Cell division is the basis of differentiation and growth. The overall process is the same everywhere—one cell that generates two cells—but there are differences in the mechanism across the tree of life. Some features such as the nature of microtubule involvement, the formation of the spindle, or the rupture of the nuclear envelope vary across taxa (Buschmann and Zachgo, 2016). Green algae, including Chlamydomonas and Volvox, are used as a model system for the study of mitosis (Birchem and Kochert, 1979) also because they possess both key animal and plant functions. In general, the simple multicellular alga Volvox is a suitable model organism for investigating cell division, cell differentiation, and morphogenesis (Matt and Umen, 2016). Additionally, the size of the reproductive cells in Volvox is an advantage for studying subcellular structures.

In this issue of The Plant Cell, work by Eva Laura von der Heyde and Armin Hallmann (von der Heyde and Hallmann, 2022) provides a comprehensive analysis of embryonic cell divisions in the green alga Volvox carteri. They selected mitosis- and cytokinesis-associated genes to generate yellow fluorescent protein (YFP)-tagged proteins to study cell division in Volvox using live-cell imaging. The selection of six proteins allowed the study of different aspects of mitosis in vivo, including nuclear envelope fate, chromatin motion, microtubule dynamics, and membrane remodeling (see Figure).

First, YFP carrying a nuclear localization signal allowed the analysis of dynamics of cell nuclei and the nuclear envelope during early embryonic cell divisions, while YFP without a targeting signal (pts-free YFP) was used to track cytosolic and nucleoplasmic processes. Histone H2B was used to monitor chromatin dynamics as the degree of condensation of the chromatin is another marker of phase transitions during cell division. Next, with β-tubulin (TubB2), the authors tracked the formation of microtubular structures, including the complete development of the mitotic spindle, and monitored how these structures are positioned. Additionally, the YFP:TubB2 signal was helpful to analyze the formation of the phycoplast (a microtubule array, function-related to the phragmoplast in plants). The authors also studied membrane remodeling using the dynamin-related protein 1 and Ran GTPase activating protein 1. Finally, the authors provide a detailed description of the overall process and a model for mitosis in V. carteri.

The cell division in V. carteri has five crucial features: the high degree of interchange between cytosol and nucleoplasm, the persistence of the nuclear envelope until telophase, the organization of the spindle by cytoplasmic centrosomes, the involvement of the phycoplast in cytokinesis, and when viewed as a whole, the enormous dynamics of cytoskeletal and membranous structures. These observations were possible with the use of live-cell imaging, providing time-lapse data of the complete cell division process at high optical resolution.

This work sheds light on the understanding of the assembly and dynamics of key structures that participate in cell division. Additionally, it provides a reference for comparative studies not only to understand the evolution of cell division in the large group of algae but also to get hints regarding the evolutionary history of cell division in plants and animals.
References

Birchem R, Kochert G (1979) Mitosis and cytokinesis in androgonia of Volvox carteri f. weismannia. Protoplasma 100: 1–12

Buschmann H, Zachgo S (2016) The evolution of cell division: From streptophyte algae to land plants. Trends Plant Sci 21: 872–883

Matt G, Umen J (2016) Volvox: A simple algal model for embryogenesis, morphogenesis and cellular differentiation. Dev Biol 419: 99–113

von der Heyde EL, Hallmann A (2022) Molecular and cellular dynamics of early embryonic cell divisions in Volvox carteri. Plant Cell 34: 1326–1353