Explaining leaf venation through auxin signaling

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January 27, 2015

How does a plant 'know' how to avoid obstacles while growing a root system? How can leaves 'repair' their vasculature after being teared by a falling branch? Plants have proven to be remarkable organism, with a highly complex developmental process and exceptional adaptability capacities. The purpose of this project will be to try and understand an important process of plant morphogenesis, namely that of tissue polarisation.

The field of tissue polarisation analyses the way in which individual cells arrange themselves in order to transmit a specific signal from one side of the tissue to the other. An analogy with the human body would be the way in which neurons transmit electrical signals in order to connect the Central and Peripheral Nervous Systems. In the case of plants, tissue polarities enable them to adjust their physiology and development according to environmental changes.

An important question which arises when thinking about this sort of polarity is how can individual cells 'communicate' with one another in order to transmit a specific signal. It has been shown that the plant hormone auxin drives the emergence of polarity. Auxin is a substance that is also in charge of controlling cell identity as well as cell expansion. Although it is known that auxin regulates cell polarity, it is not known how it does it exactly. The main problem lies in the fact that up to this day it is not known the exact mechanism in which auxin gets transported throughout plant tissues.

Although auxin is able to passively diffuse inside the cell cytoplasm from the outside intercellular space, it cannot diffuse outside as it gets deprotonated and the resulting auxin ions cannot pass across the membrane. Thus, they require a means to be actively transported. Recently, it has been shown that a specialised family of proteins called PIN which rest on the cell membrane are responsible for pumping auxin out of the cell. But again, how can a cell know how many of these PIN proteins should be on the membrane? Can a cell sense how much auxin there is in neighbouring cells? Or can it perceive in some way the incomming auxin flux?

Throughout this project, you will be looking at various hypotheses that have been proposed for describing auxin transport (see e.g., [1, 2, 3]). You will need some knowledge of dynamical systems and of numerical simulations of ordinary differential equations. The goal will then be to compare the models both qualitatively and quantitatively and to determine their viability as a basis for tissue polarisation.

References

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