Pillars of Plant Cell Polarity: 3-D Automated Microtubule Ordering & Asymmetric Cell Pattern Analysis

G. J. Harlow[1], A. C. Cruz[2], S. Li[1], B. Bhanu[2] and Z. Yang[1]
gharl001@ucr.edu, acruz@ee.ucr.edu, shuo.li@ucr.edu,
bhanu@ee.ucr.edu, zhenbiao.yang@ucr.edu
[1]Botany and Plant Sciences, University of California, Riverside, Riverside, CA 92521
[2]Center of Research in Intelligent Systems, University of California, Riverside, Riverside, CA 92521

Introduction and Motivation

- Cell polarity is the asymmetric development of three-dimensonal structures on cells.
- Pavement Cells are jigsaw-like interlocking cells on the epidermal surface layer of leaves.
- ROP GTPases are molecular switches directing cell polarity ("lobe" and "indentation" formation) [Fig. 4], in pavement cells of *A. thaliana*, but this process is not fully understood. [Fig. 5]
- We are the first to ***automate*** pavement cell phenotype analysis and microtubule ordering.
- We hypothesize ARK2 (Armadillo Repeat Kinesin) is a key interactor in cell polarity maintenance through stabilization of microtubule orientation.

Fig. 1. Microtubules (GFP-TuA): Wild Type (Top) vs. *ark2-1* mutant (Bottom)

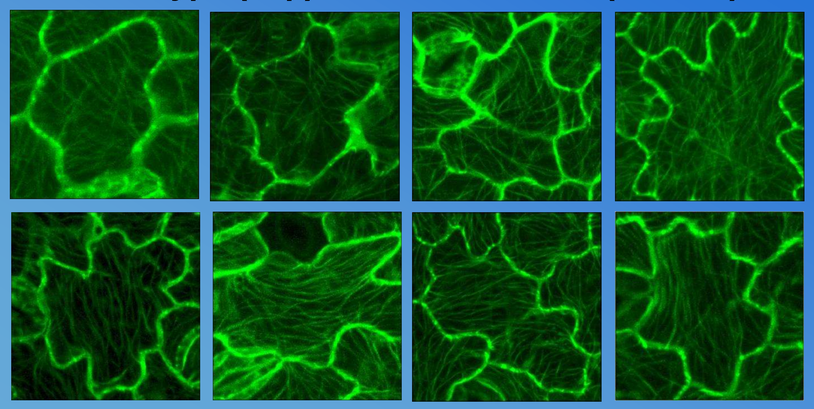


Fig. 2. Shape: Wild Type (Top) vs. *ark2-1* (Bottom)

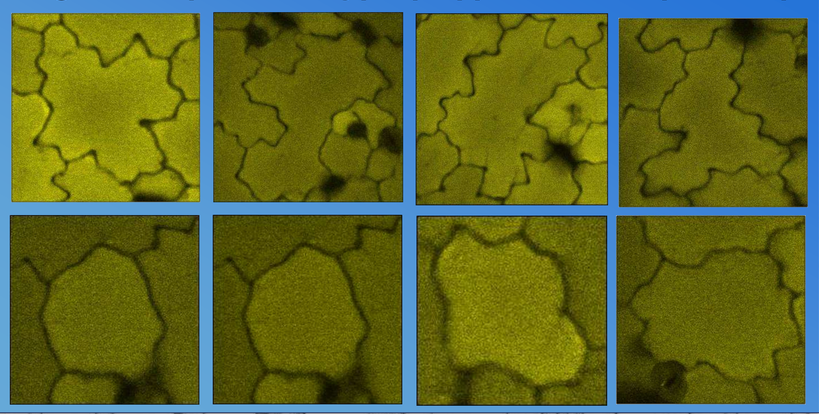
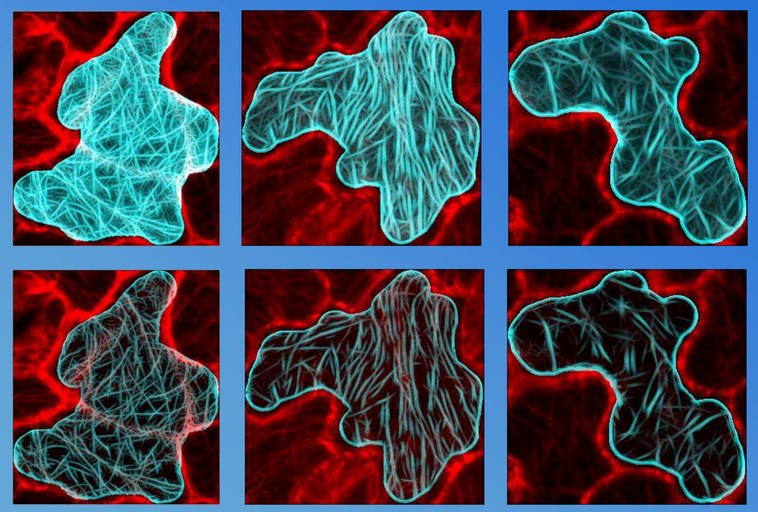


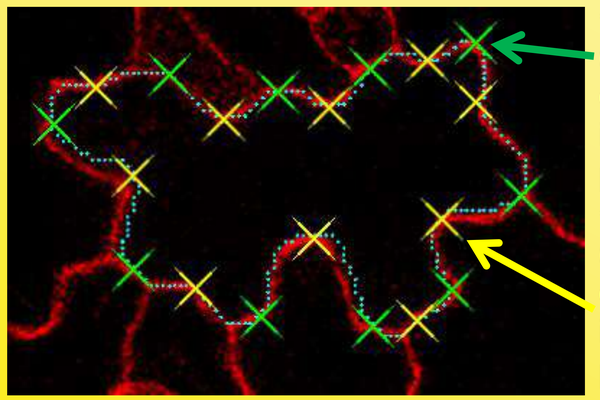
Fig. 3. Microtubule Orientation Detection



Red: TubA; Cyan: detected microtubule.

Microtubule orientation quantified as kurtosis, found to be significantly different ($p = .005$) between wild type and *ark2-1*.

Fig. 4. Defining Lobes Objectively

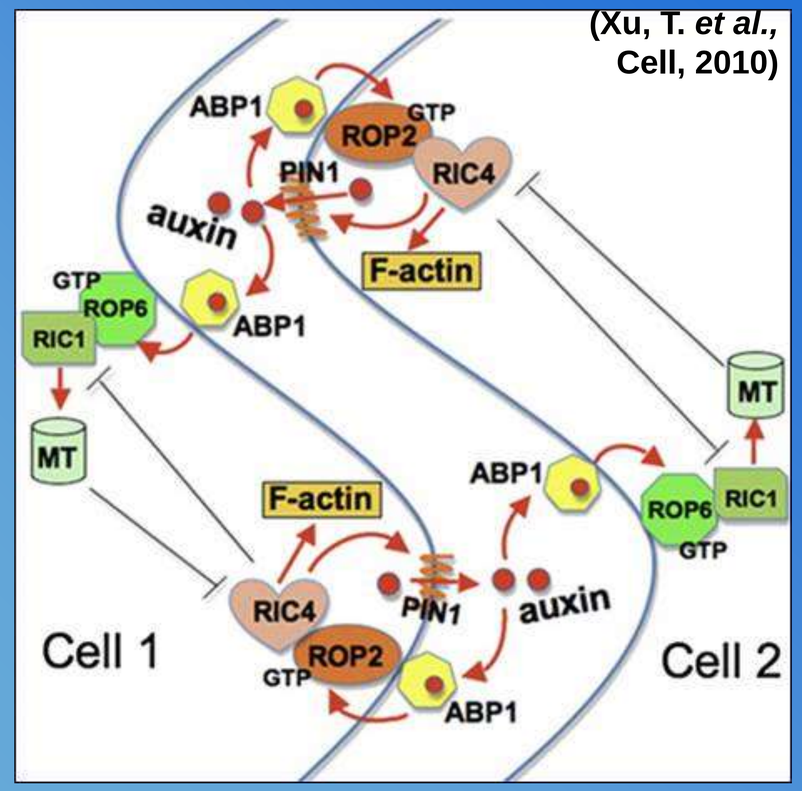


- Lobe (green): concave inflection points
- Indentation (yellow): convex inflection points

- Shape attributes were shown to be significantly different between wild type and *ark2-1*.
- Abridged summary of 3-D parameters being quantified: ***3D Cell Volume, Cell Height, 2D Cell area, number of lobes, lobe area, lobe height, lobe width, cell perimeter, number of cells, kurtosis, hu moment, eccentricity, orientation, solidity, circularity, orientation, convex area.***

Fig. 4 Pavement Cell Signaling Network

(Xu, T. *et al.*, Cell, 2010)



Conclusion

- A new algorithm was developed specifically suited to characterize and quantify the physiological consequences of the *ark2-1* mutant.
- This procedure is well suited for other life science microtubule quantification studies and will be distributed openly.
- *Ark2-1* dramatically increases microtubule ordering, thus restricting cell expansibility, exhibiting reduced lobe number and size, conferring a higher degree of circularity.
- This work based on research presented by our cross-disciplinary team at the International Symposium on Biomedical Imaging 2013 (Harlow, G.J. & Cruz, A.C. *et. al*., ISBI 2013).

[Support for this work was provided by NSF IGERT: Video Bioinformatics Grant DGE 0903667.]