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# **Lipid Droplets Breakdown: Adipose Triglyceride Lipase Leads the Way**

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1 **Previously in *Current Protein & Peptide Science*, Cerk *et al.* (2018) presented an updated review**  
2 **of concepts and knowledge regarding structure, function and regulatory mechanism of the**  
3 **adipose triglyceride lipase (ATGL), one of the key-enzyme required for intracellular lipolysis.**

4

5 Until recently, lipid droplets (LDs) were just considered as neutral lipid storage sites, thus providing  
6 energy through lipolysis and  $\beta$ -oxidation pathway when required during stressful conditions [1].  
7 Nowadays, it's clearly established that LDs are well-organized and extremely dynamic cellular  
8 organelles, conserved in eubacteria, fungi, plants and animals, where they are essential for lipid  
9 homeostasis and energy maintenance[2]. Alteration of these two critical physiological processes can  
10 lead to important metabolic disorders [3]. The "conventional snapshot representation" of LDs remains  
11 a suitable model for defining their general composition which is based on a central organic core of  
12 neutral lipids (mainly triacylglycerol (TAG) and sterol esters) surrounded by a monolayer of  
13 phospholipids [4], associated with a wide range of structural [5], enzymatic [6] and membrane-  
14 trafficking proteins [7]. However, we also know that proteins and lipid species of such structures can  
15 be extremely diversified depending on the different cell types or metabolic status. Interestingly, LDs  
16 anabolism and catabolism are well-balanced and tightly controlled biological mechanisms involving a  
17 large number of actors at both transcriptional, translational and post-translational levels [8]. TAG-  
18 containing LDs breakdown is achieved during extended starvation period or enhanced energy demand,  
19 and this phenomenon is mainly mediated by three distinct lipolytic enzymes (*i.e.* the adipose  
20 triglyceride lipase (ATGL), the hormone-sensitive lipase (HSL) and the monoglyceride lipase (MGL))  
21 that act sequentially to finally generate free fatty acids (FFA) and glycerol molecules [8]. Since ATGL  
22 is catalyzing the first step of this essential lipolytic pathway, it's crucial to fully define physiological  
23 function(s) and structural properties of this protein but also to obtain further insights onto the  
24 regulatory mechanisms governing ATGL action towards LDs [9].

25 In a fascinating way, ATGL was discovered fourteen years ago by three independent groups at the  
26 same time [10-12]. Reports described that the protein was displaying a strong TAG-hydrolase activity  
27 in both *in-vitro* and *ex-vivo* experimental conditions [10-12]. Moreover, *Atgl* gene was highly

28 expressed within adipose tissues, and to a lesser level in liver, spleen, kidney, heart and skeletal  
29 muscle [10, 12]. To better understand the physiological role of this 54 kDa protein in lipid  
30 homeostasis, an *Atgl*<sup>-/-</sup> mutant mouse was generated, and study of this mouse permitted to obtained the  
31 first evidences that the ATGL protein is playing an essential role in TAG hydrolysis *in-vivo* [13].  
32 Indeed, several phenotypes related to lipid metabolism disorder were easily observed within an *Atgl*  
33 null mutant such as increase in body weight, fat mass, fat accumulation in non-adipose tissues, and  
34 also a greater resistance to glucose and insulin. In addition, this deficiency rapidly triggered TAG  
35 accumulation within cardiac muscle thus leading to cardiac dysfunction and premature death [9, 13].  
36 All these findings suggested that a new essential component was involved in central lipid metabolism,  
37 and thus opening new perspectives to better control lipid metabolic disorder in patients.

38 These information prompted several teams to further investigate, during the last decade, the potential  
39 regulatory mechanisms involved in ATGL activity and to date, a large number of ATGL post-  
40 translational modifications have been identified. In this context Cerk, Wechselberger and Oberer  
41 report in their recent paper published in *Current Protein & Peptide Science*, 2018;19(2):221-233, an  
42 updated and nice overview of knowledge regarding ATGL function with special focus onto these  
43 post-translational regulatory mechanisms impacting its TAG-hydrolase activity during LDs  
44 breakdown [14].

45 Among the proteins involved in this regulation process, Plin1 (one of the five members of the perilipin  
46 family (Plin1-Plin5)) CGI-58, G0S2 and PEDF are probably the most important factors impacting  
47 ATGL activity [14]. Plin1 is mastering the switch from basal to stimulated lipolysis, and this is  
48 mediated by its C-terminal domain which sequesters the CGI-58 protein and so prevents the action of  
49 the ATGL [15]. Upon specific hormonal stimulation Plin1 is phosphorylated and releases the CGI-58  
50 co-activator protein which binds to ATGL and leads to its translocation at the LDs surface [15]. Point  
51 mutations, insertions or deletions within the *cgi-58* gene trigger a drastic neutral lipid storage disorder  
52 also called Chanarin-Dorfman syndrome thus emphasizing the role of CGI-58 protein in LDs  
53 degradation [15, 16]. In addition to CGI-58, the PEDF protein is also known for interacting with  
54 ATGL and stimulating lipolysis in adipocytes [17]. In contrast to CGI-58 and PEDF which are

55 activators, GOS2 protein is negatively regulating ATGL activity in both *in-vitro* and *in-vivo* conditions  
56 where overexpression leads to an almost identical phenotype than an *Atgl*<sup>-/-</sup> mutant [18-20].

57 Another important part of their manuscript was dedicated to the inhibition of ATGL activity by either  
58 natural or synthetic small molecules [14]. One of the main inhibitory mechanism towards ATGL and  
59 also HSL is mediated by acyl-CoA availability within the cells [21, 22]. Indeed, an increase level of  
60 such molecules drastically impairs LDs-associated lipases activities and could directly contribute to  
61 the feedback inhibition of lipolysis. Finally, during high throughput screening of chemical compounds,  
62 one specific synthetic molecule has been identified as powerful inhibitor of ATGL. This compound  
63 named Atglistatin selectively inhibits the mouse ATGL activity at a micro/nanomolar range and  
64 drastically reduce TAG and FFA plasma level [23].

65 A large number of open questions needs to be further investigated regarding these dynamic  
66 interactions and new approaches a currently developed to better understand such mechanisms. For  
67 example, by generating translational fusions between the APEX2 protein and either the Plin2 or the  
68 ATGL protein, Bersuker *et al.*, recently define with an high confidence a dynamic LD proteome in  
69 human cells [24]. By using this powerful proximity labelling strategy, they were able to identify new  
70 LDs-associated proteins but also to describe new potential interactions between structural, enzymatic  
71 and membrane-trafficking proteins [24]. LDs metabolism plays an important role in several diseases,  
72 such as obesity, atherosclerosis, metabolic syndrome, neurodegenerative diseases and mitochondrial  
73 disorders, which often lead to diabetes and cardiovascular complications. Altogether, these  
74 information summarized by Cerk *et al.*, demonstrated that understanding the molecular mechanism of  
75 ATGL action and its regulation are crucial to further developed potent molecules for the treatment of  
76 such neutral lipid storage disorder.

77

- 79
- 80 1. Farese, R.V., Jr. and T.C. Walther, *Lipid droplets finally get a little R-E-S-P-E-C-T.*  
81 *Cell*, 2009. **139**(5): p. 855-60.
- 82 2. Murphy, D.J., *The biogenesis and functions of lipid bodies in animals, plants and*  
83 *microorganisms.* *Prog Lipid Res*, 2001. **40**(5): p. 325-438.
- 84 3. Welte, M.A., *Expanding roles for lipid droplets.* *Curr Biol*, 2015. **25**(11): p. R470-81.
- 85 4. Tauchi-Sato, K., et al., *The surface of lipid droplets is a phospholipid monolayer with*  
86 *a unique Fatty Acid composition.* *J Biol Chem*, 2002. **277**(46): p. 44507-12.
- 87 5. Greenberg, A.S., et al., *Perilipin, a major hormonally regulated adipocyte-specific*  
88 *phosphoprotein associated with the periphery of lipid storage droplets.* *J Biol Chem*,  
89 1991. **266**(17): p. 11341-6.
- 90 6. Sztalryd, C., et al., *Perilipin A is essential for the translocation of hormone-sensitive*  
91 *lipase during lipolytic activation.* *J Cell Biol*, 2003. **161**(6): p. 1093-103.
- 92 7. Liu, P., et al., *Chinese hamster ovary K2 cell lipid droplets appear to be metabolic*  
93 *organelles involved in membrane traffic.* *J Biol Chem*, 2004. **279**(5): p. 3787-92.
- 94 8. Lass, A., et al., *Lipolysis - a highly regulated multi-enzyme complex mediates the*  
95 *catabolism of cellular fat stores.* *Prog Lipid Res*, 2011. **50**(1): p. 14-27.
- 96 9. Zechner, R., et al., *Adipose triglyceride lipase and the lipolytic catabolism of cellular*  
97 *fat stores.* *J Lipid Res*, 2009. **50**(1): p. 3-21.
- 98 10. Zimmermann, R., et al., *Fat mobilization in adipose tissue is promoted by adipose*  
99 *triglyceride lipase.* *Science*, 2004. **306**(5700): p. 1383-6.
- 100 11. Jenkins, C.M., et al., *Identification, cloning, expression, and purification of three*  
101 *novel human calcium-independent phospholipase A2 family members possessing*  
102 *triacylglycerol lipase and acylglycerol transacylase activities.* *J Biol Chem*, 2004.  
103 **279**(47): p. 48968-75.
- 104 12. Villena, J.A., et al., *Desnutrin, an adipocyte gene encoding a novel patatin domain-*  
105 *containing protein, is induced by fasting and glucocorticoids: ectopic expression of*  
106 *desnutrin increases triglyceride hydrolysis.* *J Biol Chem*, 2004. **279**(45): p. 47066-75.
- 107 13. Haemmerle, G., et al., *Defective lipolysis and altered energy metabolism in mice*  
108 *lacking adipose triglyceride lipase.* *Science*, 2006. **312**(5774): p. 734-7.
- 109 14. Cerk, I.K., L. Wechselberger, and M. Oberer, *Adipose Triglyceride Lipase Regulation:*  
110 *An Overview.* *Curr Protein Pept Sci*, 2018. **19**(2): p. 221-233.
- 111 15. Lass, A., et al., *Adipose triglyceride lipase-mediated lipolysis of cellular fat stores is*  
112 *activated by CGI-58 and defective in Chanarin-Dorfman Syndrome.* *Cell Metab*, 2006.  
113 **3**(5): p. 309-19.
- 114 16. Lefevre, C., et al., *Mutations in CGI-58, the gene encoding a new protein of the*  
115 *esterase/lipase/thioesterase subfamily, in Chanarin-Dorfman syndrome.* *Am J Hum*  
116 *Genet*, 2001. **69**(5): p. 1002-12.
- 117 17. Borg, M.L., et al., *Pigment epithelium-derived factor regulates lipid metabolism via*  
118 *adipose triglyceride lipase.* *Diabetes*, 2011. **60**(5): p. 1458-66.
- 119 18. Yang, X., et al., *The G(0)/G(1) switch gene 2 regulates adipose lipolysis through*  
120 *association with adipose triglyceride lipase.* *Cell Metab*, 2010. **11**(3): p. 194-205.
- 121 19. Heckmann, B.L., et al., *Defective adipose lipolysis and altered global energy*  
122 *metabolism in mice with adipose overexpression of the lipolytic inhibitor G0/G1*  
123 *switch gene 2 (GOS2).* *J Biol Chem*, 2014. **289**(4): p. 1905-16.
- 124 20. Cerk, I.K., et al., *A peptide derived from G0/G1 switch gene 2 acts as noncompetitive*  
125 *inhibitor of adipose triglyceride lipase.* *J Biol Chem*, 2014. **289**(47): p. 32559-70.

- 126 21. Severson, D.L. and B. Hurley, *Inhibition of the hormone-sensitive lipase in adipose*  
127 *tissue by long-chain fatty acyl coenzyme A*. *Lipids*, 1984. **19**(2): p. 134-8.
- 128 22. Nagy, H.M., et al., *Adipose triglyceride lipase activity is inhibited by long-chain acyl-*  
129 *coenzyme A*. *Biochim Biophys Acta*, 2014. **1841**(4): p. 588-94.
- 130 23. Mayer, N., et al., *Development of small-molecule inhibitors targeting adipose*  
131 *triglyceride lipase*. *Nat Chem Biol*, 2013. **9**(12): p. 785-7.
- 132 24. Bersuker, K., et al., *A Proximity Labeling Strategy Provides Insights into the*  
133 *Composition and Dynamics of Lipid Droplet Proteomes*. *Dev Cell*, 2018. **44**(1): p. 97-  
134 112 e7.
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