

Arabidopsis root regeneration and tropism in external electric fields

Giovanni Sena

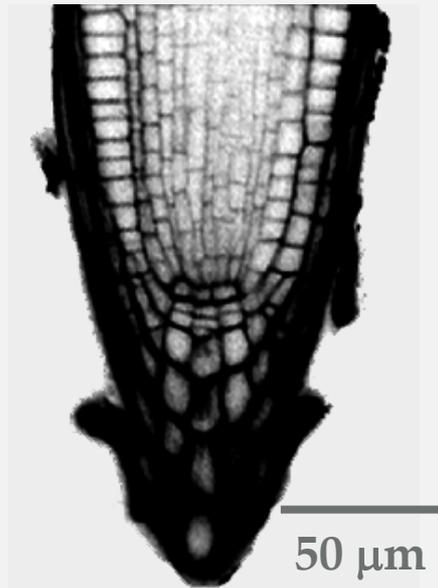
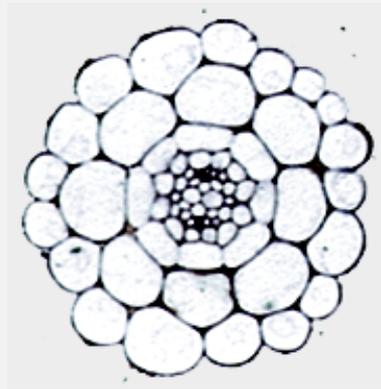
*The Laboratory of Plant Morphogenesis
Imperial College London*

May 2018

Arabidopsis root



—
1 mm

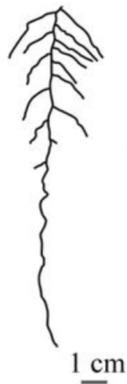


—
50 μ m

- Symmetric structure
- Few cell types
- Transparent tissue

Root morphology

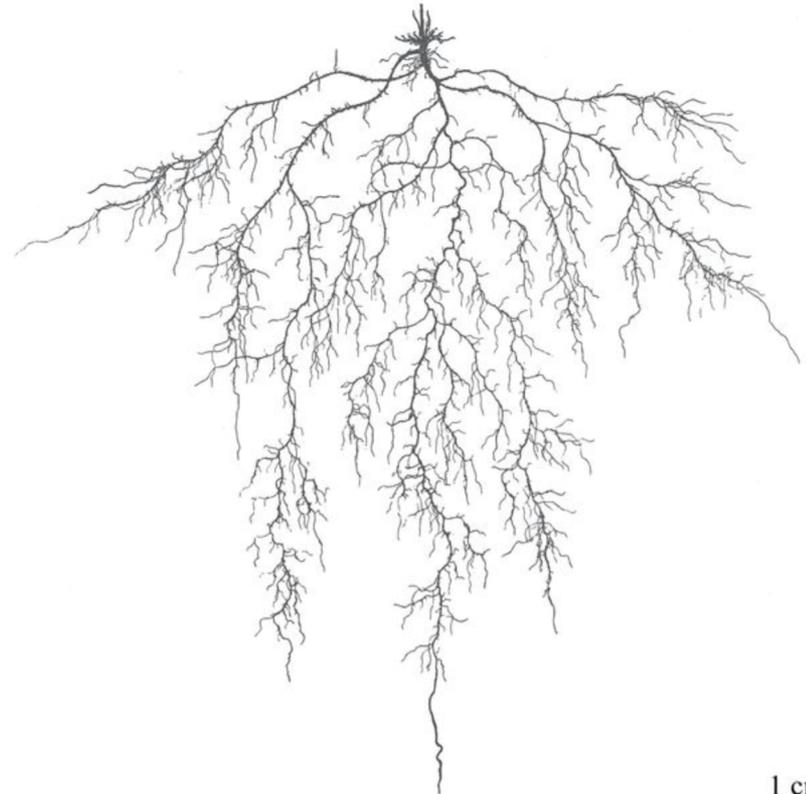
Arabidopsis root
system day 14



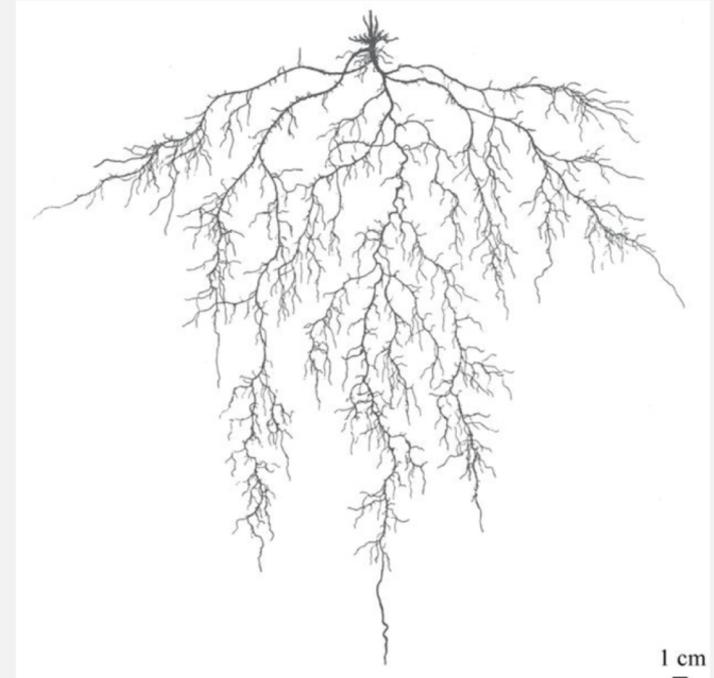
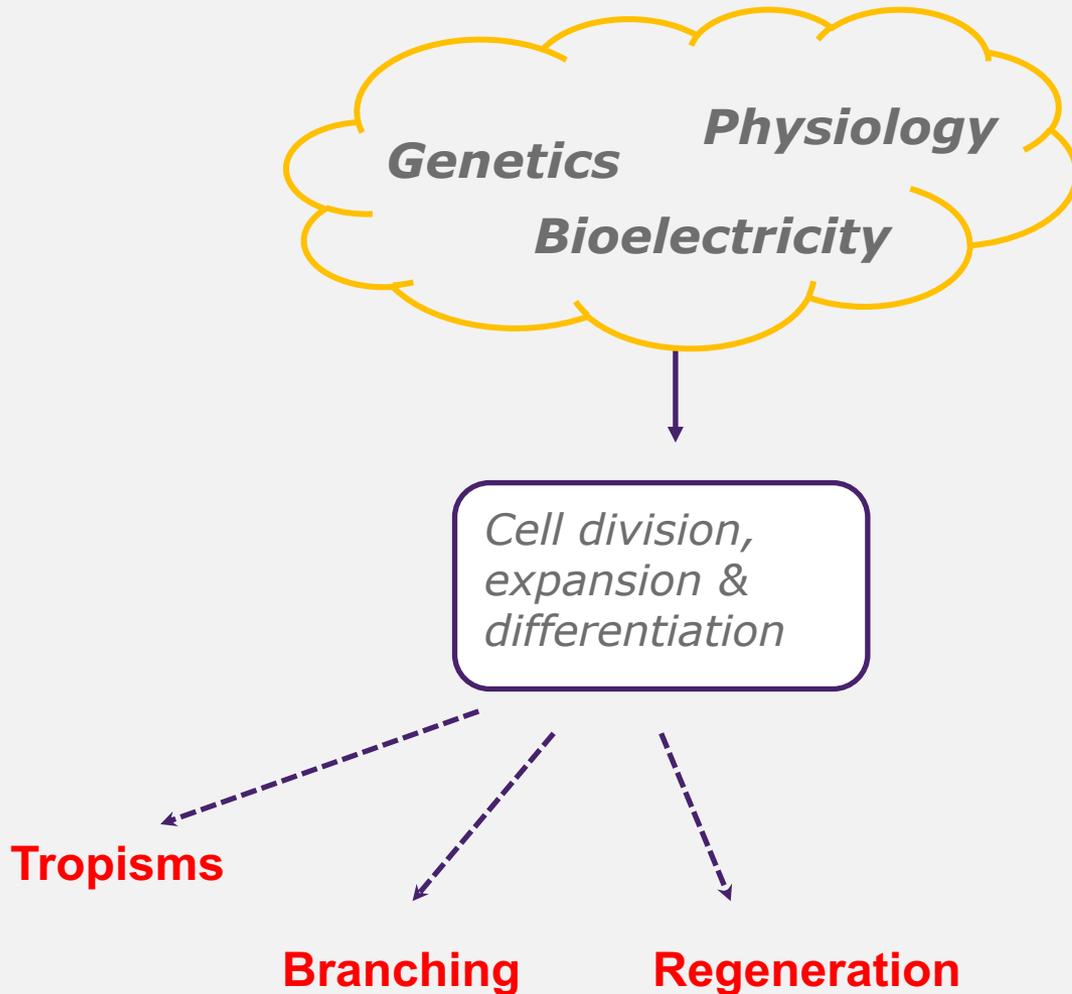
Root Growth Rate
Root Growth Direction
Root Branching
Secondary Root Growth



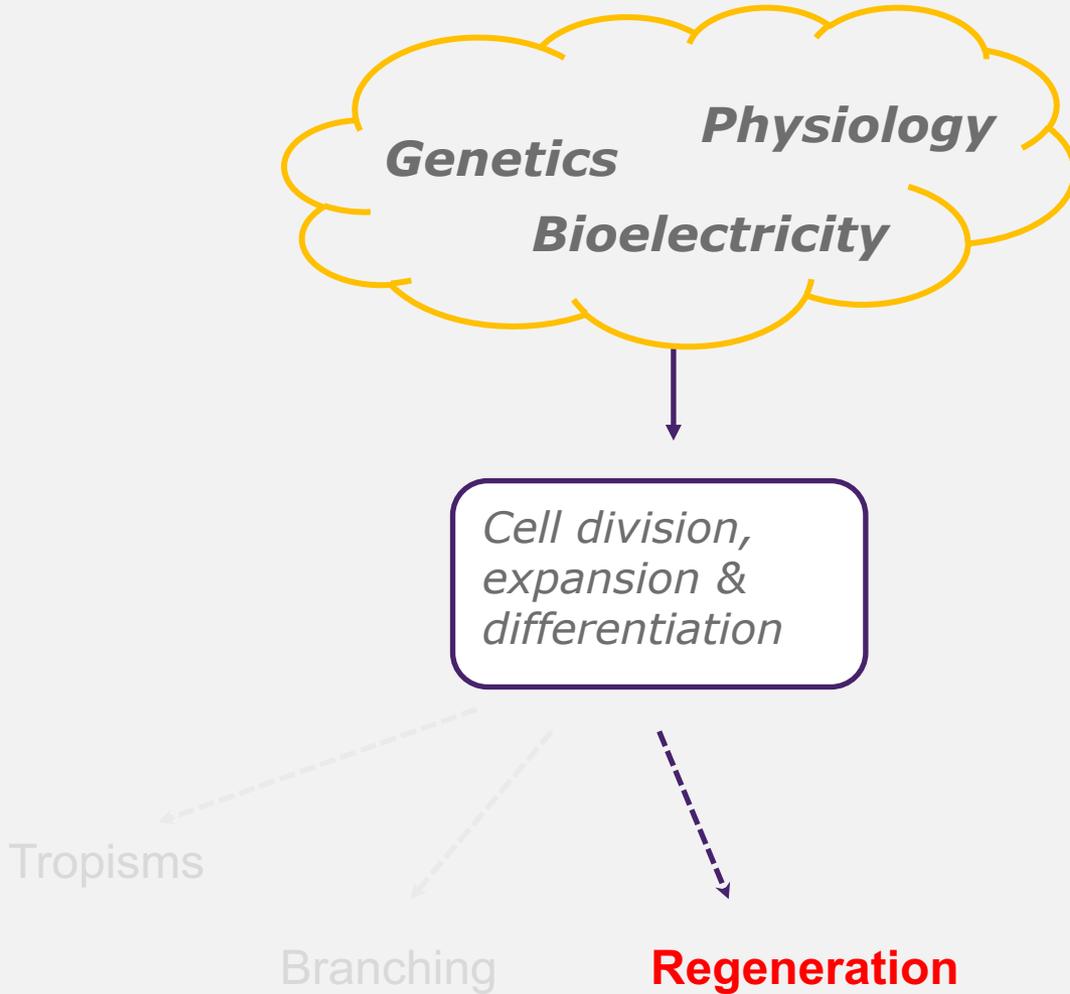
Arabidopsis mature
root system



Big picture



Big picture



Root tip regeneration



cut

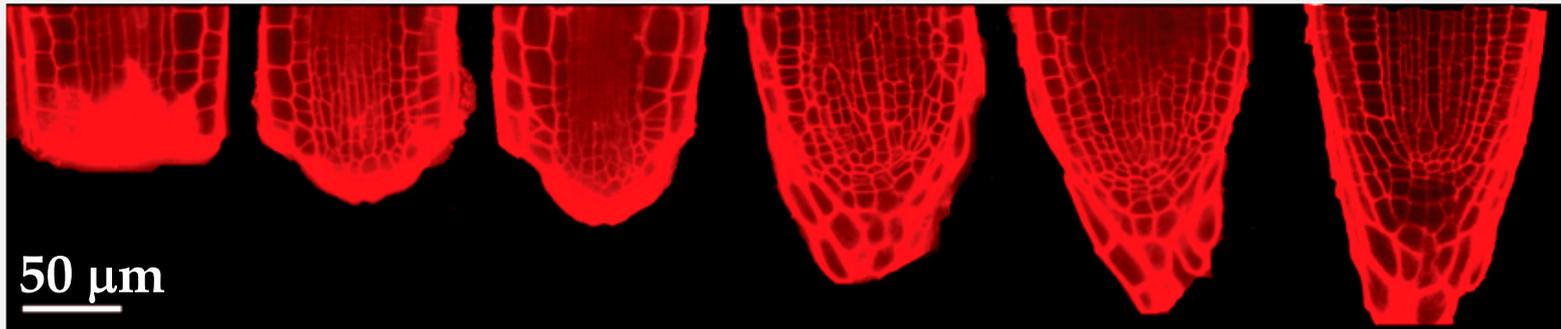
1 dpc

2 dpc

3 dpc

4 dpc

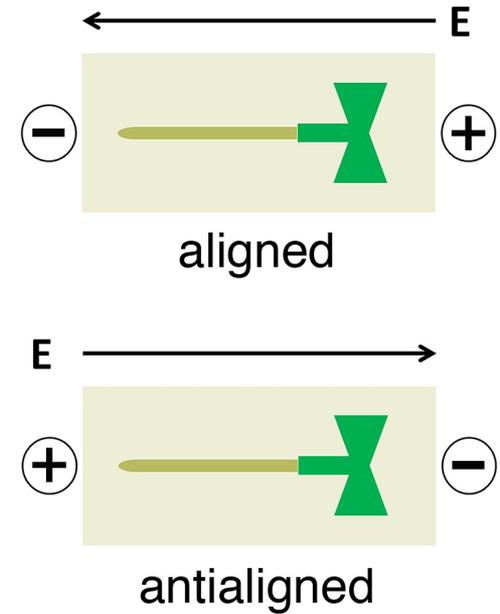
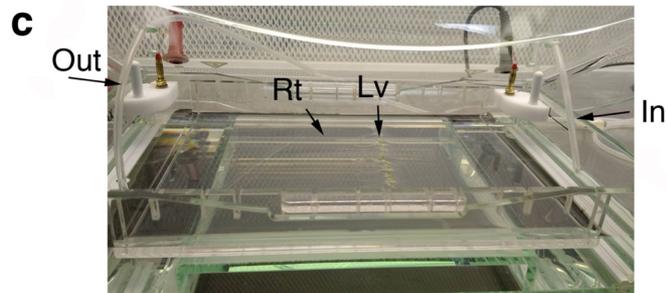
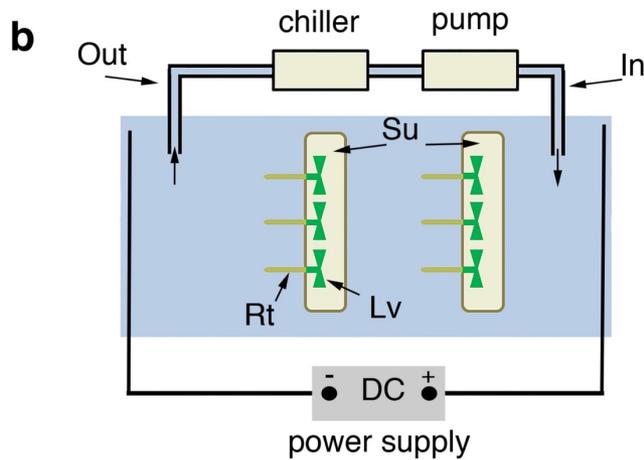
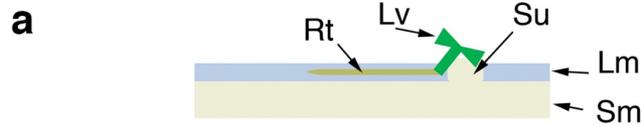
5 dpc



50 μm

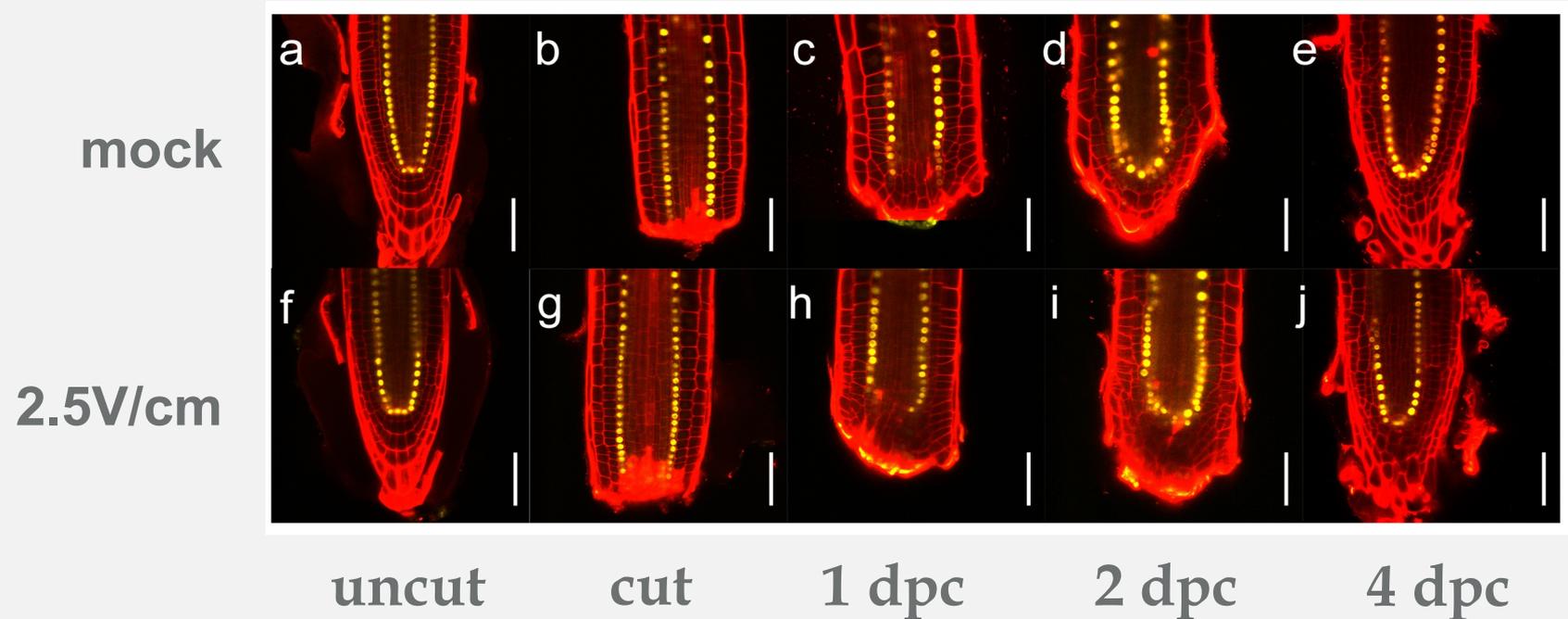
dpc = days post-cut

Arabidopsis roots in electric field

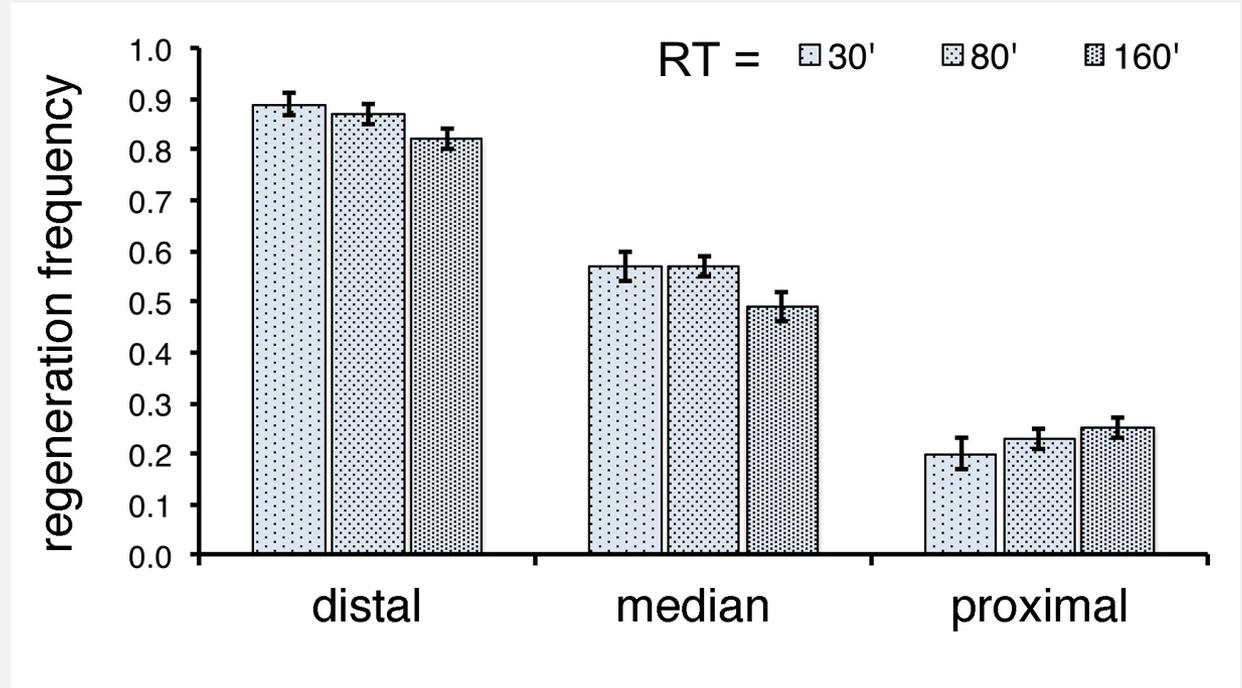
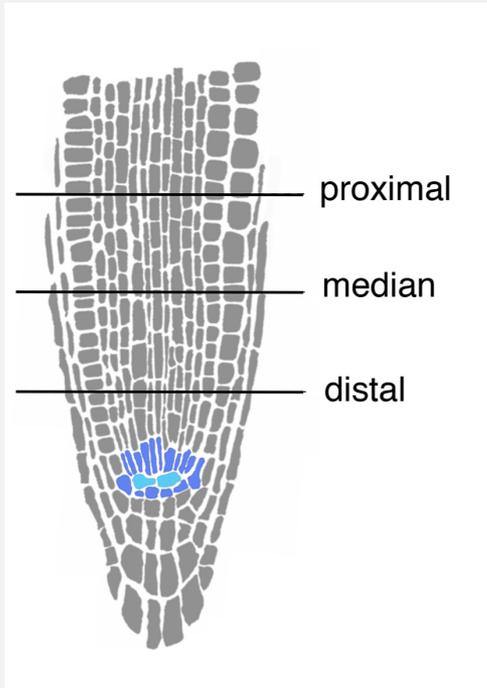


Unperturbed regeneration sequence

pSCR::H2B::YFP

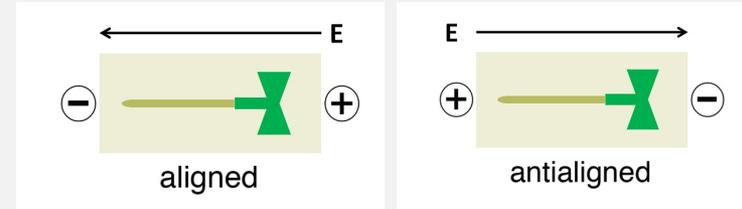


Regeneration competence

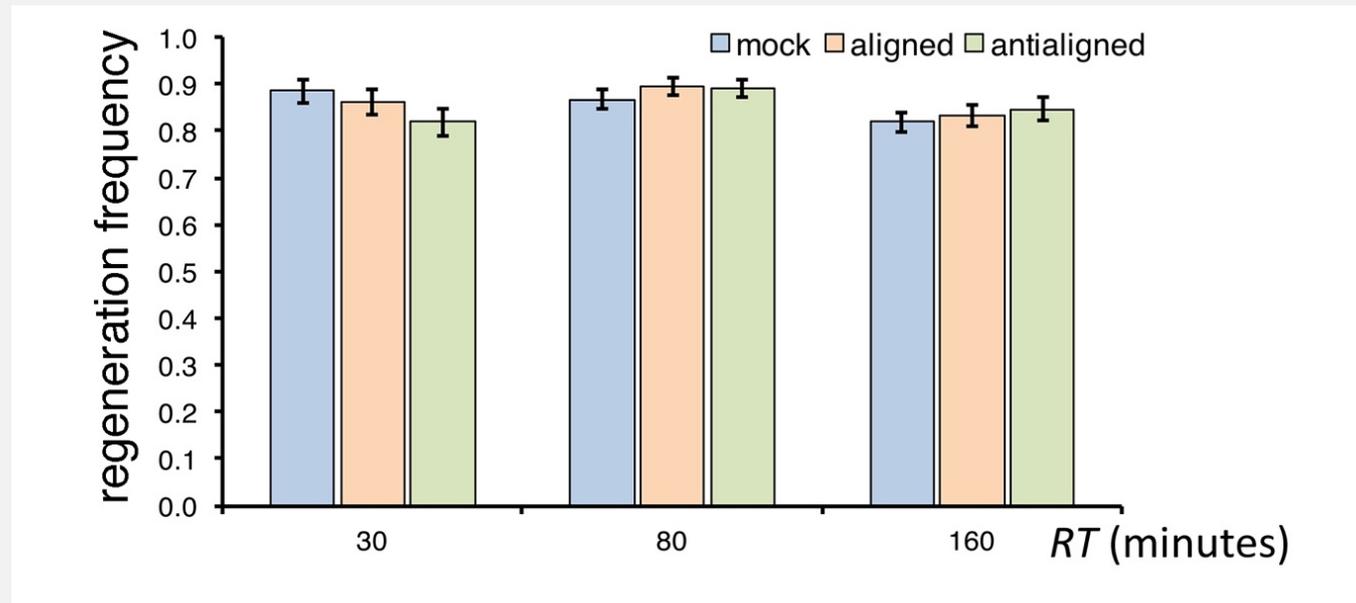
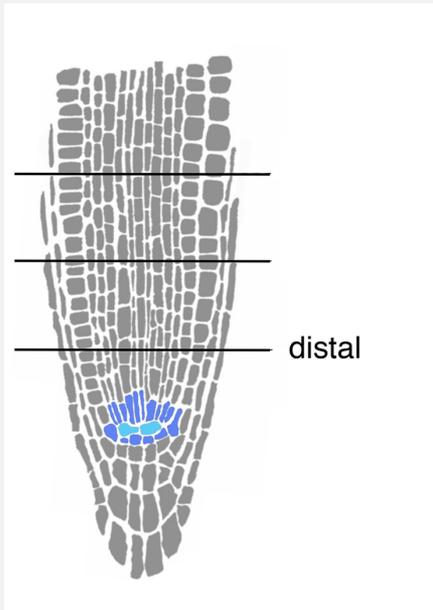


Post-cut exposure

2.5V/cm

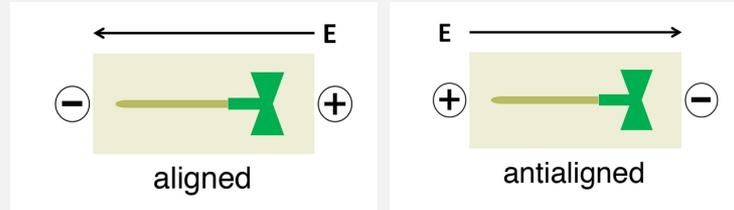


Distal cut

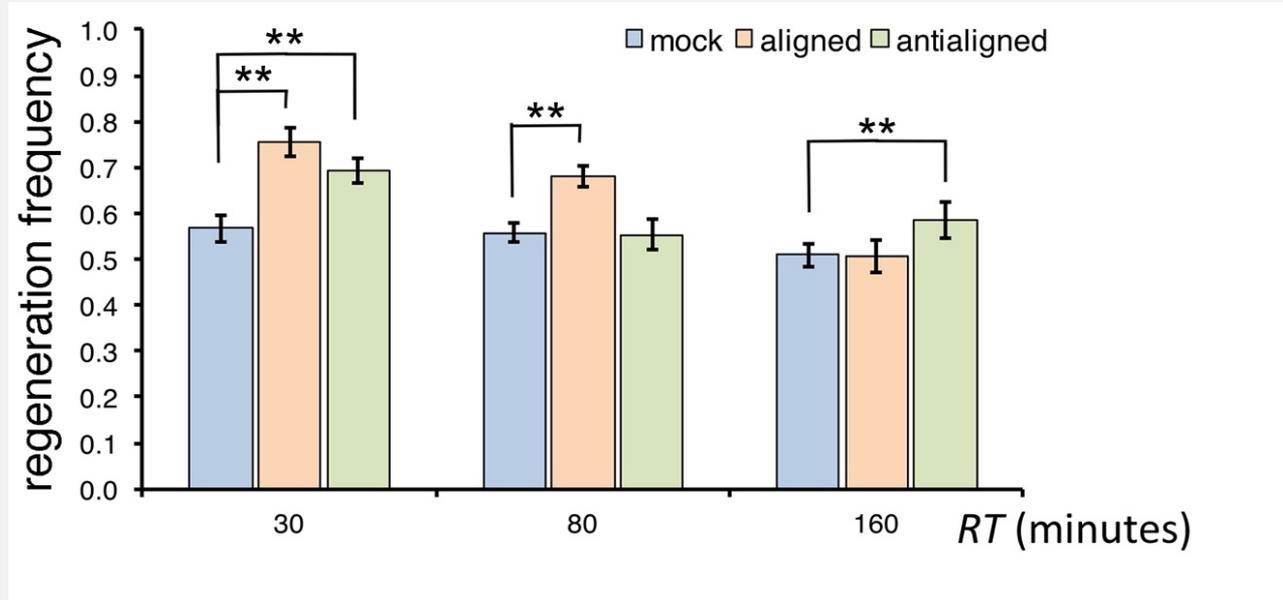
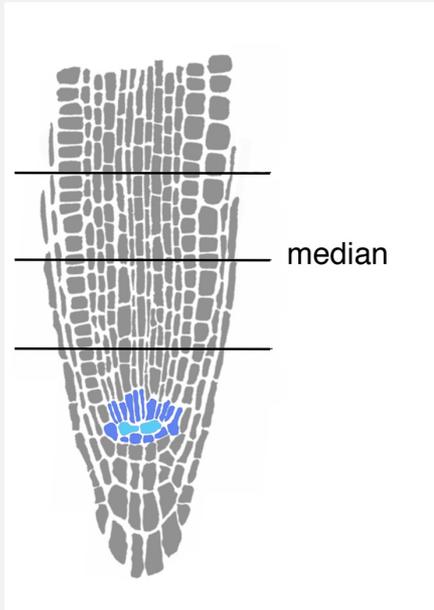


Enhanced regeneration competence

2.5V/cm

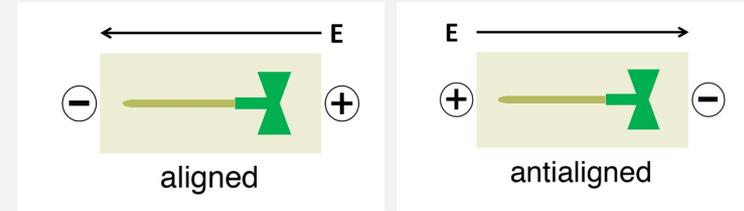


Median cut

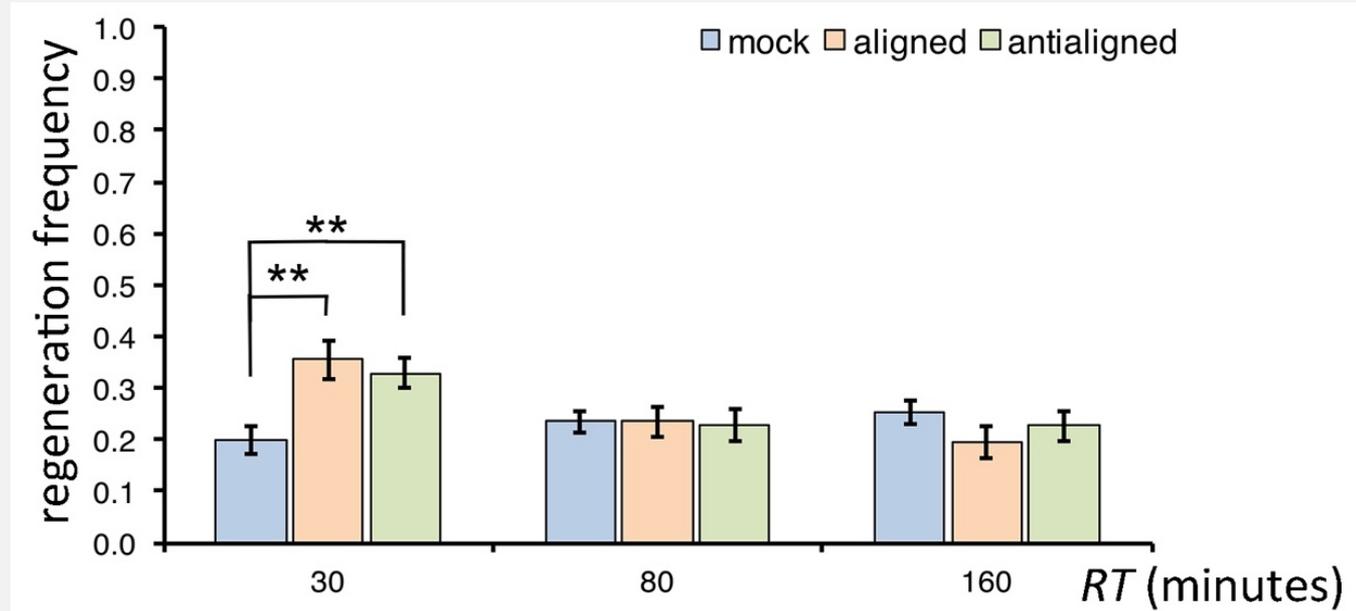
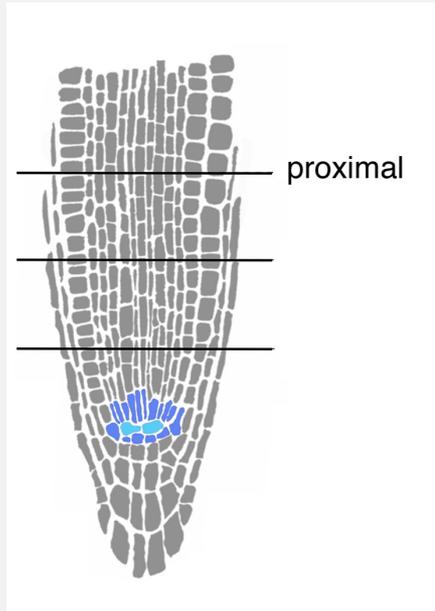


Enhanced regeneration competence

2.5V/cm

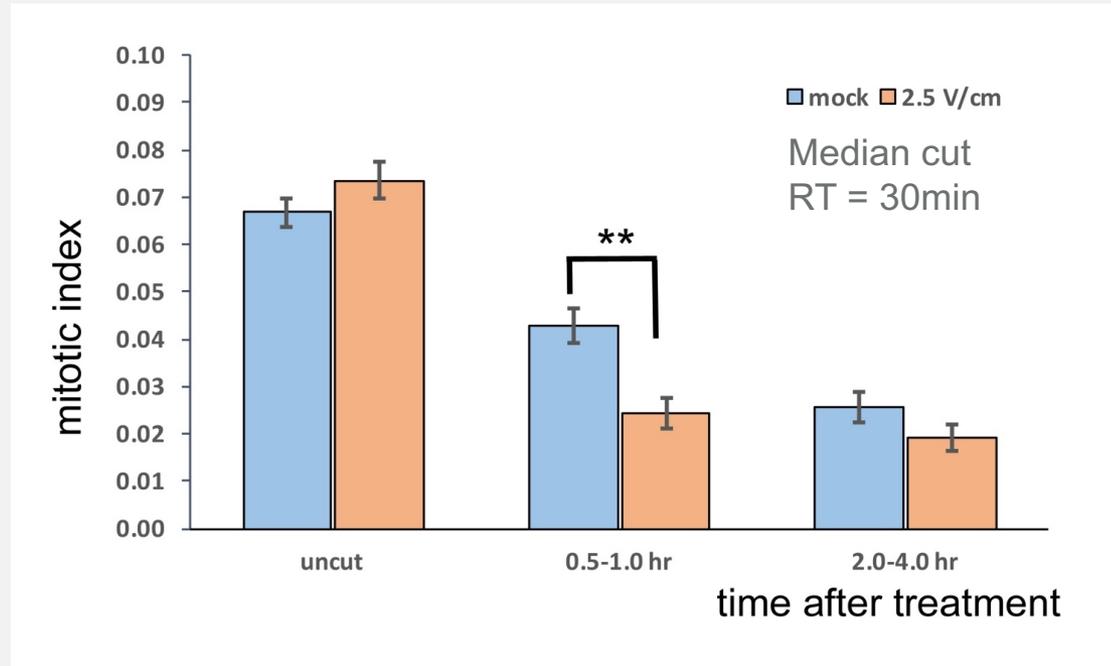
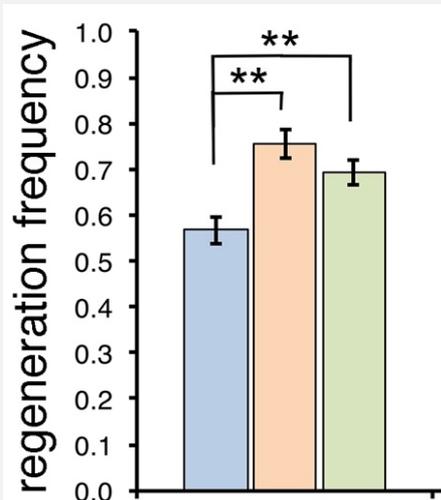
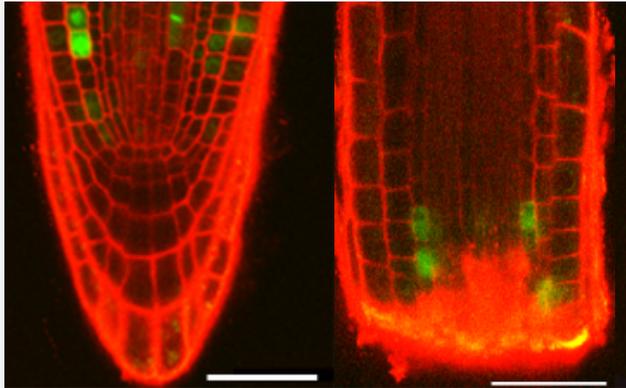


Proximal cut



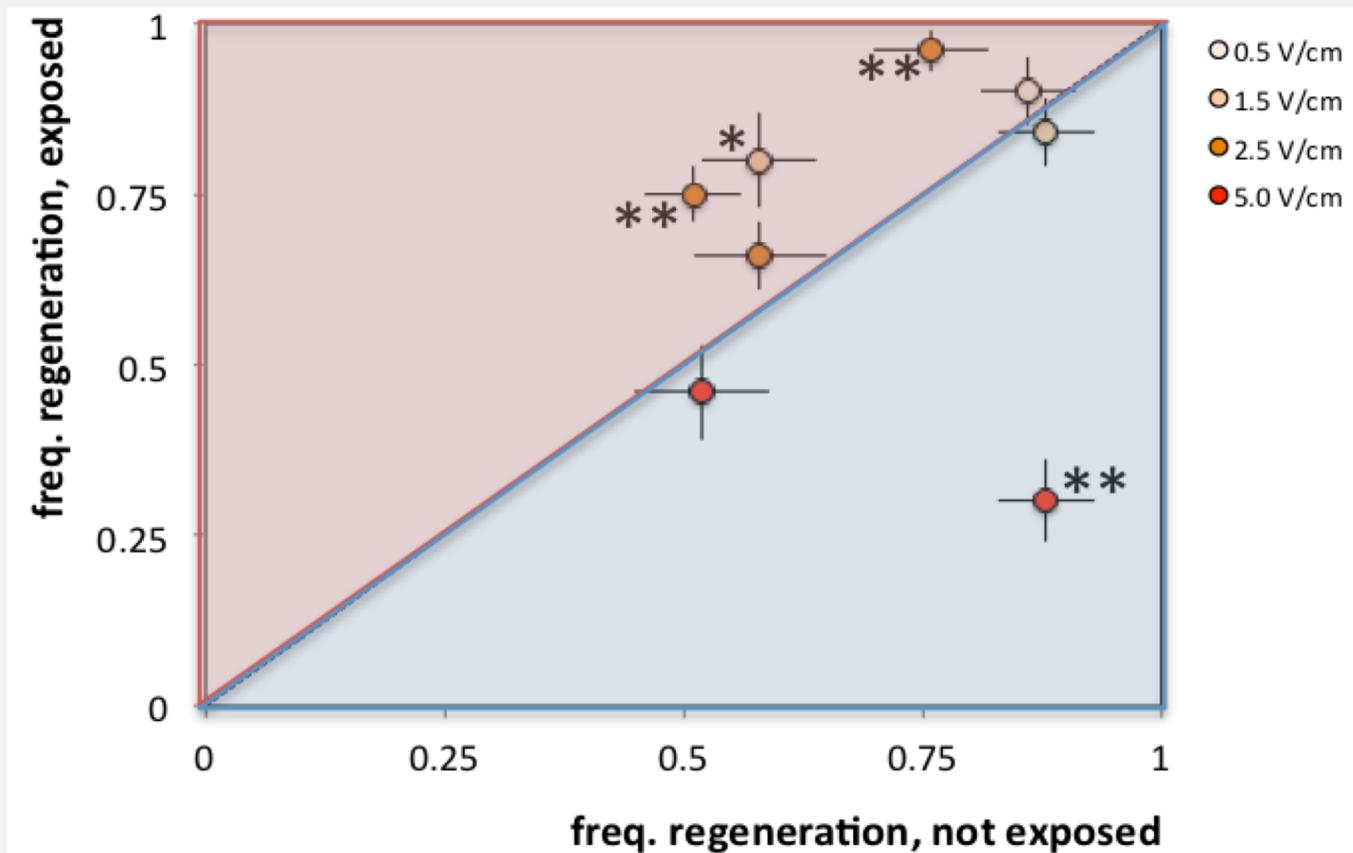
Reduced cell proliferation?

CYCB::GFP

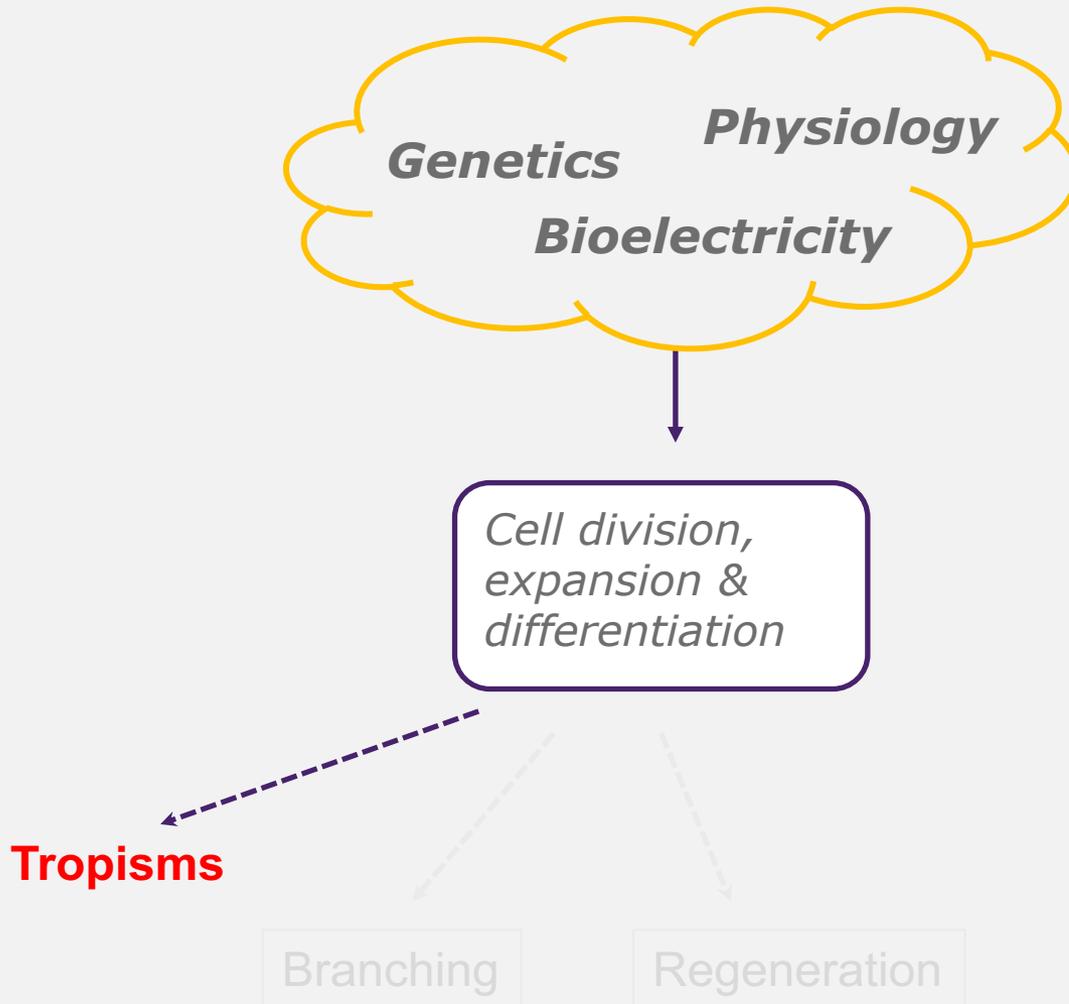


Electric field magnitudes

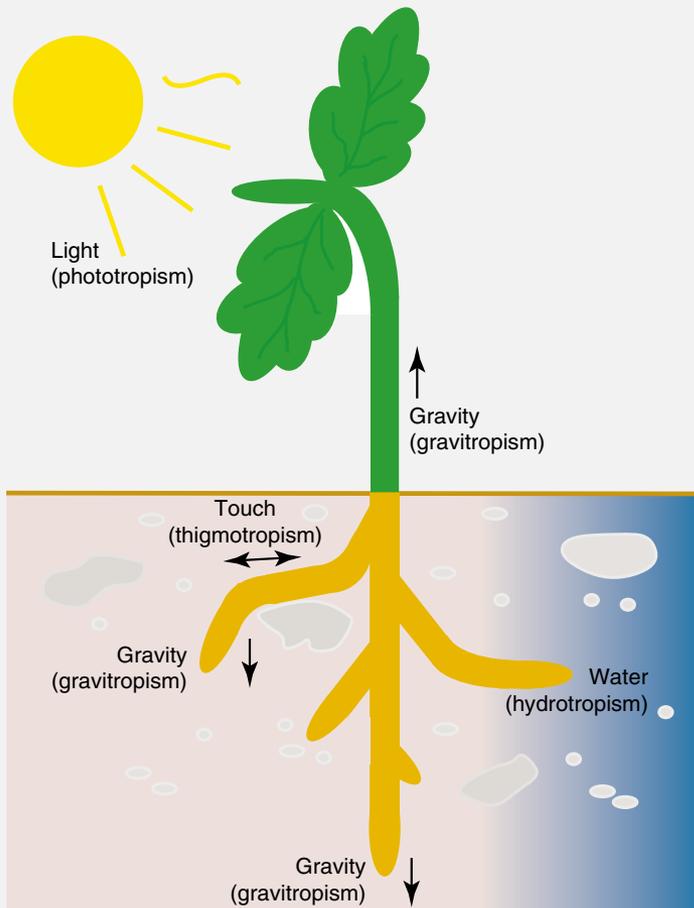
Median cut, RT = 30'



Big picture



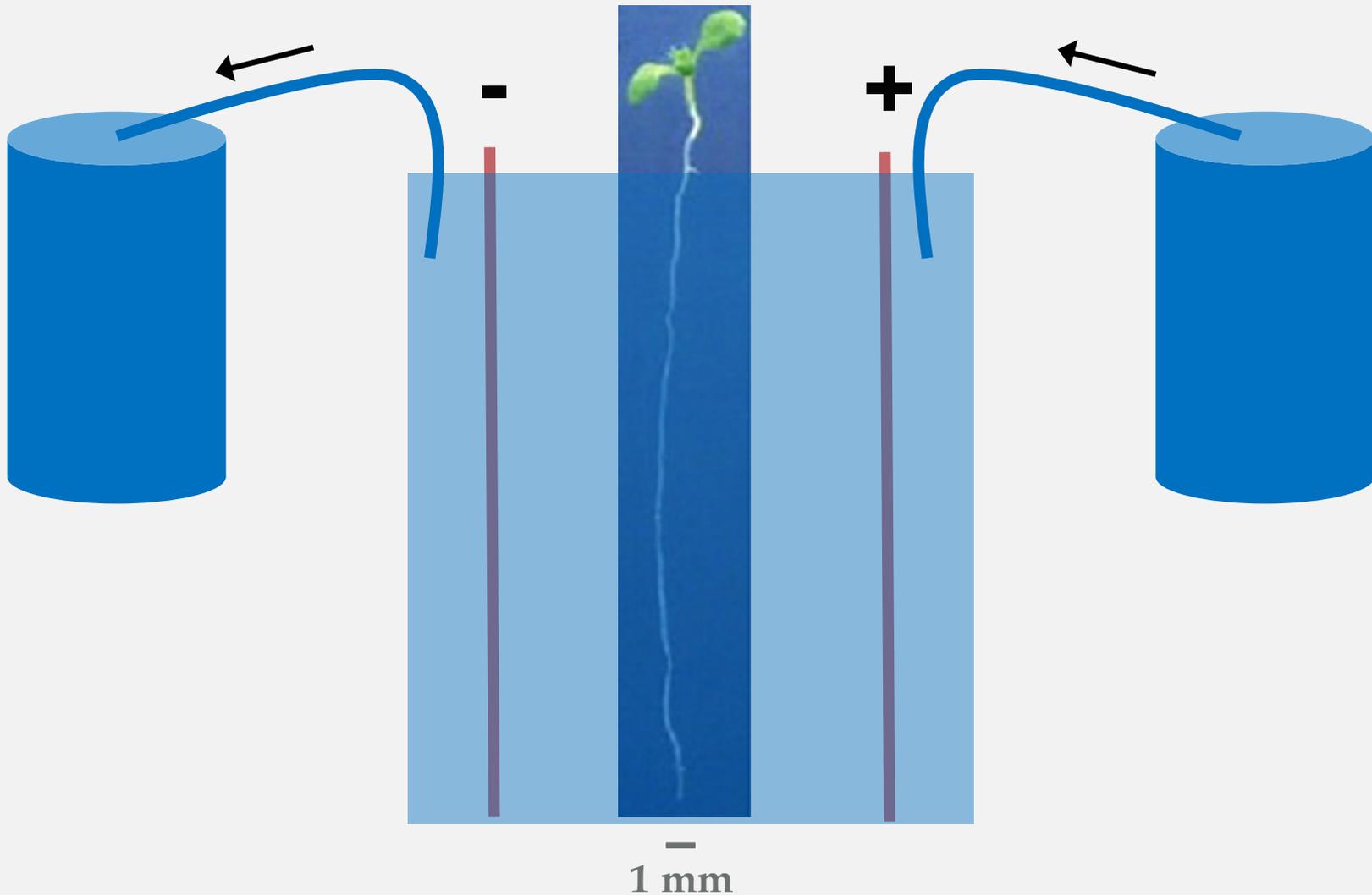
Tropism = growth towards/away from stimulus



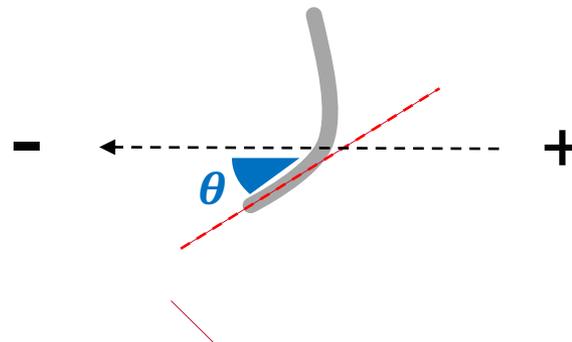
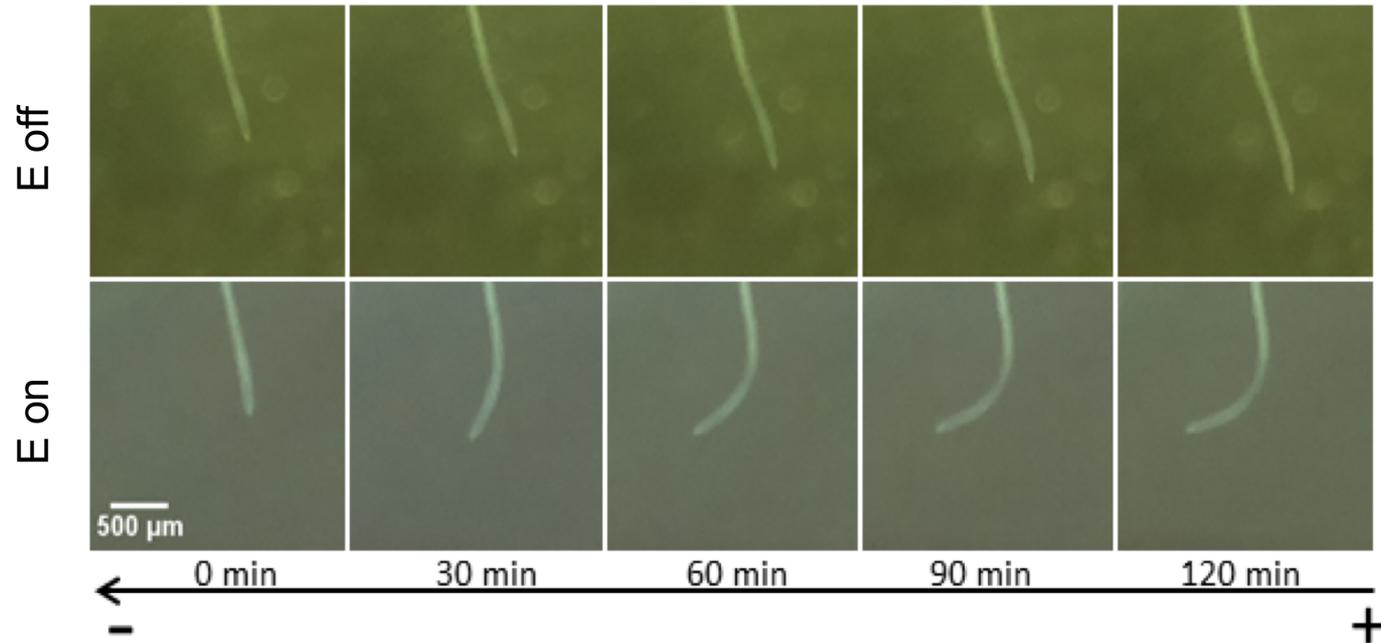
Gilroy, S. Plant tropisms. *Current Biology* 18, R275–R277 (2008).

- Gravitropism (gravity)
- Phototropism (light)
- Hydrotropism (water)
- Oxytropism (oxygen)
- Electrotropism (electric charges)
- Thermotropism (temperature)
- Thigmotropism (pressure)
- Chemotropism (molecules)
- ...

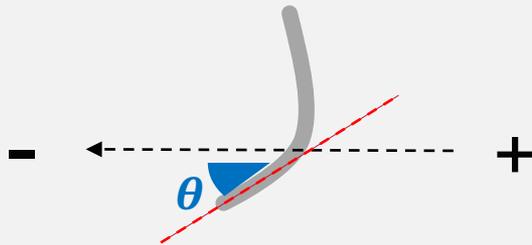
Assay for root electrotropism



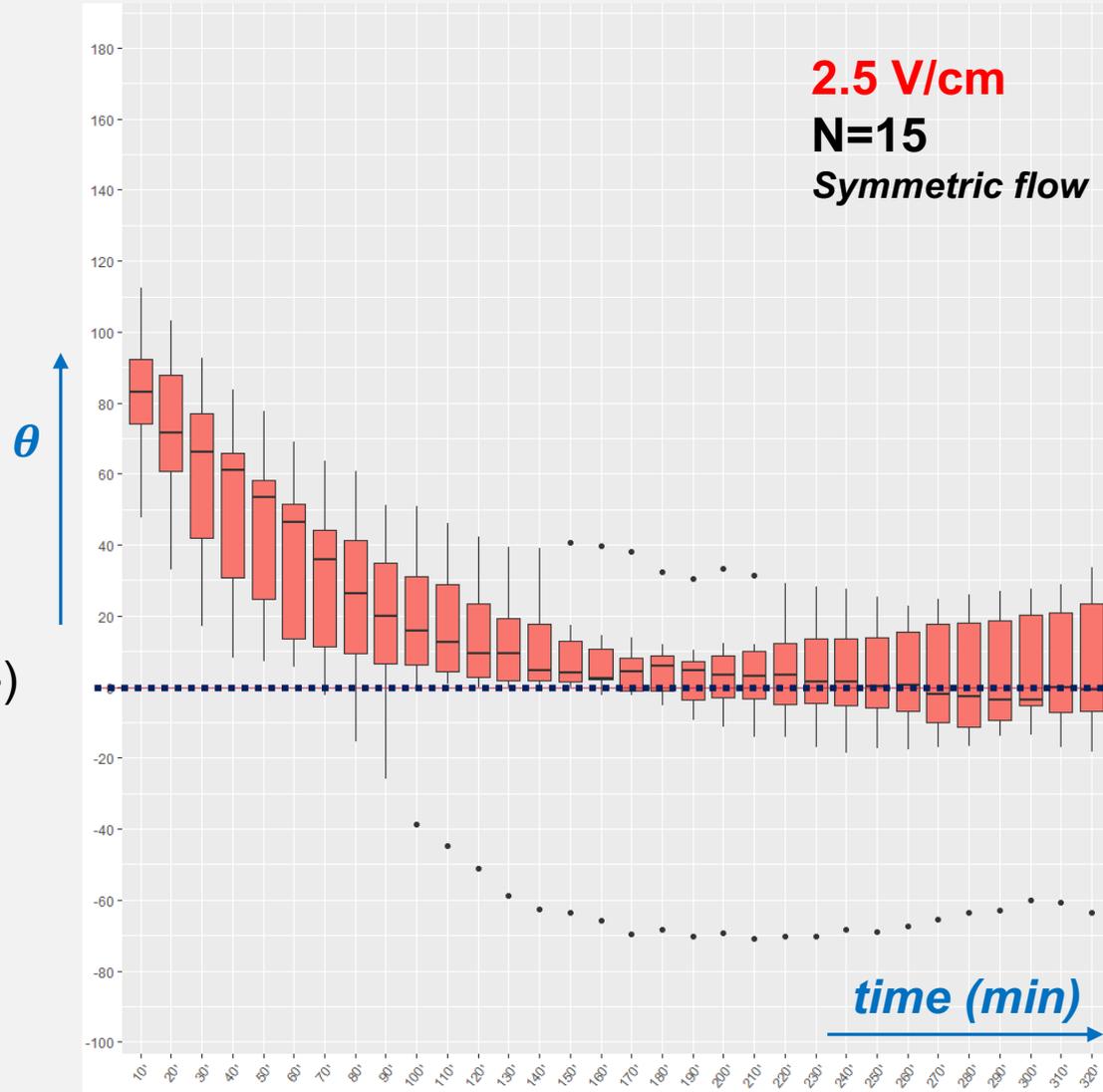
Root electrotropism: phenomenology



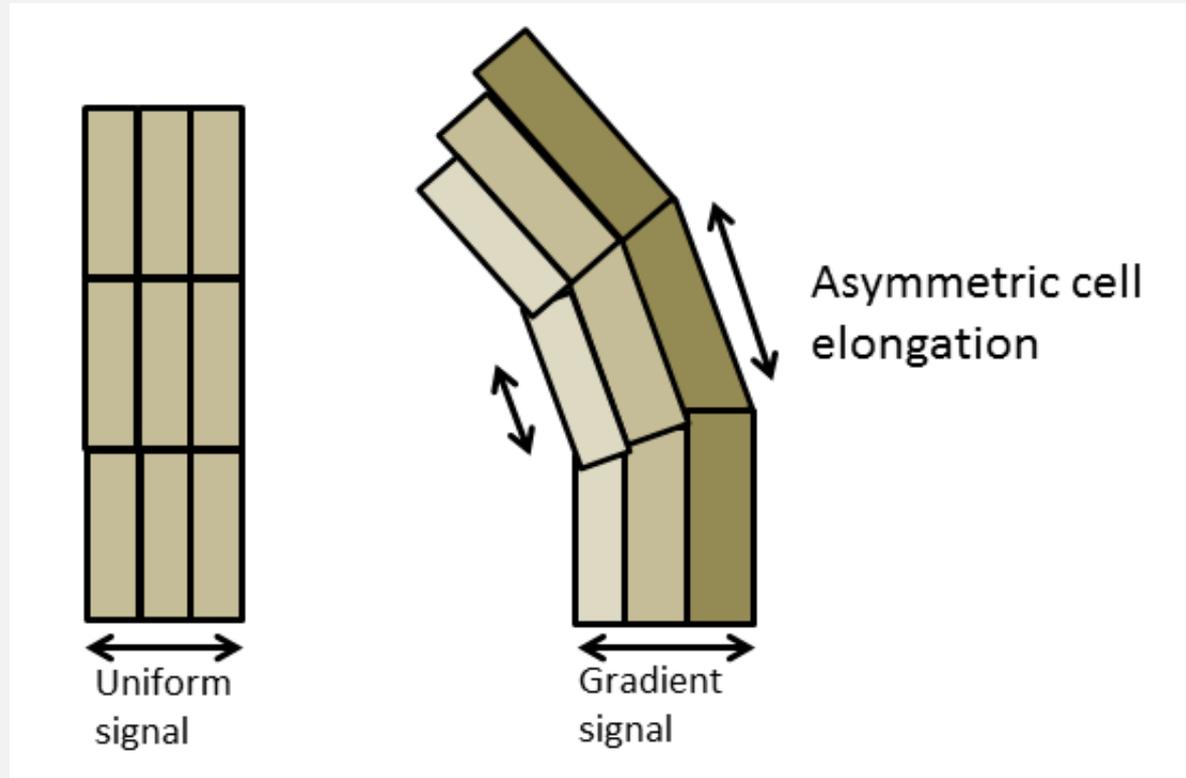
Response to DC electric field



aligned towards (-)



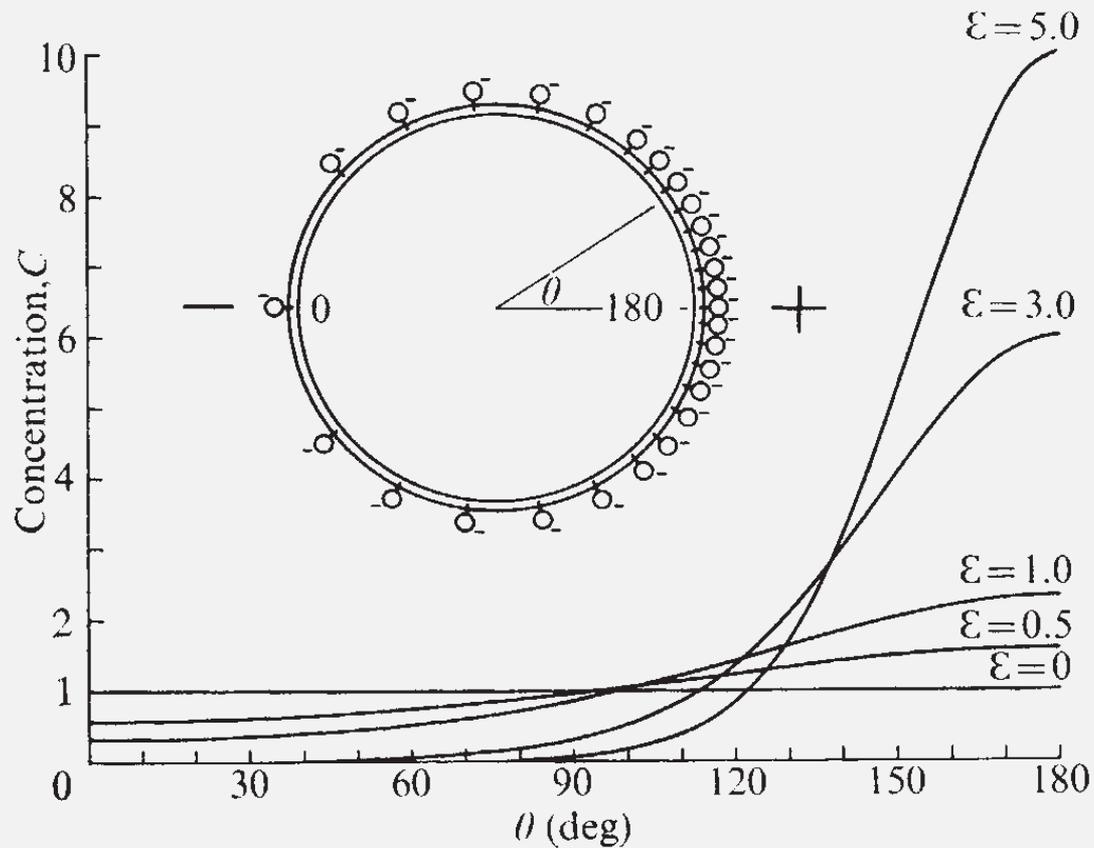
Possible mechanism?



?

E

Membrane electrophoresis



Induced trans-membrane voltage

$$\Delta\Phi_m(t) = f_s ER \cos \theta \left[1 - \exp\left(-\frac{t}{\tau}\right) \right]$$

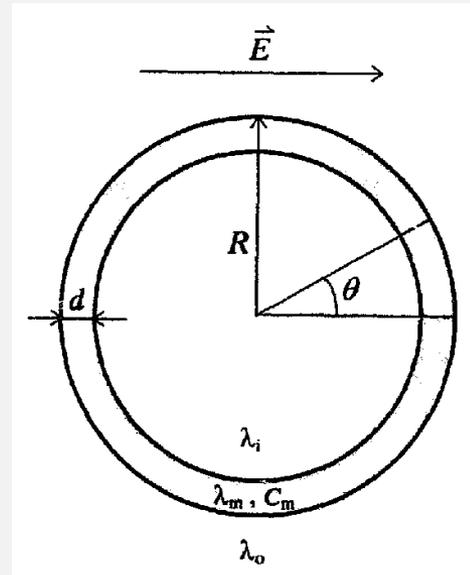
Where:

$$f_s = \frac{3\lambda_o [3dR^2\lambda_i + (3d^2R - d^3)(\lambda_m - \lambda_i)]}{2R^3(\lambda_m + 2\lambda_o)(\lambda_m + \frac{1}{2}\lambda_i) - 2(R-d)^3(\lambda_o - \lambda_m)(\lambda_i - \lambda_m)}$$

$$\tau = \frac{RC_m}{\frac{2\lambda_o\lambda_i}{2\lambda_o + \lambda_i} + \frac{R}{d}\lambda_m}$$

Specific conductivities: λ_i = cytoplasm
 λ_m = membrane
 λ_o = extracellular

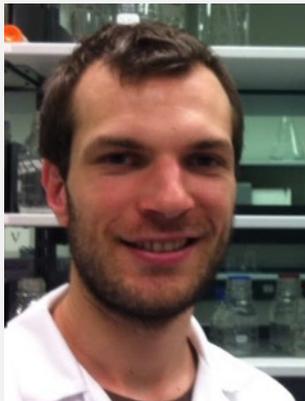
Capacitance: C_m = membrane



The Laboratory
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Allen Discovery Center



Nick Kral



Deniz Tiknaz



Nick Oliver