

FREE1 takes its position in peroxisomal engulfment of lipid droplets

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Many seeds do not germinate immediately at maturity but remain in soil seed banks until suitable environmental cues wake them up. However, it takes a lot of energy for germinating seedlings to emerge before they can perform photosynthesis. Many plants store lipid in the form of triacylglycerols (TAGs) as seed reserve, which will be mobilized to fuel the germinating seedlings. It has been well demonstrated that suppression of β -oxidation and the glyoxylate cycle by abscisic acid inhibits lipid catabolism in quiescent seeds (Penfield et al., 2006). However, it remains largely unknown how lipid metabolism is activated in germinating seeds. Recently, Shuxian Huang and colleagues (Huang et al., 2022) provided a wonderful look behind the scenes of lipid metabolism in germinating *Arabidopsis* (*Arabidopsis thaliana*) seedlings using the powerful tool of high-resolution electron tomography (ET).

Lipid metabolism has been demonstrated to occur mainly in peroxisomes and mitochondria. Very long-chain fatty acids in lipid droplets (LDs) are subjected to β -oxidation in peroxisomes to generate energy. Thus, the interaction between peroxisomes and LDs is a critical step in lipid catabolism. To capture the early events of peroxisome-LD interaction, Huang et al. (2022) profiled various LDs and peroxisomes on continuous 300-nm-thick sections of *Arabidopsis* root tip cells, using nanometer-resolution ET technology. LDs and peroxisomes at different stages were successfully illustrated via three-dimensional ET modeling, which vividly captured scenes of peroxisomal extension and tubulation and engulfment of LDs by tubular peroxisomes.

Huang and colleagues further investigated the process of peroxisomal engulfment of LDs by using *Arabidopsis*

mutants deficient in the plant-unique endosomal sorting complex for transport (ESCRT) component FYVEDOMAIN PROTEIN REQUIRED FOR ENDOSOMAL SORTING 1 (FREE1; Gao et al., 2014). ET analyses revealed accumulated LDs and impaired peroxisomal engulfment in the mutant root cells, which was validated by transmission electron microscopic examination and confocal microscopic observation (Huang et al., 2022). These results showed a clear picture of the ESCRT-mediated peroxisomal extension and following engulfment of LDs during lipid mobilization in germinating seedlings.

Previously, it was proposed that some lipases might be delivered from peroxisomes to the LD surface to hydrolyze TAGs (Thazar-Poulot et al., 2015). Huang et al. (2022) further demonstrated a direct interaction between FREE1 and the lipase SUGAR DEPENDENT 1 (SDP1) via pull-down and co-immunoprecipitation (co-IP) analyses. The tubulation of SDP1-marked peroxisomes and the migration of SDP1-positive peroxisomes to the LD surface were disrupted in the *free1* mutant. In addition to SDP1, FREE1 was also demonstrated to interact with PEROXIN11e, a peroxisomal membrane protein promoting peroxisomal proliferation and tubulation (Huang et al., 2022). These results revealed the fundamental roles of the plant-unique ESCRT component FREE1 in mediating peroxisomal tubulation and SDP1 targeting to LDs (Figure).

The authors demonstrated pivotal roles of FREE1 in lipid metabolism in germinating *Arabidopsis* seedlings. Depletion of FREE1 was previously reported to cause seedling lethality (Gao et al., 2014, 2015). It thus suggests a possible approach of weed control by disrupting the FREE1 function in

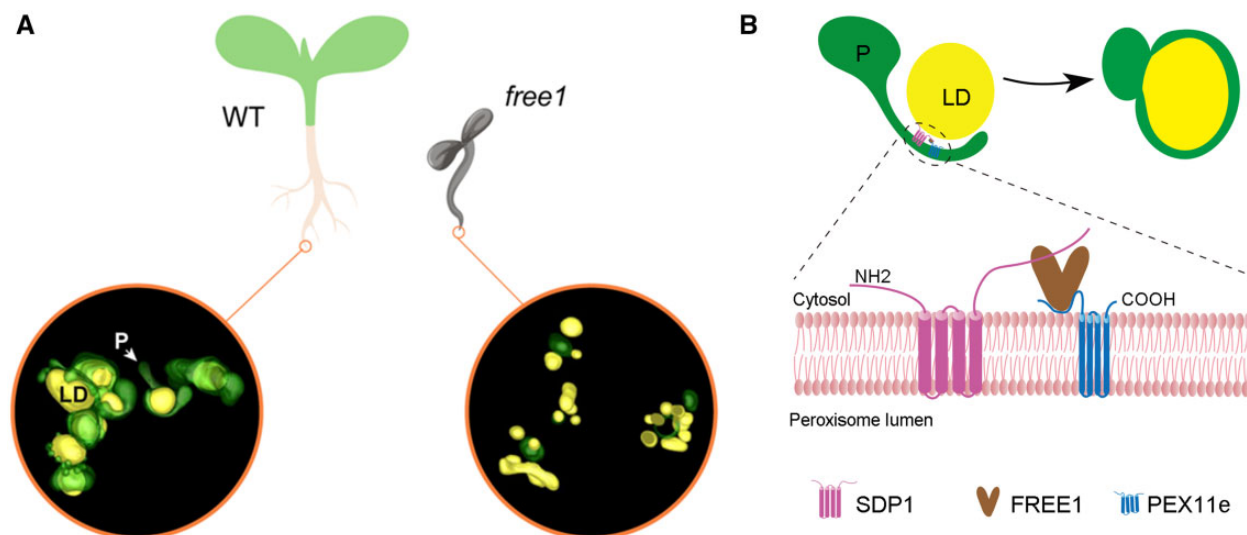


Figure FREE1 functions in lipid mobilization via mediating peroxisomal tubulation and engulfment of LDs in germinating seedlings. A, Peroxisomes (P) extend and engulf LDs to fuel wild-type (WT) seedlings, while peroxisomal extension and engulfment of LDs are impaired in the *free1* mutant. B, A conceptual model for the function of FREE1. Adapted from Huang et al. (2022), Figures 2 and 7.

seedlings. Small-molecular inhibitors are well studied and have proved to be powerful tools to manipulate target proteins (Hicks and Raikhel, 2012). Further study to explore small-molecular inhibitors of FREE1 could provide valuable tools for weed control.

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