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Nuclear positioning: a matter of life

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Cell organization, and in particular how organelles are distributed in the cell, is often used by physiopathologists to visually identify cell types in an organism. Behind this simple fact, it suggests that the positioning of sub-cellular structures is not occurring randomly but by active manners. Three hundred years ago, Leeuwenhoek reported the existence of a structure which will be then called the nucleus. It is the biggest organelle in eukaryotic cells, and has been described to be actively displaced in a large range of organisms and tissues. One of the first nuclear movements in an organism life occurs just after fecondation, when the two pronuclei moves towards each other in the egg (Van Beneden, 1883). After this first discovery, other nuclear movements has been described, such as in plants in 1903 (SENN, 1908) or occurring during neuroepithelium development in 1935 (Sauer, 1935). The latter was called interkinetic nuclear movement (INM). Whether nuclear movement has a function for cell fate and also how this is achieved needed to be further investigated. Several groups have tackled this question in different organisms and cell systems; it reveals similarities in the *modus operandi* between them but also particularities that could be associated with specific requirements for cell function. INM, for example, has been observed in other tissues and organisms, and defects in this movement lead to severe developmental defects, such as Lissencephaly. In *Drosophila*, inhibiting nuclear movement in the oocyte affects the polarity and therefore the future segmentation of the embryo.

Nuclear positioning can be achieved cell autonomously but is often induced by external cues, such as light for plants or a wound for fibroblasts. Interestingly, it appeared that mechanical forces applied to a cell are transmitted by the cytoskeleton to the nucleus, modifying its shape and position, but can also modulate gene expression and therefore cell fate. This can be achieved by one or more different cytoskeletons, with a direct or indirect interaction with the nuclear envelope. It also implies the existence of specific proteins located on both sides of the nuclear envelope able to transmit and buffer this convoluted mechanical signal. A complex, called LINC for Linker of Nucleoskeleton and Cytoskeleton, composed of outer and inner nuclear membrane proteins, has been associated with several nuclear movements and is thought to act as a buffer of mechanical forces for the nucleus (Crisp et al., 2006). It is bound to the different cytoskeletons on one side and to the lamin meshwork on the other side.

In this special issue are collected several reviews on different types of nuclear movement and positioning, from fungi to mammals. I invited several renowned researchers to assemble and discuss the knowledge produced so far about the current situation in their respective systems. Even though the collection is not exhaustive, it shows the differences, commonalities and sometimes conservation of the mechanisms at stake. X Xiang proposes a comprehensive and discussed inventory of studies on nuclear movements in fungi, particularly important for cell division and organism function. M Wada presents a review on plant nuclear movements, in particular the light-induced nuclear movement. This particular nuclear movement purpose is to protect leaf cells from UV radiation and therefore DNA mutations. In M Almonacid *et al* review on nuclear movement in the mouse oocyte, we can see the fundamental differences with what occurs in the drosophila oocyte, described by F Bernard *et al*. It is achieved by complete different mechanisms and ends with a perfect centering in the cell. In *Drosophila*, the off-

centering is managed by microtubules whereas in mouse, the centering is governed by an active actin meshwork. A role for nuclear positioning has been found in fibroblast migration studies that are thoroughly reviewed by R Zhu *et al.* Several mechanisms were discovered using this in vitro system, in particular the arrangements between nuclear envelope proteins and the actin cytoskeleton, called TAN lines, required for nuclear movement. Roman and Gomes, in their review on nuclear movement in muscle, present the last discoveries and the implications in cell and organ function. The muscle cell is a powerful system to study different types of nuclear movements. In the review from R Vallee et al, we have a complete and detailed overview of the mechanisms involved in nuclear migration during brain development, in particular the radial glial cells. Finally, Lee and Burke gathered all the knowledge about the LINC complex and its role in nuclear positioning in different cellular contexts.

Besides being repository of the genome, the nucleus can also, by its position inside the cells, affect cell fate and behavior. We might distinguish nuclear movement in cycling cells, where it can affect spindle formation or the symmetry of cell division, and nuclear movement in differentiating cells, where it can affect the cell final function. Studying the mechanisms of cell organization is a challenge to understand how cells operate, explain cause of diseases and pave the way towards new therapies.

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Van Beneden, É.J.L.M.A. du texte (1883). Recherches sur la maturation de l'oeuf, la fécondation et la division cellulaire, par Édouard Van Beneden,... (Gand et Leipzig: Clemm).