Frontiers in Bioscience Scholar

Front. Biosci. (Schol Ed) **2026**; 18(1): 47458
https://doi.org/10.31083/FBS47458

Short Communication

Glut1 Acts in Corazonin-Producing Neurons to Regulate Glycogen Storage in *Drosophila*

Prem Patel[1], Justin R. DiAngelo[1,*]

[1]Science Division, Pennsylvania State University, Berks Campus, Reading, PA 19610, USA
*Correspondence: jrd5671@psu.edu (Justin R. DiAngelo)
Academic Editor: Gustavo Caetano-Anollés
Submitted: 18 October 2025 Revised: 26 November 2025 Accepted: 26 December 2025 Published: 19 March 2026

Abstract

Background: Metabolic homeostasis is regulated by numerous genes, whose dysregulation leads to metabolic diseases such as obesity and diabetes. Several genes important for lipid storage were identified in a buoyancy-based screen in *Drosophila* larvae, including *Glucose transporter 1* (*Glut1*), which encodes a glucose uniporter. Previous studies have identified metabolic functions of *Glut1* in the whole fly brain; however, the specific neurons in which Glut1 acts to regulate nutrient storage remain unknown. **Methods**: To determine the neuronal populations in which *Glut1* regulates lipid and carbohydrate storage, *Glut1* levels were decreased in specific neurons, and triglycerides (TAGs) and glycogen levels were measured. We specifically decreased *Glut1* expression in corazonin (*Crz*)-expressing neurons, a neuronal population that expresses the corazonin gene (*Crz*), which encodes a neuropeptide involved in carbohydrate metabolism. **Results**: Targeting RNAi against *Glut1* in *Crz* neurons reduced glycogen levels in males but did not alter TAG levels. To further characterize this nutrient storage phenotype, we measured the expression of two genes involved in glycogen storage, *glycogen phosphorylase* (*Glyp*) and *glycogen synthase* (*Glys*) as well as the *Crz* transcript. Notably, knocking down *Glut1* in *Crz*-expressing neurons increased *Glys* and *Crz* transcript levels. **Conclusions**: These data suggest that Glut1 acts in the *Crz*-expressing neurons to regulate *Crz* levels and organismal glycogen metabolism.

Keywords: *Drosophila*; corazonin (Crz); glycogen; neuropeptides; glycogen synthase; glycogen phosphorylase; carbohydrate metabolism

1. Introduction

Over the years, various metabolic disorders such as type 2 diabetes and obesity have been linked to one or more genetic defects within the human genome [1]. Understanding how these genes function to regulate metabolic homeostasis has provided insight into potential drug development and treatments against these metabolic diseases. However, the full complement of genes that regulate organismal metabolism are not fully understood. The fruit fly, *Drosophila melanogaster*, has recently emerged as an excellent model for studying metabolism [2]. For example, the *Drosophila* genome contains homologs of approximately 75% of known human disease genes, many of which are involved in metabolism-related diseases [3]. Additionally, *Drosophila* has many conserved metabolic pathways and analogous metabolic organs compared with mammals allowing for information gained in *Drosophila* to be applied to mammalian systems [2]. Taking advantage of the rich genetic tools available in *Drosophila*, a number of genetic screens were performed to identify genes important for fat storage [4–7]. One of the genes that was identified in one of these screens and we decided to study further was *Glucose transporter 1* (*Glut1*) [7].

Glut1 encodes a glucose uniporter ubiquitously expressed in adult *Drosophila*; however, how Glut1 functions in different tissues to regulate the storage of triglycerides (TAGs) and glycogen is still unknown. Previous studies in our lab focused on the role of Glut1 in different metabolic tissues in *Drosophila*, such as its involvement within the fly's adipocytes and neurons to regulate nutrient storage. For example, when RNAi was targeted against *Glut1* in all adipocytes, there was a decrease in organismal TAG and glycogen levels [8]. Similarly, when RNAi was targeted against *Glut1* in all neurons, there was a decrease in organismal TAG and glycogen storage [9]. To determine whether this metabolite storage defect is potentially due to Glut1 acting in specific neuronal populations to regulate nutrient storage, we aimed to characterize Glut1 function within neuronal populations that have been shown to be involved in modulating metabolic homeostasis and/or were glucose responsive in *Drosophila*. So far, decreasing *Glut1* levels in the insulin-producing cells (IPCs) has been shown to recapitulate the phenotype seen when *Glut1* levels were decreased in all neurons [9].

Corazonin (Crz) is a well-characterized neuropeptide that acts on the corazonin receptor (CrzR) to regulate various homeostatic processes, including ethanol metabolism, stress responses, male reproductive behavior, and systemic growth [10]. Crz is produced in a specific group of glucose-sensing neurons that act on the IPCs [11,12]. In addition, targeting RNAi against *CrzR* on the IPCs causes an increase in starvation resistance and circulating glucose lev-

els in well-fed male flies [11,12]; however, targeting RNAi against *Crz* in cells producing Crz (using *Crz-Gal4*) results in no changes in *ilp2*, *ilp3*, and *ilp5* transcript levels [11]. Furthermore, targeting RNAi against *Crz* in Crz-producing neurons causes an increase in glycogen, circulating glucose, and trehalose under well-fed conditions, with an increase in TAG levels after a 24-hour starvation period [11]. These results suggest that *Crz*-expressing neurons may function independently of the IPCs to regulate metabolic homeostasis in response to glucose availability; however, whether Glut1 acts in these neurons to regulate their function is unknown. This study will focus on identifying a potential role of Glut1 within the *Crz*-expressing neurons by decreasing *Glut1* expression in these cells using RNAi and measuring TAGs and glycogen storage levels in well-fed male flies. The results of these experiments will increase our understanding of the role of the Crz-producing neurons in maintaining metabolic homeostasis.

2. Materials and Methods

2.1 Fly Genetics

The following flies were used in this study: w^{1118}; *P{w[+mC]=Crz-GAL4.391}4M* (BL#51977, referred to as *Crz-Gal4* here); *y[1] v[1]; P{y[+t7.7] v[+t1.8]=TRiP.JF01355}attP2* (BL#31603, referred to as *UAS-LucRNAi* here), *y[1] v[1]; P{y[+t7.7] v[+t1.8]=TRiP.JF03060}attP2* (BL#28645, referred to as *UAS-Glut1RNAi-TRiP* here), w^{1118}; *UAS-GFP RNAi* (BL#9330, referred to as *UAS-GFPRNAi* here), w^{1118}; *UAS-Glut1 RNAi* (VDRC#13326, referred to as *UAS-Glut1RNAi-VDRC* here). Flies were fed on cornmeal-sugar-yeast food (9 g *Drosophila* agar (66-103 Genesee Scientific, San Diego, CA, USA), 100 mL Karo Lite Corn Syrup, 65 g cornmeal, 40 g sucrose, and 25 g whole yeast in 1.25 L water) and grown at 25 °C in a 12 h:12 h light:dark cycle. *Crz-Gal4* virgins were crossed with males from each UAS line and approximately one-week old male progeny were used. One-week old flies were chosen as the remnants of the larval fat body have been completely broken down and the adult fat body is fully formed by this time.

2.2 Protein, TAG and Glycogen Measurements

Two approximately one-week old male adult flies were homogenized in lysis buffer (140 mM NaCl; 50 mM Tris-HCl, pH 7.4; 0.1% Triton-X; 1X Pierce Protease Inhibitor Cocktail (A32965, Thermo Fisher Scientific, Waltham, MA, USA)). Homogenates were centrifuged at 13,000 rpm for 15 minutes at 4 °C. Protein levels were measured using the Pierce BCA Protein Assay Kit (PI23225, Thermo Fisher Scientific, Waltham, MA, USA), according to manufacturer instructions. TAG levels were measured using Infinity Triglyceride Reagent (TR22421, Thermo Fisher Scientific, Waltham, MA, USA), according to manufacturer instructions. Free glucose was measured using the Pointe Scientific Liquid Glucose Oxidase Reagent (23-666-288, Thermo Fisher Scientific, Waltham, MA, USA), according to manufacturer instructions. Total glucose was measured by combining each sample in a 1:1 ratio with 8 mg/mL amyloglucosidase (A1602-100mg, Sigma, St. Louis, MO, USA) in 0.2 M citrate buffer, pH. 5.0, and incubating at 37 °C for 2 hours. After incubation, total glucose was measured using the Liquid Glucose Oxidase Reagent (23-666-288, Thermo Fisher Scientific, Waltham, MA, USA). Glycogen concentrations were calculated by subtracting the free glucose from the total glucose. TAG and glycogen levels were normalized by their respective protein concentrations.

2.3 RNA Isolation and qPCR

Ten approximately one-week old male flies were homogenized in Trizol (15-596-026, Thermo Fisher Scientific, Waltham, MA, USA), and RNA was extracted according to manufacturer instructions. 5 µg of RNA was DNase treated with a DNA-free kit (AM1906, Thermo Fisher Scientific, Waltham, MA, USA), according to manufacturer instructions, and then 0.25 µg of DNase-treated RNA was reverse-transcribed using qScript Ultra cDNA Supermix (76533-176, Quanta Biosciences, Beverly, MA, USA), according to manufacturer instructions. The relative expression of *glycogen phosphorylase* (*Glyp*), *glycogen synthase* (*Glys*) and *corazonin* (*Crz*) was quantitated using qPCR and the following reaction mixture: 1 µL cDNA, 200 nM primers, and 1X Perfecta SYBR Green Mix Master Mix (101414-160, Quanta Biosciences, Beverly, MA, USA) in a 25 µL reaction. The qPCR cycling conditions were 3 minutes at 95 °C and 40 cycles of the following conditions: 30 seconds at 95 °C, 1 minute at 60 °C, and 30 seconds at 72 °C followed by a melt curve. *Glyp*, *Glys*, *Crz* and *rp49* expression was determined using a relative standard curve. *Glyp*, *Glys*, and *Crz* levels were then divided by *rp49* levels for normalization. Relative expression of each normalized transcript in each genetic background control strain was set to 1 and expression in the genetic background matched *Glut1RNAi* line was calculated relative to the control. The following forward (F) and reverse (R) primer sequences were used: rp49-F 5′GACGCTTCAAGGGACAGTATCTG3′; rp49-R 5′AAACGCGGTTCTGCATGAG3′; Glyp-F 5′AACTTCCAGCGCAATGTAGC3′; Glyp-R 5′TGGGATCCTTCTTGATCCTG3′; Glys-F 5′CGCGAGGCTATAAAATCCAC3′; Glys-R 5′GGCAATCATAAAGCCAAGGA3′; Crz-F 5′GGCTCGAGCGCTGTCTATC3′; Crz-R 5′ACTCGGTTGGCATTGAAGTC3′.

2.4 Statistics

Normality tests were performed using the Shapiro-Wilk test on the Statistics Kingdom website (https://www.statskingdom.com/shapiro-wilk-test-calculator.html). The

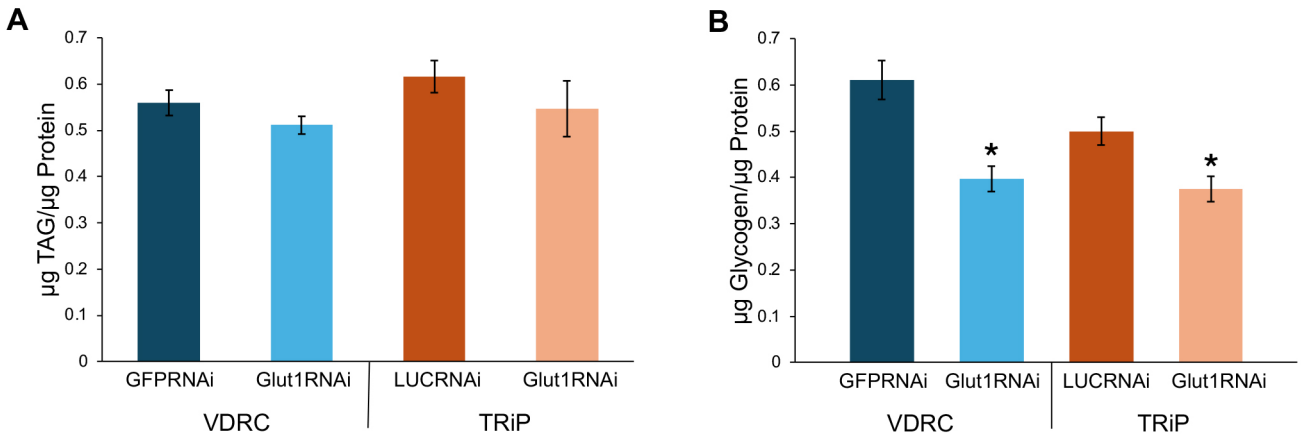

Fig. 1. Targeting RNAi against *Glucose transporter 1* (*Glut1*) in *Crz*-expressing neurons decreases glycogen storage. (A) TAGs normalized by protein content were measured in *Crz-Gal4>Glut1-VDRC RNAi* male flies and compared to *Crz-Gal4>GFPRNAi* controls (n = 36–40) and in *Crz-Gal4>Glut1-TRiP RNAi* male flies and compared to *Crz-Gal4>LUCRNAi* controls (n = 30). The bars indicate the mean TAG/protein ± standard error. (B) Glycogen normalized by protein content was measured in *Crz-Gal4>Glut1RNAi-VDRC RNAi* male flies and compared to *Crz-Gal4>GFPRNAi* controls (n = 36–40) and in *Crz-Gal4>Glut1-TRiP RNAi* male flies and compared to *Crz-Gal4>LUCRNAi* controls (n = 30). The bars indicate the mean glycogen/protein ± standard error. **p* value < 0.05 as determined by a Mann-Whitney U test.

TAG and glycogen data were not normally distributed, so a Mann-Whitney U test was performed to compare the averages between the *Glut1RNAi* and appropriate control flies using the Statistics Kingdom website (https://www.statskingdom.com/170median_mann_whitney.html). The qPCR data were normally distrubuted, so a two-tailed students *t*-test was performed to compare the averages between the *Glut1-RNAi* and the appropriate control flies using Excel software. The *p*-value < 0.05 was considered statistically significant for all the statistical tests performed.

3. Results

To understand the role of Glut1 in *Crz*-expressing neurons, *Glut1* was decreased in all *Crz*-expressing neurons using the Gal4/UAS system, and the storage of triglycerides (TAGs) and glycogen was measured in male flies. *Glut1* levels were decreased in these cells by combining the Crz-specific *Crz-Gal4* line with two distinct *Glut1-RNAi* lines (indicated as VDRC & TRiP). TAG and glycogen levels were measured in whole animal extracts and normalized by their respective protein content. The glycogen/protein concentrations were decreased in these *Crz*-specific *Glut1-RNAi* flies compared to their respective genetic background controls (Fig. 1B), while there was no change in TAG/protein concentrations (Fig. 1A). This suggests that Glut1 functions specifically in the neurons that produce Crz to regulate organismal glycogen storage.

To further characterize the glycogen storage defect in Crz-specific *Glut1-RNAi* flies, we measured the expression of two regulators of glycogen metabolism, *glycogen phosphorylase* (*Glyp*) and *glycogen synthase* (*Glys*), using quantitative PCR. Glyp cleaves the alpha glycosidic linkages between glucose molecules stored in glycogen promoting glycogen breakdown while Glys makes the alpha glycosidic linkages between glucose molecules to synthesize glycogen [13]. While there was no consistent change in *Glyp* expression in *Glut1-RNAi* flies (Fig. 2A), *Glys* levels were increased when *Glut1* was decreased in Crz neurons (Fig. 2B). Since glycogen levels were blunted in Crz-specific *Glut1-RNAi* flies (Fig. 1B), this elevation of *Glys* expression is likely compensating for the low glycogen storage.

A previous study has shown that targeting *Crz* with RNAi increases glycogen levels [11]; thus, the decrease in glycogen storage shown here could be due to excess *Crz* upregulation in these neurons in response to low glucose levels when *Glut1* was knocked down in these cells. To test this hypothesis, *Crz* transcript levels were measured in *Glut1-RNAi* flies using quantitative PCR. There was a nearly 2-fold increase in *Crz* transcript levels in these Crz-specific *Glut1-RNAi* flies compared to their respective controls (Fig. 3). This suggests that in response to low glucose levels, *Crz*-expressing neurons upregulate *Crz*, leading to a decrease in glycogen storage presumably caused by activated downstream effectors of Crz signaling in target tissues.

4. Discussion

Here we show that decreasing *Glut1* levels in *Crz*-expressing neurons in male flies led to a decrease in glycogen storage, but no changes in TAG levels (Fig. 1). This is consistent with a previous study where glycogen levels were increased when RNAi was targeted towards *Crz* in well-fed male flies [11]. However, in the same study when *Crz* levels were decreased with RNAi, there was only an in-

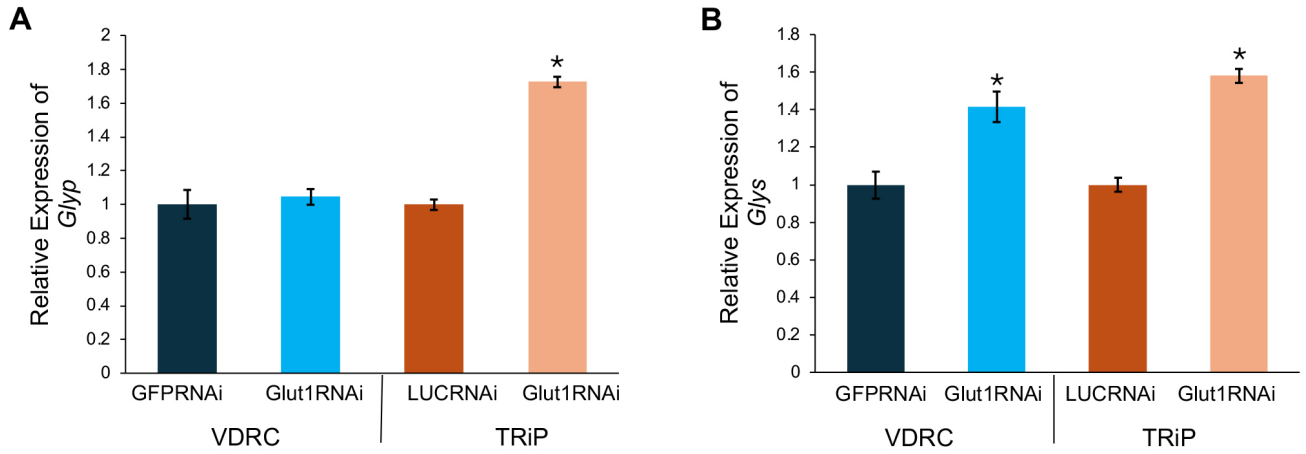

Fig. 2. Targeting RNAi against *Glut1* in *Crz*-expressing neurons increases *glycogen synthase* (*Glys*) expression. (A) *Glycogen phosphorylase* (*Glyp*) transcript levels normalized by *rp49* levels were measured in *Crz-Gal4>Glut1RNAi-VDRC RNAi* male flies (n = 8) and compared to *Crz-Gal4>GFPRNAi* controls (n = 8) and in *Crz-Gal4>Glut1-TRiP RNAi* male flies (n = 4) and compared to *Crz-Gal4>LUCRNAi* controls (n = 4). The bars indicate the mean relative expression ± standard error. (B) *Glys* transcript levels normalized by *rp49* levels were measured in *Crz-Gal4>Glut1RNAi-VDRC RNAi* male flies (n = 8) and compared to *Crz-Gal4>GFPRNAi* controls (n = 8) and in *Crz-Gal4>Glut1-TRiP RNAi* male flies (n = 4) and compared to *Crz-Gal4>LUCRNAi* controls (n = 4). The bars indicate the mean relative expression ± standard error. **p* value < 0.05 as determined by a student's *T*-test.

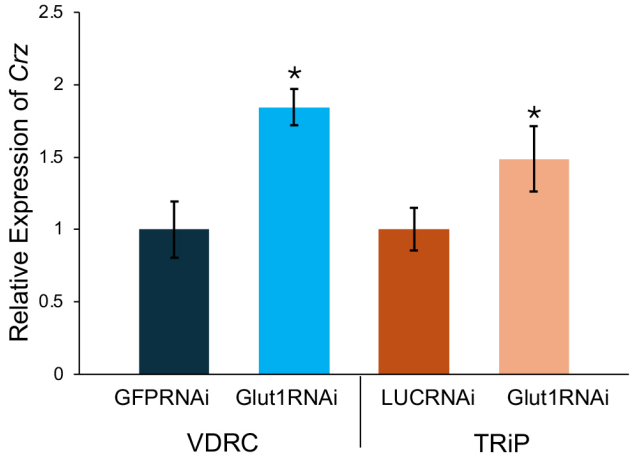

Fig. 3. Targeting RNAi against *Glut1* in *corazonin* (*Crz*)-expressing neurons increases *Crz* transcript levels. *Crz* transcript levels normalized by *rp49* levels were measured in *Crz-Gal4>Glut1RNAi-VDRC RNAi* male flies (n = 8) and compared to *Crz-Gal4>GFPRNAi* controls (n = 8) and in *Crz-Gal4>Glut1-TRiP RNAi* male flies (n = 12) compared to *Crz-Gal4>LUCRNAi* controls (n = 12). The bars indicate the mean relative expression +/- standard error. **p* value < 0.05 as determined by a student's *T*-test.

crease in TAG levels after a 24-hour starvation period [11], suggesting that Crz has a starvation-specific role in regulating TAG levels; therefore, it is possible that TAG levels could be altered in *Crz*-specific *Glut1-RNAi* flies after a 24-hour starvation period. Additionally, the decrease in glycogen storage phenotype shown here matches the phenotype observed when RNAi was targeted against *Glut1* in all neurons [9], suggesting that *Glut1* may act in *Crz* neurons to regulate nutrient homeostasis by modulating glycogen metabolism.

Glycogen metabolism is regulated by two major enzymes, Glyp and Glys [13], and we tested whether their expression was altered in *Glut1-RNAi* flies. Interestingly, *Glys* transcript levels were elevated when *Glut1* was decreased in Crz-producing neurons (Fig. 2B), despite the low glycogen in these flies suggesting a compensatory transcriptional mechanism to regulate glycogen storage. However, we did not measure Glyp or Glys enzyme activity in this study and it is possible that the activity of the glycogen breakdown enzyme Glyp could be increased or the activity of the glycogen synthesis enzyme Glys could be decreased resulting in the low glycogen storage phenotype observed here. Future experiments designed to measure Glyp and Glys enzymatic activity in *Glut1-RNAi* flies could help clarify the function of the Crz-producing neurons in regulating glycogen metabolism.

We have also shown that decreasing *Glut1* levels in *Crz*-expressing neurons led to an increase in *Crz* transcript levels (Fig. 3). This suggests that when glucose levels are low, *Crz* levels increase so that Crz can be secreted to act on Crz receptors (CrzR) expressed on target tissues. However, while we show here that *Crz* transcript levels are increased in *Glut1-RNAi* flies, we did not measure Crz secretion directly and future experiments aimed at measuring Crz secretion in these flies and perhaps other Crz-regulated phenotypes would help support this claim. Interestingly, when *CrzR* levels are decreased in fat body cells, there is an increase in glycogen storage, but no change in circu-

lating glucose levels in well-fed male flies [14]. Therefore, it is possible that when *Glut1* levels were decreased in *Crz*-expressing neurons, the excess Crz likely acted directly on the fat body to promote glycogen breakdown. While little is known about CrzR and its downstream targets in the fat body, multiple studies have characterized the receptor in *Drosophila* and other insects as a GPCR. Interestingly, CrzR shares a high percentage of amino-acid identity with the adipokinetic hormone receptor (AKHR) [15], which promotes glycogen breakdown in fly fat tissue [16]. Therefore, it is possible that the downstream target effectors of AKHR involved in promoting glycogen breakdown can also be targeted by CrzR to perform that same function. Further investigation is required to identify the downstream targets of CrzR in the fat body to understand the mechanism of how Crz modulates glycogen storage.

5. Conclusions

Overall, this study has characterized the role of Glut1 in *Crz*-expressing neurons to regulate *Crz* expression and overall glucose homeostasis. Crz-producing neurons are part of a growing group of neuronal populations in *Drosophila* such as the IPCs, adipokinetic hormone-producing neurons and neuropeptide F-producing neurons that respond to nutrients and regulate metabolism [9,17–19]. The results described here will help to expand our understanding of the mechanisms whereby the nervous system detects changes in nutrient availability and alters organismal metabolism accordingly.

6. Limitations

One of the limitations of this study is that the increases in Glys and *Crz* reported here are at the RNA level; the production of these proteins was not measured. While in many instances the levels of a gene's transcript correlate with the protein produced, this is not always the case, so future analysis of Glys protein production and enzyme activity and *Crz* protein production and secretion will increase our understanding of how Glut1 acts in *Crz*-expressing neurons to regulate glycogen metabolism.

Availability of Data and Materials

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Author Contributions

Conceptualization, JRD; methodology, JRD; validation, PP; formal analysis, PP; investigation, JRD and PP; resources, JRD; writing—original draft preparation, PP; writing—review and editing, JRD and PP; visualization, PP; supervision, JRD; project administration, JRD; funding acquisition, JRD. Both authors have read and agreed to the final version of the manuscript. Both authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

Not applicable.

Acknowledgment

The authors would like to thank Matthew Kauffman for technical assistance and helpful discussions. Stocks obtained from the Bloomington *Drosophila* Stock Center (NIH P40OD018537) and the Vienna *Drosophila* Resource Center (VDRC, https://www.vdrc.at) were used in this study.

Funding

This research received no external funding.

Conflict of Interest

The authors declare no conflict of interest.

References

[1] Claussnitzer M, Cho JH, Collins R, Cox NJ, Dermitzakis ET, Hurles ME, *et al*. A brief history of human disease genetics. Nature. 2020; 577: 179–189. https://doi.org/10.1038/s41586-019-1879-7.

[2] Chatterjee N, Perrimon N. What fuels the fly: Energy metabolism in *Drosophila* and its application to the study of obesity and diabetes. Science Advances. 2021; 7: eabg4336. https://doi.org/10.1126/sciadv.abg4336.

[3] Reiter LT, Potocki L, Chien S, Gribskov M, Bier E. A systematic analysis of human disease-associated gene sequences in Drosophila melanogaster. Genome Research. 2001; 11: 1114–1125. https://doi.org/10.1101/gr.169101.

[4] Beller M, Sztalryd C, Southall N, Bell M, Jäckle H, Auld DS, *et al*. COPI complex is a regulator of lipid homeostasis. PLoS Biology. 2008; 6: e292. https://doi.org/10.1371/journal.pbio.0060292.

[5] Guo Y, Walther TC, Rao M, Stuurman N, Goshima G, Terayama K, *et al*. Functional genomic screen reveals genes involved in lipid-droplet formation and utilization. Nature. 2008; 453: 657–661. https://doi.org/10.1038/nature06928.

[6] Pospisilik JA, Schramek D, Schnidar H, Cronin SJF, Nehme NT, Zhang X, *et al*. Drosophila genome-wide obesity screen reveals hedgehog as a determinant of brown versus white adipose cell fate. Cell. 2010; 140: 148–160. https://doi.org/10.1016/j.cell.2009.12.027.

[7] Reis T, Van Gilst MR, Hariharan IK. A buoyancy-based screen of Drosophila larvae for fat-storage mutants reveals a role for Sir2 in coupling fat storage to nutrient availability. PLoS Genetics. 2010; 6: e1001206. https://doi.org/10.1371/journal.pgen.1001206.

[8] Betz LS, DiAngelo JR. The regulation of triglyceride and glycogen storage by Glucose transporter 1 (*Glut1*) in *Drosophila* fat tissue. MicroPublication Biology. 2024; 2024. https://doi.org/10.17912/micropub.biology.001134.

[9] Kauffman MR, DiAngelo JR. Glut1 Functions in Insulin-Producing Neurons to Regulate Lipid and Carbohydrate Storage in *Drosophila*. Biomolecules. 2024; 14: 1037. https://doi.org/10.3390/biom14081037.

[10] Khan Z, Tondravi M, Oliver R, Vonhoff FJ. *Drosophila* Corazonin Neurons as a Hub for Regulating Growth, Stress Re-

sponses, Ethanol-Related Behaviors, Copulation Persistence and Sexually Dimorphic Reward Pathways. Journal of Developmental Biology. 2021; 9: 26. https://doi.org/10.3390/jdb9030026.

[11] Kapan N, Lushchak OV, Luo J, Nässel DR. Identified peptidergic neurons in the Drosophila brain regulate insulin-producing cells, stress responses and metabolism by coexpressed short neuropeptide F and corazonin. Cellular and Molecular Life Sciences: CMLS. 2012; 69: 4051–4066. https://doi.org/10.1007/s00018-012-1097-z.

[12] Oh Y, Lai JSY, Mills HJ, Erdjument-Bromage H, Giammarinaro B, Saadipour K, *et al*. A glucose-sensing neuron pair regulates insulin and glucagon in Drosophila. Nature. 2019; 574: 559–564. https://doi.org/10.1038/s41586-019-1675-4.

[13] Roach PJ, Depaoli-Roach AA, Hurley TD, Tagliabracci VS. Glycogen and its metabolism: some new developments and old themes. The Biochemical Journal. 2012; 441: 763–787. https://doi.org/10.1042/BJ20111416.

[14] Kubrak OI, Lushchak OV, Zandawala M, Nässel DR. Systemic corazonin signalling modulates stress responses and metabolism in Drosophila. Open Biology. 2016; 6: 160152. https://doi.org/10.1098/rsob.160152.

[15] Cazzamali G, Saxild N, Grimmelikhuijzen C. Molecular cloning and functional expression of a Drosophila corazonin receptor. Biochemical and Biophysical Research Communications. 2002; 298: 31–36. https://doi.org/10.1016/s0006-291x(02)02398-7.

[16] Bharucha KN, Tarr P, Zipursky SL. A glucagon-like endocrine pathway in Drosophila modulates both lipid and carbohydrate homeostasis. The Journal of Experimental Biology. 2008; 211: 3103–3110. https://doi.org/10.1242/jeb.016451.

[17] Braco JT, Gillespie EL, Alberto GE, Brenman JE, Johnson EC. Energy-dependent modulation of glucagon-like signaling in Drosophila via the AMP-activated protein kinase. Genetics. 2012; 192: 457–466. https://doi.org/10.1534/genetics.112.143610.

[18] Ikeya T, Galic M, Belawat P, Nairz K, Hafen E. Nutrient-dependent expression of insulin-like peptides from neuroendocrine cells in the CNS contributes to growth regulation in Drosophila. Current Biology: CB. 2002; 12: 1293–1300. https://doi.org/10.1016/s0960-9822(02)01043-6.

[19] Yoshinari Y, Kosakamoto H, Kamiyama T, Hoshino R, Matsuoka R, Kondo S, *et al*. The sugar-responsive enteroendocrine neuropeptide F regulates lipid metabolism through glucagon-like and insulin-like hormones in Drosophila melanogaster. Nature Communications. 2021; 12: 4818. https://doi.org/10.1038/s41467-021-25146-w.