1D MODELING OF AUXIN DISTRIBUTION IN PLANT ROOTS

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Distribution of the hormone auxin in a plant root determines cell differentiation and direction of cell division, thereby forming the general root structure [1]. The highest auxin concentration is accumulated in the root meristem (Fig 1A), whereto auxin is delivered from the aerial parts of the plant along the longitudinal root axis through the vascular system. The main contribution to the auxin flow is made by PIN protein-facilitated auxin transport [2]. Experimental studies show that auxin increases its own transport at low concentrations and suppresses at higher ones [3]. We present the 1D-model of mechanism controlling the formation of the auxin distribution along the root longitudinal axis:

$$\frac{da_n}{dt} = \alpha + P_t a_{n-1} - P_t a_n - K_d\, a_n - K_o\, a_n\, f(a_n)$$

$$\frac{da_i}{dt} = P_t(a_{i+1} + a_{i-1}) + K_o a_{i+1} f(a_{i+1}) - 2P_t a_i - K_d\, a_i - K_o\, a_i\, f(a_i),\; i = \overline{n-1,2} \qquad (1)$$

$$\frac{da_1}{dt} = -P_t a_1 - K_d a_1 + P_t a_2 + K_o\, a_2\, f(a_2).$$

$$f(a) = \frac{(\frac{a}{q_{11}})^{p_1}}{1 + (\frac{a}{q_{12}})^{p_1}} \cdot \frac{1}{1 + (\frac{a}{q_2})^{p_2}}$$

Here n is the number of cells in the longitudinal axis. The cell in the shoot/root junction is numbered n, and the most apical cell is numbered 1. a_i is auxin concentration in cell i; K_d, coefficient of dissipation; P_t, rate coefficient of diffusion, which is the same in both directions; $K_o>0$, the rate constant of active transport, α , auxin influx from shoot into the root. Generalized Hill’s function *f(y)* is used to describe active transport with the following positive coefficients: $q_{11}, q_{12}, q_2, p_1, p_2$.

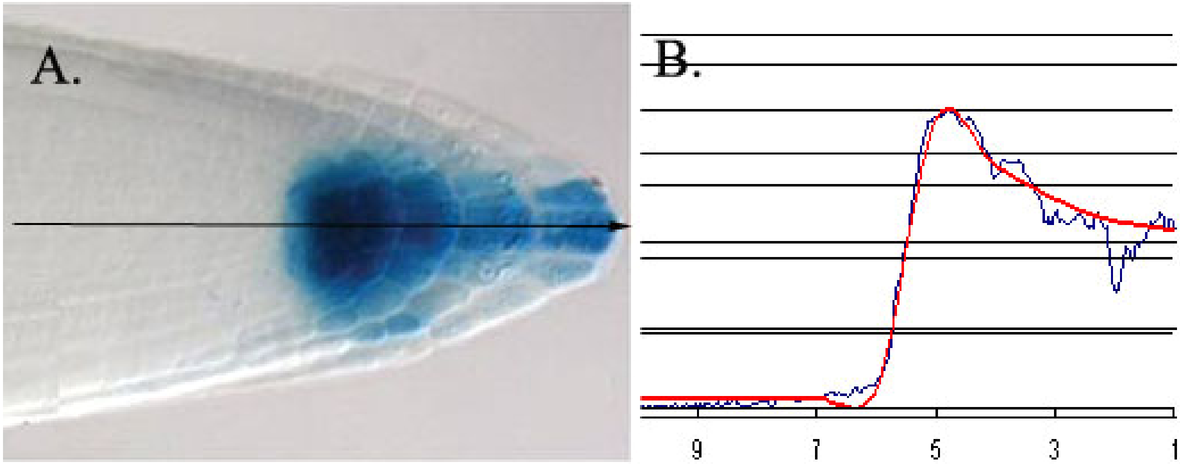

Figure 1. Correspondence of the simulation to the real auxin gradient in roots. **A.** Auxin distribution pattern in the root of *A .thaliana* and formation of the maximum in the root meristem. The arrow is the longitudinal axis considering in the model. [4]. **B.** One of the steady state solutions of the model (red curve) plotted altogether with auxin distribution curve obtained by scanning of Panel A (blue curve).

We have found parameter values at which steady-state auxin distribution were in qualitative agreement with distribution of the auxin in the root tip [1,4] (Fig. 1B). At this set of parameters and different initial auxin distributions the model has numerous steady-state solutions (Fig.2A), but all of them can be grouped into 4 types according to overall picture of location of auxin maximums (Fig 2B). All the steady states have a feature in common: the presence of an auxin maximum at the root tip qualitatively corresponding to the experimental one (Fig. 2A, the frame) The transitions between steady states can occur if auxin concentration increased in the cell i (due to auxin biosynthesis in this cell) or decreased (due to transport of auxin into cells laying further in the radial axis) (Fig 2B). Additionally, the model reproduces experiments on root tip regeneration after root tip laser ablation [5]. In the model it means the establishment of steady state solutions stating from [0,0,0] initial distribution. The additional peaks in the intermediate zone may be attributed to experimentally shown fluctuations in auxin distribution along the auxin flow in protoxylem in the region between the RAM and the elongation zone [6]. In these experiments each peak in the auxin-reporter maximum correlated with the formation of a consecutive lateral root.

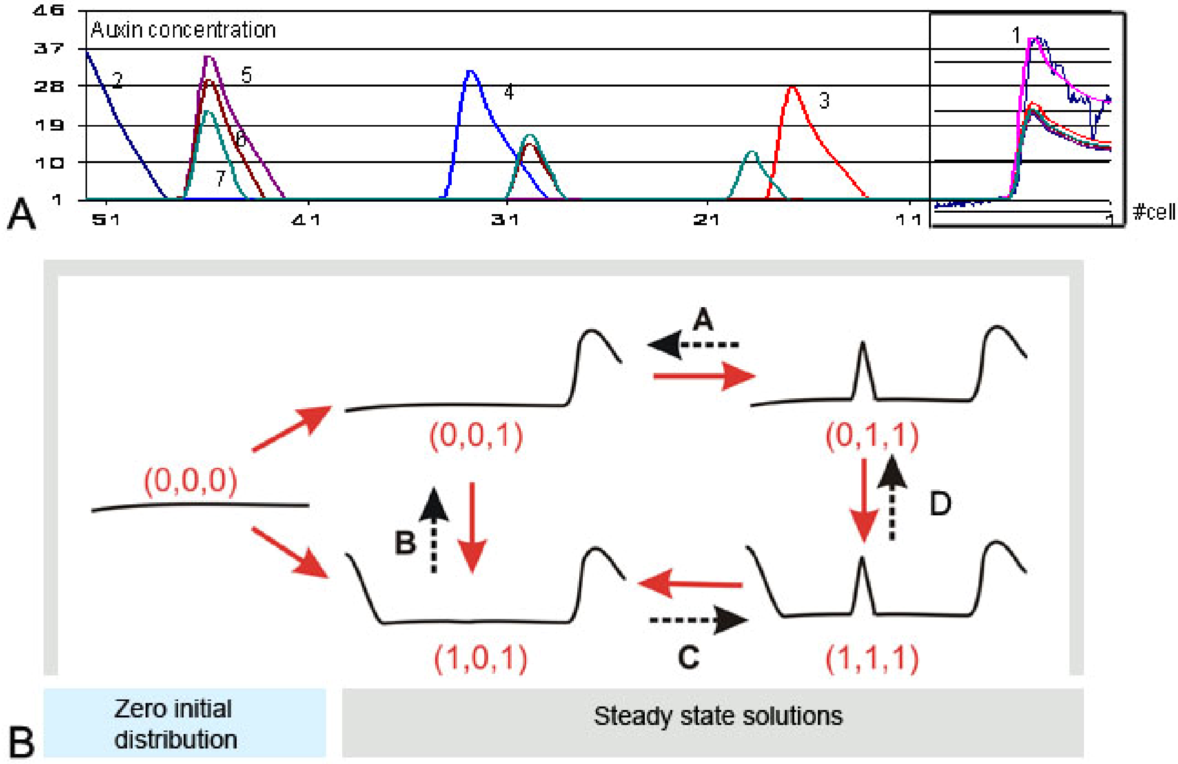

Figure 2. **A.** The steady state solutions of the model with $\alpha=1$, $P_t=0.08$, $K_d=0.0045$, $K_o=0.25$, $q_{11}=1$, $q_{12}=100$, $q_2=3$, $p_1=1$ $p_2=10$, $n=52$ and different initial conditions. The area in the frame coincides with Fig1B. **B**. The transitions between steady states can occur due to fluctuations in auxin concentration in the cell i. The types of steady state solutions are named as [0,0,1], [0,1,1], [1,0,1], and [1,1,1]. The numbers 1 or 0 in the name of distribution means correspondingly the existence or absence of auxin maximum in the root at the following order [at the shoot/root junction, in the intermediate zone, and at the root tip]. Red solid arrows mark more probable transitions.

1. Sabatini et al. (1999) *Cell*. **99**: 463–472
2. Friml et al. (2003) *Nature*. **426:** 147-153
3. Vieten et al. (2005) *Development.* **132:** 4521-4531
4. Wang et al. (2005) *The Plant Cell*. **17**: 2204–2216,
5. Xu et al. (2006) *Science*. **311:** 385-388
6. de Smet et al. (2007) *Development*. **134**: 681-690