Eurasia Specialized Veterinary Publication

Entomological Research Letters

ISSN: 3108-639X

2024, Volume 4, Issue 2, Page No: 84-92
Copyright CC BY-NC-SA 4.0
Available online at: www.esvpub.com/

Ecological Chemosensory Decisions Emerge from the Functional Organization of Receptor Repertoires, Neural Processing, and Behavioral Output

Alejandro Torres[1]*, Miguel Fernandez[1], Daniela Rojas[2], Andres Castro[3]

[1]Department of Chemosensory Repertoires and Neural Processing, Faculty of Life Sciences, University of Chile, Santiago, Chile.
[2]Department of Receptor Organization and Behavioral Decisions, Faculty of Biosciences, Pontifical Catholic University of Chile, Santiago, Chile.
[3]Department of Olfactory Ecology and Output Integration, Faculty of Sciences, University of Concepcion, Concepcion, Chile.

***E-mail** ✉ alejandro.torres@fen.uchile.cl

ABSTRACT

Insect chemosensory behavior is often interpreted as though ecological decisions can be read directly from receptor identity, receptor abundance, or ligand sensitivity. That interpretation is increasingly difficult to sustain. Receptor repertoires differ in size, evolutionary history, co-expression, and functional specialization; peripheral neurons transform chemical input through receptor architecture, adaptation, and temporal coding; central circuits recode odor through inhibition, convergence, learning, and multisensory integration; and internal state changes how otherwise similar sensory information is translated into action. This article develops a proposed functional chemosensory architecture that treats ecological decision making as an emergent property of transformations across these levels rather than as the output of a single molecular detector. The framework distinguishes receptor repertoire composition from ligand tuning, peripheral coding from central representation, sensory representation from state-dependent valuation, and motor output from ecological signal value. It also preserves negative and limiting evidence, including weak correspondence between receptor repertoire size and eusociality, incomplete behavioral valence of individual olfactory receptor neurons, limited plasticity after naturalistic chronic odor exposure, and cases in which accessory proteins are not obligatory for robust odor responses. The framework is not presented as a universal mechanism. Instead, it organizes testable cross-level predictions while identifying taxonomic, developmental, environmental, methodological, and laboratory-to-field boundaries that must be resolved before receptor-level findings can support ecological inference.

Keywords: Odorant receptors, Ionotropic receptors, Peripheral coding, Olfactory circuits, Internal state, Insect chemical ecology

Received: 19 September 2024
Revised: 09 November 2024
Accepted: 11 November 2024

How to Cite This Article: Torres A, Fernandez M, Rojas D, Castro A. Ecological Chemosensory Decisions Emerge from the Functional Organization of Receptor Repertoires, Neural Processing, and Behavioral Output. Entomol Res Lett. 2024;4(2):84-92.
https://doi.org/10.51847/cmjTypesnQ

Introduction

Insect chemosensation is often described through a detector-centered logic: a receptor recognizes a ligand, a sensory neuron responds, and behavior follows. Recent evidence makes that sequence too simple for many ecological decisions. In *Aedes aegypti*, individual olfactory sensory neurons can express combinations of receptors rather than conforming to a strict one-receptor/one-neuron organization, creating potential redundancy and overlap before central processing begins [1]. Chemoreceptor co-expression also crosses conventional receptor-family boundaries in *Drosophila* and mosquito olfactory neurons, showing that receptor identity and neuronal channel identity are not necessarily equivalent [2]. At the behavioral end of the pathway, systematic optogenetic

© 2024 Entomological Research Letters

activation of *Drosophila* olfactory receptor neuron classes found that most individual classes did not independently impose strong attractive or aversive valence, although important exceptions remained [3].

These observations change the inferential problem. The question is not simply which receptor detects an ecologically relevant molecule, but how receptor repertoires, peripheral dynamics, central transformations, internal state, and action selection are functionally organized so that chemical information acquires behavioral significance. Evidence at one level cannot automatically substitute for evidence at another. A receptor-ligand interaction can establish molecular sensitivity without proving ecological importance; neural activity can establish representation without demonstrating a fixed action; and laboratory behavior can reveal a sensorimotor transformation without establishing field performance or fitness consequences.

This article therefore develops a proposed functional architecture for ecological chemosensory decisions. Its purpose is organizational rather than empirical: to identify where information is transformed, where inference commonly overreaches, and which cross-level relationships require direct validation. The framework deliberately retains taxonomic, life-stage, sex, environmental, temporal, and methodological boundaries rather than treating insect chemosensation as a single conserved decision system.

Receptor repertoire composition

Receptor repertoires define the molecular search space available to a sensory system, but repertoire size alone is a weak proxy for ecological or behavioral complexity. Across Hymenoptera, comparative analysis found no general relationship between odorant-receptor repertoire size or evolutionary tempo and the evolution of eusociality [4]. That negative result is important because it separates numerical expansion from functional organization: social complexity may coexist with receptor diversification, but receptor number by itself does not demonstrate why particular cues are behaviorally privileged.

The evolutionary history of insect chemoreceptors is also deeper and less modular than a simple list of lineage-specific receptor families implies. Structure-informed remote homology places insect chemoreceptors within a cryptic seven-transmembrane ion-channel superfamily that extends far beyond insects [5]. Such ancestry helps explain structural relationships, but it cannot by itself predict present-day ligand ecology. Functional specialization must therefore be established independently. In the ant *Harpegnathos saltator*, members of a large odorant-receptor subfamily showed narrow responses to cuticular hydrocarbons and candidate pheromonal cues, demonstrating that repertoire substructure can contain receptors with highly specialized chemical sensitivity [6].

Comparative genomics can identify candidate repertoire changes associated with ecological transitions, but the inferential boundary remains equally important. In the *Anopheles farauti* complex, chemosensory-gene variation and signatures of selection were associated with differences in host use, nominating candidate loci relevant to anthropophily [7]. These associations do not establish that any one receptor generated the behavioral transition, because demographic history, linked evolution, expression, neural integration, and environmental context remain plausible contributors.

Repertoire composition can also influence neural organization indirectly. In the clonal raider ant *Ooceraea biroi*, *orco* disruption caused severe olfactory-system abnormalities and impaired social behavior [8]. Because Orco loss affects development as well as sensory function, the result supports coupling between receptor-system integrity and neural architecture but does not isolate a purely acute adult sensory mechanism. Repertoire composition should therefore be treated as the first level of a chemosensory architecture, not as a self-sufficient explanation of ecological decisions.

Ligand tuning and peripheral coding

Peripheral coding begins with molecular architecture. Cryo-electron microscopy of Orco established a tetrameric ion-channel organization that provides a structural basis for understanding conserved co-receptor function [9]. A later structure of the odorant receptor MhOR5 identified a ligand-binding pocket whose residues influence sensitivity to chemically distinct odorants, demonstrating how receptor structure can constrain ligand recognition [10]. These structures establish molecular possibilities, not ecological value: neither receptor geometry nor affinity alone identifies which signals matter in a natural decision.

Recent structures of heteromeric odorant-receptor complexes sharpen that distinction. In the pea aphid, an odorant receptor–Orco complex was resolved with one tuning receptor associated with three Orco subunits, with ligand binding coupled to pore opening [11]. Independent work on mosquito heteromeric receptors similarly supported an asymmetric one-to-three organization in the tested complexes [12]. Together, these studies provide strong

structural support for asymmetric heteromeric gating, while leaving open whether the same stoichiometry and dynamics dominate every receptor complex in intact neurons across insect orders.

Ligand access itself is also dynamic. Molecular-dynamics analysis combined with electrophysiology identified conserved residues involved in entry and binding of the synthetic Orco agonist VUAA1 [13]. That result supports a mechanistically structured access pathway for Orco agonism but should not be generalized to natural odorant entry into all tuning receptors. Computational prediction faces a related validation problem. In a benchmark of insect odorant-receptor ligand modeling, template-based modeling outperformed AlphaFold3 for the tested ligand-binding discrimination tasks [14]. The relevant conclusion is methodological: structural predictions require receptor- and ligand-specific validation rather than automatic ecological interpretation.

Functional tuning can also diverge from simple phylogenetic expectation. In *Spodoptera frugiperda*, SfruOR23 responded preferentially to a sex-pheromone component despite belonging to a lineage that extends conventional pheromone-receptor classifications [15]. Such findings argue against equating receptor lineage with a fixed ecological role.

Peripheral output further contains temporal information. Moth olfactory receptor neurons can encode stimulus duration through adaptation dynamics before central processing [16]. Locust olfactory receptor neurons generate several temporal response motifs and can shift among motifs with odor context and repetition, expanding the dimensionality of peripheral coding [17]. Thus, what reaches the brain is already a transformed representation of chemical identity, concentration history, and time.

Receptor-family contributions are likewise non-equivalent. In *Aedes aegypti*, disruption of the IR8a pathway reduced responses to acidic human-associated volatiles and impaired host-seeking responses, while other sensory pathways remained available [18]. Conversely, deletion of several abundant *Drosophila* odorant-binding proteins did not abolish robust olfactory responses in the tested basiconic sensilla [19]. These cases caution against assuming either that a single receptor family is sufficient for a behavioral decision or that the presence of a peripheral accessory component proves obligatory function. Peripheral coding is therefore best treated as a set of molecular and temporal transformations whose ecological interpretation remains conditional on subsequent neural and behavioral processing.

Central neural processing

Central processing changes the representational problem from "which molecules activated receptors?" to "which combinations, contrasts, and contextual signals are preserved for action?" In female *Aedes aegypti*, neural imaging and odor chemistry identified glomerular response patterns that distinguished human odor features and supported host-seeking behavior [20]. The result shows selective central representation of ecologically relevant blends, but it does not reduce human preference to a single glomerulus or universal mosquito code.

A complementary ecological example comes from mosquito attraction to orchid scent. Behavioral, chemical, and neural measurements indicated that attraction depended on the balance between excitation and inhibition produced by particular floral blends, whereas related odor mixtures were less effective [21]. Ecological signal value can therefore emerge from relational neural processing rather than from the presence of one attractive compound. At a deeper circuit level, locust mushroom-body coding is shaped by feedback inhibition, which regulates the timing and sparseness of downstream odor representations [22]. Such recurrent processing demonstrates that central coding is not a passive relay of peripheral activity.

Chemosensory action also depends on information that is not itself chemical. In *Drosophila*, odor and wind pathways converge within a circuit that supports wind-guided olfactory navigation [23]. The chemical signal provides evidence about odor presence, whereas mechanosensory information supplies a directional variable needed for navigation. Likewise, larval *Drosophila* circuits contain convergence points through which learned and innate valence information can influence action-related pathways [24]. These findings support a central principle of the proposed architecture: ecological decisions depend not simply on the strength of an odor representation but on how that representation is combined with spatial information, memory, and action-selection circuitry. Because the detailed circuits were established in particular species and developmental stages, their topology should not be treated as a universal insect blueprint.

Internal-state modulation

The same sensory representation can have different behavioral consequences when the animal's internal state changes. In *Aedes aegypti*, a brief carbon-dioxide stimulus can initiate a host-search state that persists well beyond stimulus termination, with strong dependence on sex and feeding condition [25]. This demonstrates that a transient chemosensory event can alter the temporal context in which later cues are evaluated.

Experience creates another state-dependent layer. *Aedes aegypti* can learn host-associated odors through dopamine-dependent processes, modifying subsequent odor preference rather than expressing a fixed valuation for every host cue [26]. Learning should therefore be distinguished from evolutionary adaptation: it is a within-lifetime change in the weighting of sensory information. Yet plasticity should not be assumed whenever experience changes. Under chronic exposure to naturally occurring odor concentrations, early *Drosophila* olfactory processing showed only limited plasticity, with much of the response organization remaining stable [27]. This negative boundary is as informative as strong plasticity because it indicates that state dependence may be expressed downstream, under different exposure regimes, or only in selected components of the pathway.

Across these cases, internal-state modulation can be separated into three analytically different operations: persistence of motivational state after a transient cue, learned revaluation of chemical information, and constrained or absent early-circuit remapping despite prolonged exposure. The proposed synthesis is that "internal state" should not be treated as a single scalar variable. Its mechanistic location, duration, sex or feeding dependence, and interaction with the sensory stage being measured determine what kind of behavioral change can legitimately be inferred.

Because these forms of modulation differ in temporal persistence, biological context, and mechanistic location, a compact context–mechanism–outcome register is more informative than treating all state effects as equivalent.

Table 1. Internal-state modulation changes chemosensory meaning through distinct temporal and mechanistic routes

Persistent and learned revaluation routes		
Internal state comparison dimension	**Persistent host-search state after a transient cue**	**Learned revaluation of host-associated odor**
Biological setting	Adult female *Aedes aegypti*; expression differs with sex and feeding state	Adult female *Aedes aegypti*
Observable evidence	Behavioral persistence after brief carbon-dioxide exposure	Conditioning and dopamine-dependent modification of odor response
Change in chemosensory meaning	Later odor-guided behavior is evaluated within a state that outlasts the initiating cue	Chemical valence can change within an individual without receptor replacement
Boundary, test, and evidence state	Duration and ecological expression are system- and state-dependent Separate immediate stimulus effects from delayed state-dependent responses Evidence-supported pattern	Learning protocol, odor identity, and neuromodulatory context constrain transfer Compare identical sensory inputs before and after controlled learning while measuring downstream valuation Evidence-supported pattern
Chronic-exposure pathway plasticity		
Internal state comparison dimension	**Limited early-pathway plasticity under chronic naturalistic exposure**	
Biological setting	Adult *Drosophila melanogaster*	
Observable evidence	Early olfactory responses after prolonged odor exposure	
Change in chemosensory meaning	Prolonged experience need not produce strong peripheral or early-circuit remapping	
Boundary, test, and evidence state	Exposure intensity, odor identity, developmental timing, and downstream plasticity remain important Localize plasticity experimentally rather than inferring it from exposure history alone Evidence-supported boundary	
Multidimensional state synthesis		
Internal state comparison dimension	**State as a multidimensional modifier rather than a scalar "motivation" term**	
Biological setting	Cross-level synthesis derived from the contrasted state cases above	
Observable evidence	Joint comparison of persistence, learning, and limited early plasticity	

Change in chemosensory meaning	Behavioral meaning depends on where and when state enters the sensory-to-action architecture
Boundary, test, and evidence state	Not empirically validated as a universal insect state model Test state dimensions independently and map their point of entry into the pathway Proposed synthesis

Behavioral output

Neural representation becomes ecologically relevant only when it is transformed into action. In walking *Drosophila*, odor-driven locomotion cannot be described by a fixed conversion between olfactory receptor neuron activity and movement. Behavioral output depends on firing rate, temporal change in firing, neuronal identity, and time after stimulation [28]. Sensory activity is therefore an input to a sensorimotor transformation rather than a behavioral command.

Chemosensory decisions can also differ fundamentally between sensory modalities. In female *Aedes aegypti*, stylet sensory neurons discriminate combinations associated with blood and nectar, demonstrating that meal identity can be constructed from context-dependent peripheral chemosensory combinations [29]. This gustatory example should not be treated as equivalent to antennal olfaction; instead, it demonstrates a broader principle: behavioral significance depends on how a sensory system transforms chemically informative combinations into action appropriate to its organ and behavioral context.

The proposed interpretation is consequently that behavioral output reflects an interaction among sensory representation, internal state, and sensorimotor mapping. A receptor response is insufficient to specify behavior unless the transformations connecting these levels are also established.

These boundaries are condensed visually because the critical distinction is not a linear sequence of boxes but where experimentally supported transformations end and cross-level behavioral inference begins.

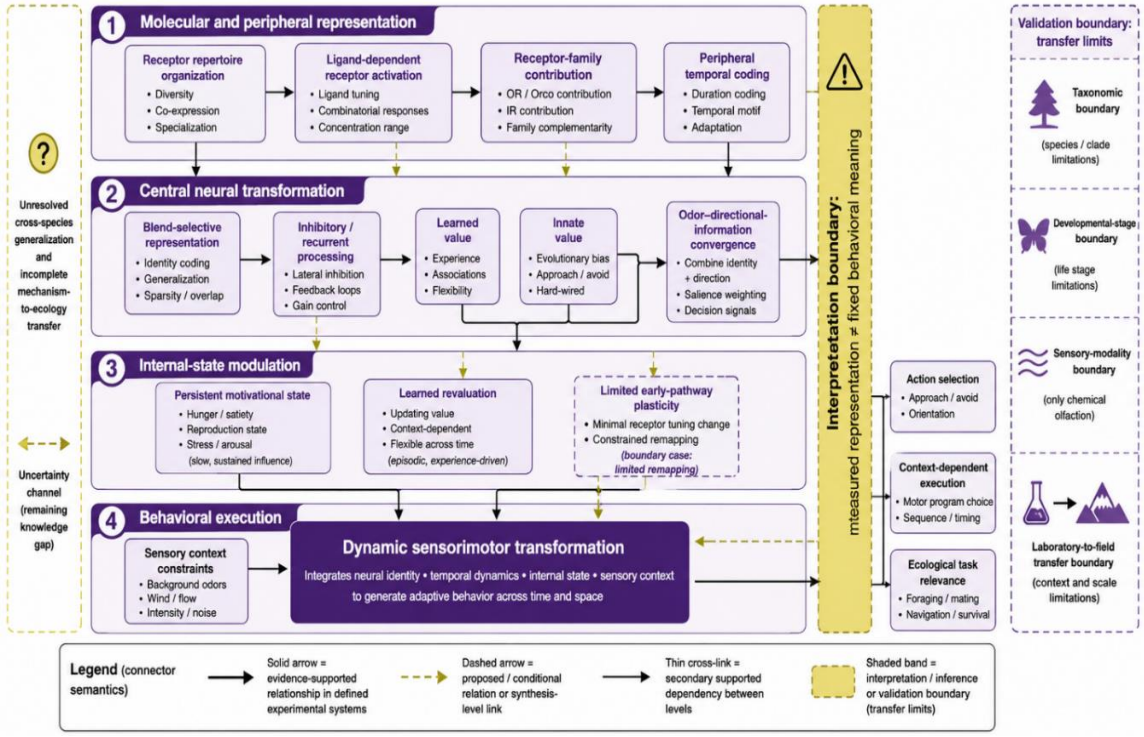


Figure 1. Decision Boundaries That Prevent Chemosensory Activity from Mapping Directly onto Fixed Behavioral Valence

Ecological context and signal value

Chemical signals acquire ecological value within particular environments rather than through molecular detectability alone. Human attractiveness to *Aedes aegypti* is associated with stable individual differences in skin-derived carboxylic-acid abundance [30]. The association links host chemistry with mosquito behavior, but it does not establish that carboxylic acids alone are sufficient causes of human attractiveness.

Chemical information can also alter the value of nonchemical cues. In *Aedes aegypti*, carbon dioxide gates attraction toward visual wavelengths associated with human skin, demonstrating that visual preference depends on olfactory context [31]. Such multimodal dependence makes ecological signal value conditional on the combination and sequence of available information.

Ecological signals can additionally incorporate compounds acquired from the environment. Male *Chloridea virescens* use a courtship signal containing plant-derived methyl salicylate, which is detected by females and contributes to courtship acceptance [32]. The result demonstrates ecological incorporation of an environmental molecule into communication, although its evolutionary origin should not be treated as proof of adaptive preadaptation.

Together, these cases indicate that ecological signal value is relational: it depends on signal abundance, sensory context, behavioral state, and the ecological task in which detection occurs. The main evidence gaps concern transfer across species, environments, life stages, sensory modalities, and laboratory versus natural conditions.

The coverage pattern and its unresolved transfer boundaries are therefore summarized separately rather than reducing ecological context to a single category.

Table 2. Ecological Conditions That Alter Chemosensory Signal Value and the Evidence Gaps Blocking Cross-Context Transfer

Ecological operation	Setting and evidential basis	Change in signal value	Coverage gap, decisive test, and state
Chemical abundance and courtship incorporation			
Host-associated chemical abundance	Human odor evaluated by host-seeking female *Aedes aegypti* Repeated behavioral differences associated with skin carboxylic-acid abundance	The same broad host category contains chemically unequal attraction profiles	Chemical association does not establish sufficiency or universal host chemistry Manipulate candidate chemical dimensions while preserving realistic host-odor backgrounds Evidence-supported association
Environmental molecule incorporated into courtship	Male and female *Chloridea virescens* Chemical analysis, receptor responsiveness, and courtship assays involving plant-derived methyl salicylate	A molecule originating outside the insect can participate in sexual communication	One species and one courtship system cannot establish a general evolutionary route Compare acquisition, detection, and behavioral function across related taxa and diets Evidence-supported case
Cross-modal gating			
Olfactory gating of visual information	*Aedes aegypti* host search under controlled airflow and visual conditions Carbon dioxide changes attraction to particular spectral cues	Visual information gains behavioral value only within an odor-defined state	Natural illumination, plume intermittency, and field-scale transfer remain unresolved Test cue combinations under progressively naturalistic spatial and temporal structure Evidence-supported interaction
Cross-level ecological value			
Ecological signal value as a cross-level property	Proposed synthesis across host-seeking, multimodal search, and courtship examples Contrast among chemically distinct ecological tasks	Signal value is assigned through context-dependent transformations rather than molecular detection alone	No universal cross-insect architecture has been prospectively validated Measure the same cue across receptor, circuit, state, behavior, and ecological-context levels Proposed synthesis

Functional chemosensory architecture

The proposed functional architecture treats ecological chemosensory decisions as relationships among distinct levels rather than as a chain in which each level predicts the next. Receptor repertoire size, for example, cannot be assumed to quantify ecological complexity [4]. Peripheral neurons can already transform temporal properties of odor input before the signal reaches central circuits [16]. Central processing can then emphasize particular blend features [20], while navigation may require convergence between odor and directional information [23].

Internal state adds another transformation rather than merely amplifying sensory gain. A transient cue can establish a persistent host-search state [25], whereas chronic exposure can leave early sensory processing

comparatively stable [27]. Behavioral execution is then produced through a dynamic sensorimotor mapping rather than a fixed receptor-to-action conversion [28]. Finally, ecological context determines whether the resulting action is meaningful for host selection, feeding, courtship, or another task.

The framework therefore distinguishes six analytical operations: repertoire availability, peripheral transformation, central representation, state-dependent valuation, sensorimotor conversion, and ecological interpretation. These operations are proposed organizational categories, not a universal sequence of experimentally validated modules. Their biological implementation can differ among Diptera, Lepidoptera, Hymenoptera, developmental stages, sexes, and sensory organs.

A second feature of the architecture is explicit uncertainty propagation. Structural evidence can establish molecular organization without ecological relevance; comparative genomics can identify candidate associations without causal adaptation; laboratory navigation can identify a circuit without guaranteeing performance in natural plumes; and behavioral association can identify signal value without demonstrating fitness consequences. Cross-level claims become stronger only when adjacent transformations are measured in the same biological context.

Testable predictions

The architecture generates predictions that are conceptual and require prospective testing. First, where receptor number poorly explains ecological complexity, functional organization—co-expression, tuning diversity, and distribution across neuronal channels—should explain behavior better than repertoire size alone. The comparative null relationship between repertoire expansion and eusociality provides a boundary condition for this prediction [4].

Second, molecular receptor structure should predict peripheral ligand responsiveness more reliably than final ecological behavior unless downstream processing is also characterized. Structural receptor studies establish ligand-recognition mechanisms [10], whereas central host-odor coding demonstrates additional transformation after peripheral detection [20].

Third, similar sensory input should produce different behavioral outputs when internal state or sensorimotor context differs. Persistent host-search state provides one experimentally established state dependency [25], and dynamic odor-to-locomotion mapping demonstrates that neural activity is not converted to movement through a fixed function [28].

Fourth, laboratory-to-field transfer should be weakest when experimental stimuli omit biologically relevant temporal or multimodal structure. Peripheral neurons can encode stimulus duration [16], while odor-guided navigation may require wind information [23]. Testing this prediction requires experiments that preserve natural plume dynamics, state, and competing sensory information rather than merely increasing laboratory stimulus complexity.

None of these predictions specifies an effect size, universal receptor rule, or expected fitness advantage. Their purpose is to identify experiments capable of falsifying or refining the proposed architecture.

Conclusion

Ecological chemosensory decisions cannot be inferred reliably from receptor identity, repertoire size, ligand affinity, neural activation, or behavioral response considered in isolation. The principal contribution of this article is a proposed architecture that separates receptor availability, peripheral coding, central transformation, internal-state modulation, sensorimotor conversion, and ecological interpretation while specifying where evidence must cross boundaries before stronger inference is justified.

This organization accommodates specialized receptors without assuming labeled-line sufficiency, plasticity without equating it with adaptation, neural representation without treating it as behavior, and laboratory behavior without assuming field generality. Its value therefore lies not in claiming a universal insect decision mechanism, but in making cross-level assumptions explicit and experimentally testable.

Acknowledgments: None

Conflict of Interest: None

Financial Support: None

Ethics Statement: None

References

1. Herre M, Goldman OV, Lu TC, Caballero-Vidal G, Qi Y, Gilbert ZN, et al. Non-canonical odor coding in the mosquito. Cell. 2022;185(17):3104-23.e28. doi:10.1016/j.cell.2022.07.024
2. Task D, Lin CC, Vulpe A, Afify A, Ballou S, Brbic M, et al. Chemoreceptor co-expression in Drosophila melanogaster olfactory neurons. Elife. 2022;11. doi:10.7554/eLife.72599
3. Tumkaya T, Burhanudin S, Khalilnezhad A, Stewart J, Choi H, Claridge-Chang A. Most primary olfactory neurons have individually neutral effects on behavior. Elife. 2022;11. doi:10.7554/eLife.71238
4. Gautam S, McKenzie S, Katzke J, Hita Garcia F, Yamamoto S, Economo EP. Evolution of odorant receptor repertoires across Hymenoptera is not linked to the evolution of eusociality. Proc Biol Sci. 2024;291(2031):20241280. doi:10.1098/rspb.2024.1280
5. Himmel NJ, Moi D, Benton R. Remote homolog detection places insect chemoreceptors in a cryptic protein superfamily spanning the tree of life. Curr Biol. 2023;33(22):5023-33.e4. doi:10.1016/j.cub.2023.10.008
6. Pask GM, Slone JD, Millar JG, Das P, Moreira JA, Zhou X, et al. Specialized odorant receptors in social insects that detect cuticular hydrocarbon cues and candidate pheromones. Nat Commun. 2017;8(1):297. doi:10.1038/s41467-017-00099-1
7. Ambrose L, Popovic I, Hereward J, Ortiz-Barrientos D, Beebe NW. Comparisons of chemosensory gene repertoires in human and non-human feeding Anopheles mosquitoes link olfactory genes to anthropophily. iScience. 2022;25(7):104521. doi:10.1016/j.isci.2022.104521
8. Trible W, Olivos-Cisneros L, McKenzie SK, Saragosti J, Chang NC, Matthews BJ, et al. orco mutagenesis causes loss of antennal lobe glomeruli and impaired social behavior in ants. Cell. 2017;170(4):727-35.e10. doi:10.1016/j.cell.2017.07.001
9. Butterwick JA, del Mármol J, Kim KH, Kahlson MA, Rogow JA, Walz T, et al. Cryo-EM structure of the insect olfactory receptor Orco. Nature. 2018;560(7719):447-52. doi:10.1038/s41586-018-0420-8
10. del Mármol J, Yedlin MA, Ruta V. The structural basis of odorant recognition in insect olfactory receptors. Nature. 2021;597(7874):126-31. doi:10.1038/s41586-021-03794-8
11. Wang Y, Qiu L, Wang B, Guan Z, Dong Z, Zhang J, et al. Structural basis for odorant recognition of the insect odorant receptor OR-Orco heterocomplex. Science. 2024;384(6703):1453-60. doi:10.1126/science.adn6881
12. Zhao J, Chen AQ, Ryu J, del Mármol J. Structural basis of odor sensing by insect heteromeric odorant receptors. Science. 2024;384(6703):1460-7. doi:10.1126/science.adn6384
13. Pacalon J, Audic G, Magnat J, Philip M, Golebiowski J, Moreau CJ, et al. Elucidation of the structural basis for ligand binding and translocation in conserved insect odorant receptor co-receptors. Nat Commun. 2023;14(1):8182. doi:10.1038/s41467-023-44058-5
14. Jabeen A, Oakeshott JG, Lee SF, Ranganathan S, Taylor PW. Template-based modeling of insect odorant receptors outperforms AlphaFold3 for ligand binding predictions. Sci Rep. 2024;14(1):29084. doi:10.1038/s41598-024-80094-x
15. Zhang S, Jacquin-Joly E, Montagné N, Liu F, Liu Y, Wang G. Identification of an odorant receptor responding to sex pheromones in Spodoptera frugiperda extends the novel type-I PR lineage in moths. Insect Sci. 2024;31(2):489-502. doi:10.1111/1744-7917.13248
16. Barta T, Monsempès C, Demondion E, Chatterjee A, Kostal L, Lucas P. Stimulus duration encoding occurs early in the moth olfactory pathway. Commun Biol. 2024;7(1):1252. doi:10.1038/s42003-024-06921-z
17. Kim B, Haney S, Milan AP, Joshi S, Aldworth ZN, Rulkov N, et al. Olfactory receptor neurons generate multiple response motifs, increasing coding space dimensionality. Elife. 2023;12. doi:10.7554/eLife.79152
18. Raji JI, Melo N, Castillo JS, Gonzalez S, Saldana V, Stensmyr MC, et al. Aedes aegypti mosquitoes detect acidic volatiles found in human odor using the IR8a pathway. Curr Biol. 2019;29(8):1253-62.e7. doi:10.1016/j.cub.2019.02.045
19. Xiao S, Sun JS, Carlson JR. Robust olfactory responses in the absence of odorant binding proteins. Elife. 2019;8. doi:10.7554/eLife.51040
20. Zhao Z, Zung JL, Hinze A, Kriete AL, Iqbal A, Younger MA, et al. Mosquito brains encode unique features of human odour to drive host seeking. Nature. 2022;605(7911):706-12. doi:10.1038/s41586-022-04675-4

21. Lahondère C, Vinauger C, Okubo RP, Wolff GH, Chan JK, Akbari OS, et al. The olfactory basis of orchid pollination by mosquitoes. Proc Natl Acad Sci U S A. 2020;117(1):708-16. doi:10.1073/pnas.1910589117
22. Ray S, Aldworth ZN, Stopfer MA. Feedback inhibition and its control in an insect olfactory circuit. Elife. 2020;9. doi:10.7554/eLife.53281
23. Matheson AMM, Lanz AJ, Medina AM, Licata AM, Currier TA, Syed MH, et al. A neural circuit for wind-guided olfactory navigation. Nat Commun. 2022;13(1):4613. doi:10.1038/s41467-022-32247-7
24. Eschbach C, Fushiki A, Winding M, Afonso B, Andrade IV, Cocanougher BT, et al. Circuits for integrating learned and innate valences in the insect brain. Elife. 2021;10. doi:10.7554/eLife.62567
25. Sorrells TR, Pandey A, Rosas-Villegas A, Vosshall LB. A persistent behavioral state enables sustained predation of humans by mosquitoes. Elife. 2022;11. doi:10.7554/eLife.76663
26. Vinauger C, Lahondère C, Wolff GH, Locke LT, Liaw JE, Parrish JZ, et al. Modulation of host learning in Aedes aegypti mosquitoes. Curr Biol. 2018;28(3):333-44.e8. doi:10.1016/j.cub.2017.12.015
27. Gugel ZV, Maurais EG, Hong EJ. Chronic exposure to odors at naturally occurring concentrations triggers limited plasticity in early stages of Drosophila olfactory processing. Elife. 2023;12. doi:10.7554/eLife.85443
28. Tao L, Wechsler SP, Bhandawat V. Sensorimotor transformation underlying odor-modulated locomotion in walking Drosophila. Nat Commun. 2023;14(1):6818. doi:10.1038/s41467-023-42613-8
29. Jové V, Gong Z, Hol FJH, Zhao Z, Sorrells TR, Carroll TS, et al. Sensory discrimination of blood and floral nectar by Aedes aegypti mosquitoes. Neuron. 2020;108(6):1163-80.e12. doi:10.1016/j.neuron.2020.09.019
30. De Obaldia ME, Morita T, Dedmon LC, Boehmler DJ, Jiang CS, Zeledon EV, et al. Differential mosquito attraction to humans is associated with skin-derived carboxylic acid levels. Cell. 2022;185(22):4099-116.e13. doi:10.1016/j.cell.2022.09.034
31. Alonso San Alberto D, Rusch C, Zhan Y, Straw AD, Montell C, Riffell JA. The olfactory gating of visual preferences to human skin and visible spectra in mosquitoes. Nat Commun. 2022;13(1):555. doi:10.1038/s41467-022-28195-x
32. Liu Y, Heath JJ, Zhang S, van Wijk M, Wang G, Buellesbach J, et al. A mosaic of endogenous and plant-derived courtship signals in moths. Curr Biol. 2023;33(16):3529-35.e4. doi:10.1016/j.cub.2023.07.010