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EDITORIAL

Cellular physics

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Physical factors shape every aspect of cellular life—temperature, gravity, electrical fields, but also, more subtle factors such as sound or magnetic fields can be perceived by living beings to adjust cellular functions with the challenges of environment. Despite their impact on biology, the mechanisms of perception and transduction of physical fields are often barely understood, in some cases, not even investigated. One reason for this "blind spot" of cell biology might be that the otherwise so efficient repertory of molecular biology is of limited help in this case—perception of physical stimuli requires a transformation process translating physics into biochemistry (so-called *susception*), and knowledge about the molecular nature of the players involved in this translation process, although important, is not sufficient. When we know that the amyloplasts triggering plant gravitropism are composed of starch, this is interesting, but it does not reveal very much about the nature of gravity perception. We need cellular physics when we want to understand cellular biology. Two contributions in the present issue have adopted a physical approach to cell biology:

Nanosecond pulsed electrical fields are used to electroporate and extract plant tissues very efficiently for industrial applications, for instance, during the processing of sugar beets. In a time of rising energy costs, this strategy is becoming progressively attractive. However, the energy input is by orders of magnitude lower than that required for membrane breakage indicating that it is a biological process rather than mere electrophysics that underlies this phenomenon. In fact, such nanosecond pulsed electrical fields have been shown to induce apoptosis in cancer cells and elicit, in the plant model tobacco BY-2, a rapid bundling of actin filaments followed by an actin-dependent permeabilization of the membrane (Berghöfer et al. 2009). This indicates that charging of the membrane, even much below the voltages required for irreversible membrane breakage, can cause a biological effect. Several theoretical, but competing, models have been proposed to explain this phenomenon, but experimental evidence was lacking, at least for plant cells. In the current issue, Flickinger et al. (2010) have used a newly developed Pulsed Laser Fluorescence Microscopy setup in combination with the voltage-sensitive fluorescent dye ANNINE-6 to follow membrane charging with an unprecedented time resolution of 5 ns in tobacco BY-2 protoplasts. They can show maximal voltage changes at the cell poles and can depict the geometrical distribution of charge revealing a distinct azimuthal pattern. This pattern is consistent with only one of the concurrent models proposing that nanosecond pulsed electrical fields induce small but reversible pores at the cell poles that reseal within microseconds after the pulse. In addition, voltage-gated ion channels at the hyperpolarized poles are detected from a reversion of membrane polarity at the hyperpolarized pole. Although these charges occur rapidly and persist only transiently in the range of microseconds, they live long enough to trigger a long-lasting response of actin filaments. In fact, previous studies on ion channel activity in BY-2 cells (Stoeckel and Takeda 2002) have led to a model, where the activity of voltage-gated K+ channels is modulated by actin filaments, indicating a close and possible physical link between the actin cytoskeleton and the machinery sensing membrane charges.

Whereas, for the perception of electrical fields, there exists at least a panel of molecular candidates and a fairly elaborate

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collection of mechanisms to explain this phenomenon, the perception of magnetic fields has remained fairly elusive. There is a highly controversial, but important, debate whether plants are able to perceive geomagnetic fields through the plant cryptochromes, photoreceptors that, by a radical pairing process, can modulate their activity depending on the ambient magnetic field and have been identified as molecular candidates in avian magnetoperception. So far, it is not even clear whether plants can perceive and respond to magnetic fields, at least to those in the range of geomagnetism. The work by Barlow et al. (2010) in the current issue contributes to this debate by an investigation of a seemingly exotic phenomenon, circalunar fluctuations of tree stem diameters. Although one would intuitively link such fluctuations to changes in transpiration, it had been shown earlier that they originate from symplastic flow. The authors have revisited a *Nature* publication from a decade ago (Zürcher et al. 1998) indicating correlations between tree-stem diameters and lunar tides. They reanalyzed previously published data sets collected by high-precision extensometry from different tree species at different locations and conducted a meticulous statistical analysis projecting lunisolar tidal acceleration, and also changes of geomagnetic flux on these time courses. They can confirm the conclusions by Zürcher et al. (1998) that stem diameter fluctuates with the tides. However, in addition, they can also infer on a weak influence of geomagnetic flux evident from a reciprocal weak relationship of the so-called Thule index with stem diameters. This contribution, although theoretical in nature, is important because it sets a formal framework by which an elusive, but important, physical factor (geomagnetic field) becomes amenable to experimental analysis.

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