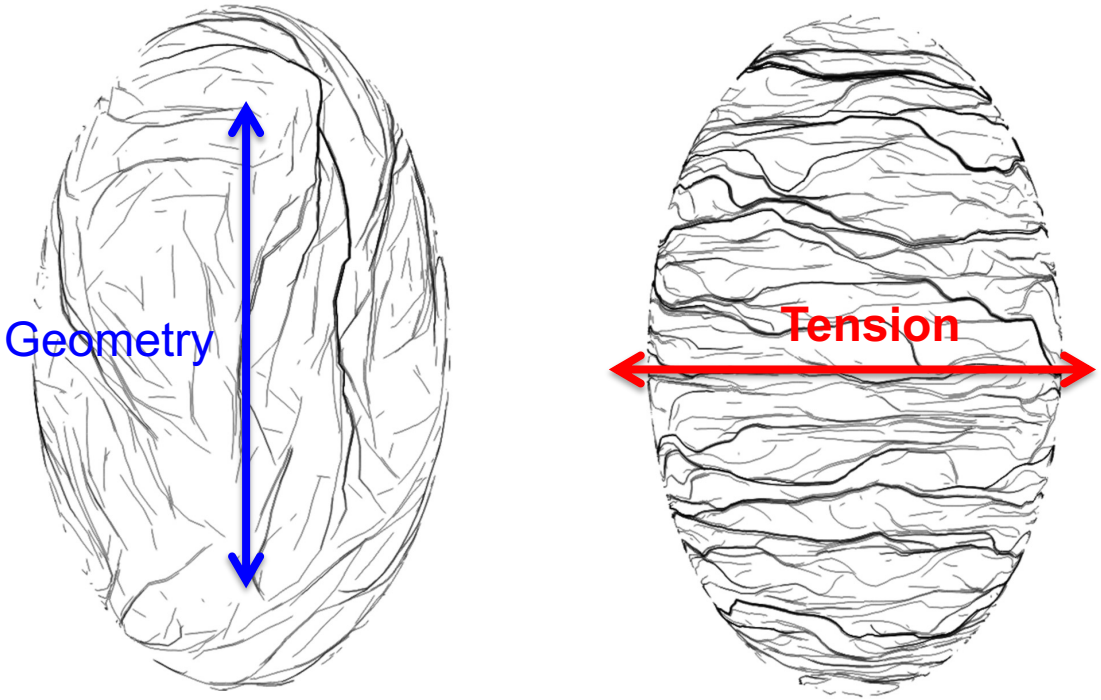
Hamant *et al.*, 2009 Nat. Com.

Modeling microtubule self-organization *in silico* in 3D



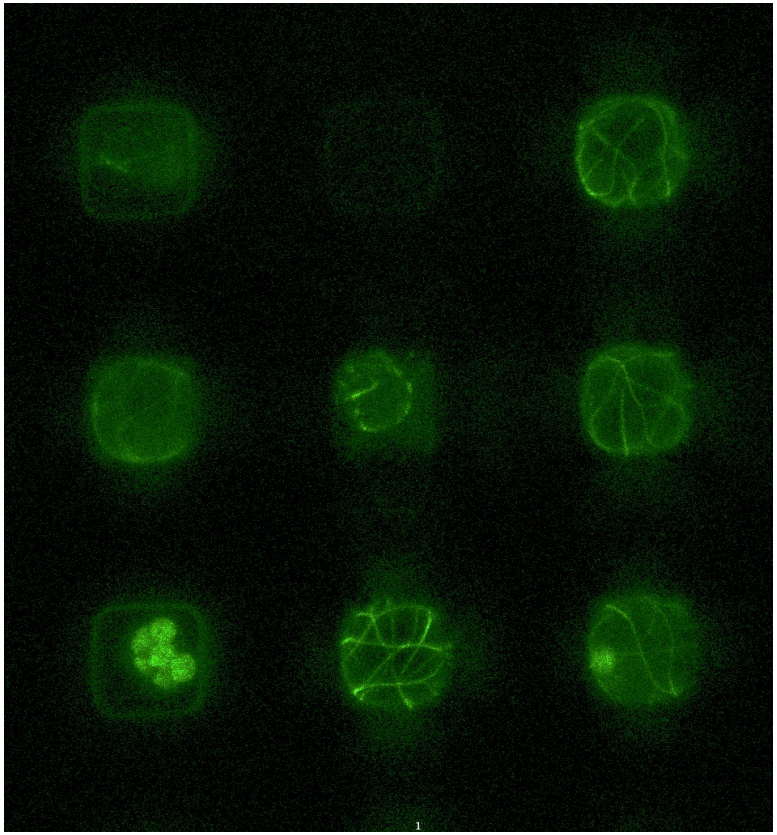
Mirabet *et al.,* 2018 Plos Comp. Biol.

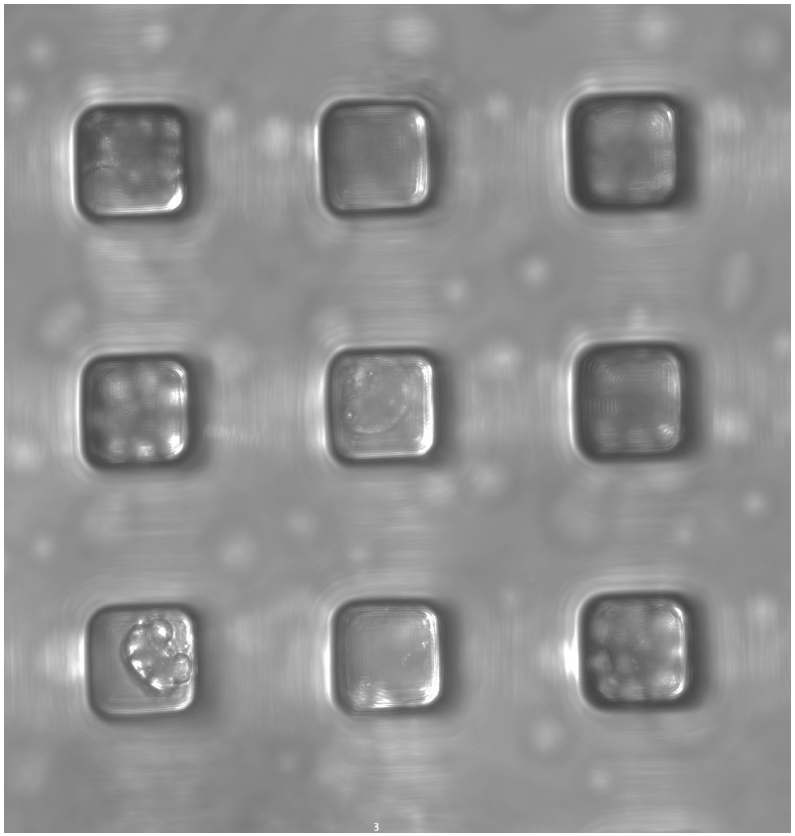
Microtubule response to stress vs. geometry



Mirabet *et al.,* 2018 Plos Comp. Biol.

Confining protoplasts in microwells

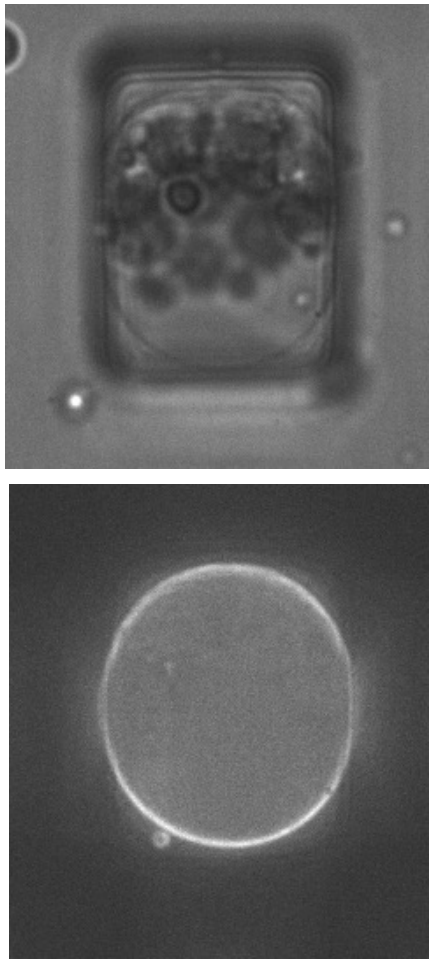


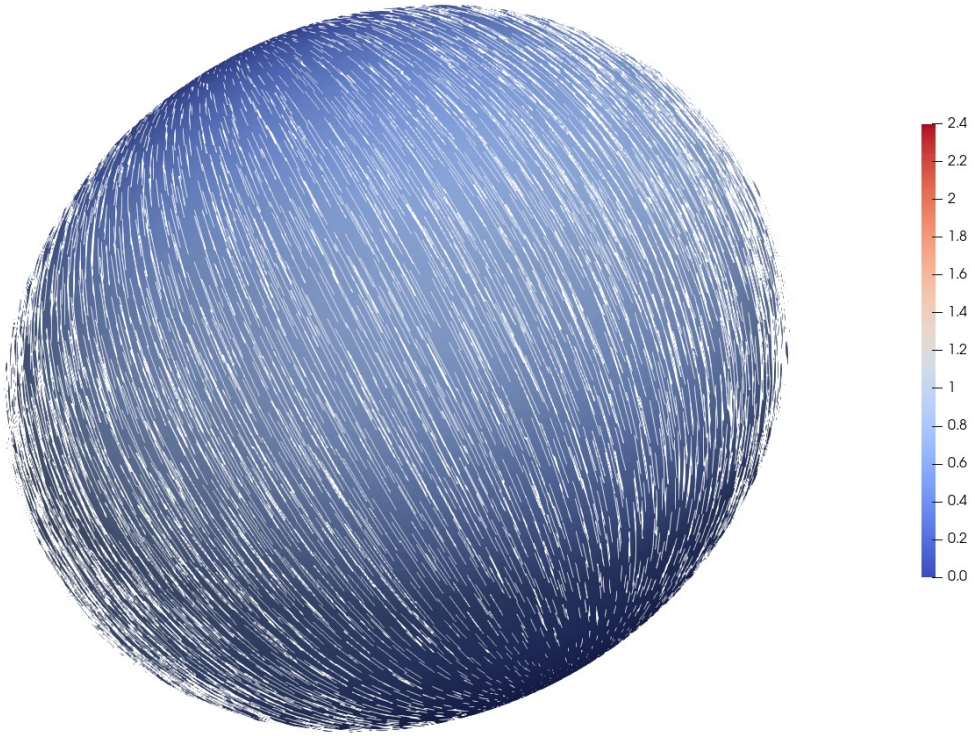


MBI
MECHANOBIOLOGY INSTITUTE
National University of Singapore

With Virgile Viasnoff & Tim Saunders

Confining protoplasts in *rectangular* microwells

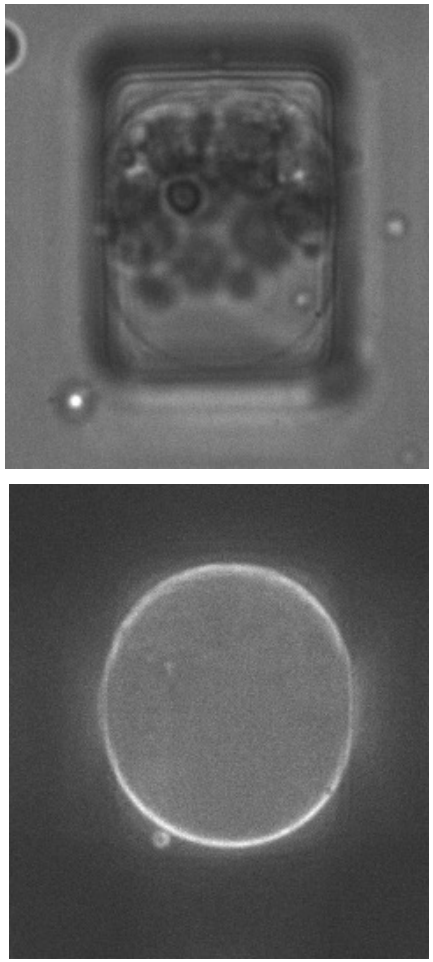


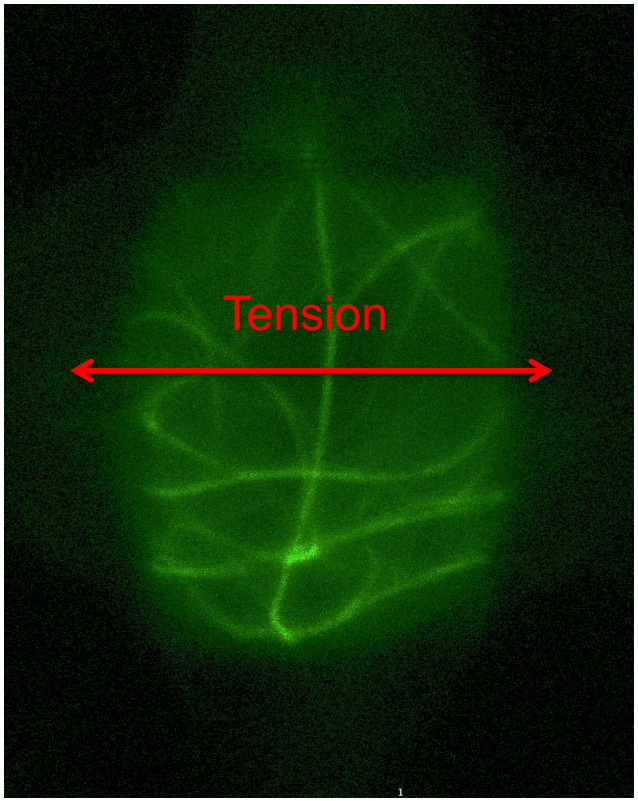


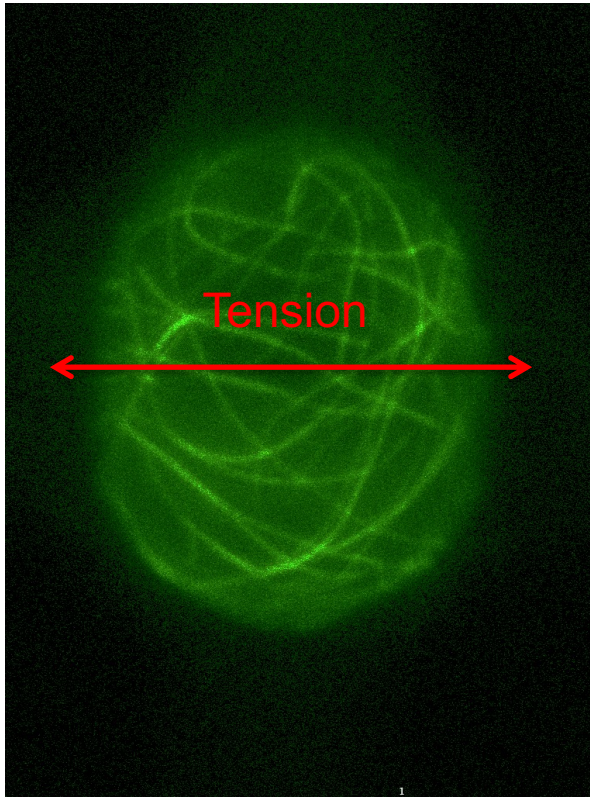
Predicted pattern of tensions
(Laplace-Young law)

Colin *et al.*, 2021 PNAS

Confining protoplasts in *rectangular* microwells

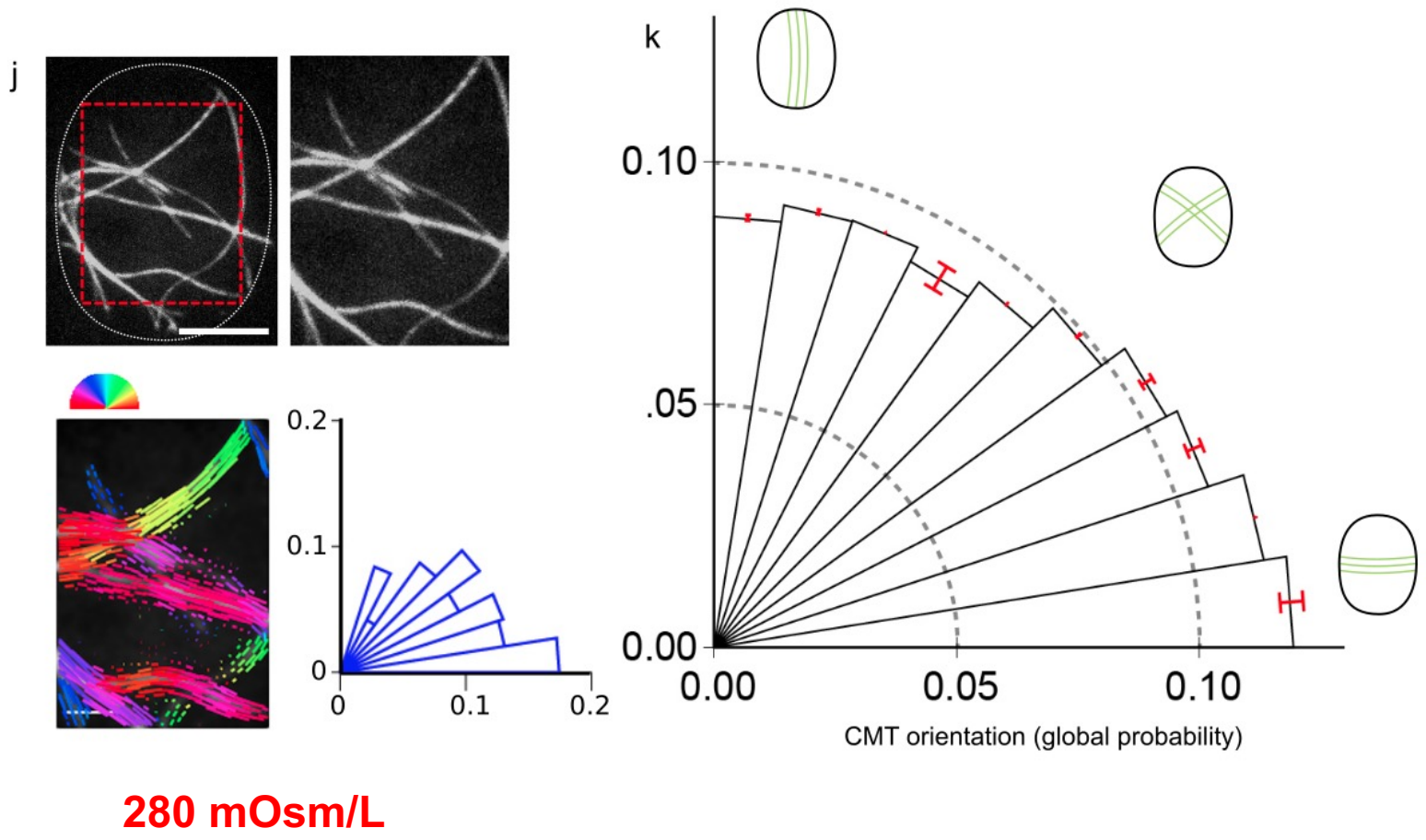






Colin *et al.*, 2021 PNAS

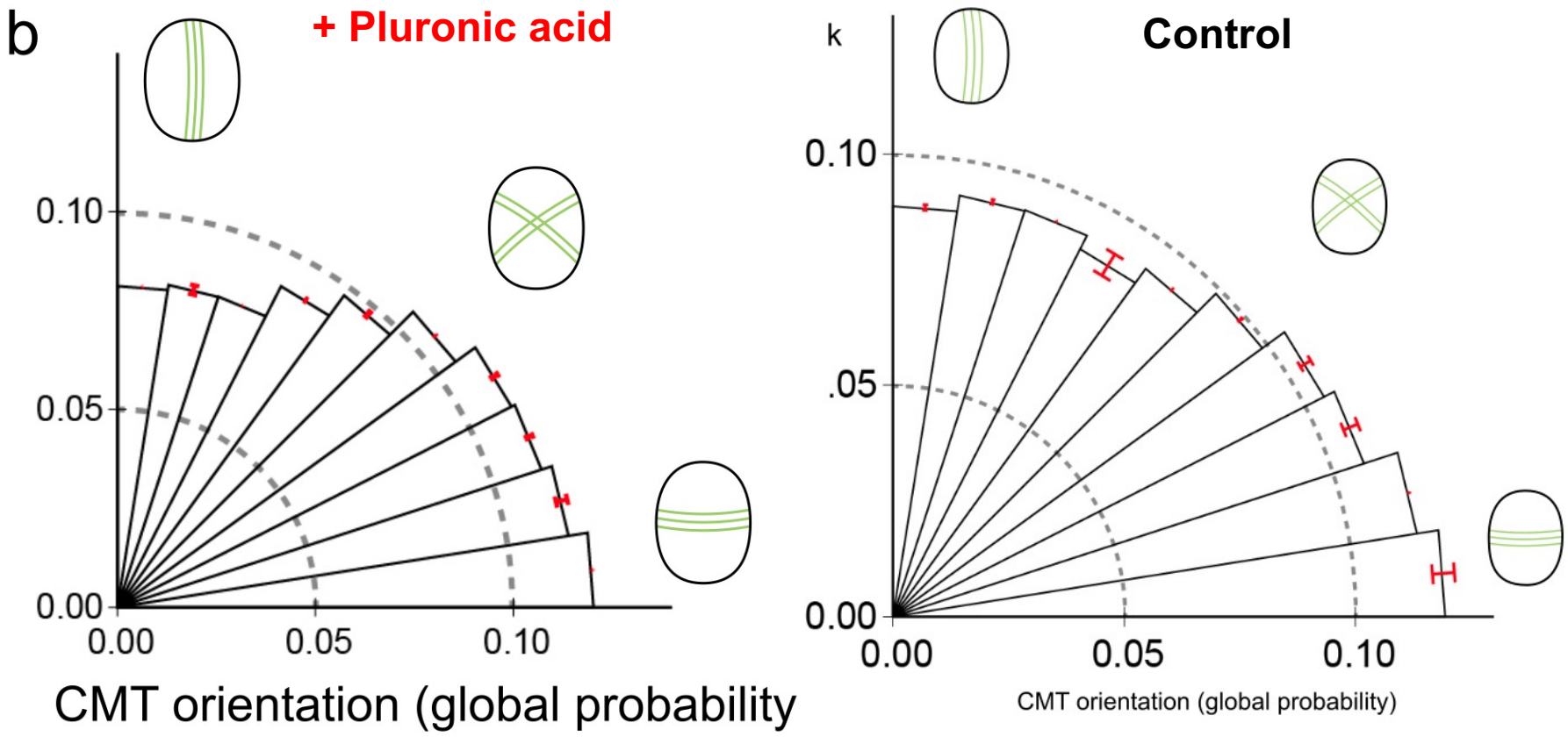
A bias in the transverse orientation



280 mOsm/L

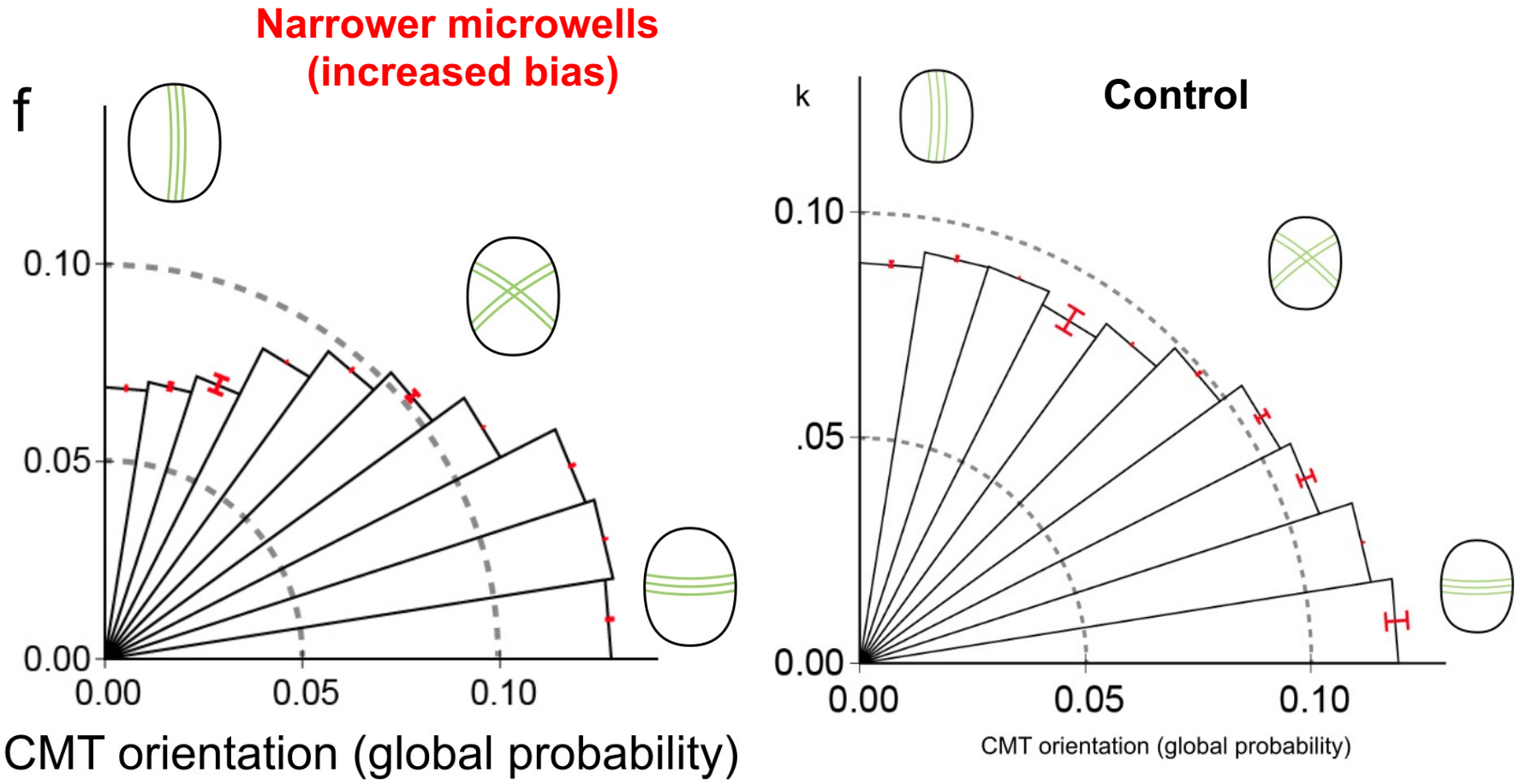
Colin *et al.*, 2021 PNAS

Transverse bias does not depend on adhesion



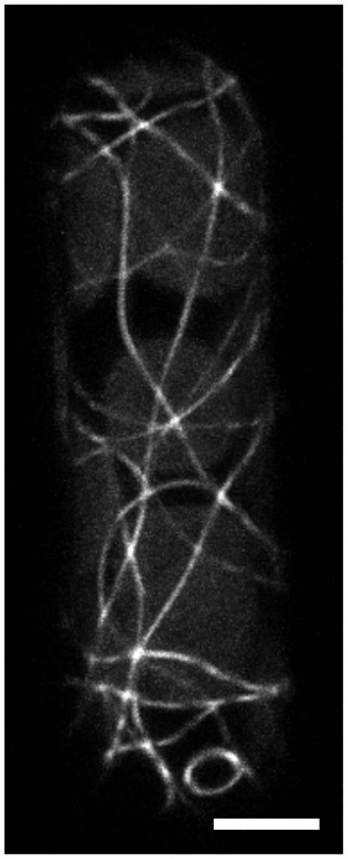
Colin *et al.*, 2021 PNAS

Transverse bias scales with predicted tension

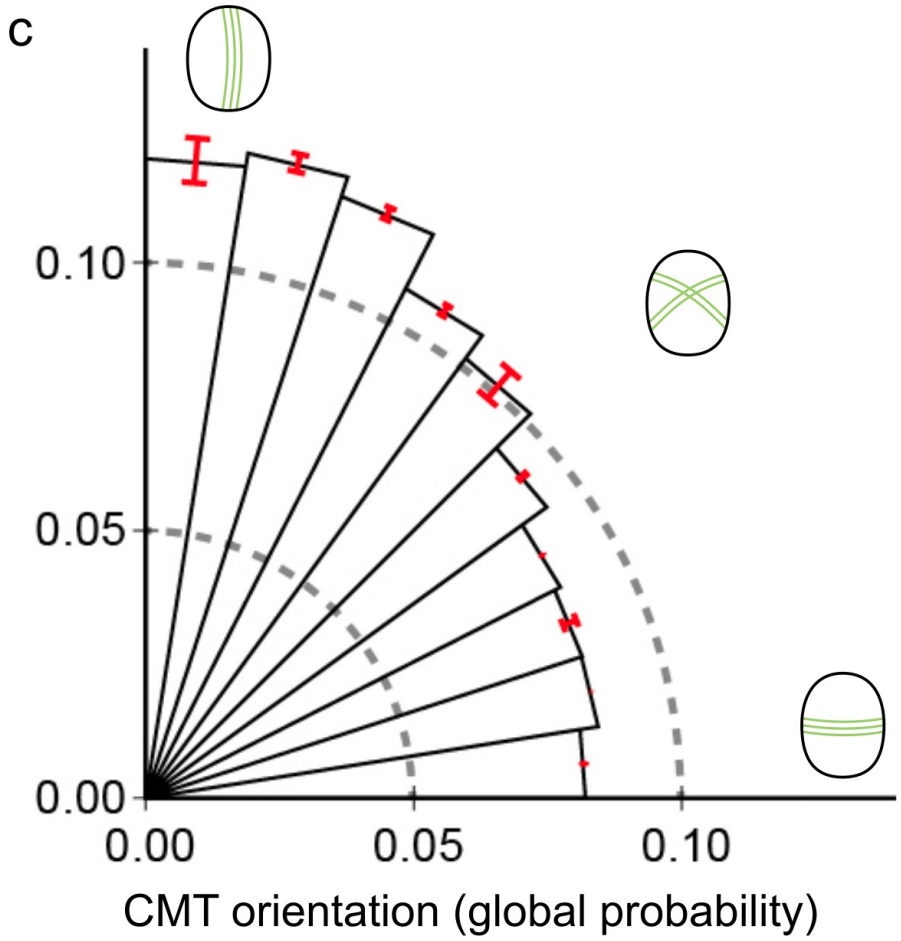


Colin *et al.*, 2021 PNAS

Transverse MT orientation depends on pressurization

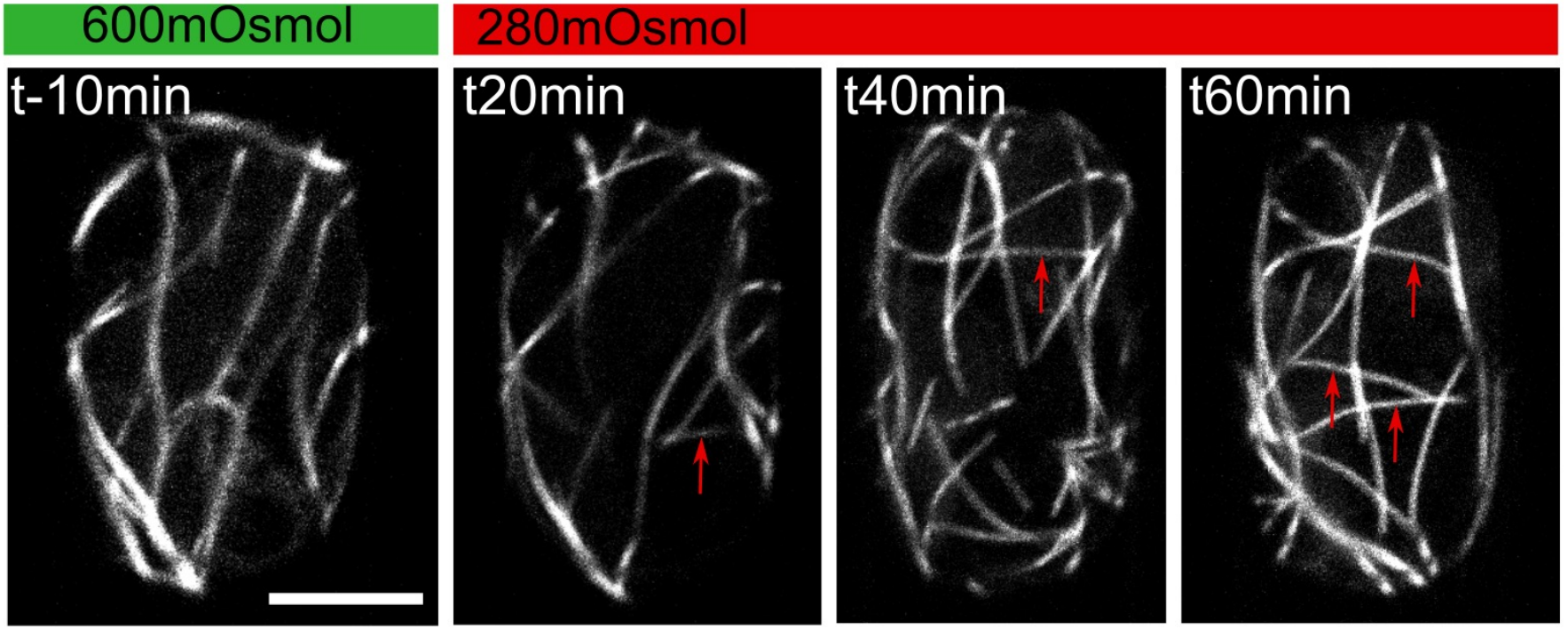


800 mOsm/L



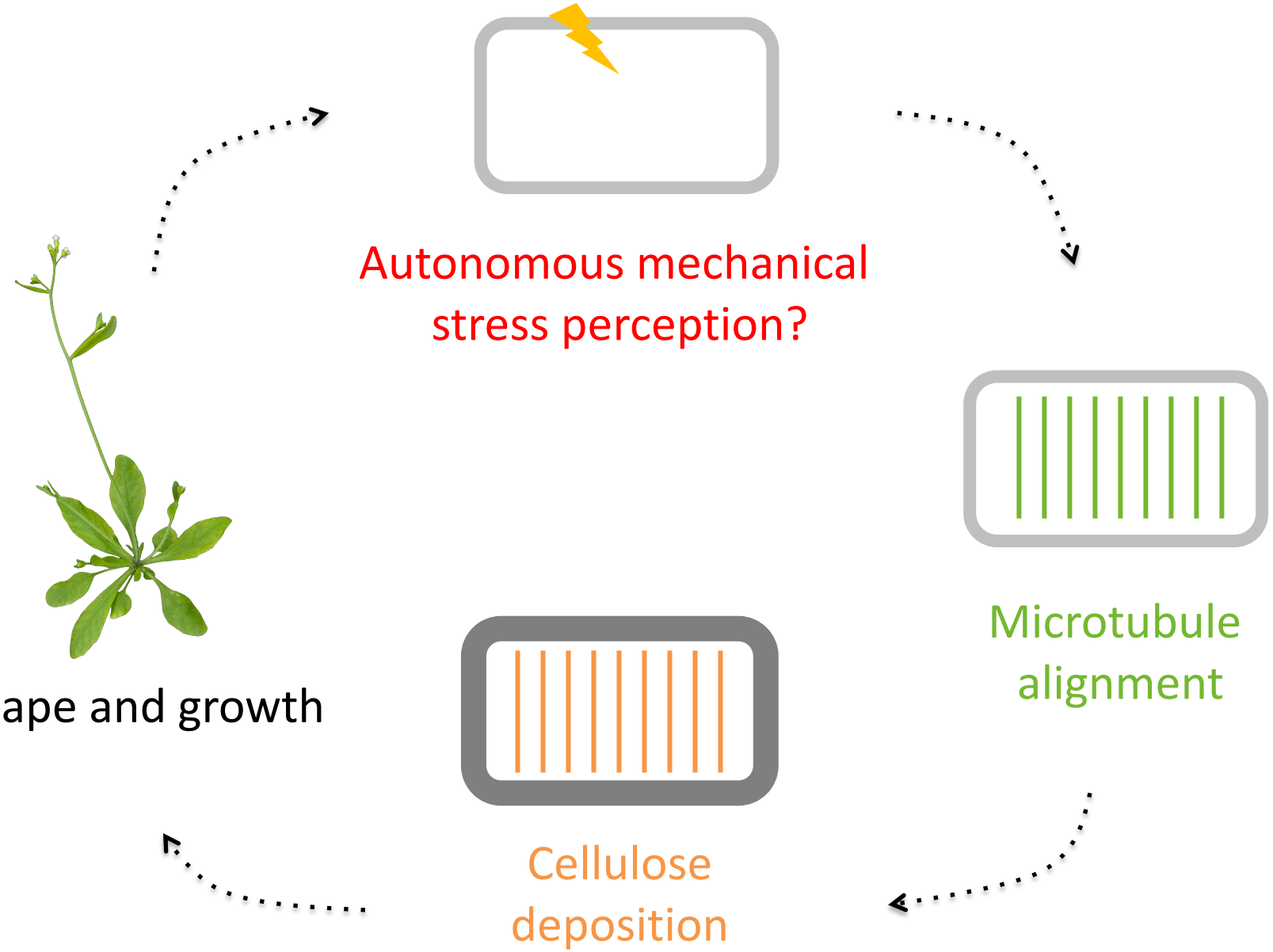
Colin *et al.*, 2021 PNAS

Dynamics:
transverse orientation induced upon pressurization

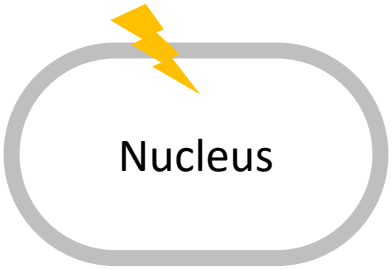


Colin *et al.*, 2021 PNAS

Microtubule mechanosensing in plant cells?

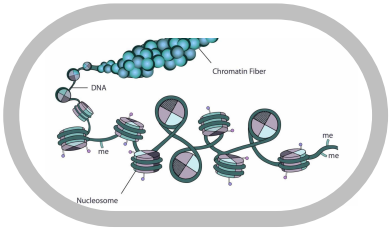


Outlook: Nuclear mechanosensing in plant cells?

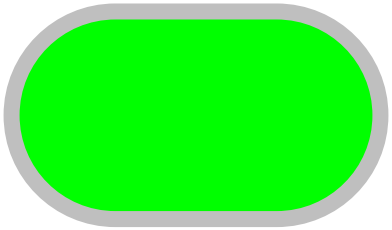


Nuclear mechanosensing?

Shape and growth

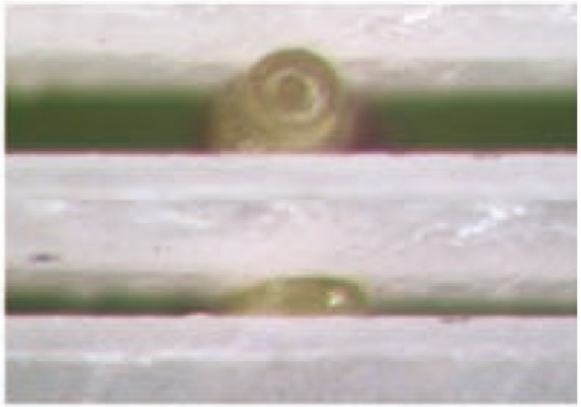


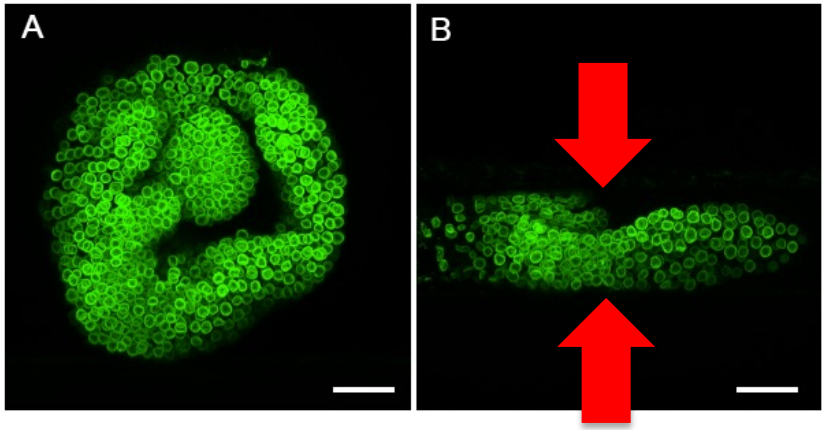
Chromatin?

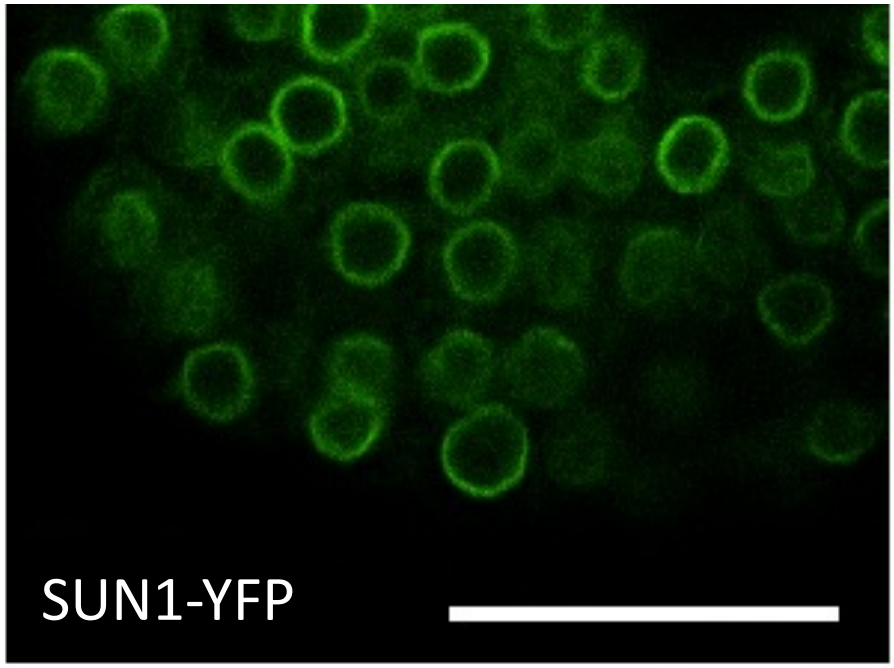


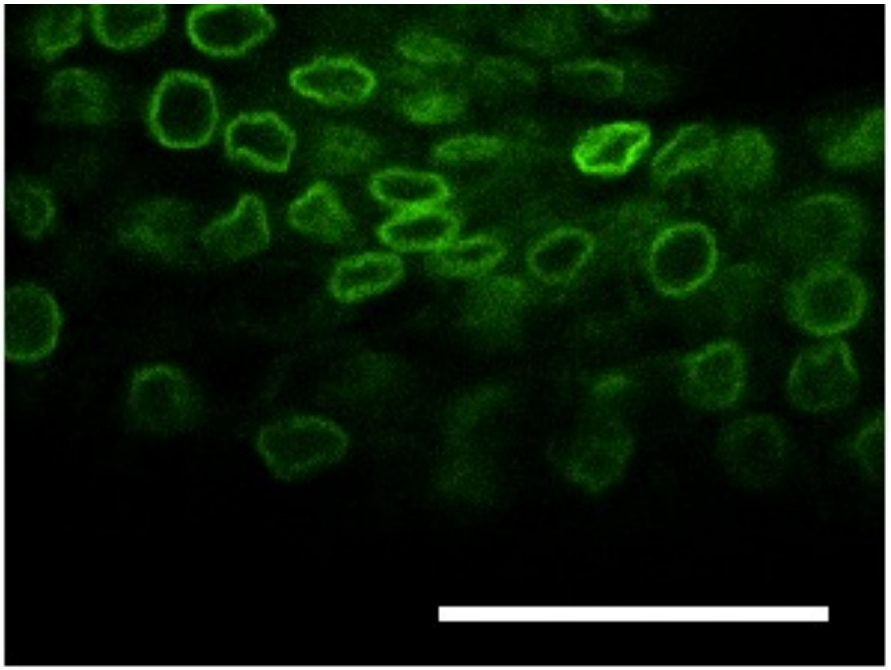
Gene expression

The nucleus is deformable

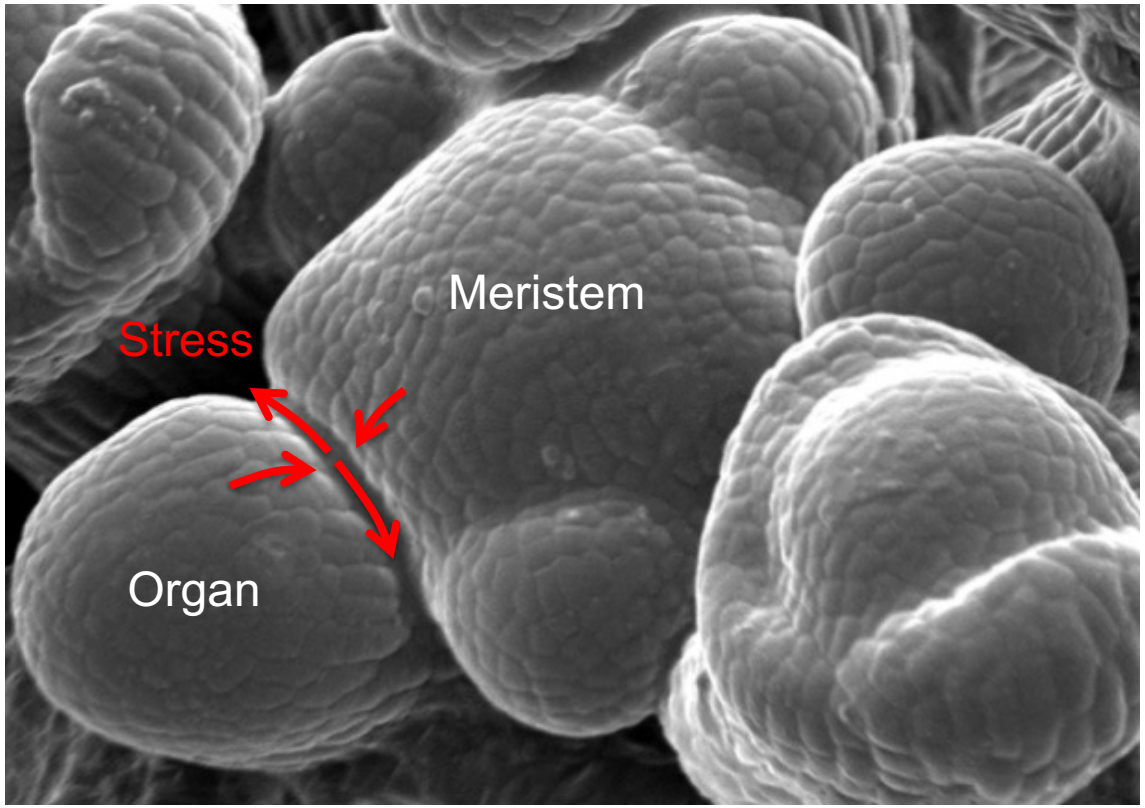






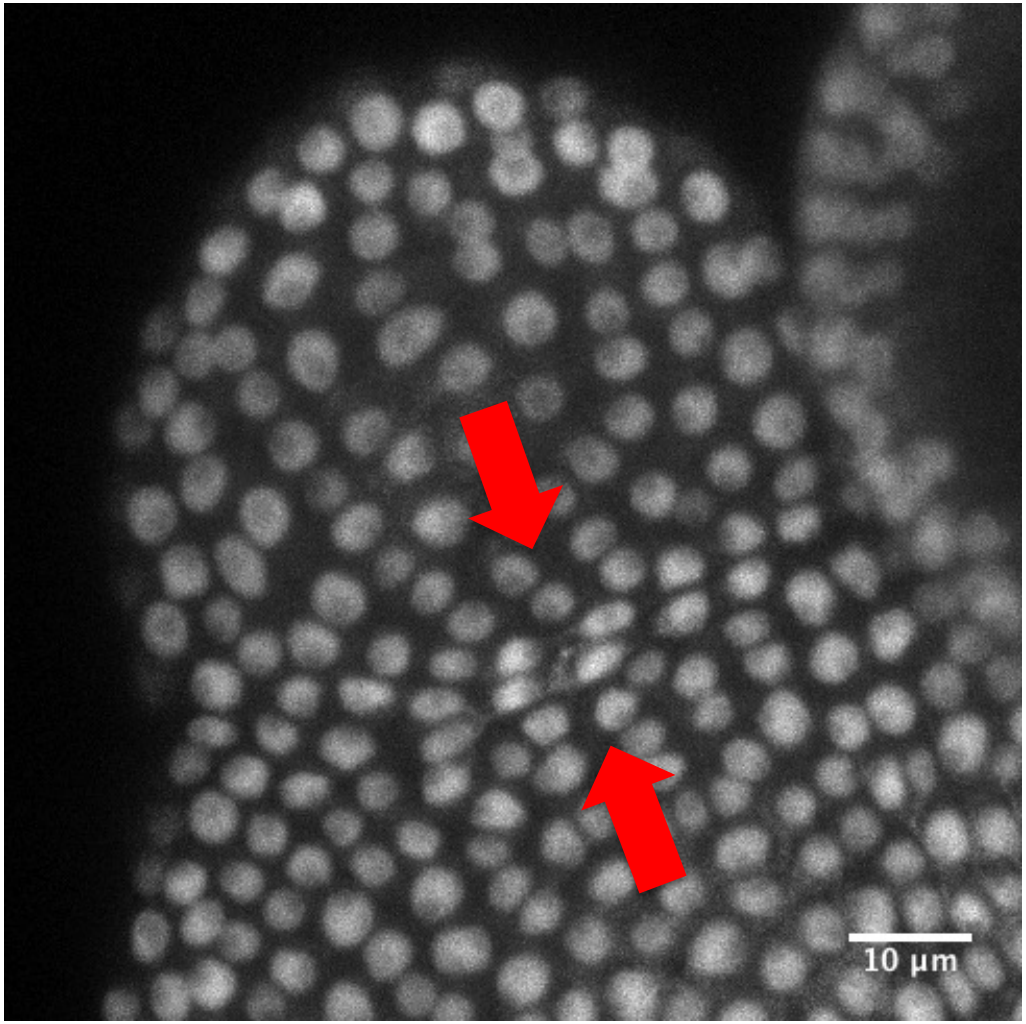


Fal *et al.* unpublished



Predicted compression during organogenesis

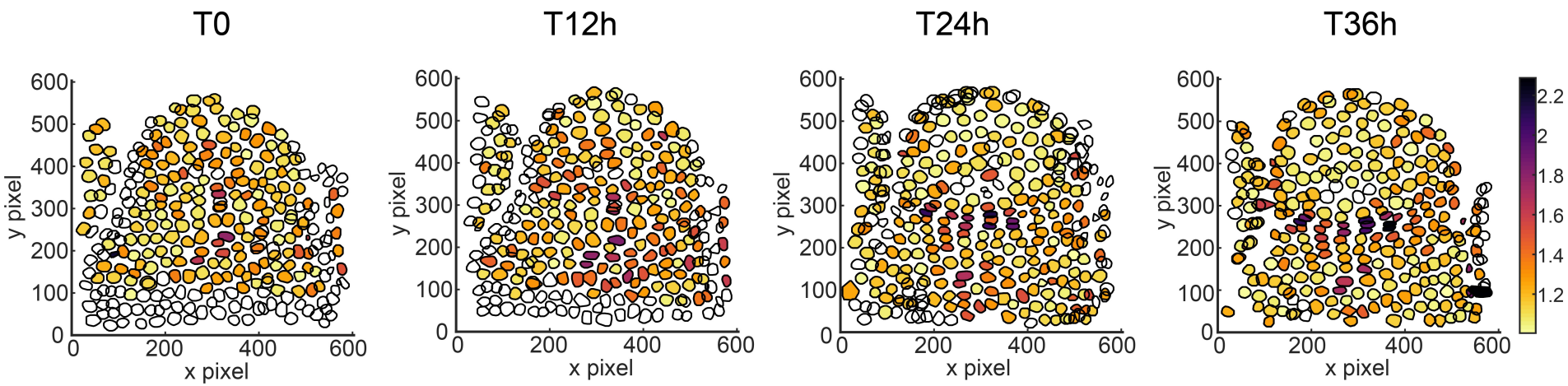
Growth-induced nucleus deformation



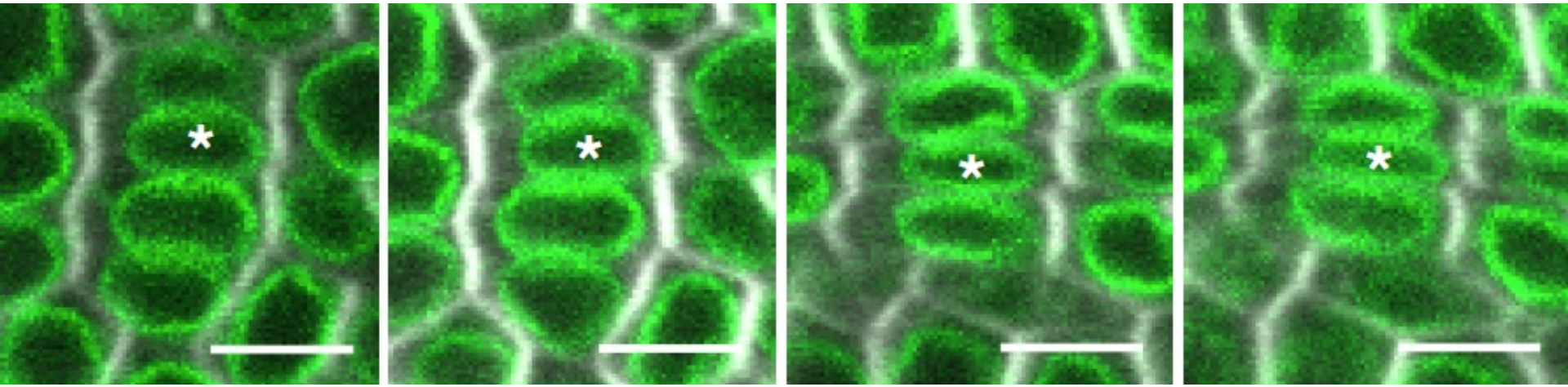
CFP-N7

With Henrik Jönsson

Growth-induced nucleus deformation



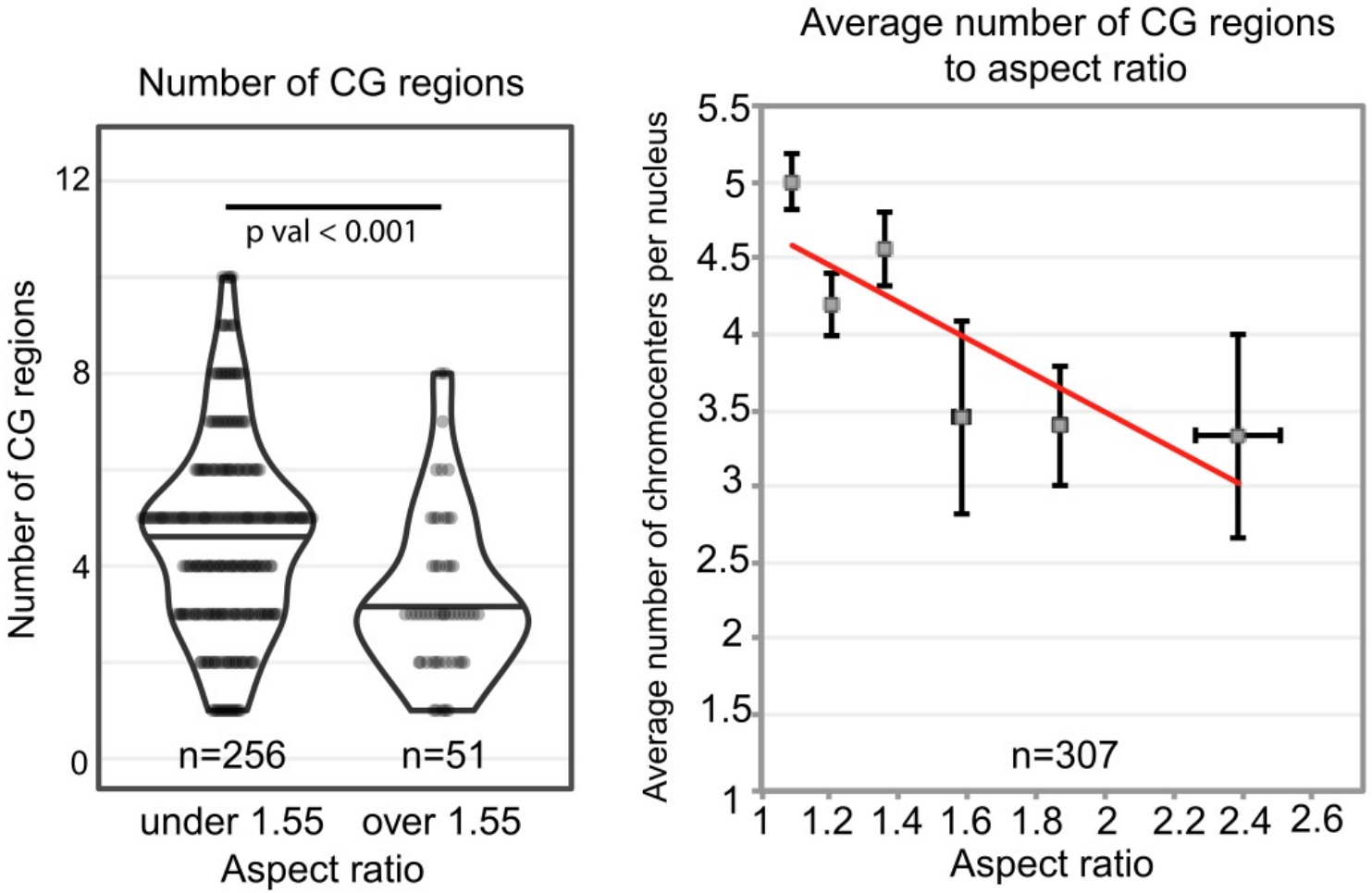
Nucleus aspect ratio



SUN1-YFP

Fal *et al.*, 2021 PNAS

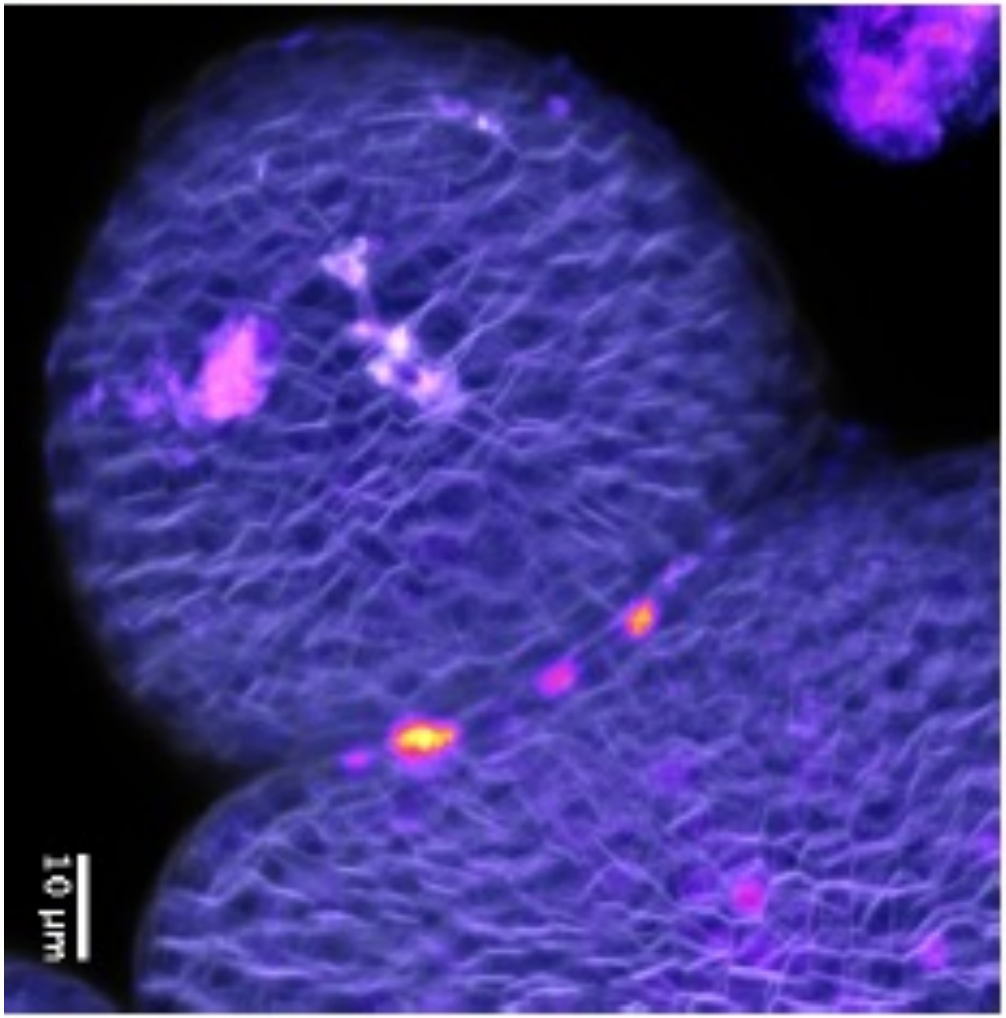
The number of chromocenters decreases in more compressed nuclei



pHTR5::mCG-MBD-GFP line (MBD for Methyl-CpG Binding Domain, marks CG methylation (a marker of heterochromatin)

Fal *et al.*, 2021 PNAS

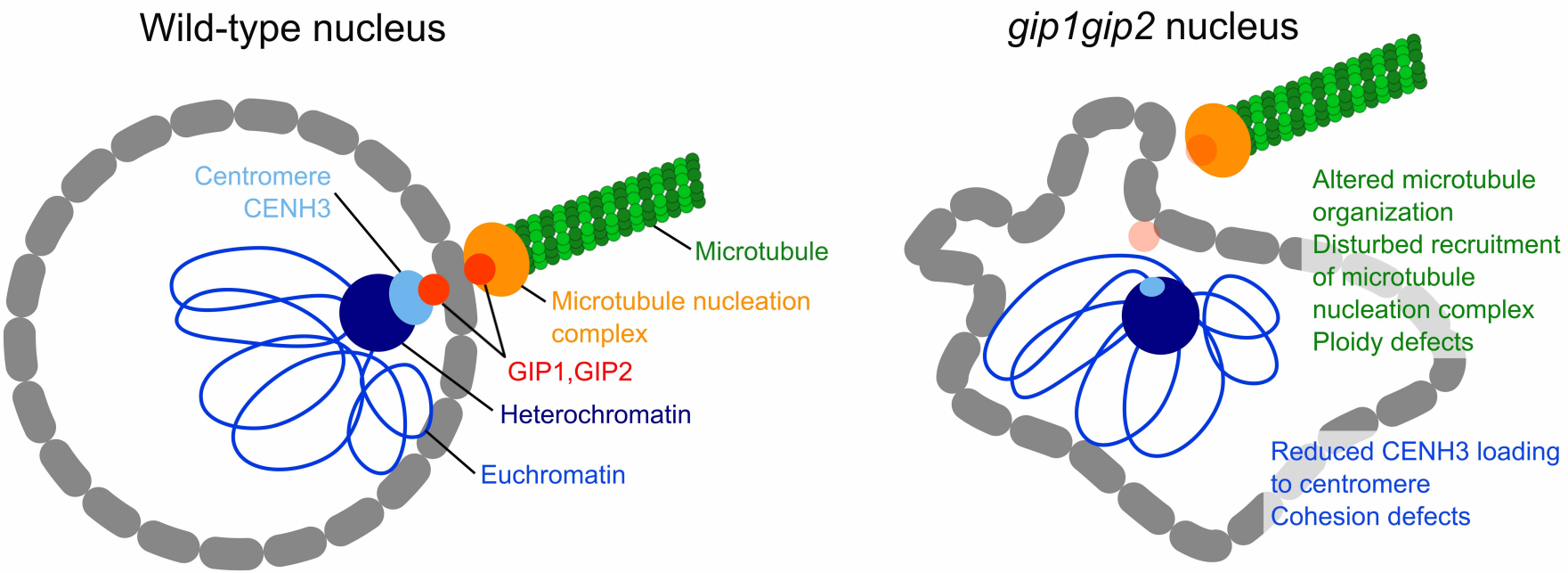
H1.3 induction
through growth-induced nucleus deformation



Histone H1.3

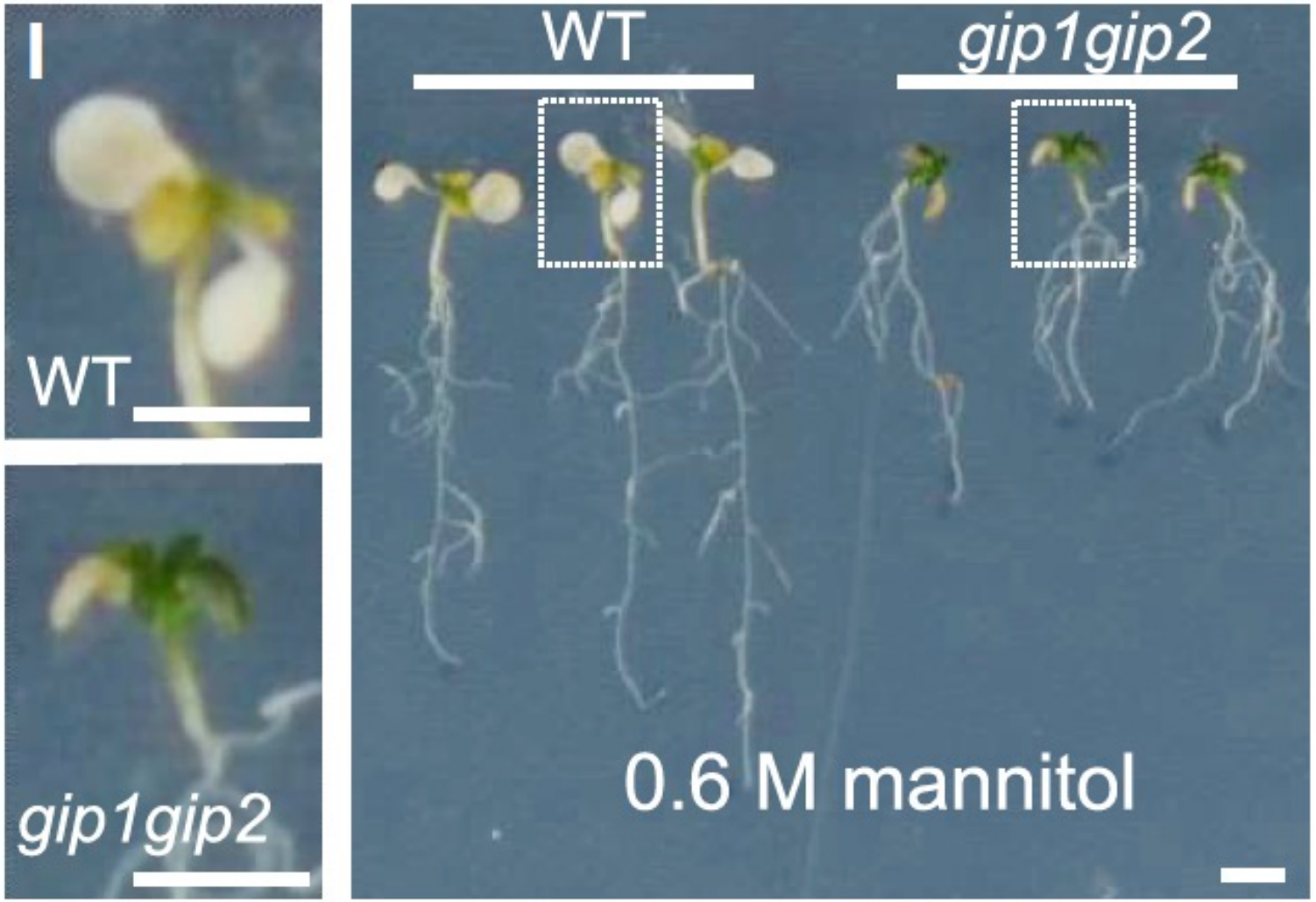
Fal *et al.*, 2021 PNAS

Nucleus shape depends on GIP (MZT homologs)



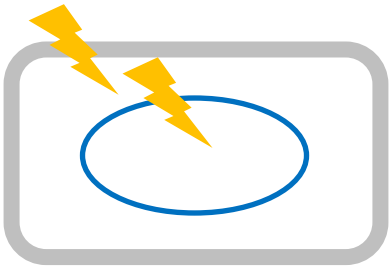
Goswami *et al.* 2020 Curr. Biol.

gip1gip2 becomes resistant to lethal hyperosmotic conditions

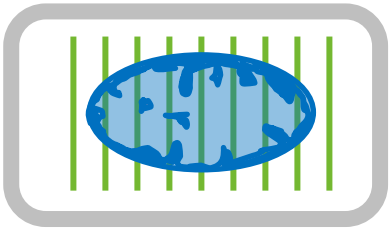


Goswami *et al.* 2020 Curr. Biol.

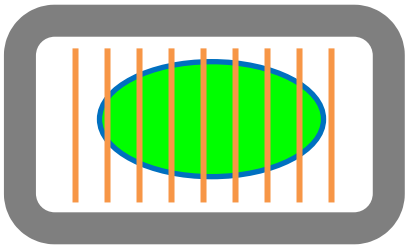
Multiscale mechanosensing in plant cells



Cortical (FER, MTs) and nuclear mechanosensing



Cytoskeleton and chromatin response



Wall reinforcement and gene expression

Shape and growth

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Team members

Juan Alonso Serra
Antoine Chevallier
Leia Colin
Sofia Correa
Matthieu Cortes
Liam Elliott
Rituparna Goswami
Charlotte Kirchhelle
Marianne Lang
Alice Malivert
Marjolaine Martin
Isaty Melogno
Shogo Takatani
Jan Traas
Christophe Tréhin
Duy-Chi Trinh

Past members

Mariko Asaoka
Léna Beauzamy
Mathilde Dumond
Kateryna Fal
Nathan Hervieux
Jean-Daniel Julien
Benoit Landrein
Mengying Liu
Yuchen Long
Marion Louveaux
Pascale Milani
Vincent Mirabet
Naomi Nakayama
Thomas Stanislas
Stéphane Verger
Feng Zhao

Collaborators

Karen Alim
Daphné Autran
Atef Asnacios
Christophe Bailly
Célia Baroux
Rishi Bhalerao
David Bouchez
Arezki Boudaoud
Hervé Canut
Marie-Edith Chabouté
Yves Couder
Jacques Dumais
Ali Ferjani
Jean-Marie Frachisse
Christophe Godin
Liz Haswell
Marcus Heisler
Gwyneth Ingram
Henrik Jönsson
Yvon Jaillais
Dorota Kwiatkowska
Chun-Biu Li
Elliot Meyerowitz
Eric Mjolsness
Hiroyasu Motose
Bruno Moulia
Utpal Nath
Stéphanie Robert
Adrienne Roeder
Arun Sampathkumar
Tim Saunders
Laura Schaedel
Richard Smith
Satoru Tsugawa
Virgile Viasnoff