How roots grow

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In contrast to animals, plants form new organs throughout their entire life, i.e. roots, branches, flowers and fruits. Researchers in Frankfurt wanted to know to what extent plants follow a pre-determined plan in the course of this process. In the renowned journal *Current Biology*, they describe the growth of secondary roots of thale cress (Arabidopsis thaliana). They have observed it cell by cell in a high-tech optical microscope and analysed it with computer simulations. Their conclusion: root shape is determined by a combination of genetic predisposition and the self-organization of cells.

"Our work shows the development of the complex organ of the secondary root with unprecedented temporal and spatial resolution", says Professor Ernst H. K. Stelzer of the Buchmann Institute for Molecular Life Sciences at Goethe University Frankfurt am Main. He is the inventor of the high-resolution and gentle light sheet fluorescence microscopy, with which the researchers recorded the development of secondary roots from the first cell division to their emergence out of the main root. For over 64 hours, they first logged the fluorescence signals from cell nuclei and plasma membrane every five minutes and then identified and followed all cells involved in root development.

The secondary roots stem from a variable number of "founder cells", of which some contribute to the development. The shape of the secondary roots and the respective growth curves show great similarities. "We classified the cell divisions on the basis of their spatial orientation in order to find out when new cell lines and cell layers form", explains Daniel von Wangenheim, first author of the study. "Surprisingly, we were not able to predict on the basis of the initial spatial arrangement where exactly the future centre of the secondary root would lie." Evidently, only the first division of the founder cells is strongly regulated, whilst the subsequent divisions do not follow any pre-determined pattern. Their behaviour is rather more adaptive. In nature, this also makes sense, for example if the roots meet with an obstacle.

In order to be able to identify the fundamental principles of secondary root development in the vast amount of data, the researchers combined methods for the quantitative analysis of cell divisions in wild and genetically modified plants (wild type and mutants) with mathematical modelling. This was undertaken by their colleague Prof. Alexis Maizel from the University of Heidelberg. He realized that the development of the secondary root is based on a limited number of rules, which account for the growth and orientation of cells. The development of a characteristic secondary root follows the principles of self-organization, which is prevalent in nature. Alexander Schmitz, co-author of the study, explains the non-deterministic part by the fact that organ development is robust as a result: "In this way, the roots are able to develop in a flexible and nevertheless controlled manner despite the varying arrangement of the cells and mechanical factors in the surrounding tissue."

More information: Daniel von Wangenheim et al. Rules and Self-Organizing Properties of Post-embryonic Plant Organ Cell Division Patterns, *Current Biology* (2016). DOI: 10.1016/j.cub.2015.12.047

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