effects on Nde1-Lis1-Brap complex formation and progenitor fate choice may help to initially test some of the predictions of the current model. Further, a matrix of different types of morphogenic gradients (e.g., dorsoventral, anterior-posterior, and midline-derived gradients) and morphogens (e.g., Wnt, BMP, Shh, and FGF) coordinate neural patterning in the CNS (Monuki, 2007; Salinas and Zou, 2008). Nde1-Lis1 complex can also interact with a number of different effectors (Wynshaw-Boris et al., 2010). In this context, it will be useful to examine whether the formation of different types of Ndel-Lis1 complexes in response to different morphogenic gradients underlie distinct patterns of progenitor fate choice in the CNS.

The localization of Nde1-Lis1-Brap near the plasma membrane appears to be critical for its effects on the MAPK pathway. But how Nde1-Lis1-Brap association at the cell periphery may influence progenitor fate choice remains an open question. For example, this complex may act to stabilize other membrane-associated scaffolding proteins that contribute to MAPK signaling (e.g., dystrophin/dystroglycan complex [Pawlisz and Feng, 2011; Spence et al., 2004]) or fate determination. Furthermore, during early CNS patterning, neural progenitors undergo symmetric or asymmetric divisions, leading to the expansion of the progenitor pool or to neurogenesis/gliogenesis, respectively. Shifts in the mitotic spindle orientation can determine the pattern of progenitor division (Morin and Bellaïche, 2011). Previous studies have demonstrated that Nde1-Lis1 deficiency in radial glial progenitors leads to abnormal spindle orientation. Does Nde1-Lis1-Brap complex modulate spindle orientation of neural progenitors? Does it differentially affect symmetric versus asymmetric patterns of proliferation? Does it affect the asymmetric or symmetric inheritance of fate determinants in daughter cells? Exploring whether and how morphogenic gradient-induced activity of Nde1-Lis1-Brap complex impacts these various mechanisms involved in fate determination of progenitors will help to refine the overall significance of the interplay between Nde1-Lis1-Brap1 complex and MAPK signaling threshold in progenitors during CNS patterning.

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When Two Plus Two Should Equal Two

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Sexual reproduction in flowering plants is a masterpiece of cell-to-cell communication involving a unique double fertilization process and an intricate sperm delivery system. Reporting in *Developmental Cell*, Maruyama et al. (2013) and Völz et al. (2013) shed light on an elaborated system that coordinates sperm delivery with fertilization status.

Ever since the late 19th century it has become clear that flowering plants deviate from the universal formula of sexual reproduction: one plus one equals one. Sergei Gawrilowitsch Nawaschin, followed by Léon Guignard, discovered in 1898 that in plants two male germ cells—sperm—will fuse with two female gametes—the egg cell and the central cell—to give rise to an embryo and embryo-supporting tissue, the endosperm (Bresinsky et al., 2008). The two sperm cells are transported to the female reproductive organs (the ovules) containing the egg and central cells by a growing pollen tube that is built from a pollen grain landing on the stigma of a flower (Figure 1). The success of this transport is not only decisive for the plant life cycle but also key in producing the endosperm that is a major nutrient source in the diets of humans and livestock.

The long and winding journey of sperm cells starts from the release of pollen in pollen sacs, also called anthers. In the reproductive season, millions of pollen grains can be produced by a single plant.

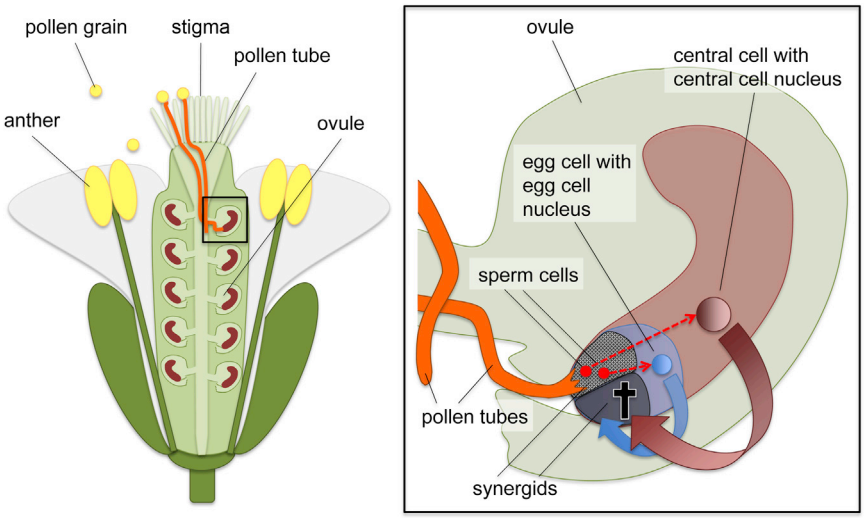

Figure 1. Scheme of Double Fertilization Process and Postfertilization Signaling
Left: schematic section through a simplified flower. Pollen can be delivered from the same flower or can come from another flower. Right: magnification of the boxed area in the left panel showing an ovule during fertilization. Upon entry of a pollen tube into one of the two synergids, the tube bursts and releases the two sperm cells. One of them will fertilize the egg cell (dashed red arrow) to give rise to a zygote and subsequently an embryo. The second sperm will fuse with the central cell (dashed red arrow), the second female gamete, producing endosperm, an embryo-supporting tissue. The fertilization status of both the egg cell and the central cell is quantitatively monitored (brown and blue arrows) and results in programmed cell death of the second synergid, shutting off attraction for any additional pollen tubes. If fertilization of either the egg cell or the central cell fails, pollen tube attraction is maintained and double fertilization can be recovered with sperm cells delivered by the second tube.

Often due to self-incompatibility systems, these pollen grains have to travel long distances, assisted by wind or animals, to find the right partner and ensure outcrossing. Once a pollen grain lands on a compatible flower, it will hydrate and start to form a tube, one of the largest cell types among eukaryotes. The tube grows within the maternal tissues, guided by several cues, to reach an ovule that holds the egg and the central cell (Figure 1) (Dresselhaus and Franklin-Tong, 2013).

Ovules also contain two synergids as a third cell type that has been found to be responsible for the final stretch of pollen tube attraction (Dresselhaus and Franklin-Tong, 2013). The arriving pollen tube will enter an ovule through one of the two synergids and discharge the sperm cells (Figure 1). This results in death of the synergid. In addition, the second synergid will undergo programmed cell death, thus shutting down the production of attraction cues for pollen tubes. How the death of this cell is triggered was so far not understood. Now, Völz et al. (2013) show in this issue of *Developmental Cell* that mutants in the ethylene signal transduction cascade fail to execute the death of the second synergid cell. Moreover, the authors establish via delicate microinjection experiment, with which they could deliver a biosynthetic precursor of ethylene to the female gamete-bearing structures, that ethylene can trigger cell death of the synergids. Thus, this work now gives a molecular framework for postfertilization signaling processes during plant reproduction and reveals a new role for ethylene during plant development.

Ethylene is a well-known and intensively studied signaling molecule that controls many processes during plant growth and development (Stepanova and Alonso, 2009). Interestingly, it has been previously implicated in the control of cell death in plants, such as in the formation of air spaces (aerenchyma) in roots under hypoxia conditions, in cell death after pathogen attack (hypersensitive response), and in leaf senescence (Trobacher, 2009). Thus, the plant appears to reuse a "death module" in different environmental and/or developmental contexts. Interestingly, Völz et al. (2013) also show that a failure to kill the remaining synergid resulted in its incorporation into the developing endosperm. Therefore, cell death might also be needed to generate a genetically homogenous tissue.

In parallel, also in this issue of *Developmental Cell*, Maruyama et al. (2013) demonstrate that the shutdown of pollen tube attraction is a well-balanced process to which both fertilization events—central-cell and egg-cell fertilization—contribute. If this double fertilization fails, pollen tube attraction is recovered to allow a second tube to enter the ovule. These insights were made possible by the combination of mutations (for instance, in cell-cycle regulators) that results in pollen with less than two functional sperm cells (Nowack et al., 2012; Zhao et al., 2012), as well as great advances in live imaging as pioneered by the team of Tetsuya Higashiyama. This fertilization recovery system can result in heterofertilization in which double fertilization is achieved from two genetically different pollen grains. Maruyama et al. (2013) beautifully illustrate this by generating seeds in which the endosperm contains an RFP reporter gene and the embryo harbors a GFP reporter gene.

Searching for components of the underlying molecular mechanism of pollen tube attraction control, Maruyama et al. (2013) show that mutants in the evolutionarily conserved chromatin-remodeling factor Polycomb repressive complex 2 (PRC2) fail to shut down pollen tube attraction. This was not the case for mutants in other chromatin-modifying enzymes. PRC2 acts as a transcriptional repressor and is well known to regulate various aspects of seed development, such as the parent-of-origin-dependent expression of many genes in the developing endosperm (Bemer and Grossniklaus, 2012).

These two studies, taken together, give rise to the exciting hypothesis that the ethylene signal transduction pathway and PRC2-mediated chromatin remodeling interact. The identities of the target genes of both pathways now need to be assessed. A key question is then what their epistatic relationships is (i.e., are components of the ethylene signal transduction cascade under PRC2 control or vice versa?). Another interesting question for the future is how the fertilization status of ovules is translated and/or interpreted into a graded response. This is based on the observation that a

second pollen tube is attracted more frequently if neither egg cell nor central cell is fertilized versus if one of the female gametes is fertilized. Could this be due to central-cell and egg-cell fertilization each contributing to ethylene signaling, or are additional signals (e.g., a combination of repulsive and attractive agent) involved? Thus, 100 years after the discovery of double fertilization, the curtains on the molecular control system are just starting to be lifted, and more fascinating insights into the reproduction of flowering plants are still ahead.

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