Eurasia Specialized Veterinary Publication

Entomological Research Letters

ISSN: 3108-639X

2025, Volume 5, Issue 2, Page No: 22-31
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Available online at: www.esvpub.com/

Energy Balance and Neuroendocrine Signaling Jointly Regulate Motivation, Behavioral State, and Action Selection in Insects

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ABSTRACT

Insect behavior is continuously constrained by energetic condition, but energetic state is not translated into action through a single hunger variable or a fixed endocrine switch. Evidence from *Drosophila*, mosquitoes, and lepidopteran larvae instead indicates distributed sensing of nutrient availability, peptide and hormonal modulation, competition among homeostatic and reproductive priorities, persistence of internal states, and context-dependent selection among actions. This article develops a proposed neurophysiological architecture in which energetic signals alter the weighting of sensory evidence, motivational priorities, and behavioral-state stability, while neuromodulators and hormones coordinate these effects across central and peripheral targets. Behavioral outcomes then modify subsequent state through sensory, ascending neural, and post-ingestive feedback. The framework distinguishes energetic state sensing from motivation, behavioral-state switching from motor choice, and current-action encoding from demonstrated causal feedback. It further treats sex, life stage, taxon, sensory context, and timescale as boundary conditions rather than nuisance variation. The resulting account does not posit a universal insect controller; instead, it organizes experimentally supported mechanisms into a testable, recursive state-and-action architecture whose cross-taxon validity remains to be established.

Keywords: Energy homeostasis, Neuropeptides, Motivation, Behavioral-state switching, Action selection, Interoception

Received: 21 August 2025
Revised: 08 October 2025
Accepted: 10 October 2025

How to Cite This Article: Eriksen K, Berg S, Dahl M. Energy Balance and Neuroendocrine Signaling Jointly Regulate Motivation, Behavioral State, and Action Selection in Insects. Entomol Res Lett. 2025;5(2):22-31. https://doi.org/10.51847/9F2q8UJTvn

Introduction

Insect behavior is often described as if nutritional deficit were translated directly into feeding. That view is too coarse for current neurophysiology. Peptidergic systems can coordinate metabolism, sensory processing, locomotion, sleep, reproduction, and feeding in state-dependent combinations rather than acting as isolated "hunger signals" [1]. More generally, feeding itself is assembled from sensory valuation, internal-state information, neuromodulation, learning, and motor control, so similar energetic conditions need not generate the same behavioral output [2]. Nutrient sensing is also ecologically contingent: insects differ in resource composition, sensory access, life history, and the costs attached to accepting or rejecting food, limiting claims of a taxon-invariant nutritional decision rule [3].

Even within *Drosophila*, hunger is not behaviorally unitary. Experimental dissection separates components related to homeostatic demand and hedonic feeding motivation, with partially distinguishable circuit contributions [4].

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This matters because “energy balance” can refer to stored reserves, recent nutrient ingestion, circulating signals, predicted nutritional value, or the energetic consequences of ongoing behavior. These variables may covary, but the evidence does not justify treating them as one scalar state.

The article therefore addresses a specific inferential gap: how can evidence distributed across nutrient sensing, neuroendocrine signaling, motivational persistence, behavioral-state transitions, and motor selection be organized without claiming one universal control center? The proposed solution is a recursive architecture in which energetic information changes the weights assigned to competing needs and actions, neuroendocrine signals alter processing at several levels, and behavioral outcomes update the state from which subsequent actions are selected. The architecture is functional rather than anatomically unitary and is intended to generate discriminating experiments, not to imply that the complete loop has already been demonstrated in any insect.

Energetic state sensing

Energetic state first has to be represented, but the relevant representation is already multidimensional. In adult *Drosophila*, hunger- and thirst-related interoceptive neurons converge on neuroendocrine circuitry that coordinates sugar and water ingestion, showing that homeostatic deficits can be evaluated in relation to one another rather than read out independently [5]. Thus, low energy cannot be interpreted without asking which other deficits are active and which action classes are currently available.

Insulin-producing cells provide a more direct example of dynamic nutritional encoding. Their electrical activity declines with increasing starvation and rises after nutritive feeding, whereas glucose perfusion alone does not reproduce the full feeding-associated effect [6]. The distinction argues against equating a single circulating substrate with the complete sensed state. Energetic representation can depend on ingestion-linked information, endocrine context, and the time elapsed since food acquisition.

State sensing is also inseparable from mobilization. TRPγ function in Dh44 neuroendocrine cells contributes to lipid homeostasis and starvation-dependent lipid use, but downstream relationships among Dh44, its receptor, and peripheral metabolic targets remain incompletely resolved [7]. The evidence therefore supports a role for this neuroendocrine pathway in metabolic regulation without establishing a complete brain-to-fat-body causal chain.

Internal condition can also alter sensory processing before an overt choice is made. Molecular and functional characterization of second-order gustatory neurons shows convergence of gustatory and metabolic information within central taste pathways [8]. Likewise, TRPγ-dependent neuroendocrine signaling contributes to post-ingestive food selection, indicating that consequences detected after ingestion can modify later dietary choice [9].

Together, these findings support a layered interpretation: energetic state is represented through partially distinct interoceptive, endocrine, sensory, and post-ingestive channels whose relative influence depends on physiological context. The proposed framework therefore treats energetic sensing as a distributed input field, not a single upstream meter.

Neuromodulators and hormones

Neuropeptides and hormones provide mechanisms through which distributed state information can modify behavior, but their effects are strongly context and target dependent. During starvation, a specific leucokinin neuronal pair in *Drosophila* becomes more active and contributes to sleep suppression through pathways involving AMPK, leucokinin signaling, and insulin-producing cells [10]. This establishes that an energetic deficit can reorganize a nonfeeding behavioral state, but it does not demonstrate that reduced sleep is universally adaptive or that leucokinin has the same function across insects.

Leucokinin also illustrates why peptide action cannot be represented as a one-node switch. Distinct leucokinin neuronal populations and peripheral targets contribute to water balance, feeding, locomotor activity, metabolism, and insulin-related physiology after feeding [11]. A single peptide family can therefore distribute state effects across tissues and behaviors without implying that all outputs arise from one neuron or one causal route.

Classical neuromodulators interact with peptide systems as well. In *Drosophila* larvae, STIM-dependent excitability in a dopaminergic neuronal subset supports dopamine release and influences neurosecretory pathways required for continued feeding and growth [12]. Because this work concerns larval development, it supports a dopamine–neuropeptide mechanism for developmental feeding drive but not an adult-general rule.

Reproductive state adds another layer. Mating activates neuroendocrine pathways associated with increased feeding motivation in female *Drosophila* [13], yet the nutritional consequence of mating is not directionally identical between sexes. Mated females increase yeast preference whereas males can transiently reduce it, with

the male response involving a corazonin–leucokinin–sNPF circuit [14]. Reproductive state should therefore be treated as a modifier of motivational weighting rather than a proxy for energetic deficit.

Cross-taxon evidence strengthens the case for functional diversity. In female *Aedes aegypti*, neuropeptide F and RYamide vary reciprocally through the gonotrophic cycle and have opposing effects on host attraction [15]. In *Plutella xylostella* larvae, adipokinetic-hormone receptor disruption alters food intake, lipid accumulation, and development [16]. These studies show that neuroendocrine regulation of behavioral priorities and energy use extends beyond *Drosophila*, but they do not establish conservation of identical circuits, receptor logic, or behavioral meanings across Diptera and Lepidoptera.

Motivational state

Motivation is most useful here as a state-dependent weighting of possible behaviors, not as an unobserved force inferred from whichever action occurs. In thirsty *Drosophila*, identified interneurons promote water seeking while limiting feeding-related behavior [17]. Competing needs can therefore inhibit one another, making motivation intrinsically relational: the relevant question is not only how strongly one action is promoted, but how alternative actions are suppressed or maintained.

Internal state also gates access to learned information. Hunger- and thirst-dependent leucokinin and dopaminergic pathways bias expression of deprivation-relevant memories [18]. This supports motivational control over which stored information gains behavioral influence, while stopping short of showing that all decision processes use the same memory-gating mechanism.

Motivation additionally affects persistence. Hungry flies persist in tracking food odor when reinforcement is absent, and mushroom-body, dopaminergic, and octopaminergic circuits contribute to the balance between persistence and withdrawal [19]. Persistence is therefore one measurable consequence of motivational state, but it should not be equated with motivation itself. In the proposed architecture, motivation is represented as the changing relative gain assigned to action classes, cue values, and disengagement thresholds.

Behavioral-state switching

A behavioral-state switch occurs when the currently dominant action policy is reorganized, not merely when movement changes. Peripheral sulfakinin signaling can contribute to starvation-associated switching between mating and foraging, showing that state transitions need not originate solely in the central brain [20]. Conversely, nutrient acquisition can rapidly reprioritize behavior from the periphery inward: amino-acid-sensitive gut Dh31 signaling changes the balance between feeding and courtship in starved male *Drosophila* within minutes [21]. These examples place peripheral endocrine information within, rather than outside, the control of behavioral state.

Energetic state can also alter choices that are not themselves feeding acts. In *Drosophila* larvae, feeding condition changes the probability of mechanically evoked competing actions through NPF/sNPF-sensitive reciprocal inhibitory circuitry [22]. Importantly, the effect is a bias, not a deterministic switch. External sensory context provides an independent source of bias: competing defensive responses can be reweighted by cue context at second-order interneurons even when energetic state is not the manipulated variable [23]. Internal energetic information and external sensory evidence must therefore remain analytically separate.

The proposed state-switching construct follows from these convergent but nonidentical mechanisms. A switch is treated as a transition in the relative stability of behavioral policies, produced when internal need, endocrine state, reproductive condition, sensory context, and recent outcomes jointly alter the competitive balance among action systems. This is not a claim that insects possess a common discrete set of states. Rather, the framework predicts that apparently abrupt behavioral transitions may arise from continuous reweighting until a different action policy becomes more stable.

Because prose obscures the distinctions among trigger, mechanism, behavioral expression, and inferential boundary, the following stage-specific comparison matrix separates the major switch classes used in this article.

Table 1. Behavioral-state switches differ in where state information enters and what kind of behavioral priority is reweighted

Recorded evidence and warranted reading	Biological context	Critical boundary and decisive check
Competing homeostatic drives		
Evidence-supported class		

One drive promotes its own seeking while constraining another **State is relational rather than a single hunger magnitude**	Adult fly hunger versus thirst	Seeking and consumption are not interchangeable Manipulate deficits factorially while measuring both suppressed and promoted actions
Reproductive-to-foraging reallocation ***Evidence-supported class***		
Mating- or peptide-dependent change in foraging priority **Reproductive state can alter energetic priority without being reducible to starvation**	Adult reproductive context	Sex and species can reverse direction Compare homologous endocrine manipulations across sexes and reproductive stages
Post-ingestive reprioritization ***Evidence-supported class***		
Gut peptide signal rapidly changes feeding–courtship balance **Recent nutrient receipt can destabilize the previous policy**	Nutrient-deprived male flies after protein intake	Nutrient identity and male reproductive context constrain transfer Separate taste, ingestion, and post-absorptive phases experimentally
Energy-biased nonfeeding choice ***Evidence-supported class***		
Feeding condition shifts relative action probabilities **Energetic state can modulate action competition outside feeding**	Larval mechanically evoked action competition	Effect is probabilistic and task specific Test whether the same state manipulation changes other competing actions
Sensory-context-driven switching ***Evidence-supported comparator***		
Cue configuration changes which defensive response dominates **External evidence can shift state expression independently of energy**	Larval defensive action selection	Energetic state was not manipulated Cross internal-state and sensory-context manipulations
Competitive-stability transition ***Proposed synthesis***		
Inferred when multiple state variables jointly alter persistence of one behavioral policy relative to another **Behavioral switching can be modeled as a change in policy stability**	Cross-domain synthesis	No single experiment validates this combined construct Measure transition probability, persistence, and reversibility under orthogonal state manipulations

The state-switching evidence is best represented as trajectories through a competitive field rather than as a linear endocrine cascade, because internal and external variables can redirect the same animal toward different behavioral policies.

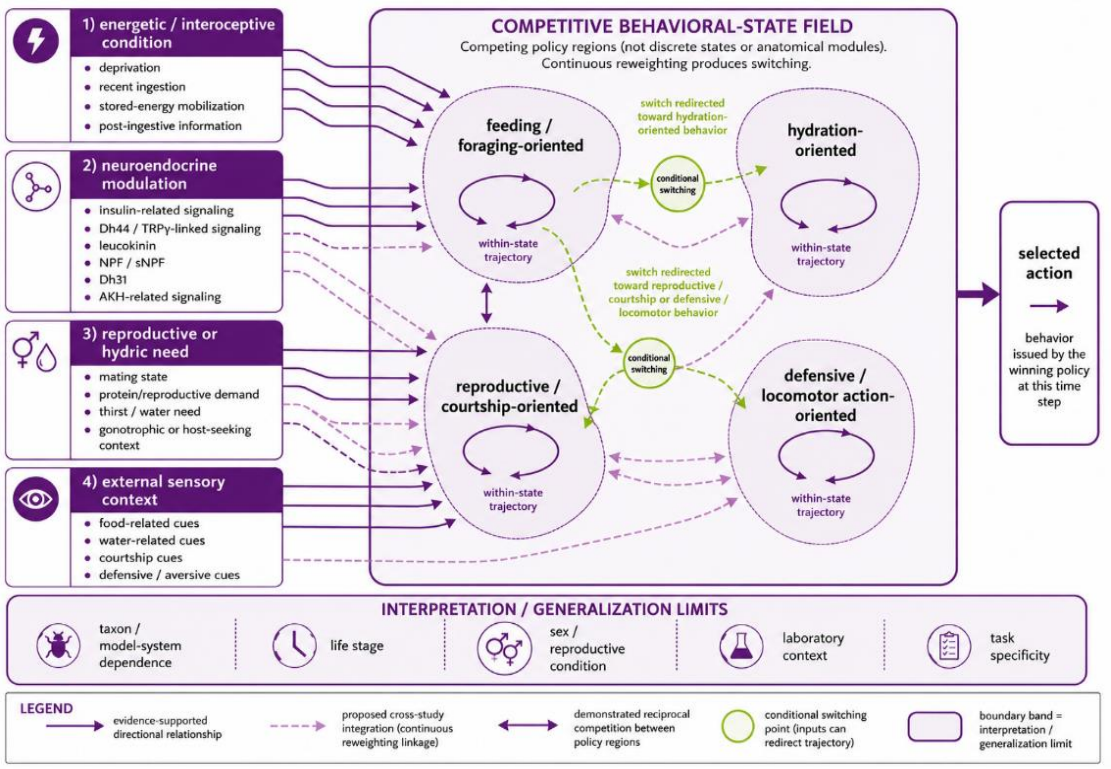


Figure 1. Competing internal needs and contextual evidence reshape trajectories between persistent and switching behavioral states

Action selection

Behavioral-state switching establishes which policies are favored, but action selection concerns the moment-to-moment transformation from available sensory evidence into an executed response. Neuromodulation can alter this transformation selectively. In *Drosophila* larvae, sNPF-mediated feedback facilitates mechanonociceptive processing, whereas comparable dependence is not seen for thermal nociception [24]. State modulation therefore need not act as a global increase in responsiveness; it can be pathway and modality specific.

At the motor-output level, even activity in a behaviorally relevant descending neuron does not imply a deterministic command. DNp03 activity associated with visually elicited flight saccades depends on behavioral state, and sustained activity predicts saccade execution without fully determining it [25]. The result supports a probabilistic view in which current state changes the relation between sensory drive, descending activity, and final action.

Action selection is also informed by the animal's ongoing behavior. Ascending neurons in *Drosophila* convey rich behavioral-state information from the ventral nerve cord to brain regions involved in sensory integration and action selection [26]. This establishes that the brain has access to signals about current action, but encoding alone does not prove that those signals causally determine the next choice. In the proposed architecture, action selection is therefore a state-conditioned competition among sensorimotor alternatives, with neuromodulatory gain, current behavioral context, and ascending state information altering action probability without requiring a single command center.

Feedback from behavioral outcomes

Action is not the end of a state-dependent decision. Whole-brain imaging during spontaneous and forced walking in *Drosophila* shows a distributed activity change associated with locomotion, assembled from heterogeneous excitatory, inhibitory, and neuromodulatory components [27]. Because this evidence is predominantly correlational, it supports behavioral-state updating accompanying action, not the stronger claim that movement-generated activity necessarily causes the next decision.

Persistence also gives state a temporal dimension. Recurrently connected circuitry in female *Drosophila* can sustain neural and behavioral states for minutes after the initiating signal [28]. Although this reproductive/social

circuit is not evidence for a metabolic-state mechanism, it demonstrates a general neurophysiological possibility: current behavior can remain conditioned by a state that outlasts the immediate trigger.

Energy-dependent processing can then reshape subsequent sensory-to-action transformations. Mushroom-body pathways integrate hunger and satiety signals with food-odor responses, allowing internal metabolic condition to alter food-seeking behavior [29]. Outcome information may enter at different timescales. In hungry flies, taste alone initiates rapid but partial recovery of starvation-associated thermopreference, whereas nutrient ingestion produces a more complete later shift [30]. Thus sensory contact, ongoing action, and post-ingestive consequences should not be collapsed into one feedback signal.

This separation is important because an executed action can alter several variables at once. Walking changes sensory inflow and motor-related neural activity, while feeding can immediately change taste exposure and later alter internal nutrient signals. The framework therefore treats outcome feedback as multiple return channels rather than a single reward term. Brain-wide movement-associated activity [27] and staged taste-versus-ingestion effects [30] support keeping those channels conceptually distinct even though their causal interaction has not been measured in one preparation.

Integrated energy–neuroendocrine architecture

The evidence supports components of a recurrent system, but no study establishes the complete architecture proposed here. The first component is distributed state representation: interoceptive competition, insulin-producing-cell activity, lipid-mobilization pathways, and post-ingestive sensing provide partially distinct information about need and recent nutritional outcome [5]. Nutritional modulation of insulin-producing cells further shows that state representation is dynamic rather than a fixed measure of stored energy [6]. Dh44-linked lipid regulation adds a metabolic-mobilization channel whose downstream organization remains incompletely resolved [7].

The second component is state-dependent weighting. Peptides can act through anatomically distinct targets [11], competing homeostatic drives can constrain one another [17], and feeding state can bias reciprocal inhibitory circuits controlling nonfeeding actions [22]. The proposed architecture therefore places neuroendocrine modulation at multiple processing stages rather than between a hypothetical energy meter and a motor output.

The third component is recursive updating. Ascending neurons make ongoing behavioral information available to integrative brain regions [26]; walking is accompanied by widespread changes in brain activity [27]; and taste versus nutrient receipt can update behavior over distinguishable timescales [30]. These findings justify representing feedback channels, but not claiming that any one identified signal closes the entire loop. The architecture is consequently a functional reconciliation of evidence classes: energetic representation alters motivational and sensorimotor weighting, selected actions change sensory and physiological conditions, and those consequences become candidate inputs to subsequent selection.

Two further constraints follow. First, different signals can operate on different timescales: rapidly changing sensory and neural information may modify the next action before slower metabolic consequences are available. Second, an identical behavioral output can arise from different internal configurations. A feeding action following prolonged deprivation is not assumed equivalent to feeding elicited by palatability or reproductive demand. The proposed architecture therefore represents state as a configuration of partially separable variables whose behavioral relevance depends on the available alternatives. It avoids assigning quantitative weights because the approved studies use different species, stages, assays, and physiological readouts.

A prediction-and-test ledger is useful here because the architecture can only be scientifically informative if each proposed cross-level link can be distinguished from plausible alternatives.

Table 2. Discriminating tests for recurrent links in the energy–neuroendocrine state-and-action architecture

Interpretation/consequence, boundary or competing explanation, and discriminating check	Biological context with observed basis	Architecture distinction with evidential standing
Energy balance is represented through partially separable channels	Interoceptive, insulin-related, lipid-mobilization, and post-ingestive systems	Distributed energetic representation
Signals may converge downstream or reflect correlated physiology	Different state signals respond to deprivation, ingestion, or metabolic mobilization	Evidence-grounded; integration proposed
Manipulate channels independently while matching gross nutritional condition		

Endocrine state can alter relative action weighting without one master switch **Pleiotropy, arousal, or tissue-specific effects can mimic a common state change** **Localize receptors and perturb targets while measuring competing actions**	Peptide action across sensory, motivational, and motor-related circuits Identified peptide systems modify different processing stages	State-dependent neuroendocrine weighting Evidence-grounded; integration proposed
Selection is probabilistic and context dependent **Stimulus intensity or motor capacity can change output independently** **Cross energetic state with matched competing stimuli**	Alternative homeostatic, reproductive, and defensive actions Internal state or sensory context shifts relative action frequencies	Competitive action field Proposed cross-domain synthesis
Sensory outcome may revise action policy before metabolic restoration **Taste-specific reinforcement may be sufficient for the measured task** **Separate cue detection from ingestion and absorption in time**	Immediate contact with behaviorally relevant cues Rapid behavioral adjustment before full nutrient consequences	Fast sensory updating Evidence-grounded; architectural role proposed
Physiological feedback can stabilize or reverse earlier sensory-driven states **Gut distension, learned expectation, or circadian state may contribute** **Track endocrine, metabolic, and behavioral measures on matched timescales**	Nutrient receipt and metabolic consequences Later changes in choice or state-associated behavior	Slow post-ingestive updating Evidence-grounded; integration proposed
Current action can become information available to future selection **Encoding may be consequence rather than causal feedback** **Perturb ascending feedback while preserving the executed movement**	Ongoing locomotion or selected action Ascending and brain-wide signals encode current behavior	Behavior-to-state recurrence Proposed causal role; not yet established

Testable predictions

The framework yields predictions about interactions rather than fixed behavioral outputs. First, energetic-state manipulations should exert their strongest effects when alternative actions are sufficiently competitive for modest changes in weighting to alter selection. Feeding state already biases reciprocally organized larval actions [22], whereas sensory context independently changes defensive competition [23]. A factorial experiment crossing energetic condition with cue competition could distinguish a state-dependent weighting effect from a nonspecific increase in activity.

Second, the behavioral stage affected by a peptide should depend partly on where its receptors and downstream partners operate. Leucokinin acts through distinct neuronal and peripheral targets [11], while gut-derived Dh31 can rapidly change feeding–courtship priority [21]. Tissue-selective perturbation should therefore test whether an endocrine manipulation changes cue evaluation, persistence, switching, or final motor selection rather than treating all behavioral changes as equivalent.

Third, recent behavioral history should matter even when measured nutritional stores are matched. Ascending neurons encode ongoing actions [26], and movement is accompanied by distributed brain-state changes [27]. The prediction is that disrupting selected ascending pathways while preserving movement will alter subsequent state dependence only if those signals participate causally rather than simply report behavior.

Finally, sensory and post-ingestive updating should operate on partially separable timescales. Rapid taste-dependent thermopreference changes precede the fuller effects of nutrient ingestion [30], while post-ingestive neuroendocrine sensing alters later food selection [9]. Time-resolved experiments within one species and task are required before this temporal ordering can be generalized.

For all four predictions, the decisive result is an interaction or dissociation, not a simple main effect of deprivation or peptide manipulation. A manipulation that increases locomotion would not by itself validate state-dependent action weighting. Experiments should instead measure competing actions, verify the relevant physiological or neural state, and test whether the intervention changes relative choice, persistence, or switching while controlling gross motor capacity.

Results and Discussion

The proposed architecture changes the unit of explanation from "which hormone causes a behavior?" to "where and under what state does a signal change the competition among behaviors?" This shift preserves evidence that would otherwise appear contradictory. Neuropeptide F and RYamide oppositely regulate mosquito host attraction across the gonotrophic cycle [15], whereas adipokinetic-hormone receptor signaling in a lepidopteran larva couples food intake with lipid physiology [16]. These are evidence for state-sensitive endocrine control, not for homologous decision circuitry.

Energy balance must also remain distinct from other determinants of action. Mating changes dietary preference differently between male and female flies [14]. Thirst can suppress feeding despite nutritional need [17]. Sensory context can change defensive action selection without an energetic manipulation [23]. A framework that absorbs all three into an undefined "internal state" would lose the explanatory distinction it is intended to create.

The evidence base is strongest in laboratory *Drosophila*, with important but narrower mosquito and lepidopteran examples. Ecological nutrient sensing varies with resource structure and species biology [3], so mechanistic resolution in controlled assays does not establish equivalent weighting in heterogeneous field environments. Developmental stage is similarly important: larval feeding-drive and action-selection circuits cannot simply be projected onto adults.

The architecture also separates functional analogy from evolutionary conservation. Similar peptide families can influence energetic or behavioral variables in different insects without demonstrating that the same ancestral circuit computation is retained. Comparative tests should therefore align receptor expression, tissue targets, physiological state, and behavioral task before interpreting cross-species similarity. The same caution applies to apparent fitness consequences: a mating-associated dietary shift or starvation-induced persistence may be beneficial in context, but the mechanistic studies considered here do not establish adaptive value.

Evidence status also matters. A descending neuron's activity can predict an action without uniquely determining it [25]. Ascending neurons can encode current behavior without proving that the encoded information controls the next choice [26]. Brain-wide activity can correlate with locomotion without identifying whether it is motor command, reafference, metabolic consequence, or some combination [27]. Accordingly, causal perturbation, functional encoding, association, and cross-study synthesis should not be represented by identical mechanistic language.

Finally, the framework should be evaluated against simpler models. If one endocrine manipulation changes all measured behaviors in parallel with locomotor arousal, a global-state account may suffice. If effects are confined to one sensory pathway or one competing-action pair, a local circuit explanation may be more parsimonious. Support for the proposed architecture would require repeated evidence that energetic variables, endocrine signals, and outcome feedback interact across processing stages while retaining route specificity.

Validation should therefore proceed by crossing boundaries that existing studies usually examine separately: energetic condition with sensory competition; endocrine manipulation with receptor location; behavioral history with matched nutrient stores; and sex, life stage, or species with homologous but not presumed-identical signals. The framework will gain explanatory value only if such experiments discriminate its proposed recurrent weighting mechanism from simpler alternatives such as generalized arousal, motor limitation, sensory adaptation, or independent parallel pathways.

Conclusion

Insects do not appear to translate energetic deficit directly into a single behavioral command. Current evidence instead supports distributed sensing of nutritional condition, state-dependent peptide and hormonal modulation, competition among behavioral priorities, and action-related updating at multiple timescales. The principal contribution of this article is a proposed recurrent architecture that keeps those processes analytically separate while explaining how they could jointly shape motivation, behavioral-state stability, and action probability. Its value lies in specifying boundaries and discriminating tests, not in claiming a conserved anatomical controller. Cross-taxon, developmental, sex-specific, and field validation will be necessary before the architecture can be treated as broadly generalizable.

Acknowledgments: None

Conflict of Interest: None

Financial Support: None

Ethics Statement: None

References

1. Nässel DR. What Drosophila can tell us about state-dependent peptidergic signaling in insects. Insect Biochem Mol Biol. 2025;179:104275. doi:10.1016/j.ibmb.2025.104275
2. Mahishi D, Agrawal N, Jiang W, Yapici N. From mammals to insects: Exploring the genetic and neural basis of eating behavior. Annu Rev Genet. 2024;58(1):455-85. doi:10.1146/annurev-genet-111523-102202
3. Ruedenauer FA, Parreño MA, Grunwald Kadow IC, Spaethe J, Leonhardt SD. The ecology of nutrient sensation and perception in insects. Trends Ecol Evol. 2023;38(10):994-1004. doi:10.1016/j.tree.2023.05.006
4. Weaver KJ, Raju S, Rucker RA, Chakraborty T, Holt RA, Pletcher SD. Behavioral dissection of hunger states in Drosophila. Elife. 2023;12:RP84537. doi:10.7554/eLife.84537
5. González Segarra AJ, Pontes G, Jourjine N, Del Toro A, Scott K. Hunger- and thirst-sensing neurons modulate a neuroendocrine network to coordinate sugar and water ingestion. Elife. 2023;12:RP88143. doi:10.7554/eLife.88143
6. Bisen RS, Iqbal FM, Cascino-Milani F, Bockemühl T, Ache JM. Nutritional state-dependent modulation of insulin-producing cells in Drosophila. Elife. 2025;13:RP98514. doi:10.7554/eLife.98514
7. Nath DK, Dhakal S, Lee Y. TRPγ regulates lipid metabolism through Dh44 neuroendocrine cells. Elife. 2025;13:RP99258. doi:10.7554/eLife.99258
8. Mollá-Albaladejo R, Jiménez-Caballero M, Sanchez-Alcaniz JA. Molecular characterization of gustatory second-order neurons reveals integrative mechanisms of gustatory and metabolic information. Elife. 2025;13:RP100947. doi:10.7554/eLife.100947
9. Dhakal S, Ren Q, Liu J, Akitake B, Tekin I, Montell C, et al. Drosophila TRPγ is required in neuroendocrine cells for post-ingestive food selection. Elife. 2022;11:e56726. doi:10.7554/eLife.56726
10. Yurgel ME, Kakad P, Zandawala M, Nässel DR, Godenschwege TA, Keene AC. A single pair of leucokinin neurons are modulated by feeding state and regulate sleep-metabolism interactions. PLoS Biol. 2019;17(2):e2006409. doi:10.1371/journal.pbio.2006409
11. Zandawala M, Yurgel ME, Texada MJ, Liao S, Rewitz KF, Keene AC, et al. Modulation of Drosophila post-feeding physiology and behavior by the neuropeptide leucokinin. PLoS Genet. 2018;14(11):e1007767. doi:10.1371/journal.pgen.1007767
12. Kasturacharya N, Dhall JK, Hasan G. A STIM dependent dopamine-neuropeptide axis maintains the larval drive to feed and grow in Drosophila. PLoS Genet. 2023;19(6):e1010435. doi:10.1371/journal.pgen.1010435
13. Laturney M, Sterne GR, Scott K. Mating activates neuroendocrine pathways signaling hunger in Drosophila females. Elife. 2023;12:e85117. doi:10.7554/eLife.85117
14. Liu C, Tian N, Chang P, Zhang W. Mating reconciles fitness and fecundity by switching diet preference in flies. Nat Commun. 2024;15(1):9912. doi:10.1038/s41467-024-54369-w
15. Dou X, Chen K, Brown MR, Strand MR. Reciprocal interactions between neuropeptide F and RYamide regulate host attraction in the mosquito Aedes aegypti. Proc Natl Acad Sci U S A. 2024;121(28):e2408072121. doi:10.1073/pnas.2408072121
16. Hou QL, Fang M, Zhu JN, O'Sullivan DM, Chen EH. Adipokinetic hormone receptor is required for larval food intake and development of Plutella xylostella. J Insect Physiol. 2025;167:104913. doi:10.1016/j.jinsphys.2025.104913
17. Landayan D, Wang BP, Zhou J, Wolf FW. Thirst interneurons that promote water seeking and limit feeding behavior in Drosophila. Elife. 2021;10:e66286. doi:10.7554/eLife.66286
18. Senapati B, Tsao CH, Juan YA, Chiu TH, Wu CL, Waddell S, et al. A neural mechanism for deprivation state-specific expression of relevant memories in Drosophila. Nat Neurosci. 2019;22(12):2029-39. doi:10.1038/s41593-019-0515-z

19. Sayin S, De Backer JF, Siju KP, Wosniack ME, Lewis LP, Frisch LM, et al. A neural circuit arbitrates between persistence and withdrawal in hungry Drosophila. Neuron. 2019;104(3):544-58.e6. doi:10.1016/j.neuron.2019.07.028
20. Li HF, Dong B, Peng YY, Luo HY, Ou XL, Ren ZL, et al. The neuropeptide sulfakinin is a peripheral regulator of insect behavioral switch between mating and foraging. Elife. 2025;13:RP100870. doi:10.7554/eLife.100870
21. Lin HH, Kuang MC, Hossain I, Xuan Y, Beebe L, Shepherd AK, et al. A nutrient-specific gut hormone arbitrates between courtship and feeding. Nature. 2022;602(7898):632-8. doi:10.1038/s41586-022-04408-7
22. de Tredern E, Manceau D, Blanc A, Parameswaran A, Sakagiannis P, Barre C, et al. Feeding state-dependent neuropeptidergic modulation of reciprocally interconnected inhibitory neurons biases sensorimotor decisions in Drosophila. Nat Commun. 2025;16:8198. doi:10.1038/s41467-025-61805-y
23. Lehman M, Barré C, Hasan MA, Flament B, Autran S, Dhiman N, et al. Neural circuits underlying context-dependent competition between defensive actions in Drosophila larvae. Nat Commun. 2025;16(1):1120. doi:10.1038/s41467-025-56185-2
24. Hu C, Petersen M, Hoyer N, Spitzweck B, Tenedini F, Wang D, et al. Sensory integration and neuromodulatory feedback facilitate Drosophila mechanonociceptive behavior. Nat Neurosci. 2017;20(8):1085-95. doi:10.1038/nn.4580
25. Buchsbaum E, Schnell B. Activity of a descending neuron associated with visually elicited flight saccades in Drosophila. Curr Biol. 2025;35(3):665-71.e4. doi:10.1016/j.cub.2024.12.001
26. Chen CL, Aymanns F, Minegishi R, Matsuda VDV, Talabot N, Günel S, et al. Ascending neurons convey behavioral state to integrative sensory and action selection brain regions. Nat Neurosci. 2023;26(4):682-95. doi:10.1038/s41593-023-01281-z
27. Aimon S, Cheng KY, Gjorgjieva J, Grunwald Kadow IC. Global change in brain state during spontaneous and forced walk in Drosophila is composed of combined activity patterns of different neuron classes. Elife. 2023;12:e85202. doi:10.7554/eLife.85202
28. Deutsch D, Pacheco D, Encarnacion-Rivera L, Pereira T, Fathy R, Clemens J, et al. The neural basis for a persistent internal state in Drosophila females. Elife. 2020;9:e59502. doi:10.7554/eLife.59502
29. Tsao CH, Chen CC, Lin CH, Yang HY, Lin S. Drosophila mushroom bodies integrate hunger and satiety signals to control innate food-seeking behavior. Elife. 2018;7:e35264. doi:10.7554/eLife.35264
30. Umezaki Y, Hidalgo S, Nguyen E, Nguyen T, Suh J, Uchino SS, et al. Taste triggers a homeostatic temperature control in hungry flies. Elife. 2024;13:RP94703. doi:10.7554/eLife.94703