From genes to plant architecture: the shoot apical meristem in all its states
28-30 Nov. 2022, Poitiers, France

Tight control of division plane orientation is necessary to optimize the growth capacity of tissues and organs in *Arabidopsis thaliana*

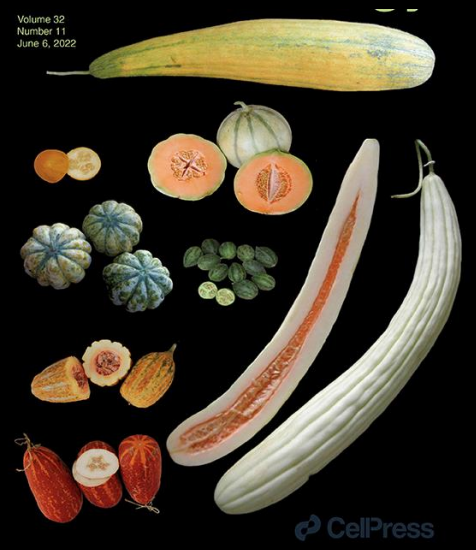
Analysis of replum development in the *trm1234* mutant

Magalie Uyttewaal

The SPACE team (Spatial Control of Cell Division)
Institut Jean-Pierre Bourgin, INRAE Versailles

Diversity of fruit shapes among Angiosperms and among families

Snyders Frans 1960, Musée du Louvre

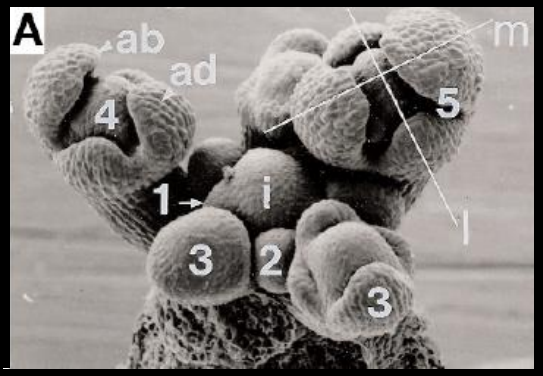


Boualem et al., 2022, Current Biology

In numerous species fruit shape is correlated to ovary shape

Simonini and Østergaard 2019
, Monforte et al., 2014, Boualem et al., 2022

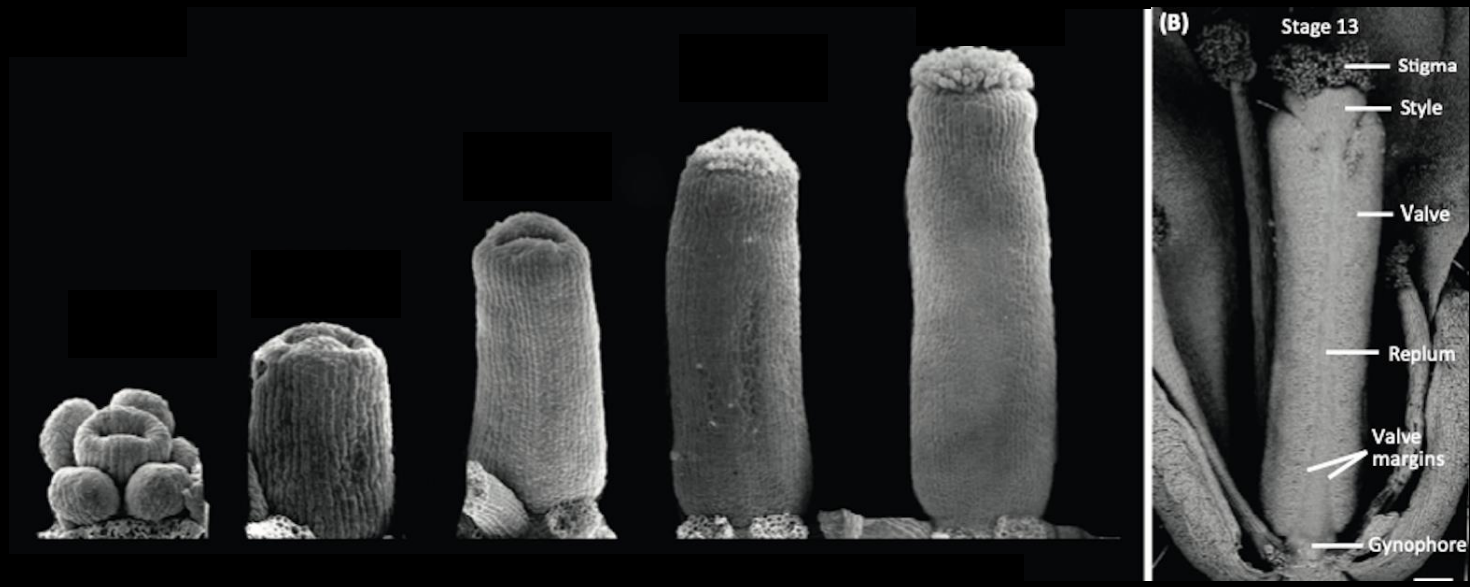
Arabidopsis female reproductive organ development: from the SAM to the mature pistil

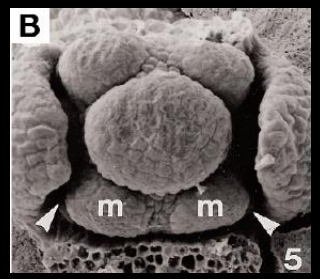


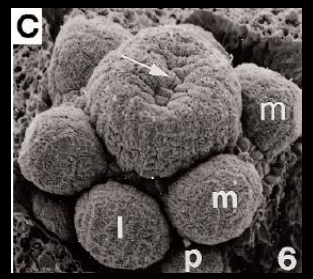
Stage 1-4

Organ Specification

Arabidopsis gynoecium is composed of 2 fused carpels that arise from a single primordium







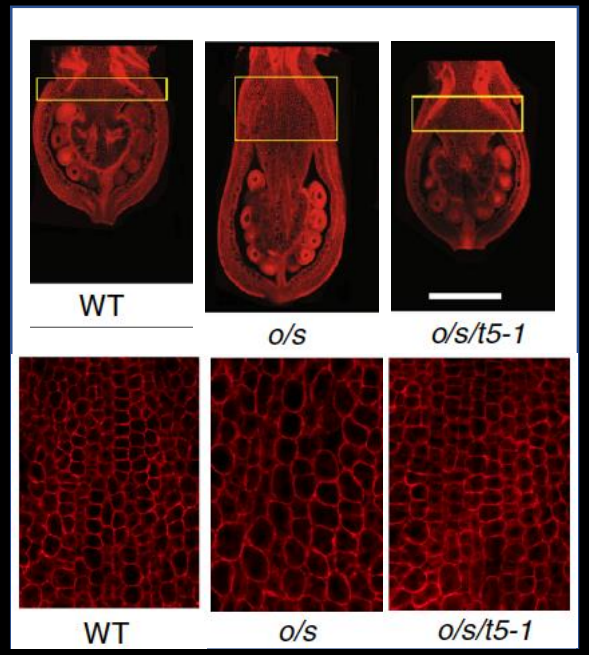
Stage 5 Stage 6 Stage 7 Stage 8 Stage 9 Stage 11 Stage 12 Stage 13

Promotion of organ growth through cell division and elongation

Fertilization

Adapted from Roeder and Yanofsky (2006), Rayes-Olalde et al. (2013)

Determinants of gynoecium and fruit size and shape are related to growth and division effectors and TRM genes



Wu et al., 2018

Differential cell patterning in round versus elongated ovary
(Pan et al 2020, Wu et al 2018).

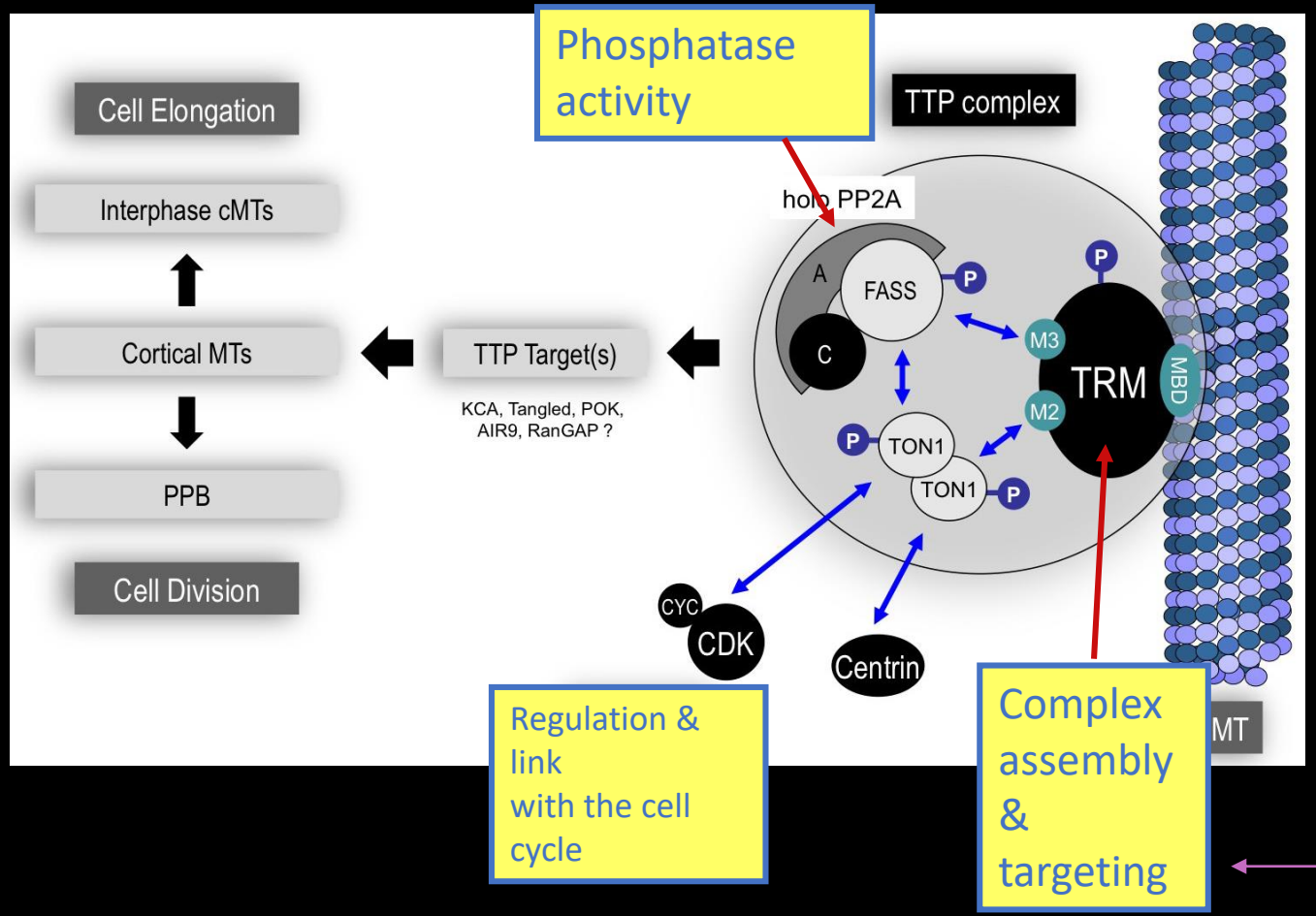
The TRM-OVATE module controls fruit shape in several species (Wu et al., 2018, Boualem et al., 2022)

Grain shape in rice
(Wang et al., 2015)

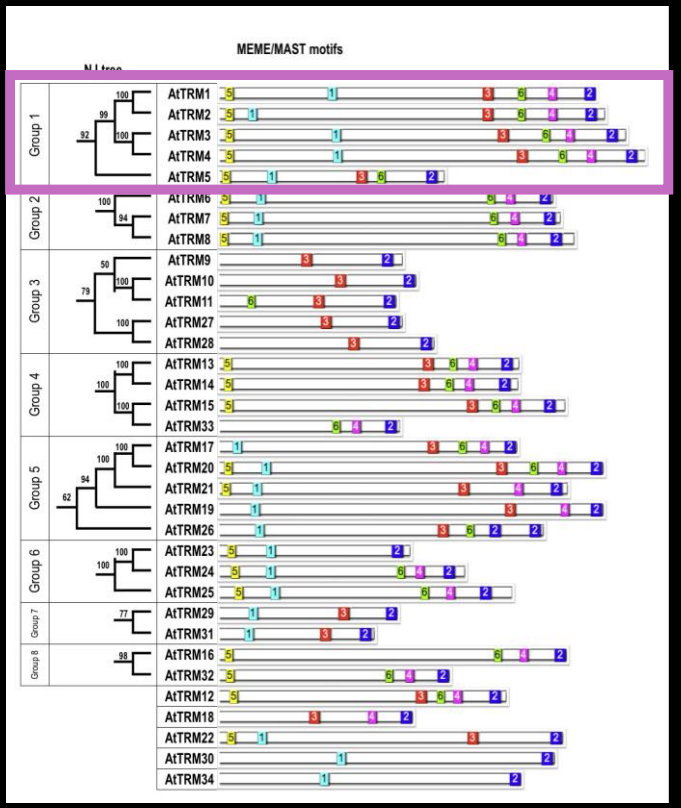
Species	Gene	Trait	Reference
Maize	ZmGW7-GRMZM2G061562	kernel size	Li et al., 2022
Melon	TRM	fruit shape	Boualem et al., 2022
Maize	GRMZM2G403003	root hair length	Liu et al., 2021
Cotton	OsGL7 Homolog	seed size	Liu et al., 2020
Tomato	TRM	fruit shape	Wu et al., 2018
Cucumber	TRM	fruit shape	Wu et al., 2018
Wheat	TaGW7	fruit shape and weight	Wang et al., 2019
Rice	OsGL7/OsGW7	grain size	Wang et al., 2015
Rice	OsGW7	grain shape, yield, quality	Wang et al., 2015
Arabidopsis	TRMs	Silique size and shape	Unpublished data, SPACE group

The TTP protein complex regulates cortical microtubule arrays

The TTP complex



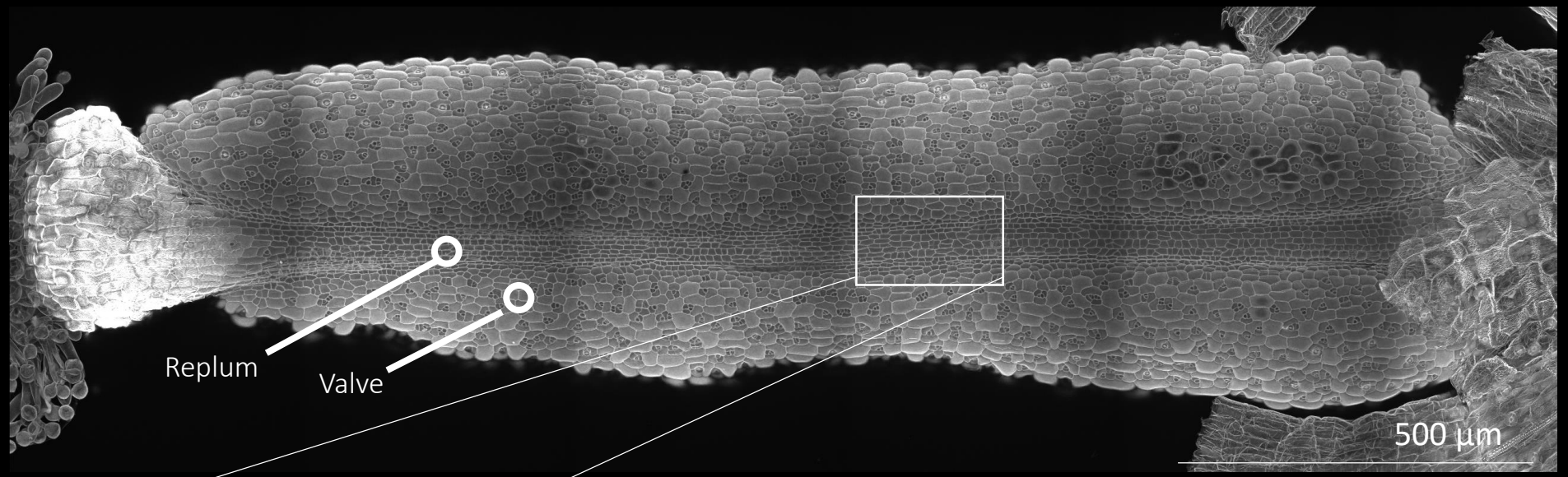
The Arabidopsis TRM family

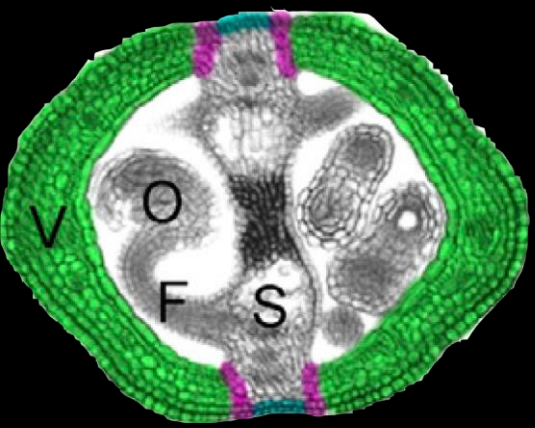


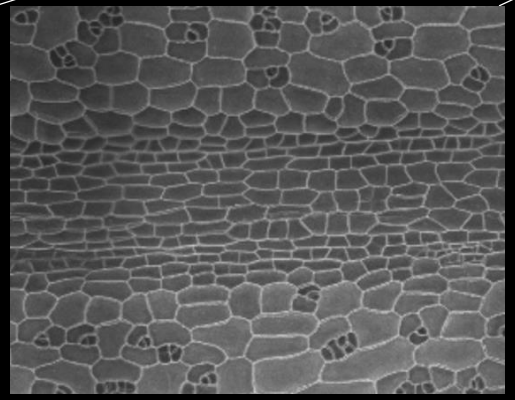
Sub-group 1

Drevensek et al., 2012
Spinner et al., 2013
Schaefer et al., 2017

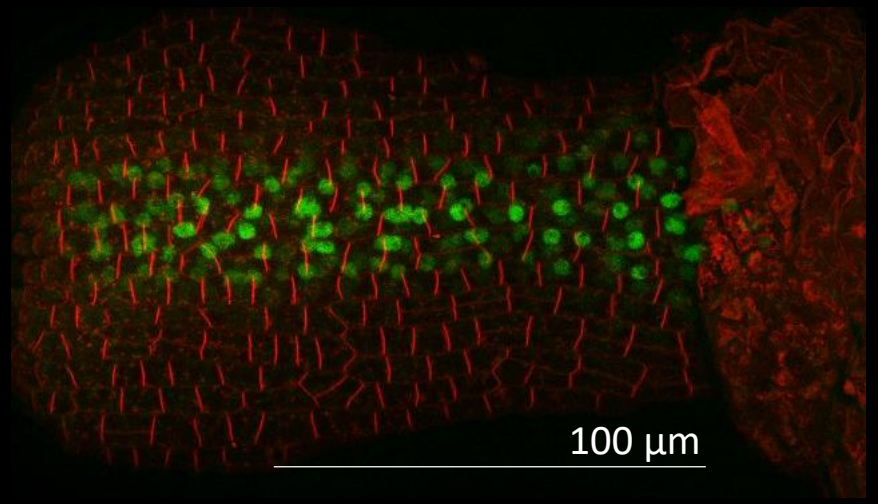
The Arabidopsis Gynoecium: a complex organ with parallel cell files in the replum





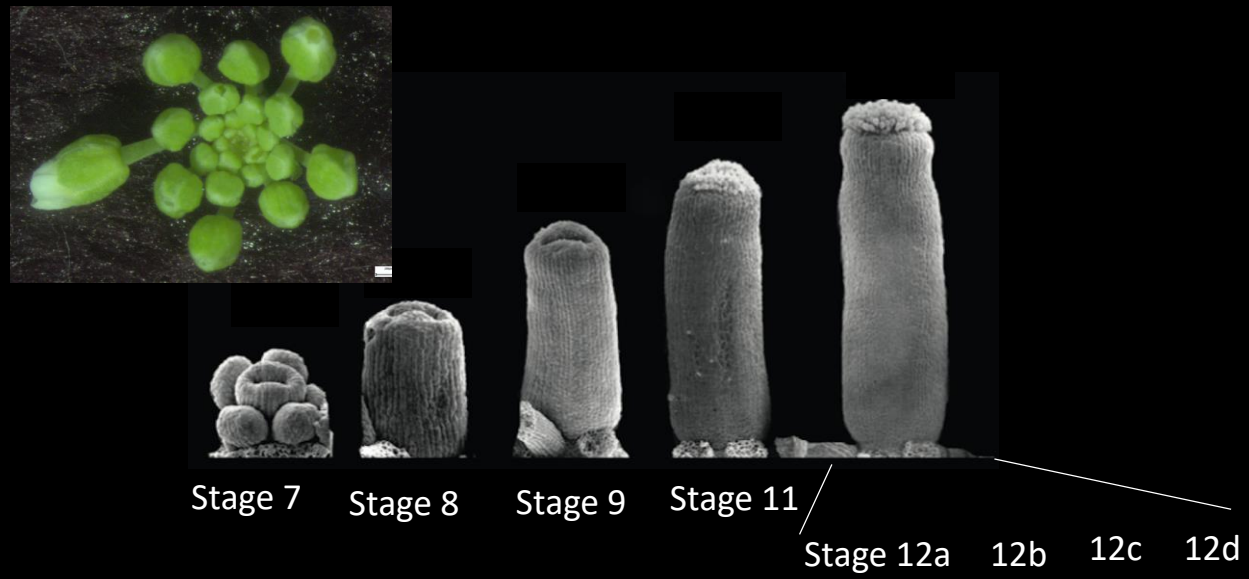


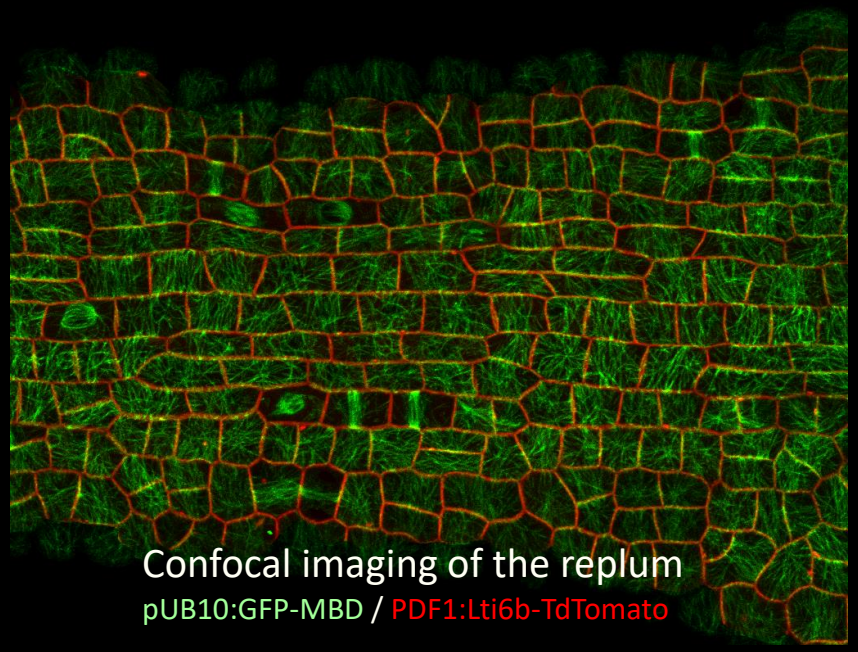
The replum epidermis is made of parallel cell files



Cell files Identifiable from early stages of development (FM4-64, RPL1-GFP)

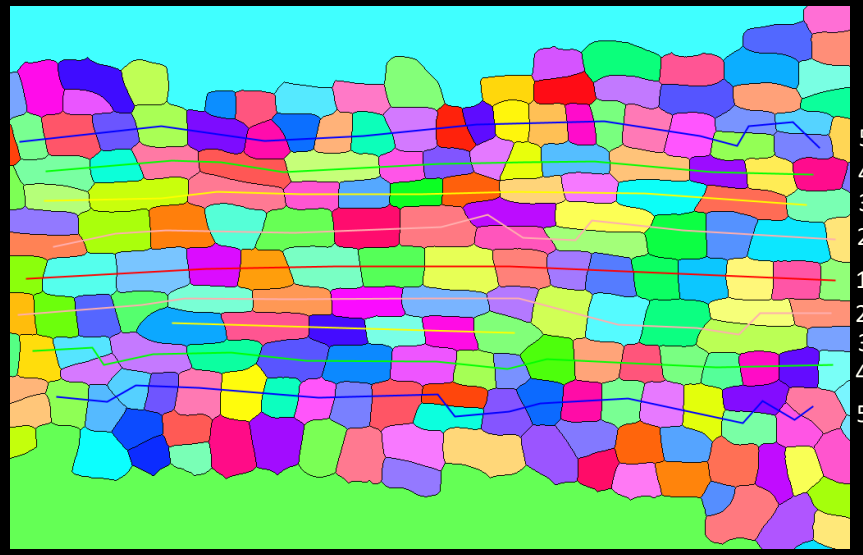
Quantitative analysis of cellular and sub-cellular parameters of the quadruple *trm1234* mutant



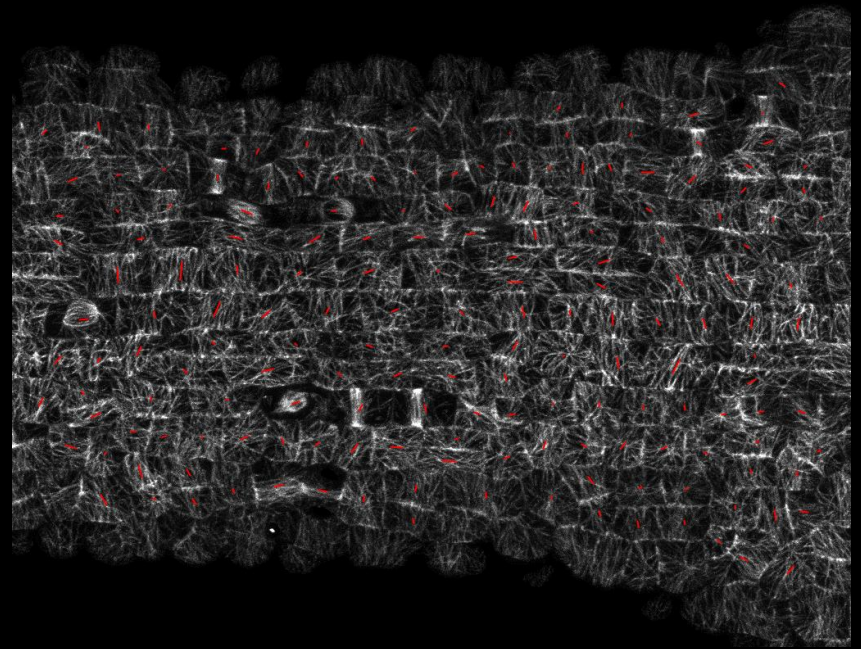


Confocal imaging of the replum

pUB10:GFP-MBD / PDF1:Lti6b-TdTomato



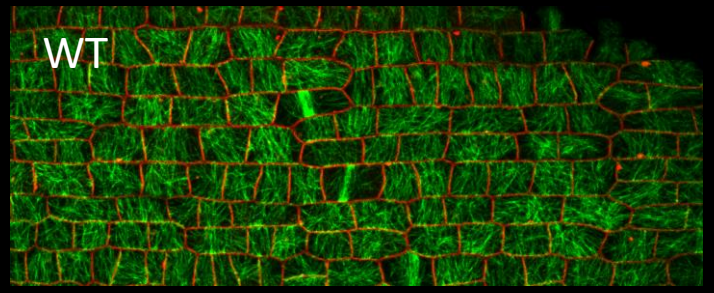
- 2D segmentation
  -Cell morphology
  -Cell file identification
  -Transverse angles
  -Skeletonization and vertex analysis

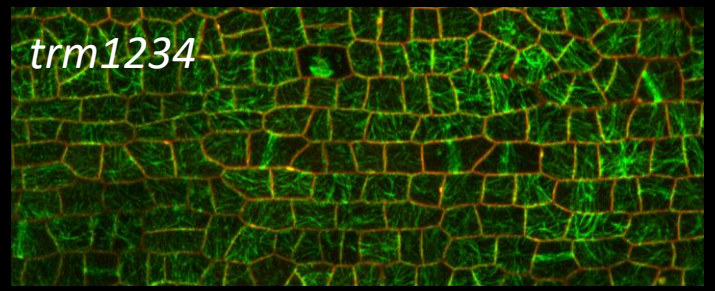


- MT array anisotropy and orientation (FibrilTool)

-Mitotic index

TRM1234 control interphasic cortical microtubule array organization

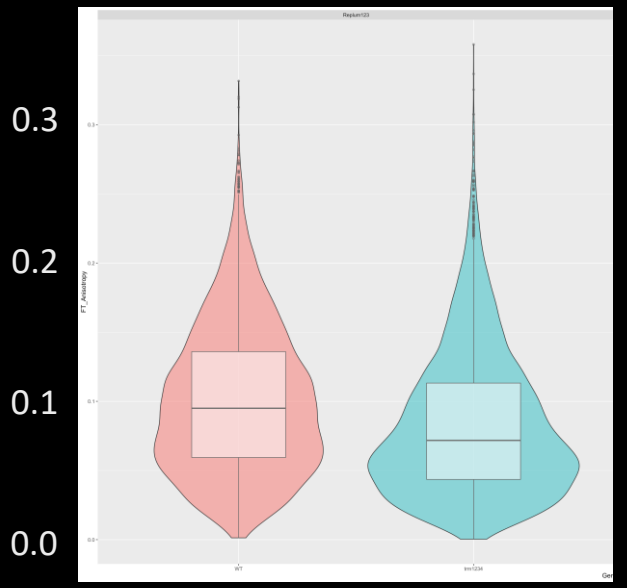




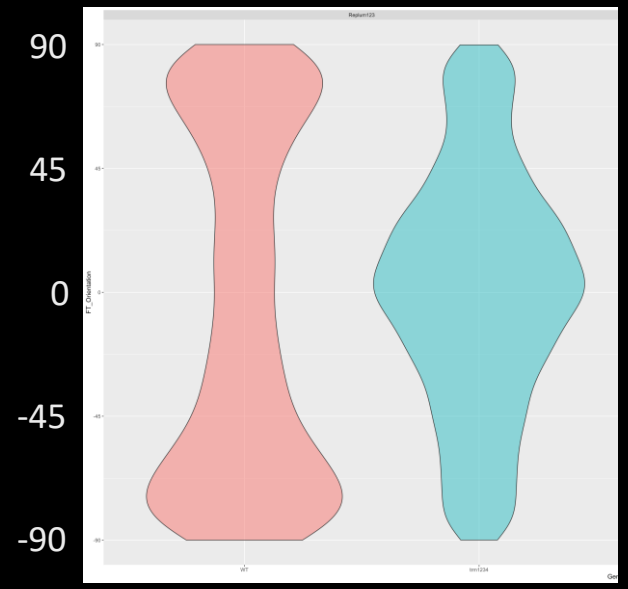
Replum apico-basal axis

(FibrilTool analysis)

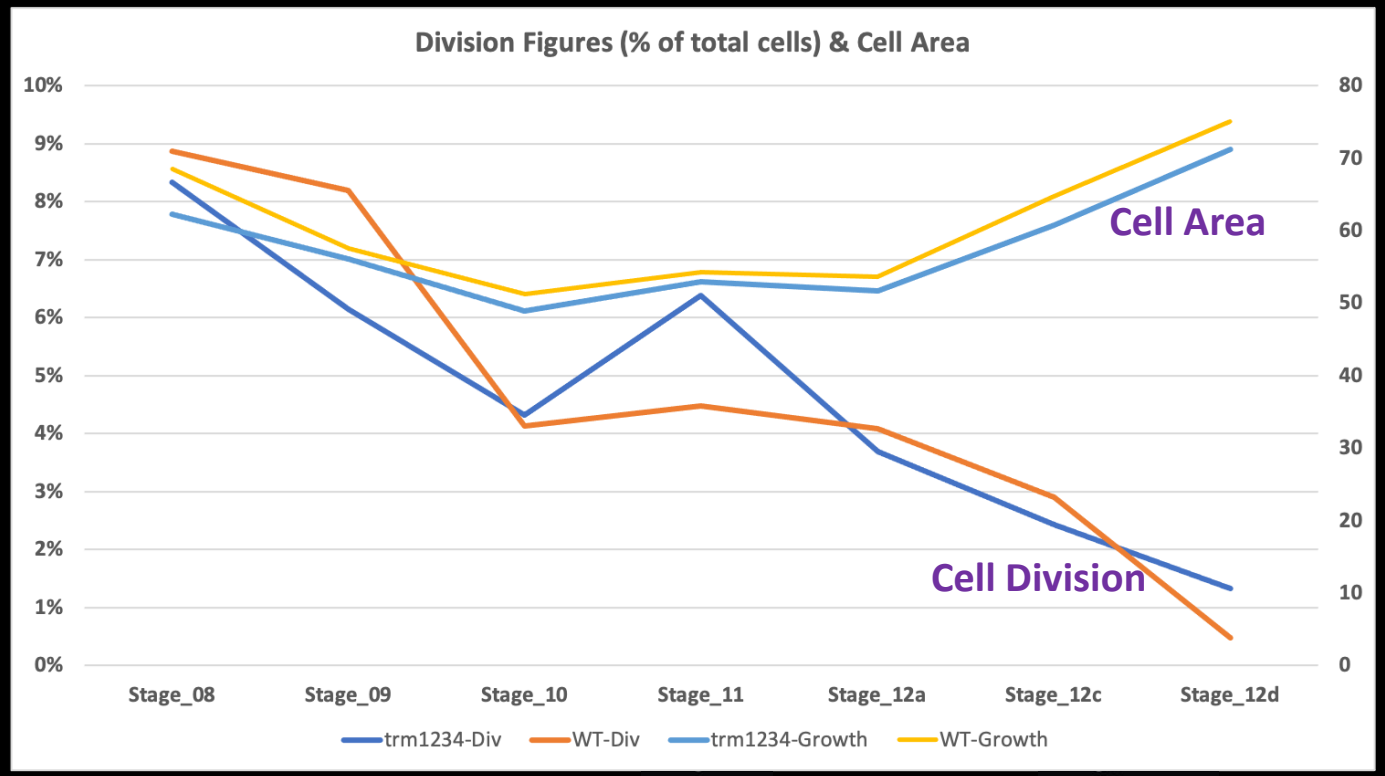
Anisotropy of cMT arrays



Orientation of cMT arrays



Cell growth and cell division during replum development

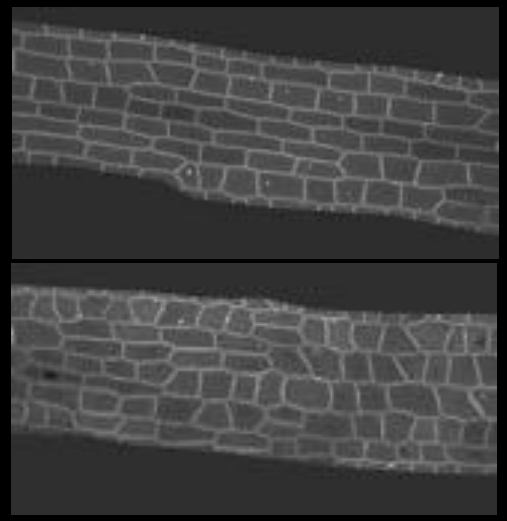


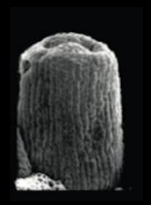
WT

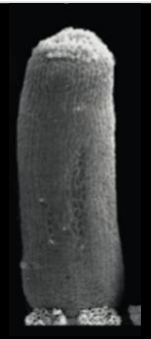
trm1234

WT

trm1234







Stage 8

Stage 9

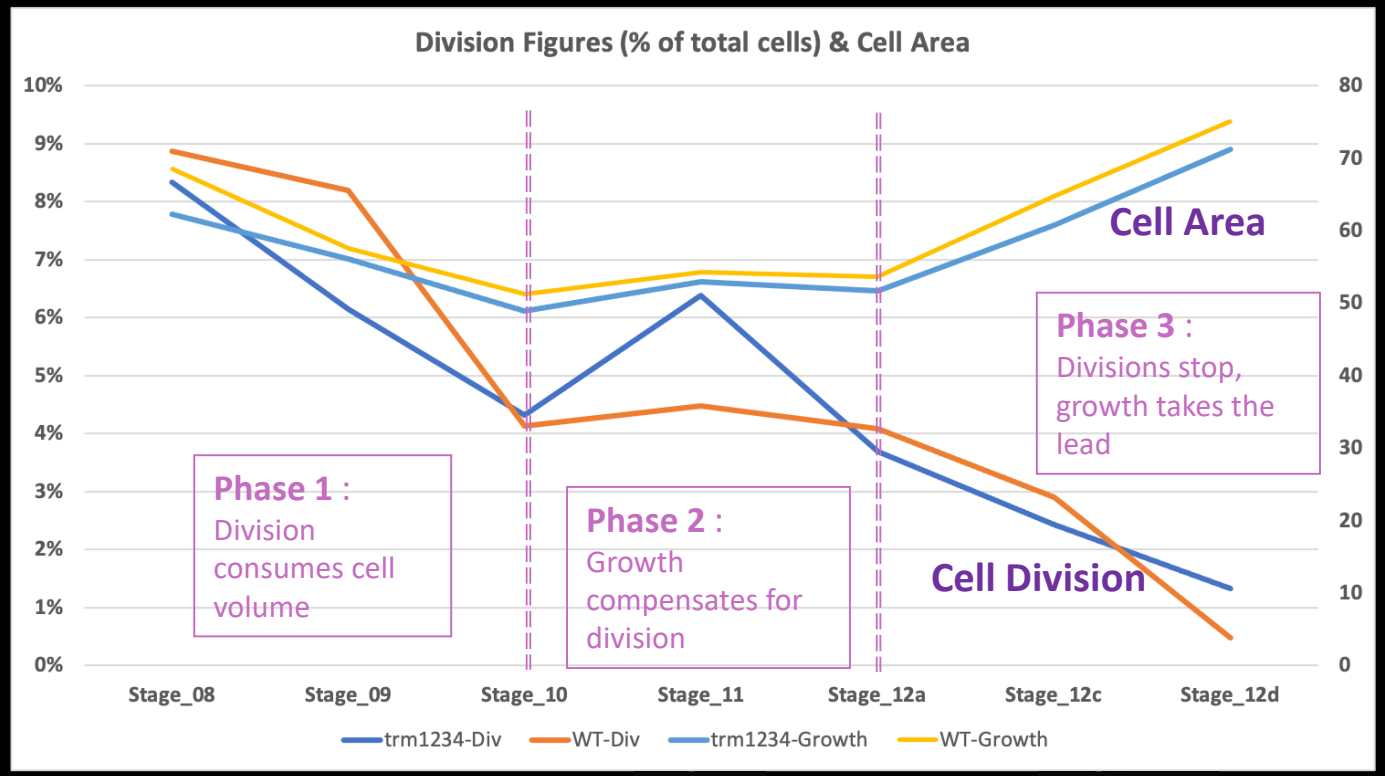
Stage 11

Stage 12a

Stage 12c

Stage 12d

Cell growth and cell division during replum development

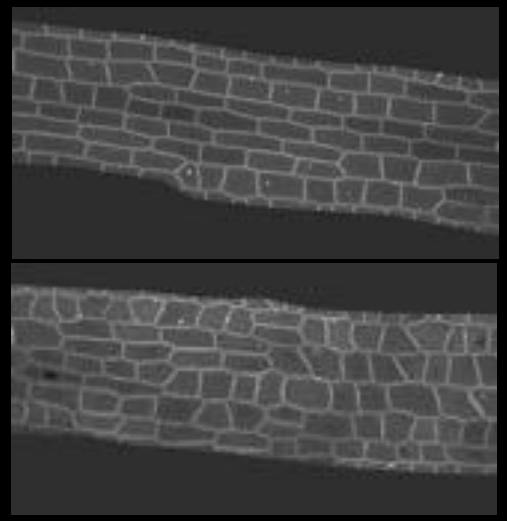


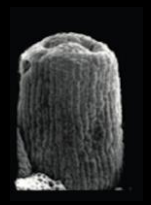
WT

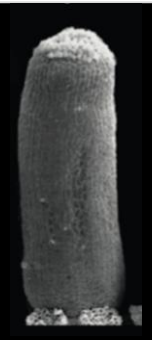
trm1234

WT

trm1234







Stage 8

Stage 9

Stage 11

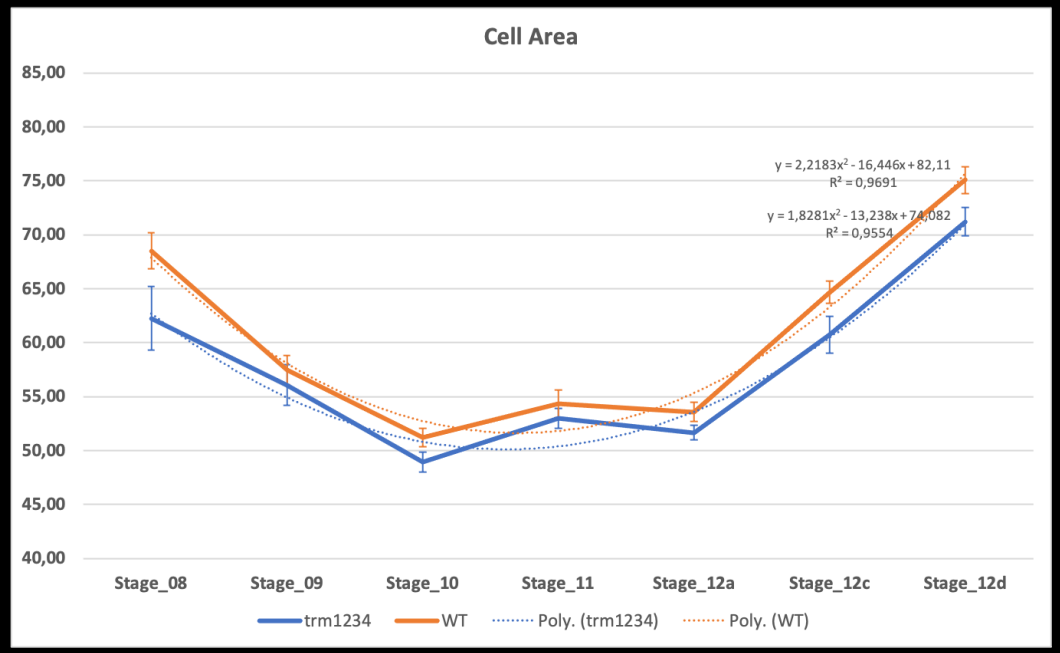
Stage 12a

Stage 12c

Stage 12d

Cell growth is not strongly affected in *trm1234*,…

… Cell elongation is reduced in *trm1234*

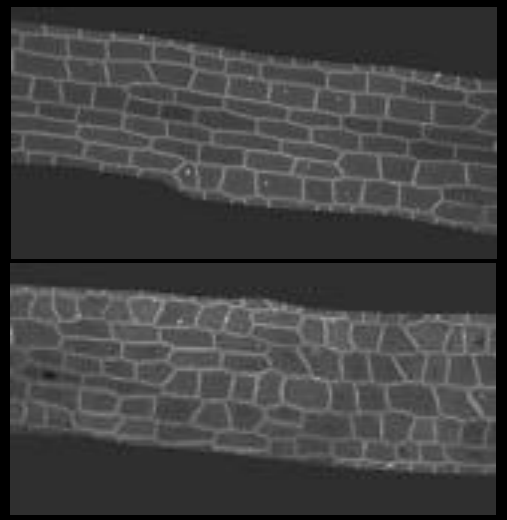


WT

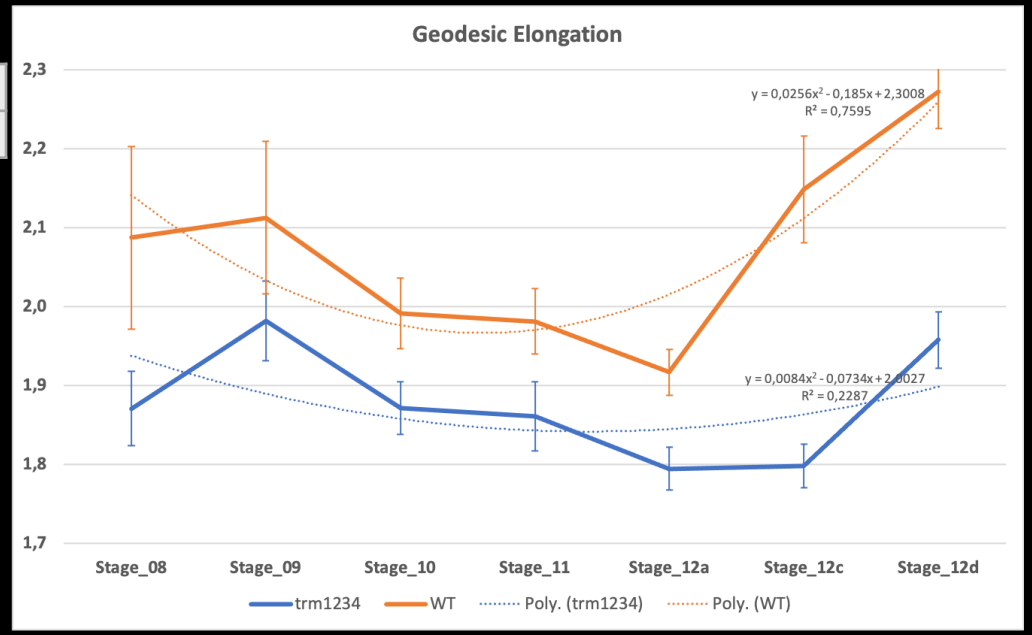
trm1234

WT

trm1234



Stage_08	Stage_09	Stage_10	Stage_11	Stage_12a	Stage_12c	Stage_12d
+ 10,0 %	+ 2.5 %	+ 4.6 %	+ 2.5 %	+ 3.7 %	+ 6.5 %	+ 5.4 %

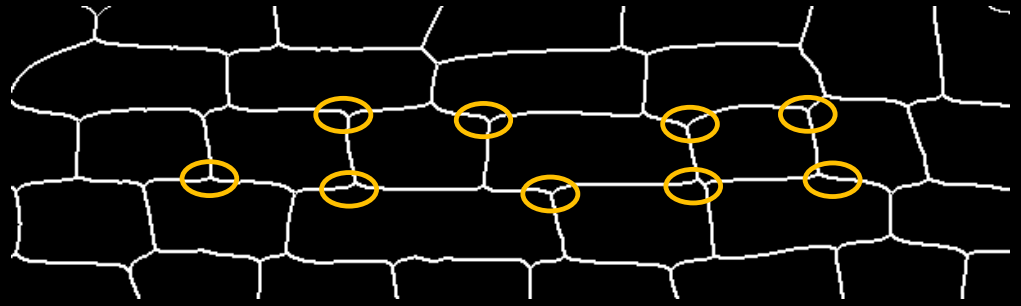


WT

trm1234

The cellular topology of the replum is altered in *trm1234*

WT



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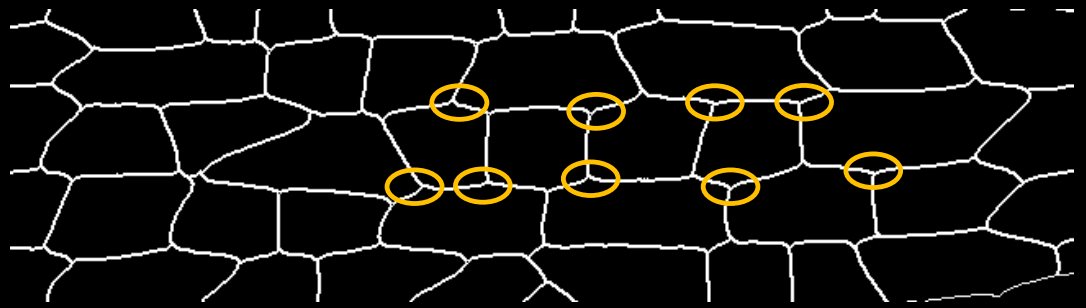
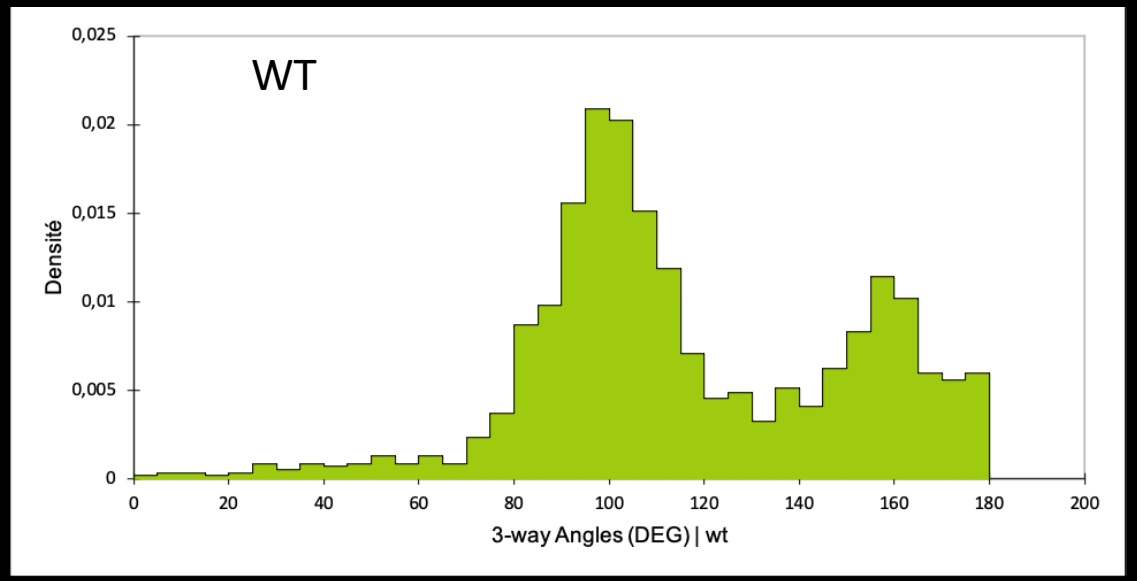
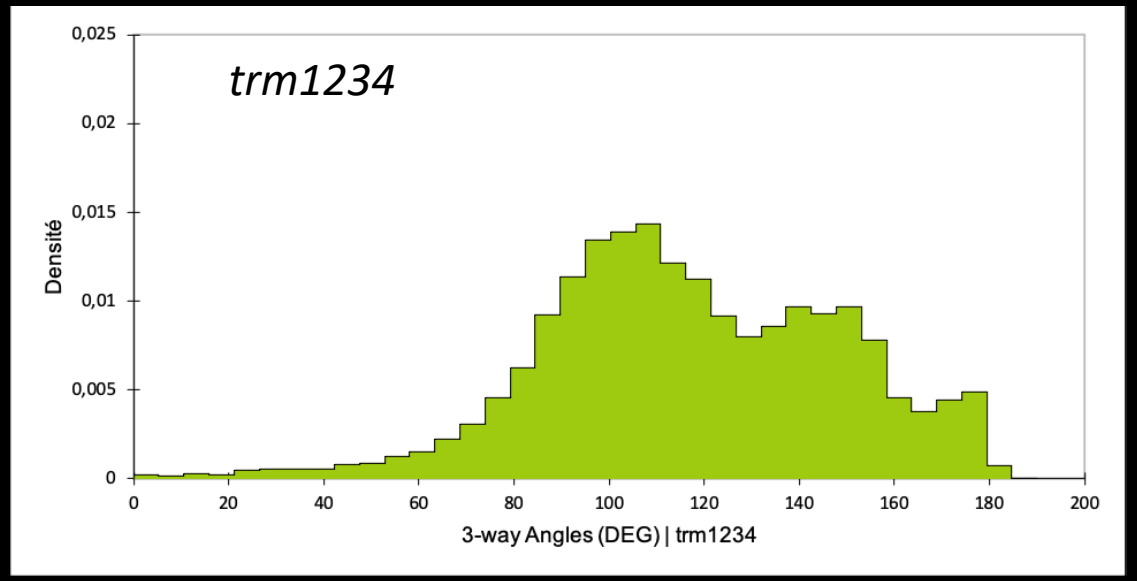
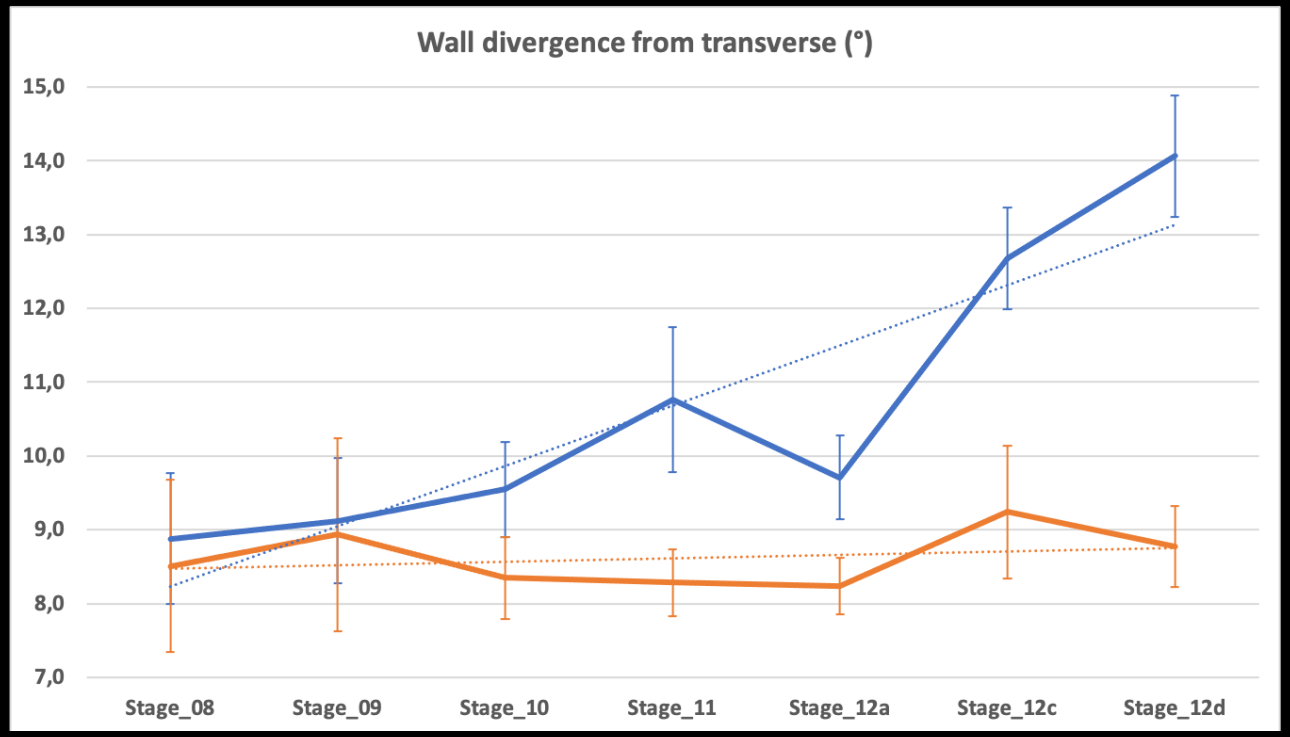


BoneJ skeleton Analysis

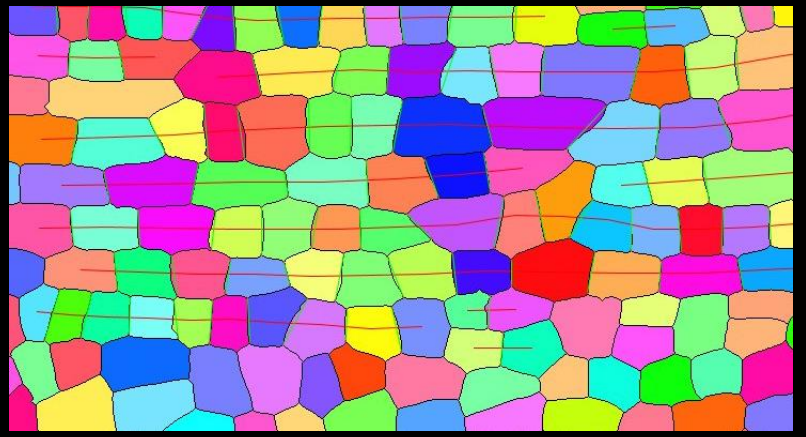




Walls diverge from transverse in the *trm1234* mutant



trm1234



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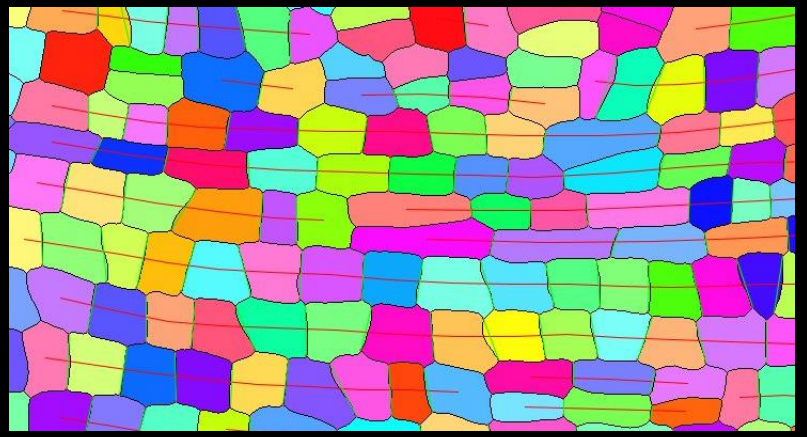
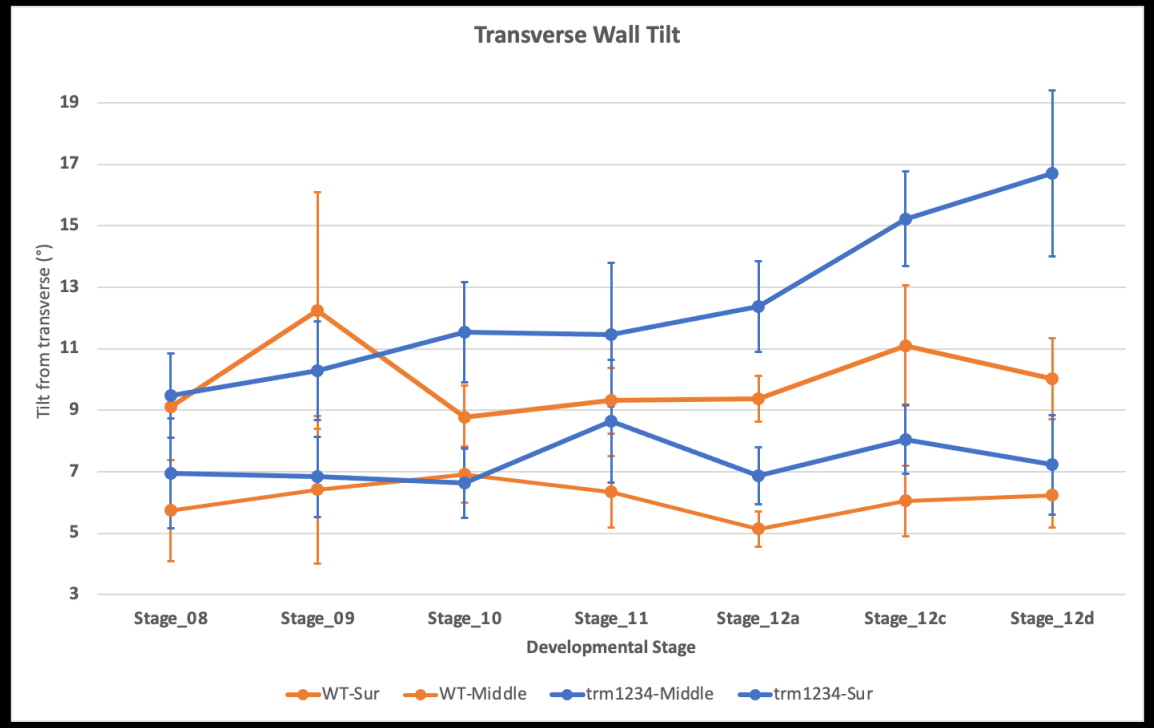


Cell File Angle Tool (IJPB-plugin in Fiji, Schaefer et al., 2017)

Recent cell walls are only slightly tilted the *trm1234* mutant

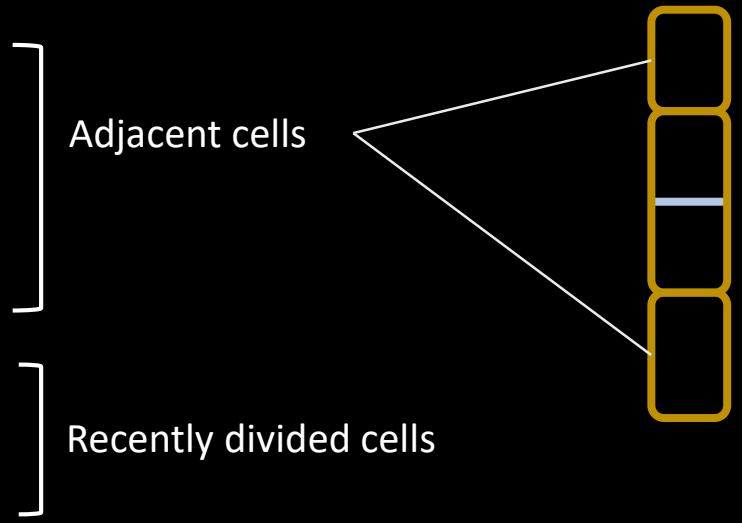


trm1234

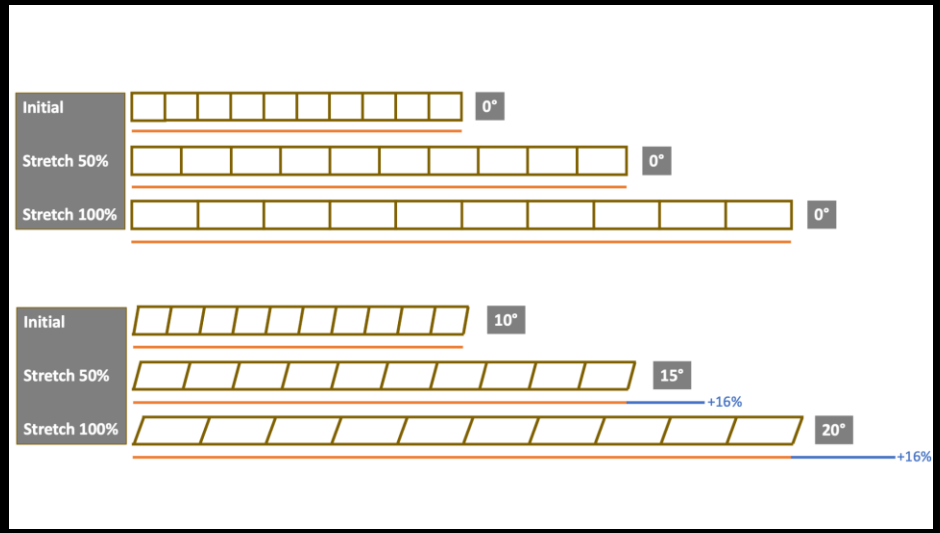
WT

trm1234

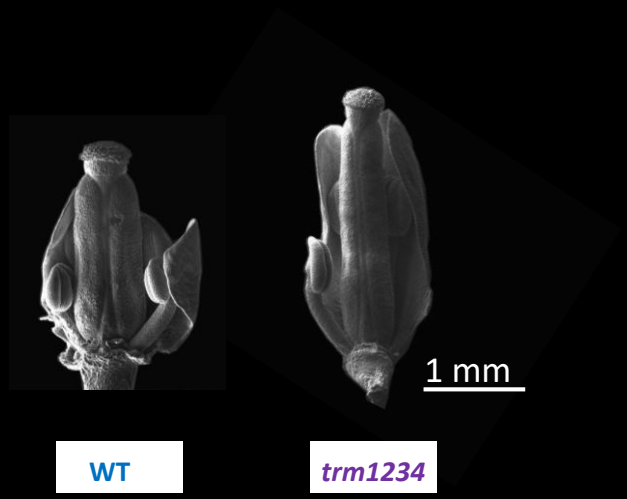
WT



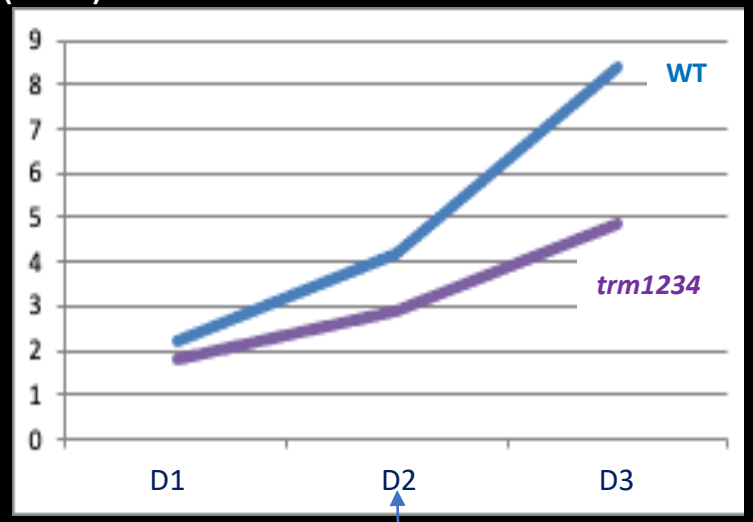
Non-transverse angles can be amplified by elastic stretching



As a consequence, pistil growth, fruit size and seed number are reduced in the *trm1234* mutant



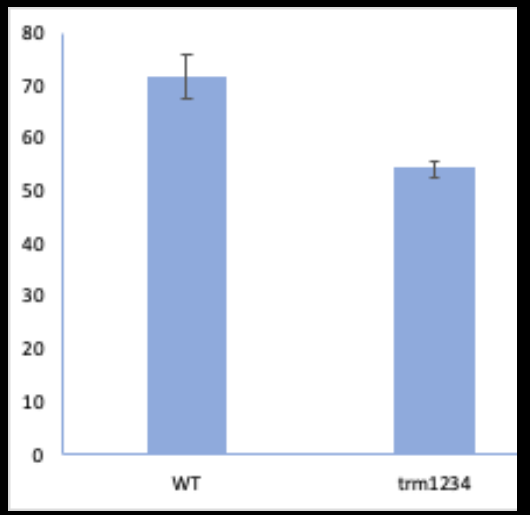
Stage 12



Pistil growth after petal emergence

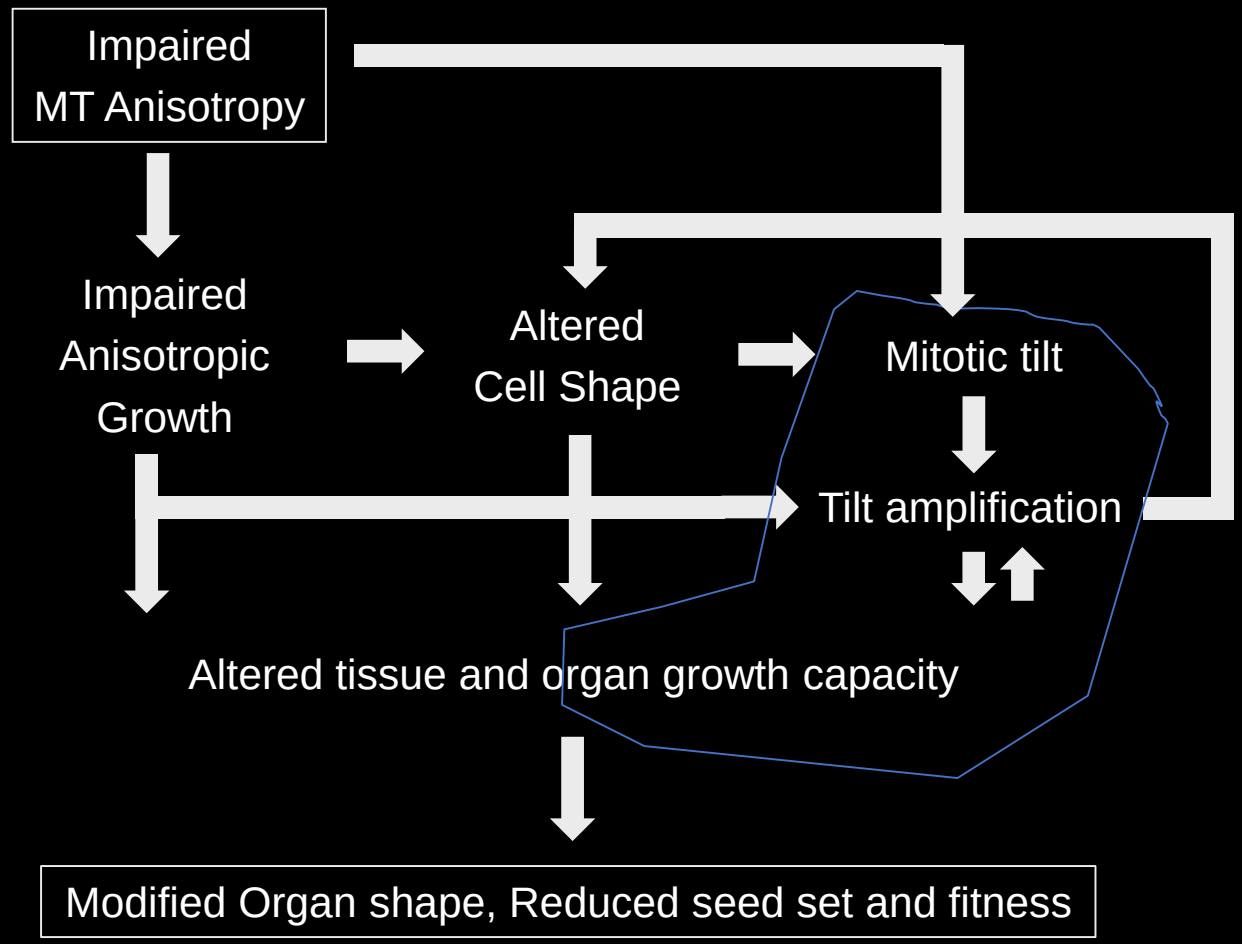
Pollinization

Mature siliques



Seed number per silique

Cellular function of TRM 1-2-3-4 in fruit development, from sub-cellular events to organ shape



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Coralie Goncalves

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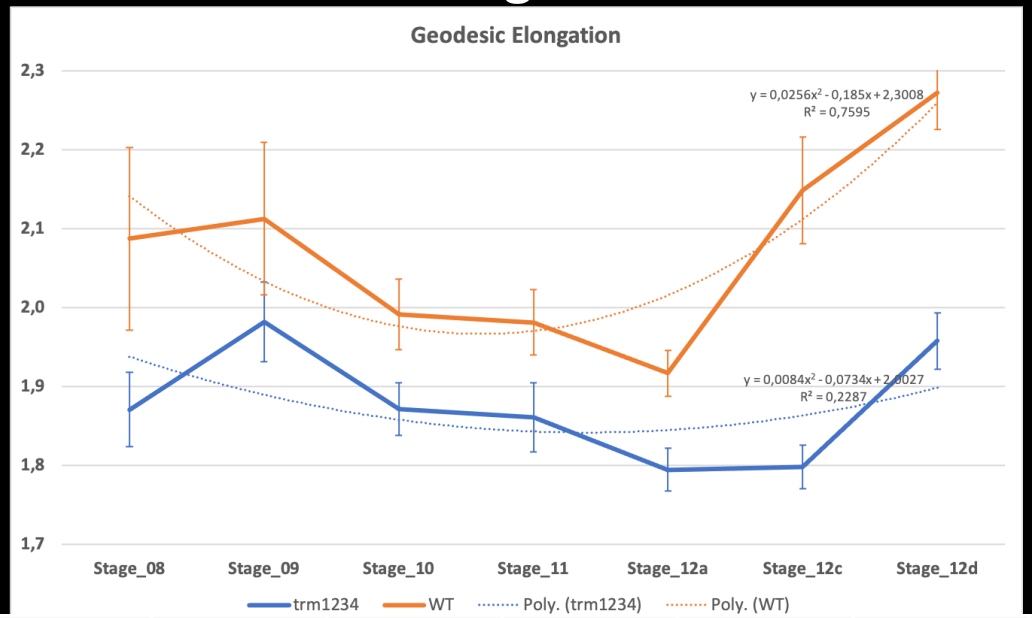
OV – Cytologie / Imagerie, Gladys Cloarec
OV – Plant facilities

Collaborations:
Sarah Robinson, Léo Serra (Sainsbury Laboratory, Cambridge)

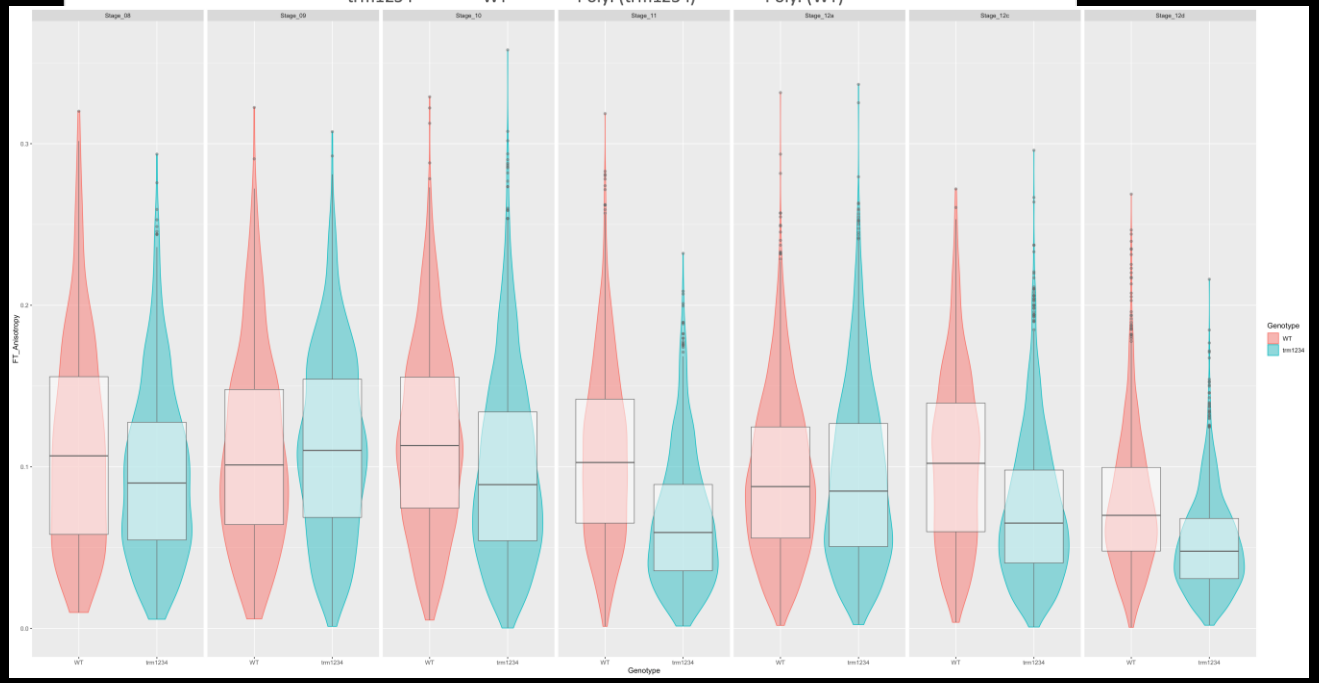
Philippe Andrey, Eric Biot, Sandrine Lefranc (MIN group, IJPB-INRAE de versailles)

… Cell elongation is reduced in trm1234



WT

trm1234

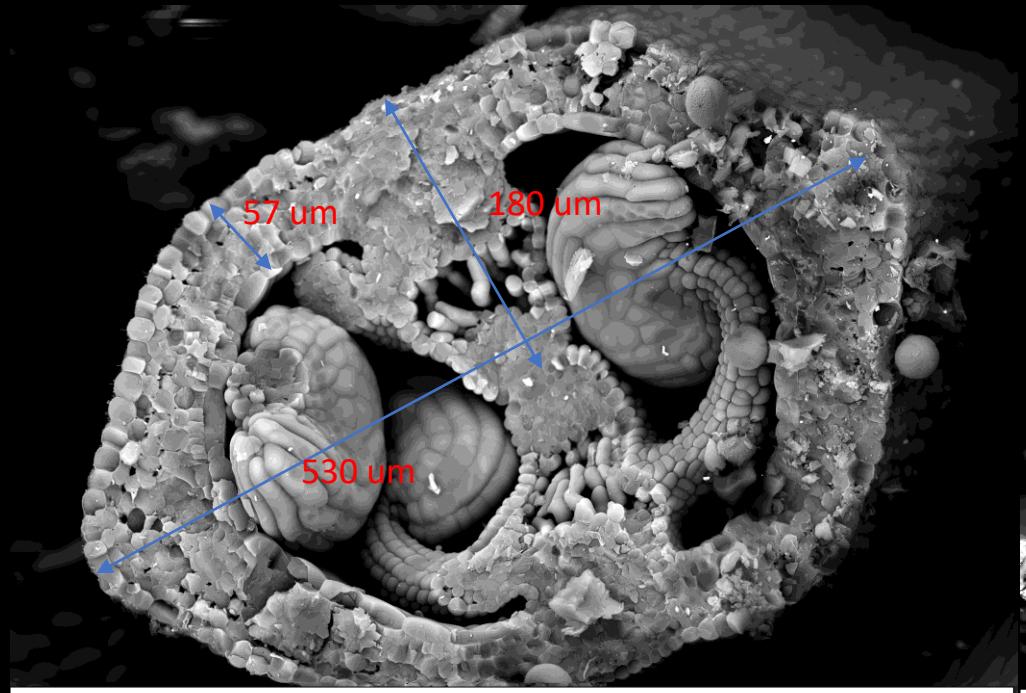


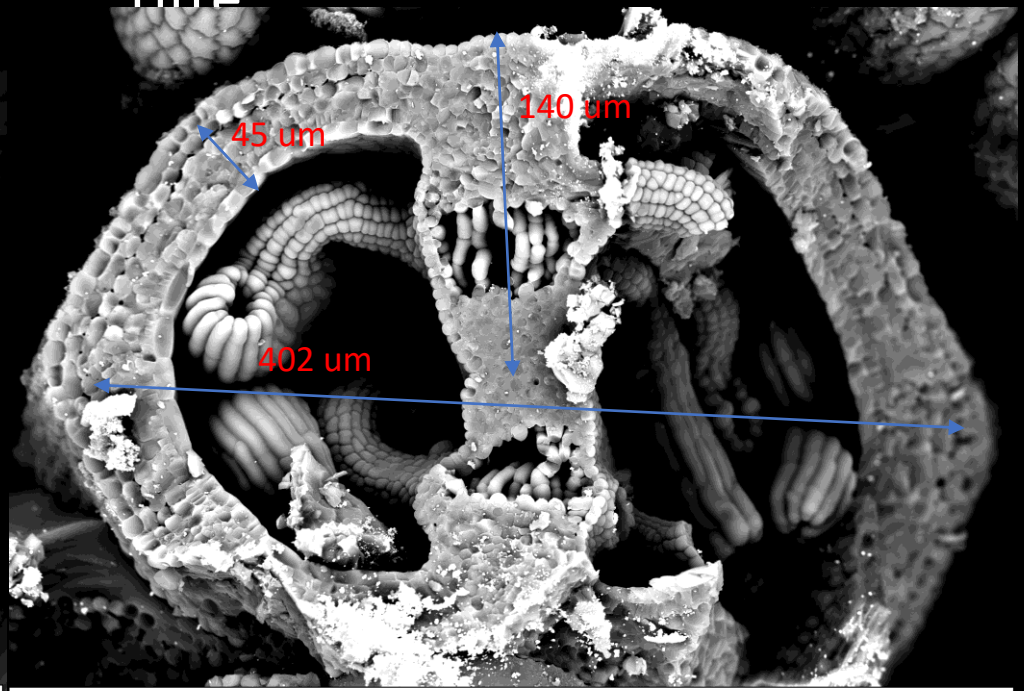
(anisotropic growth requires an highly ordered interphasic cortical MT array)

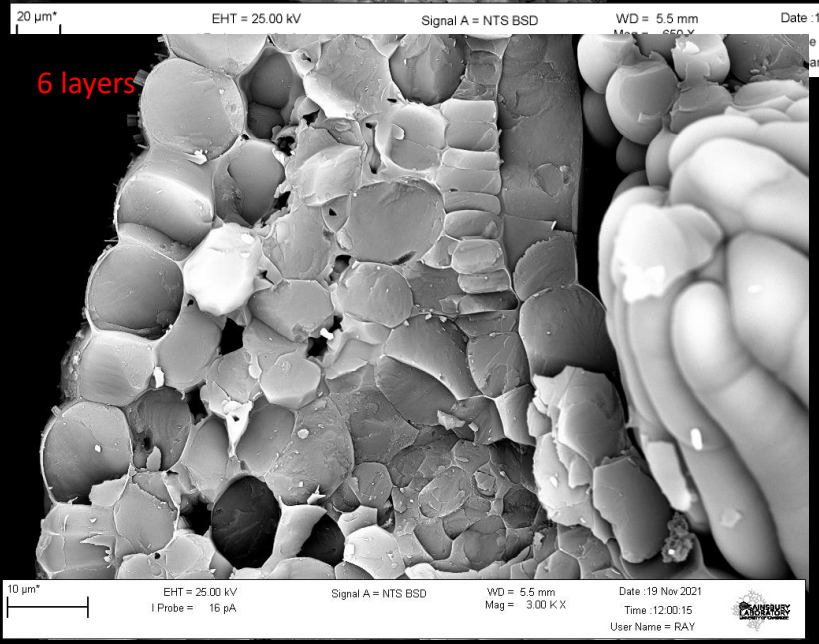
WT

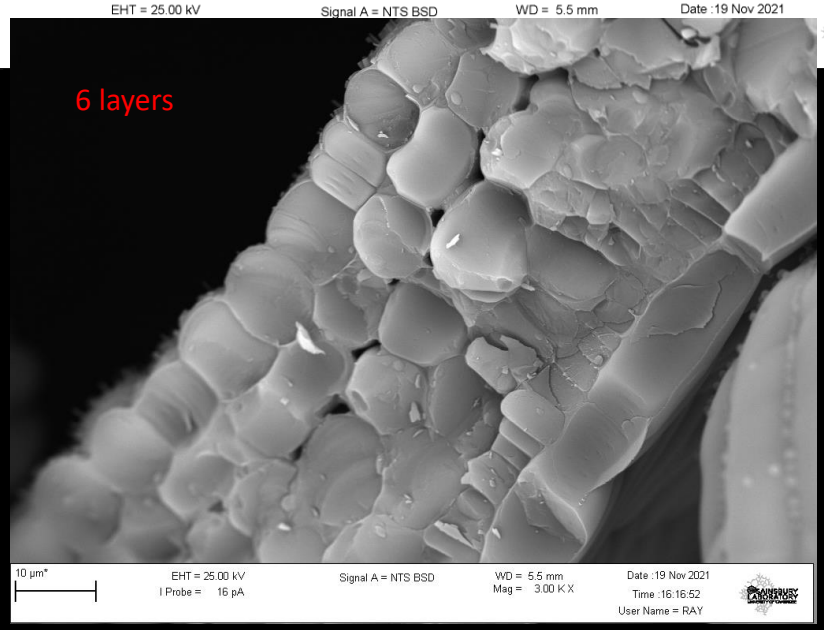
Titre

trm1234



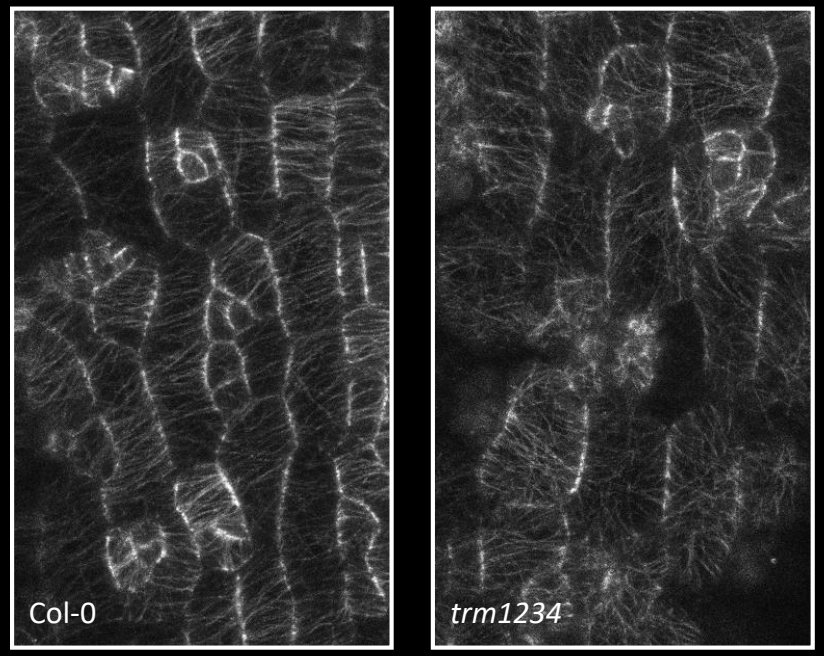




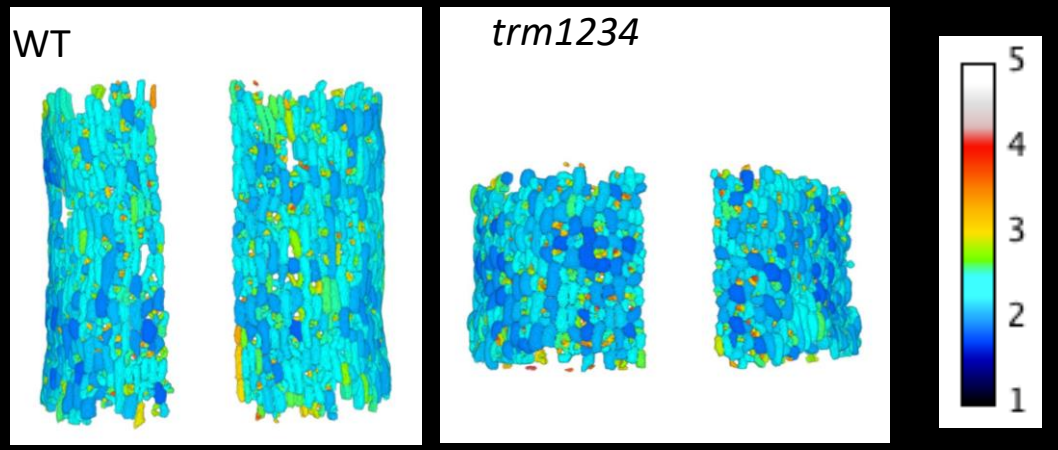


3D morphological cell fruit parameters

(mCherry-TUBULIN6, outer epidermal cell face)



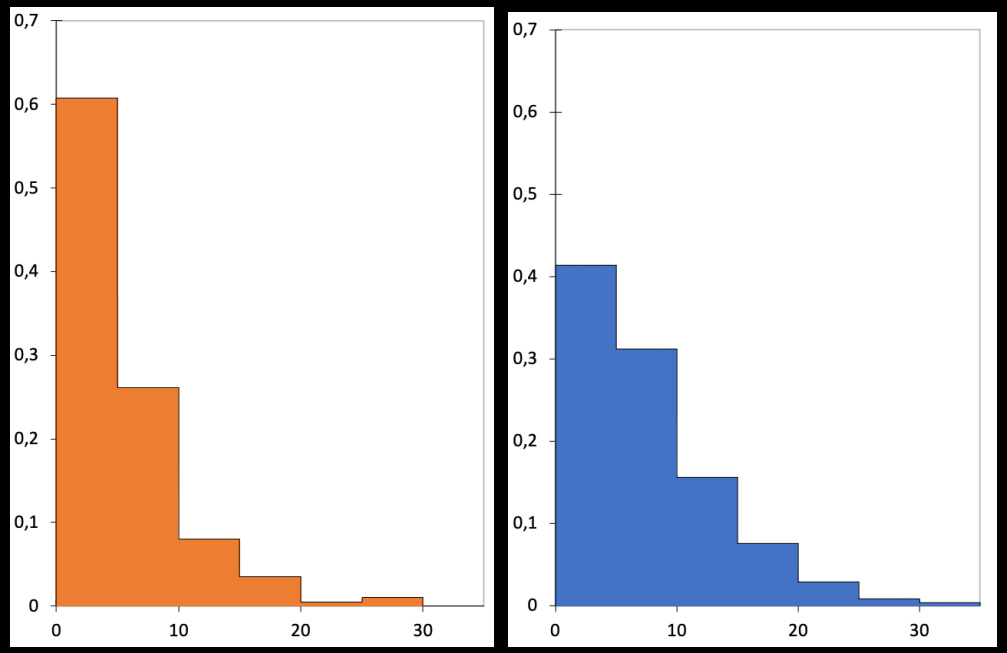
shortest/longest perimeters



Mitotic figures are slightly more tilted in the *trm1234* mutant

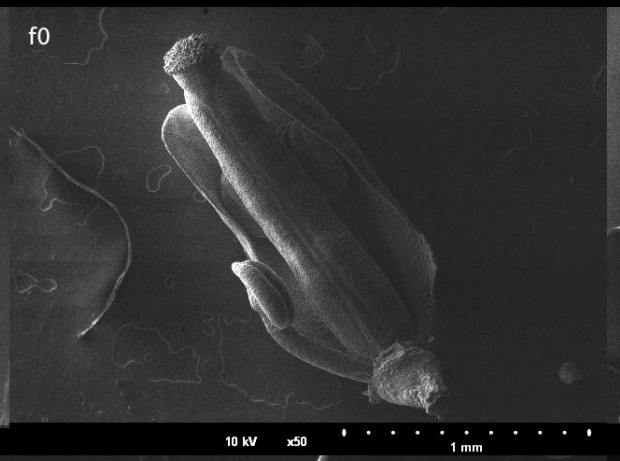
Orientation of mitotic MT arrays (PPB & phragmoplast)

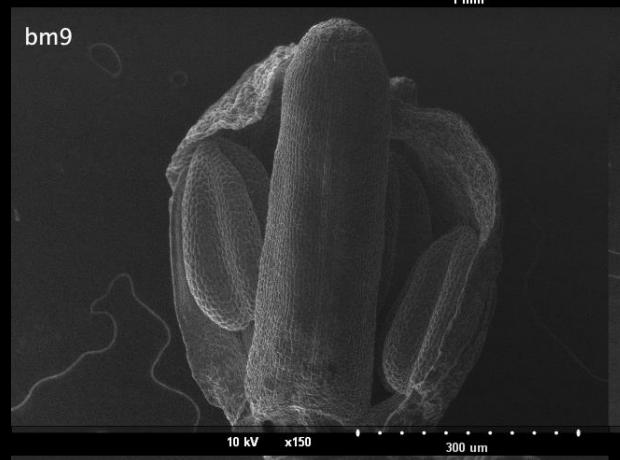
WT *trm1234*

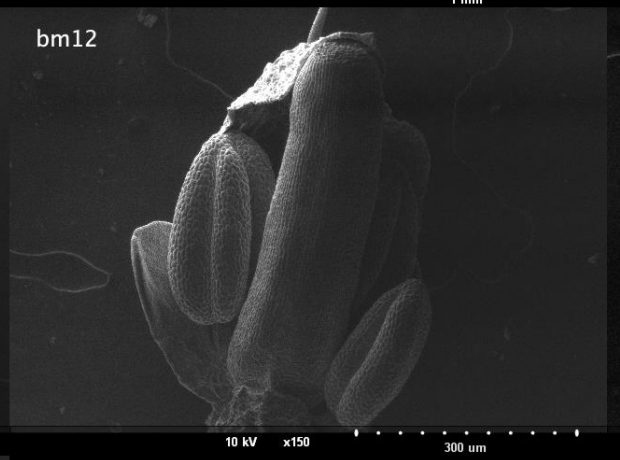


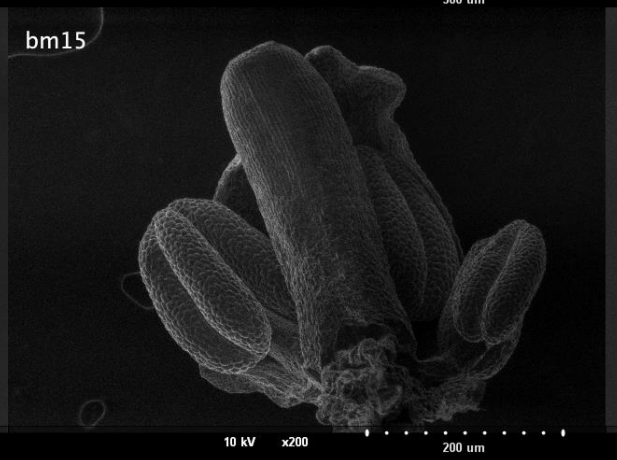
WT : **5.09** ± 4.63 (n = 199)
trm1234 : **7.54** ± 5.94 (n = 237)

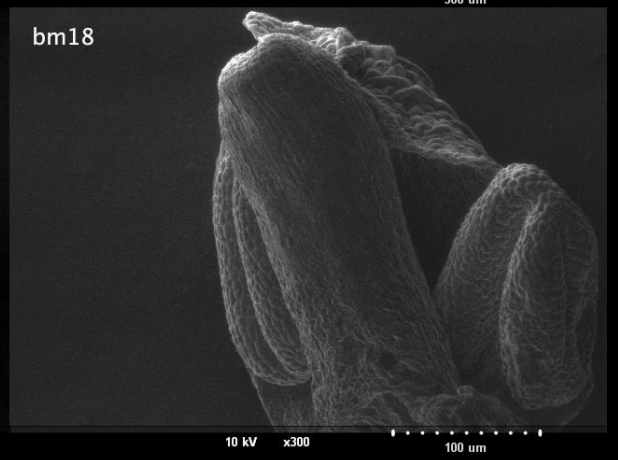
Morphology of the WT gynoecium

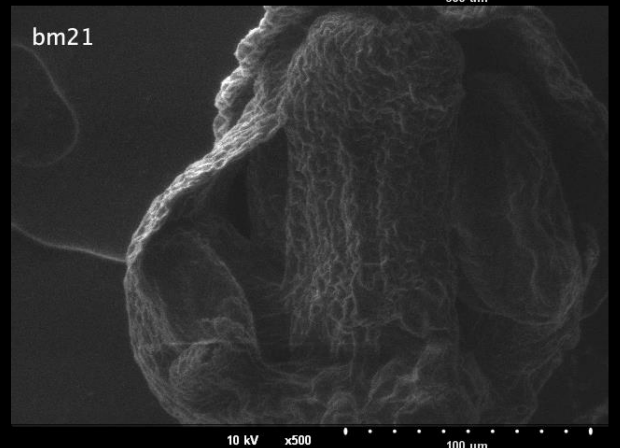


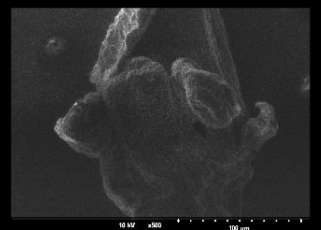












Morphology of the *trm1234* mutant gynoecium