

177. Regulation of Neutral Lipid Compartmentalization in Vegetative Plant Tissues

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Project Goal:

The overall goal of our research program is to identify, characterize and manipulate the cellular machinery that influences the accumulation and compartmentalization of neutral lipids in vegetative tissues of plants.

Our research is focused on identifying the subcellular machinery that plants use to compartmentalize neutral lipids in cells of vegetative tissues. Virtually all cells in plants (and other organisms) synthesize triacylglycerols (TAGs) and deposit them in cytosolic lipid droplets (LDs). While seed tissues accumulate large amounts of TAGs in specialized, oleosin protein- coated LDs, most non-seed tissues do not. TAGs normally accumulate to a very small percentage in vegetative tissues of plants such as in leaves and stems. Recent work by our lab and others has demonstrated that it is possible to substantially increase the percentage of TAG in leaf tissues, raising the prospects for enhancing the bioenergy content in crop biomass. Still, there is little detailed mechanistic information available regarding the cellular machinery involved in the formation, packaging and turnover LDs, especially in cells of non-seed tissues.

In our work supported by BER, we have taken a combination of approaches to discover previously underappreciated proteins that participate in LD formation and turnover. First, proteins known to be involved in LD biogenesis in mammalian cells have been tested for their ability to modulate LD formation in plant cells, including several endogenous Arabidopsis homologues of mammalian proteins (e.g., CGI-58, seipins), or other genes encoding foreign proteins that are not found in plants (e.g., the mammalian fat-inducing transmembrane protein 2, FIT2). Further, our recent proteomics analysis of non-seed LDs derived from avocado tissues, revealed a new class of LD-associated proteins (LDAPs) that are highly conserved in plants, and we are currently investigating the ability of these proteins to influence the formation and/or regulation of LDs in leaves of tobacco and Arabidopsis. We are also stacking together various genes and/or gene knockouts to determine which combinations are most effective for elevating oil content in plant leaves. Collectively, our research has important bioenergy applications, but also will help to unravel the complex machinery in eukaryotes that is deployed for the metabolism and maintenance of neutral lipids in LDs. Our results are also expected to stimulate new ideas about the dynamic interplay between lipid storage, mobilization and signaling in eukaryotic systems -- an understanding that will be important to achieving the broader BER goal of “sustainable and affordable production of renewable biofuels in an environmentally conscientious manner”.

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1. Chapman KD, Dyer JM, Mullen RT. (2013) Commentary: why don't plant leaves get fat? *Plant Science* 207:128-34. doi: 10.1016/j.plantsci.2013.03.003.
2. Park S, Gidda SK, James CN, Horn PJ, Khoo N, Seay DC, Keereetaweeep J, Chapman KD, Mullen RT, Dyer JM. (2013) The α/β hydrolase CGI-58 and peroxisomal transport protein PXA1 coregulate lipid homeostasis and signaling in Arabidopsis. *Plant Cell* 25(5):1726-39. (Faculty of 1,000 recommended)
3. Horn PJ, Silva JE, Anderson D, Fuchs J, Borisjuk L, Nazarenus TJ, Shulaev V, Cahoon EB, Chapman KD (2013) Imaging heterogeneity of membrane and storage lipids in transgenic *Camelina sativa*

- seeds with altered fatty acid profiles. *Plant Journal*, 76(1):138-50. doi: 10.1111/tpj.12278. Epub 2013 Aug 5.
4. Horn PJ, James CN, Gidda SK, Kilaru A, Dyer JM, Mullen RT, Ohlrogge JB, Chapman KD. (2013) Identification of a new class of lipid droplet-associated proteins in plants. *Plant Physiology*, 162(4):1926-36. doi: 10.1104/pp.113.222455.
 5. Gidda SK, Watt S, Collins-Silva J, Kilaru A, Arondel V, Yurchenko O, Horn PJ, James CN, Shintani D, Ohlrogge JB, Chapman KD, Mullen RT, Dyer JM (2013) Lipid droplet-associated proteins (LDAPs) are involved in the compartmentalization of lipophilic compounds in plant cells. *Plant Signaling and Behavior*, 8(11). pii: e27141.
 6. Chapman KD, Dyer JM, Mullen RT (2013). Deciphering the role of CGI-58 in lipid regulation: more than one way to trim the fat? *ASBMB Today* 12(11):26-27.
 7. Park S, Keereetawee J, James CN, Gidda S, Chapman KD, Mullen RT, Dyer JM (2014) CGI-58, a key regulator of lipid homeostasis and signaling in plants, also regulates polyamine metabolism. *Plant Signaling and Behavior*, 9(2):e27723.
 8. Vanhercke T, El Tahchy A, Liu Q, Zhou XR, Shrestha P, Divi UK, Ral JP, Mansour MP, Nichols PD, James CN, Horn PJ, Chapman KD, Beaudoin F, Ruiz- López N, Larkin PJ, de Feyter RC, Singh SP, Petrie JR (2014) Metabolic engineering of biomass for high energy density: oilseed-like triacylglycerol yields from plant leaves. *Plant Biotechnology Journal* 12(2):231-9. doi: 10.1111/pbi.12131.
 9. Yurchenko OP, Park S, Ilut DC, Inmon JJ, Millhollon JC, Liechty Z, Page JT, Jenks MA, Chapman KD, Udall JA, Gore MA, Dyer JM (2014) Genome-wide analysis of the omega-3 fatty acid desaturase gene family in *Gossypium*. *BMC Plant Biology*. 18;14(1):312.
 10. Horn PJ, Chapman KD (2014) Lipidomics in situ: insights into plant lipid metabolism from high resolution spatial maps of metabolites. *Progress in Lipid Research*, 54:32-52.
 11. Horn PJ, Sturtevant D, Chapman KD (2014) Modified oleic cottonseeds show altered content, composition and tissue-specific distribution of triacylglycerol molecular species. *Biochimie*, 96:28-36.

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