The nature and nurture of female receptivity

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References

A

Abuin, L., Bargeton, B., Ulbrich, M. H., Isacoff, E. Y., Kellenberger, S., and Benton, R. (2011). Functional architecture of olfactory ionotropic glutamate receptors. *Neuron* 69, 44–60. doi:10.1016/j.neuron.2010.11.042.

Aigaki, T., Fleischmann, I., Chen, P.-S., and Kubli, E. (1991). Ectopic expression of Sex peptide reproductive behaviour of female *D. melanogaster*. *Neuron* 7, 557–563.

Akhund-Zade, J., Bergland, A. O., Crowe, S. O., and Unckless, R. L. (2017). The genetic basis of natural variation in *Drosophila* (Diptera: *Drosophilidae*) virgin egg retention. *J Insect Sci* 17, 5–9. doi:10.1093/jisesa/iew094.

Aranha, M. M., Herrmann, D., Cachitas, H., Neto-Silva, R. M., Dias, S., and Vasconcelos, M. L. (2017). *Apterous* brain neurons control receptivity to male courtship in *Drosophila melanogaster* females. *Sci Rep*, 1–12. doi:10.1038/srep46242.

Archetti, M. (2013). Evolution of polygamous marriage by maximization of inclusive fitness. *J Theor Biol* 319, 134–143. doi:10.1016/j.jtbi.2012.11.017.

Arnqvist, G., and Nilsson, T. (2000). The evolution of polyandry: multiple mating and female fitness in insects. *Anim Behav* 60, 145–164. doi:10.1006/anbe.2000.1446.

Arya, G. H., Magwire, M. M., Huang, W., Serrano-Negron, Y. L., Mackay, T. F. C., and Anholt, R. R. H. (2015). The genetic basis for variation in olfactory behaviour in *Drosophila melanogaster*. *Chem Senses* 40, 233–243. doi:10.1093/chemse/bjv001.

Aso, Y., Grübel, K., Busch, S., Friedrich, A. B., Siwanowicz, I., and Tanimoto, H. (2009). The mushroom body of adult *Drosophila* characterized by GAL4 drivers. *J Neurogenet* 23, 156–172. doi:10.1080/01677060802471718.

Avila, F. W., Cohen, A. B., Ameerudeen, F. S., Duneau, D., Suresh, S., Mattei, A. L., et al. (2015). Retention of ejaculate by *Drosophila melanogaster* females requires the male-derived mating plug protein PEBme. *Genetics* 200, 1171–1179. doi:10.1534/genetics.115.176669.

Avila, F. W., Sirot, L. K., LaFlamme, B. A., Rubinstein, C. D., and Wolfner, M. F. (2011). Insect seminal fluid proteins: identification and function. *Annu Rev Entomol* 56, 21–40. doi:10.1146/annurev-ento-120709-144823.

B

Baines, R. A., Uhler, J. P., Thompson, A., T, S. S., and Bate, M. (2001). Altered electrical

properties in Drosophila neurons developing without synaptic transmission. *J Neurosci* 21, 1523–1531.

Bartelt, R. J., Schaner, A. M., and Jackson, L. L. (1985). *cis*-Vaccenyl acetate as an aggregation pheromone in *Drosophila melanogaster*. *J Chem Ecol* 11, 1747–1757.

Bastock, M. (1956). A gene mutation which changes a behaviour pattern. *Evolution* 10, 421–439.

Bastock, M., and Manning, A. (1955). The courtship of *Drosophila melanogaster*. *Behaviour*, 85–110.

Bateman, A. J. (1948). Intra-sexual selection in *Drosophila*. *Heredity* 2, 349–368.

Bath, E., Bowden, S., Peters, C., Reddy, A., Tobias, J. A., Easton-Calabria, E., et al. (2017). Sperm and sex peptide stimulate aggression in female *Drosophila*. *Nat Ecol Evol* 1, 1–6. doi:10.1038/s41559-017-0154.

Becher, P. G., Bengtsson, M., Hansson, B. S., and Witzgall, P. (2010). Flying the fly: long-range flight behaviour of *Drosophila melanogaster* to attractive odours. *J Chem Ecol* 36, 599–607. doi:10.1007/s10886-010-9794-2.

Becher, P. G., Flick, G., Rozpędowska, E., Schmidt, A., Hagman, A., Lebreton, S., et al. (2012). Yeast, not fruit volatiles mediate *Drosophila melanogaster* attraction, oviposition and development. *Funct Ecol* 26, 822–828. doi:10.1111/j.1365-2435.2012.02006.x.

Bellen, H. J., and Kiger, J. A., Jr (1987). Sexual hyperactivity and reduced longevity of *dunce* females of *Drosophila melanogaster*. *Genetics* 115, 153–160.

Benton, R., Sachse, S., Michnick, S. W., and Vosshall, L. B. (2006). Atypical membrane topology and heteromeric function of *Drosophila* odorant receptors in vivo. *PLoS Biol* 4, e20–19. doi:10.1371/journal.pbio.0040020.

Benton, R., Vannice, K. S., Gomez-Diaz, C., and Vosshall, L. B. (2009). Variant ionotropic glutamate receptors as chemosensory receptors in *Drosophila*. *Cell* 136, 149–162. doi:10.1016/j.cell.2008.12.001.

Bhalerao, S., Sen, A., Stocker, R., and Rodrigues, V. (2003). Olfactory neurons expressing identified receptor genes project to subsets of glomeruli within the antennal lobe of *Drosophila melanogaster*. *J. Neurobiol.* 54, 577–592. doi:10.1002/neu.10175.

Bialecki, M., Shilton, A., Fichtenberg, C., Segraves, W. A., and Thummel, C. S. (2002). Loss of the ecdysteroid-inducible E75A orphan nuclear receptor uncouples molting from metamorphosis in *Drosophila*. *Dev Cell* 3, 209–220. doi:10.1016/S1534-5807(02)00204-6.

Billeter, J. C., Jagadeesh, S., Stepek, N., Azanchi, R., and Levine, J. D. (2012). *Drosophila melanogaster* females change mating behaviour and offspring production based on social context. *P Roy Soc B-Biol Sci* 279, 2417–2425. doi:10.1098/rspb.2011.2676.

Billeter, J.-C., and Levine, J. D. (2013). Who is he and what is he to you? Recognition in *Drosophila melanogaster*. *Curr Opin Neurobiol* 23, 17–23. doi:10.1016/j.conb.2012.08.009.

Billeter, J.-C., Atallah, J., Krupp, J. J., Millar, J. G., and Levine, J. D. (2009). Specialized cells tag sexual and species identity in *Drosophila melanogaster*. *Nature* 461, 987–991. doi:10.1038/nature08495.

Bleu, J., Bessa-Gomes, C., and Laloi, D. (2012). Evolution of female choosiness and mating frequency: effects of mating cost, density and sex ratio. *Anim Behav* 83, 131–136. doi:10.1016/j.anbehav.2011.10.017.

Bownes, M., Scott, A., and Shirras, A. (1988). Dietary components modulate yolk protein gene transcription in *Drosophila melanogaster*. *Development* 103, 119–128.

Brand, A. H., and Perrimon, N. (1993). Targeted gene expression as a means of altering cell fates and generating dominant phenotypes. *Development* 118, 401–415.

Bretman, A., Fricke, C., and Chapman, T. (2009). Plastic responses of male *Drosophila melanogaster* to the level of sperm competition increase male reproductive fitness. *P Roy Soc B-Biol Sci* 276, 1705–1711. doi:10.1098/rspb.2008.1878.

Bretman, A., Lawniczak, M. K. N., Boone, J., and Chapman, T. (2010). A mating plug protein reduces early female remating in *Drosophila melanogaster*. *J Insect Physiol* 56, 107–113. doi:10.1016/j.jinsphys.2009.09.010.

Bretman, A., Westmancoat, J. D., Gage, M. J. G., and Chapman, T. (2011). Males Use Multiple, Redundant Cues to Detect Mating Rivals. *Curr Biol* 21, 617–622. doi:10.1016/j.cub.2011.03.008.

Bronson, F. H. (1985). Mammalian reproduction: an ecological perspective. *Biol Reprod*, 1–26.

Brown, E. B., Layne, J. E., Zhu, C., Jegga, A. G., and Rollmann, S. M. (2013). Genome-wide association mapping of natural variation in odour-guided behaviour in *Drosophila*. *Genes Brain Behav* 12, 503–515. doi:10.1111/gbb.12048.

Burke, A. R., McCormick, C. M., Pellis, S. M., and Lukkes, J. L. (2017). Impact of adolescent social experiences on behaviour and neural circuits implicated in mental illnesses. *Neurosci Biobehav R* 76, 280–300. doi:10.1016/j.neubiorev.2017.01.018.

Burke, C. J., and Waddell, S. (2011). Remembering nutrient quality of sugar in *Drosophila*. *Curr Biol* 21, 746–750. doi:10.1016/j.cub.2011.03.032.

Bussell, J. J., Yapici, N., Zhang, S. X., Dickson, B. J., and Vosshall, L. B. (2014). Abdominal-B neurons control *Drosophila* virgin female receptivity. *Curr Biol* 24, 1584–1595. doi:10.1016/j.cub.2014.06.011.

Buszczak, M., Freeman, M. R., Carlson, J. R., Bender, M., Cooley, L., and Segraves, W. A. (1999). Ecdysone response genes govern egg chamber development during mid-oogenesis in *Drosophila*. *Development* 126, 4581–4589.

C

Cacioppo, J. T., Hawkley, L. C., and Thisted, R. A. (2010). Perceived social isolation makes me sad: 5-year cross-lagged analyses of loneliness and depressive symptomatology in the Chicago Health, Aging, and Social Relations Study. *Psychol Aging* 25, 453–463. doi:10.1037/a0017216.

Chapman, T., and Partridge, L. (1996). Female fitness in *Drosophila melanogaster*: an interaction between the effect of nutrition and of encounter rate with males. *P Roy Soc B-Biol Sci*, 755–759.

Chapman, T., Bangham, J., Vinti, G., Seifried, B., Lung, O., Wolfner, M. F., et al. (2003). The sex peptide of *Drosophila melanogaster*: Female post-mating responses analysed by using RNA interference. *Proc Natl Acad Sci USA* 100, 9923–9928.

Chapman, T., Liddle, L. F., Kalb, J. M., Wolfner, M. F., and Partridge, L. (1995). Cost of mating in Drosophila melanogaster females is mediated by male accessory gland products. *Nature* 373, 241–244. doi:10.1038/373241a0.

Chen, P. S., Stumm-Zollinger, E., Aigaki, T., Balmer, J., Bienz, M., and Böhlen, P. (1988). A male accessory gland peptide that regulates reproductive behaviour of female D. melanogaster. *Cell* 54, 291–298. doi:10.1016/0092-8674(88)90192-4.

Chintapalli, V. R., Wang, J., and Dow, J. A. T. (2007). Using FlyAtlas to identify better *Drosophila melanogaster* models of human disease. *Nat Genet* 39, 715–720. doi:10.1038/ng2049.

Chow, C. Y., Wolfner, M. F., and Clark, A. G. (2013). Large neurological component to genetic differences underlying biased sperm use in *Drosophila*. *Genetics* 193, 177–185. doi:10.1534/genetics.112.146357/-/DC1.

Clark, A. G., Aguade, M., Prout, T., Harshman, L. G., and Langley, C. H. (1995). Variation in sperm displacement and tis association with accessory gland protein loci in *Drosophila melanogaster*. *Genetics* 139, 189–201.

Conolly, J. B., Roberts, I. J. H., Armstrong, D., Kaiser, K., Forte, M., Tully, T., et al. (1996).

Associative learning disrupted by impaired Gs signalling in *Drosophila* mushroom bodies. *Science* 274, 2104–2107.

Couto, A., Alenius, M., and Dickson, B. J. (2005). Molecular, anatomical, and functional organization of the *Drosophila* olfactory system. *Curr Biol* 15, 1535–1547. doi:10.1016/j.cub.2005.07.034.

Côté, I. M., and Poulin, R. (1995). Parasitism and group size in social animals: a meta-analysis. *Behav Ecol* 6, 159–165.

Crickmore, M. A., and Vosshall, L. B. (2013). Opposing dopaminergic and GABAergic neurons control the duration and persistence of copulation in *Drosophila*. *Cell* 155, 881–893. doi:10.1016/j.cell.2013.09.055.

D

Davis, R. L. (1993). Mushroom bodies and *Drosophila* learning. *Neuron* 11, 1–14.

Day, J. P., Dow, J. A. T., Houslay, M. D., and Davies, S.-A. (2005). Cyclic nucleotide phosphodiesterases in *Drosophila melanogaster*. *Biochem. J.* 388, 333–342. doi:10.1042/BJ20050057.

de Jong, G. (1995). Phenotypic plasticity as a product of selection in a variable environment. *Am Nat* 145, 493–512. doi:10.1086/285752.

de Miera, C. S., Monecke, S., Bartzen-Sprauer, J., Laran-Chich, M.-P., Pévet, P., Hazlerigg, D. G., et al. (2014). A circannual clock drives expression of genes central for seasonal reproduction. *Curr Biol* 24, 1500–1506. doi:10.1016/j.cub.2014.05.024.

Dembeck, L. M., Böröczky, K., Huang, W., Schal, C., Anholt, R. R. H., and Mackay, T. F. C. (2015). Genetic architecture of natural variation in cuticular hydrocarbon composition in *Drosophila melanogaster*. *eLife*, 1–27. doi:10.7554/eLife.09861.001.

Denis, B., Claisse, G., Le Rouzic, A., Wicker-Thomas, C., Lepennetier, G., and Joly, D. (2017). Male accessory gland proteins affect differentially female sexual receptivity and remating in closely related *Drosophila* species. *J Insect Physiol* 99, 67–77. doi:10.1016/j.jinsphys.2017.03.008.

Dickson, B. J. (2008). Wired for sex: The neurobiology of *Drosophila* mating decisions. *Schience* 322, 904–909. doi:10.1126/science.1159276.

Dietzl, G., Chen, D., Schnorrer, F., Su, K.-C., Barinova, Y., Fellner, M., et al. (2007). A genome-wide transgenic RNAi library for conditional gene inactivation in *Drosophila*. *Nature* 448, 151–156. doi:10.1038/nature05954.

Dukas, R., and Jongsma, K. (2012). Costs to females and benefits to males from forced copulations in fruit flies. *Anim Behav* 84, 1177–1182. doi:10.1016/j.anbehav.2012.08.021.

Dukas, R., and Scott, A. (2015). Fruit fly courtship: The female perspective. *Curr Zool* 61, 1008–1014. doi:10.1093/czoolo/61.6.1008.

Duménil, C., Woud, D., Pinto, F., Alkema, J. T., Jansen, I., Van Der Geest, A. M., et al. (2016). Pheromonal cues deposited by mated females convey social information about egg-Laying sites in *Drosophila Melanogaster*. *J Chem Ecol* 42, 259–269. doi:10.1007/s10886-016-0681-3.

Dweck, H. K. M., Ebrahim, S. A. M., Farhan, A., Hansson, B. S., and Stensmyr, M. C. (2015a). Olfactory proxy detection of dietary antioxidants in *Drosophila*. *Curr Biol* 25, 455–466. doi:10.1016/j.cub.2014.11.062.

Dweck, H. K. M., Ebrahim, S. A. M., Thoma, M., Mohamed, A. A. M., Keesey, I. W., Trona, F., et al. (2015b). Pheromones mediating copulation and attraction in *Drosophila*. *Proc Natl Acad Sci USA*, 201504527–7. doi:10.1073/pnas.1504527112.

E

Ejima, A., and Griffith, L. C. (2011). Assay for courtship suppression in *Drosophila*. *Cold Spring Harb Prot* 2011, pdb.prot5575–pdb.prot5575. doi:10.1101/pdb.prot5575.

Ellis, L. B., and Kessler, S. (1975). Differential posteclosion housing experiences and reproduction in *Drosophila*. *Anim Behav* 23, 949–952.

Etienne, R., Wertheim, B., Hemerik, L., Schneider, P., and Powell, J. (2002). The interaction between dispersal, the Allee effect and scramble competition affects population dynamics. *Ecol Model* 148, 153–168. doi:10.1016/S0304-3800(01)00417-3.

Everaerts, C., Farine, J.-P., Cobb, M., and Ferveur, J.-F. (2010). *Drosophila* cuticular hydrocarbons revisited: mating status alters cuticular profiles. *PLoS ONE* 5, e9607–12. doi:10.1371/journal.pone.0009607.

F

Fabre, C. C. G., Hedwig, B., Conduit, G., Lawrence, P. A., Goodwin, S. F., and Casal, J. (2012). Substrate-borne vibratory communication during courtship in *Drosophila melanogaster*. *Curr Biol* 22, 2180–2185. doi:10.1016/j.cub.2012.09.042.

Farine, J.-P., Ferveur, J.-F., and Everaerts, C. (2012). Volatile *Drosophila* cuticular pheromones are affected by social but not sexual experience. *PLoS ONE* 7, e40396–11. doi:10.1371/journal.pone.0040396.

Fedorka, K. M., Linder, J. E., Winterhalter, W., and Promislow, D. (2007). Post-mating disparity between potential and realized immune response in *Drosophila melanogaster*. *P Roy Soc B-Biol Sci* 274, 1211–1217. doi:10.1098/rspb.2006.0394.

Feng, K., Palfreyman, M. T., Häsemeyer, M., Talsma, A., and Dickson, B. J. (2014). Ascending SAG neurons control sexual receptivity of *Drosophila* females. *Neuron* 83, 135–148. doi:10.1016/j.neuron.2014.05.017.

Fernández, M. de L. P., Chan, Y.-B., Yew, J. Y., Billeter, J.-C., Dreisewerd, K., Levine, J. D., et al. (2010). Pheromonal and behavioural cues trigger male-to-female aggression in *Drosophila*. *PLoS Biol* 8, e1000541–11. doi:10.1371/journal.pbio.1000541.

Fernández, M. P., and Kravitz, E. A. (2013). Aggression and courtship in *Drosophila*: pheromonal communication and sex recognition. *J Comp Physiol A Neuroethol Sens Neural Behav Physiol* 199, 1065–1076. doi:10.1007/s00359-013-0851-5.

Ferveur, J.-F. (1997). The pheromonal role of cuticular hydrocarbons in *Drosophila melanogaster*. *BioEssays* 19, 353–358.

Ferveur, J.-F., Störtkuhl, K. F., Stocker, R., and Greenspan, R. J. (1995). Genetic feminization of brain structures and changes sexual orientation in male *Drosophila*. *Science* 267, 902–905.

Fishilevich, E., and Vosshall, L. B. (2005). Genetic and functional subdivision of the *Drosophila* antennal lobe. *Curr Biol* 15, 1548–1553. doi:10.1016/j.cub.2005.07.066.

Fleischmann, I., Cotton, B., Choffat, Y., Spengler, M., and Kubli, E. (2001). Mushroom bodies and post-mating behaviours of *Drosophila melanogaster* females. *J Neurogenet* 15, 117–144. doi:10.3109/01677060109066198.

Frank, S. A. (2007). All of life is social. *Curr Biol* 17, R648–R650. doi:10.1016/j.cub.2007.06.005.

Franssen, S. U., Nolte, V., Tobler, R., and Schlötterer, C. (2015). Patterns of linkage disequilibrium and long range hitchhiking in evolving experimental *Drosophila melanogaster* populations. *Mol Biol Evol* 32, 495–509. doi:10.1093/molbev/msu320.

Fricke, C., Bretman, A., and Chapman, T. (2010). Female nutritional status determines the magnitude and sign of responses to a male ejaculate signal in *Drosophila melanogaster*. *J Evolution Biol* 23, 157–165. doi:10.1111/j.1420-9101.2009.01882.x.

Fricke, C., Green, D., Mills, W. E., and Chapman, T. (2013). Age-dependent female responses to a male ejaculate signal alter demographic opportunities for selection. *P Roy*

Soc B-Biol Sci 280, 20130428–20130428. doi:10.1098/rspb.2013.0428.

Fujita, M., and Tanimura, T. (2011). Drosophila evaluates and learns the nutritional value of sugars. *Curr Biol* 21, 751–755. doi:10.1016/j.cub.2011.03.058.

Fukui, H. H., and Gromko, M. H. (1991a). Genetic basis for remating in *Drosophila melanogaster*. IV. A chromosome substitution analysis. *Behav Genet* 21, 169–182.

Fukui, H. H., and Gromko, M. H. (1991b). Genetic basis for remating in *Drosophila melanogaster*. V. Biometrical and planned comparisons analyses. *Behav Genet* 21, 183–197.

Fukui, H. H., and Gromko, M. H. (1991c). Genetic basis for remating in *Drosophila melanogaster*. VI. Recombination analysis. *Behav Genet* 21, 199–209.

G

Gaertner, B. E., Ruedi, E. A., McCoy, L. J., Moore, J. M., Wolfner, M. F., and Mackay, T. F. C. (2015). Heritable variation in courtship patterns in *Drosophila melanogaster*. *G3-Genes Genom Genet* 5, 531–539. doi:10.1534/g3.114.014811/-/DC1.

Ganguly, A., and Lee, D. (2013). Suppression of inhibitory GABAergic transmission by cAMP signalling pathway: alterations in learning and memory mutants. *Eur J Neurosci* 37, 1383–1393. doi:10.1111/ejn.12144.

Garbaczewska, M., Billeter, J.-C., and Levine, J. D. (2013). *Drosophila melanogaster* males increase the number of sperm in their ejaculate when perceiving rival males. *J Insect Physiol* 59, 306–310. doi:10.1016/j.jinsphys.2012.08.016.

Garlapow, M. E., Huang, W., Yarboro, M. T., Peterson, K. R., and Mackay, T. F. C. (2015). Quantitative genetics of food intake in *Drosophila melanogaster*. *PLoS ONE* 10, e0138129–25. doi:10.1371/journal.pone.0138129.

Giardina, T. J., Beavis, A., Clark, A. G., and Fiumera, A. C. (2011). Female influence on pre- and post-copulatory sexual selection and its genetic basis in *Drosophila melanogaster*. *Mol Ecol* 20, 4098–4108. doi:10.1111/j.1365-294X.2011.05253.x.

Giardina, T. J., Clark, A. G., and Fiumera, A. C. (2017). Estimating mating rates in wild *Drosophila melanogaster* females by decay rates of male reproductive proteins in their reproductive tracts. *Mol Ecol Resour* 38, 42–49. doi:10.1111/ijlh.12426.

Golovin, R. M., and Broadie, K. (2016). Developmental experience-dependent plasticity in the first synapse of the *Drosophila* olfactory circuit. *J Neurophysiol* 116, 2730–2738. doi:10.1152/jn.00616.2016.

Goncharova, A. A., Bragina, Y. V., Fedotov, S. A., and Kamyshev, N. G. (2016). Influence of group rearing on sexual behaviour of *Drosophila melanogaster* males. *J Evol Biochem Phys* 52, 454–462. doi:10.1134/S1234567816060045.

Good, T. P., and Tatar, M. (2001). Age-specific mortality and reproduction respond to adult dietary restriction in Drosophila melanogaster. *J Insect Physiol* 47, 1467–1473. doi:10.1016/S0022-1910(01)00138-X.

Gordesky-Gold, B., Rivers, N., Ahmed, O. M., and Breslin, P. A. S. (2008). *Drosophila melanogaster* prefers compounds perceived sweet by humans. *Chem Senses* 33, 301–309. doi:10.1093/chemse/bjm088.

Gorter, J. A., and Billeter, J.-C. (2017). A method to test the effect of environmental cues on mating behaviour in *Drosophila melanogaster*. *J Vis Exp*, 1–9. doi:10.3791/55690.

Gorter, J. A., Jagadeesh, S., Gahr, C., Boonekamp, J. J., Levine, J. D., and Billeter, J.-C. (2016). The nutritional and hedonic value of food modulate sexual receptivity in *Drosophila melanogaster* females. *Sci Rep*, 1–10. doi:10.1038/srep19441.

Gowaty, P. A., Kim, Y. K., Rawlings, J., and Anderson, W. W. (2010). Polyandry increases offspring viability and mother productivity but does not decrease mother survival in *Drosophila pseudoobscura*. *Proc Natl Acad Sci USA* 107, 13771–13776. doi:10.1073/pnas.1006174107.

Göpfert, M. C., and Robert, D. (2001). Turning the key on Drosophila audition. *Nature* 411, 908.

Göpfert, M. C., and Robert, D. (2002). Auditory mechanics of Drosophila melanogaster. *J Exp Biol*, 1199–1208.

Grillet, M., Dartevelle, L., and Ferveur, J.-F. (2006). A *Drosophila* male pheromone affects female sexual receptivity. *P Roy Soc B-Biol Sci* 273, 315–323. doi:10.1098/rspb.2005.3332.

Gromko, M. H., and Newport, M. E. A. (1988a). Genetic basis for remating in *Drosophila melanogaster*. II. Response to selection based on the behaviour of one sex. *Behav Genet* 18, 621–632.

Gromko, M. H., and Newport, M. E. A. (1988b). Genetic basis for remating in *Drosophila melanogaster*. III. Correlated responses to selection for female remating speed. *Behav Genet* 18, 633–643.

Grosjean, Y., Rytz, R., Farine, J.-P., Abuin, L., Cortot, J., Jefferis, G. S. X. E., et al. (2011). An olfactory receptor for food-derived odours promotes male courtship in *Drosophila*. *Nature* 478, 236–240. doi:10.1038/nature10428.

Guiraudie-Capraz, G., Pho, D. B., and Jallon, J.-M. (2007). Role of the ejaculatory bulb in

biosynthesis of the male pheromone cis-vaccenyl acetate in *Drosophila melanogaster*. *Integr Zool* 2, 89–99. doi:10.1111/j.1749-4877.2007.00047.x.

H

Hall, J. C. (1994). The mating of a fly. *Science* 264, 1702–1714.

Harshman, L. G., Hoffman, A. A., and Prout, T. (1988). Environmental effects on remating in *Drosophila melanogaster*. *Evolution* 42, 312–321.

Haussmann, I. U., Hemani, Y., Wijesekera, T., Dauwalder, B., and Soller, M. (2013). Multiple pathways mediate the sex-peptide-regulated switch in female *Drosophila* reproductive behaviours. *Proc*. *Biol*. *Sci*. 280, 20131938–20131938. doi:10.1098/rspb.2013.1938.

Hawkley, L. C., and Capitanio, J. P. (2015). Perceived social isolation, evolutionary fitness and health outcomes: a lifespan approach. *Phil Trans R Soc B* 370, 20140114–20140114. doi:10.1098/rstb.2014.0114.

Häsemeyer, M., Yapici, N., Heberlein, U., and Dickson, B. J. (2009). Sensory neurons in the *Drosophila* genital tract regulate female reproductive behaviour. *Neuron* 61, 511–518. doi:10.1016/j.neuron.2009.01.009.

Heifetz, Y., Vandenberg, L. N., Cohn, H. I., and Wolfner, M. F. (2005). Two cleavage products of the *Drosophila* accessory gland protein ovulin can independently induce ovulation. *Proc Natl Acad Sci USA* 102, 743–748. doi:10.1073/pnas.0407692102.

Heimbeck, G., Bugnon, V., Gendre, N., Keller, A., and Stocker, R. F. (2001). A central neural circuit for experience-independent olfactory and courtship behaviour in *Drosophila* melanogaster. *Proc Natl Acad Sci USA* 98, 15336–15341. doi:10.1073/pnas.011314898.

Heisenberg, M. (2003). Mushroom body memoir: from maps to models. *Nat Rev Neurosci* 4, 266–275. doi:10.1038/nrn1074.

Herndon, L. A., and Wolfner, M. F. (1995). A *Drosophila* seminal fluid protein, Acp26Aa, stimulates egg laying in females for 1 day after mating. *Proc Natl Acad Sci USA* 92, 10114–10118. doi:10.1073/pnas.92.22.10114.

Hileman, S. M., Pierroz, D. D., and Flier, J. S. (2000). Leptin, nutrition, and reproduction: timing is everything. *J Clin Endocr Metab* 85, 804–807.

Hoffman, A. A. (1990). The influences of age and experience with conspecifics on territorial behaviour in *Drosophila melanogaster*. *J Insect Behav* 3, 1–12.

Holman, L., and Kokko, H. (2013). The consequences of polyandry for population viability, extinction risk and conservation. *Philos. Trans. R. Soc. Lond., B, Biol. Sci.* 368, 20120053–20120053. doi:10.1098/rstb.2012.0053.

Huang, W., Massouras, A., Inoue, Y., Peiffer, J., Ramia, M., Tarone, A. M., et al. (2014). Natural variation in genome architecture among 205 *Drosophila melanogaster* Genetic Reference Panel lines. *Genome Res* 24, 1193–1208. doi:10.1101/gr.171546.113.

Hussain, A., Üçpunar, H. K., Zhang, M., Loschek, L. F., and Grunwald Kadow, I. C. (2016). Neuropeptides modulate female chemosensory processing upon mating in *Drosophila*. *PLoS Biol* 14, e1002455–28. doi:10.1371/journal.pbio.1002455.

I

Ihara, K., Masuda, T., Yamamoto, T., Iwata, I., Takahashi, A., Awata, H., et al. (2016). Shifting transcriptional machinery is required for long-term memory maintenance and modification in *Drosophila* mushroom bodies. *Nat Commun* 7, 1–14. doi:10.1038/ncomms13471.

Imhof, M., Harr, B., Brem, G., and Schlötterer, C. (1998). Multiple mating in wild *Drosophila melanogaster* revisited by microsatellite analysis. *Mol Ecol*, 915–917.

Ivanov, D. K., Escott-Price, V., Ziehm, M., Magwire, M. M., Mackay, T. F. C., Partridge, L., et al. (2015). Longevity GWAS Using the *Drosophila* Genetic Reference Panel. *GERONA* 70, 1470–1478. doi:10.1093/gerona/glv047.

J

Jallon, J.-M. (1984). A few chemical words exchanged by *Drosophila* during courtship and mating. *Behav Genet* 14, 441–478. doi:10.1007/BF01065444.

Jefferis, G. S. X. E., Potter, C. J., Chan, A. M., Marin, E. C., Rohlfing, T., Maurer, C. R., Jr, et al. (2007). Comprehensive maps of *Drosophila* higher olfactory centers: Spatially segregated fruit and pheromone representation. *Cell* 128, 1187–1203. doi:10.1016/j.cell.2007.01.040.

Jenett, A., Rubin, G. M., Ngo, T.-T. B., Shepherd, D., Murphy, C., Dionne, H., et al. (2012). A GAL4-driver line resource for *Drosophila* neurobiology. *Cell Rep* 2, 991–1001. doi:10.1016/j.celrep.2012.09.011.

Jennions, M. D., and Petrie, M. (2000). Why do females mate multiply? A review of the

genetic benefits. *Biol Rev* 75, 21–64.

Jiao, Y., Moon, S. J., and Montell, C. (2007). A *Drosophila* gustatory receptor required for the responses to sucrose, glucose, and maltose identified by mRNA tagging. *Proc Natl Acad Sci USA* 104, 14110–14115. doi:10.1073/pnas.0702421104.

Johnston, D. M., Sedkov, Y., Petruk, S., Riley, K. M., Fujioka, M., Jaynes, J. B., et al. (2011). Ecdysone- and NO-mediated gene regulation by competing EcR/Usp and E75A nuclear receptors during *Drosophila* development. *Mol Cell* 44, 51–61. doi:10.1016/j.molcel.2011.07.033.

Jory, A., Estella, C., Giorgianni, M. W., Slattery, M., Laverty, T. R., Rubin, G. M., et al. (2012). A Survey of 6,300 genomic fragments for cis-regulatory activity in the imaginal discs of *Drosophila melanogaster*. *Cell Rep* 2, 1014–1024. doi:10.1016/j.celrep.2012.09.010.

Joseph, R. M., Devineni, A. V., King, I. F. G., and Heberlein, U. (2009). Oviposition preference for and positional avoidance of acetic acid provide a model for competing behavioural drives in *Drosophila*. *Proc Natl Acad Sci USA* 106, 11352–11357. doi:10.1073/pnas.0901419106.

K

Kalb, J. M., DiBenedetto, A. J., and Wolfner, M. F. (1993). Probing the function of *Drosophila melanogaster* accessory glands by directed cell ablation. *Proc Natl Acad Sci USA* 90, 8093–8097.

Kamimura, Y. (2007). Twin intromittent organs of *Drosophila* for traumatic insemination. *Biol Lett* 3, 401–404. doi:10.1098/rsbl.2007.0192.

Kawahara, A. Y., Orr, A. G., and Carvalho, A. P. S. (2017). A review of the occurrence and diversity of the sphragis in butterflies (*Lepidoptera, Papilionoidea*). *ZooKeys* 694, 41–70. doi:10.3897/zookeys.694.13097.

Keesey, I. W., Koerte, S., Retzke, T., Haverkamp, A., Hansson, B. S., and Knaden, M. (2016). Adult frass provides a pheromone signature for *Drosophila* feeding and aggregation. *J Chem Ecol*, 1–9. doi:10.1007/s10886-016-0737-4.

Kim, S. E., Coste, B., Chadha, A., Cook, B., and Patapoutian, A. (2012a). The role of *Drosophila Piezo* in mechanical nociception. *Nature* 483, 209–2012. doi:10.1038/nature10801.

Kim, W. J., Jan, L. Y., and Jan, Y.-N. (2012b). Contribution of visual and circadian neural circuits to memory for prolonged mating induced by rivals. *Nat Neurosci*, 1–9.

doi:10.1038/nn.3104.

Kim, Y.-K., and Ehrman, L. (1998). Developmental isolation and subsequent adult behaviour of *Drosophila paulistorum*. IV. Courtship. *Behav Genet* 28, 57–65.

Kim, Y.-K., Ehrman, L., and Koepfer, H. R. (1992). Developmental isolation and subsequent adult behaviour of *Drosophila paulistorum*. I. Survey of the six semispecies. *Behav Genet* 22, 545–556.

Kim, Y.-K., Phillips, D. R., Chao, T., and Ehrman, L. (2004). Developmental isolation and subsequent adult behaviour of *Drosophila paulistorum*. VI. Quantitative variation in cuticular hydrocarbons. *Behav Genet* 34, 385–394.

Kokko, H., and Mappes, J. (2005). Sexual selection when fertilization is not guaranteed. *Evolution* 59, 1876–1885.

Kokko, H., and Mappes, J. (2012). Multiple mating by females is a natural outcome of a null model of mate encounters. *Entomol Exp Appl* 146, 26–37. doi:10.1111/j.1570-7458.2012.01296.x.

Kondoh, Y., Kaneshiro, K. Y., Kimura, K., and Yamamoto, D. (2003). Evolution of sexual dimorphism in the olfactory brain of Hawaiian *Drosophila*. *P Roy Soc B-Biol Sci* 270, 1005–1013. doi:10.1098/rspb.2003.2331.

Krupp, J. J., Billeter, J.-C., Wong, A., Choi, C., Nitabach, M. N., and Levine, J. D. (2013). Pigment-dispersing factor modulates pheromone production in clock cells that influence mating in *Drosophila*. *Neuron* 79, 54–68. doi:10.1016/j.neuron.2013.05.019.

Krupp, J. J., Kent, C., Billeter, J.-C., Azanchi, R., So, A. K. C., Schonfeld, J. A., et al. (2008). Social experience modifies pheromone expression and mating behaviour in male *Drosophila melanogaster*. *Curr Biol* 18, 1373–1383. doi:10.1016/j.cub.2008.07.089.

Kubli, E., and Bopp, D. (2012). Sexual behaviour: how Sex peptide flips the postmating switch of female flies. *Curr Biol* 22, R520–R522. doi:10.1016/j.cub.2012.04.058.

Kuijper, B., and Morrow, E. H. (2009). Direct observation of female mating frequency using time-lapse photography. *Fly* 3, 118–120. doi:10.4161/fly.8053.

Kuijper, B., Stewart, A. D., and Rice, W. R. (2006). The cost of mating rises nonlinearly with copulation frequency in a laboratory population of *Drosophila melanogaster*. *J Evolution Biol* 19, 1795–1802. doi:10.1111/j.1420-9101.2006.01186.x.

Kurtovic, A., Widmer, A., and Dickson, B. J. (2007). A single class of olfactory neurons mediates behavioural responses to a *Drosophila* sex pheromone. *Nature* 446, 542–546. doi:10.1038/nature05672.

L

Larsson, M. C., Domingos, A. I., Jones, W. D., Chiappe, M. E., Amrein, H., and Vosshall, L. B. (2004). Or83b encodes a broadly expressed odorant receptor essential for *Drosophila* olfaction. *Neuron* 43, 703–714. doi:10.1016/j.neuron.2004.08.019.

Lasbleiz, C., Ferveur, J.-F., and Everaerts, C. (2006). Courtship behaviour of *Drosophila* melanogaster revisited. *Anim Behav* 72, 1001–1012. doi:10.1016/j.anbehav.2006.01.027.

Laturney, M., and Billeter, J.-C. (2014). Neurogenetics of female reproductive behaviours in *Drosophila melanogaster*. *Adv Genet* 85, 1–108. doi:10.1016/B978-0-12-800271-1.00001-9.

Laturney, M., and Billeter, J.-C. (2016). *Drosophila melanogaster* females restore their attractiveness after mating by removing male anti-aphrodisiac pheromones. *Nat Commun* 7, 1–11. doi:10.1038/ncomms12322.

Lawniczak, M. K., and Begun, D. J. (2004). A genome-wide analysis of courting and mating responses in *Drosophila melanogaster* females. *Genome* 47, 900–910. doi:10.1139/g04-050.

Lebreton, S. B., Becher, P. G., Hansson, B. S., and Witzgall, P. (2012). Attraction of *Drosophila melanogaster* males to food-related and fly odours. *J Insect Physiol* 58, 125–129. doi:10.1016/j.jinsphys.2011.10.009.

Lebreton, S., Borrero-Echeverry, F., Gonzalez, F., Solum, M., Wallin, E. A., Hedenström, E., et al. (2017a). A *Drosophila* female pheromone elicits species-specific long-range attraction via an olfactory channel with dual specificity for sex and food. *BCM Biol*, 1–14. doi:10.1186/s12915-017-0427-x.

Lebreton, S., Carlsson, M. A., and Witzgall, P. (2017b). Insulin signalling in the peripheral and central nervous system regulates female sexual receptivity during starvation in *Drosophila*. *Front Physiol* 8, 2397–10. doi:10.3389/fphys.2017.00685.

Lebreton, S., Grabe, V., Omondi, A. B., Ignell, R., Becher, P. G., Hansson, B. S., et al. (2014). Love makes smell blind: mating suppresses pheromone attraction in *Drosophila* females via Or65a olfactory neurons. *Sci Rep* 4, 7119–6. doi:10.1038/srep07119.

Lee, K. P., Simpson, S. J., Clissold, F. J., Brooks, R., Ballard, J., Taylor, P. W., et al. (2008). Lifespan and reproduction in *Drosophila*: New insights from nutritional geometry. *Proc Natl Acad Sci USA* 105, 2498–2503.

Lee, K.-M., Daubnerová, I., Isaac, R. E., Zhang, C., Choi, S., Chung, J., et al. (2015). A neuronal pathway that controls sperm ejection and storage in female *Drosophila*. *Curr Biol* 25, 790–797. doi:10.1016/j.cub.2015.01.050.

Lefevre, G. J., and Jonsson, U. B. (1962). Sperm transfer, storage, displacement, and utilization in Drosophila melanogaster. *Genetics*, 1719–1736.

Letsinger, J. T., and Gromko, M. H. (1985). The role of sperm numbers in sperm competition and female remating in *Drosophila melanogaster*. *Genetica* 66, 195–202.

Li, H.-H., Kroll, J. R., Lennox, S. M., Ogundeyi, O., Jeter, J., Depasquale, G., et al. (2014). A GAL4 driver resource for developmental and behavioural studies on the larval CNS of *Drosophila*. *Cell Rep* 8, 897–908. doi:10.1016/j.celrep.2014.06.065.

Lin, C.-C., Prokop-Prigge, K. A., Preti, G., and Potter, C. J. (2015). Food odours trigger *Drosophila* males to deposit a pheromone that guides aggregation and female oviposition decisions. *eLife*, 1–26. doi:10.7554/eLife.08688.001.

Lin, H.-H., Cao, D.-S., Sethi, S., Zeng, Z., Chin, J. S. R., Chakraborty, T. S., et al. (2016). Hormonal modulation of pheromone detection enhances male courtship success. *Neuron*, 1–16. doi:10.1016/j.neuron.2016.05.004.

Linder, J. E., and Rice, W. R. (2005). Natural selection and genetic variation for female resistance to harm from males. *J Evolution Biol* 18, 568–575. doi:10.1111/j.1420-9101.2004.00872.x.

Liu, H., and Kubli, E. (2003). Sex-peptide is the molecular basis of the sperm effect in *Drosophila melanogaster*. *Proc Natl Acad Sci USA* 100, 9929–9933.

Liu, W., Liang, X., Gong, J., Yang, Z., Zhang, Y.-H., Zhang, J.-X., et al. (2011). Social regulation of aggression by pheromonal activation of Or65a olfactory neurons in *Drosophila*. *Nat Neurosci* 14, 896–902. doi:10.1038/nn.2836.

Liu, Y.-C., Pearce, M. W., Honda, T., Johnson, T. K., Charlu, S., Sharma, K. R., et al. (2014). The *Drosophila melanogaster* phospholipid flippase dATP8B as required for odorant receptor function. *PLoS genet* 10, e1004209–9. doi:10.1371/journal.pgen.1004209.

Liu, Z., Steward, R., and Luo, L. (2000). *Drosophila Lis1* is required for neuroblast proliferation, dendritic elaboration and axonal transport. *Nat Cell Biol* 2, 776–783.

Lof, M. E., de Gee, M., and Hemerik, L. (2009). Odour-mediated aggregation enhances the colonization ability of *Drosophila melanogaster*. *J Theor Biol* 258, 363–370. doi:10.1016/j.jtbi.2008.08.019.

Lone, S. R., Venkataraman, A., Srivastava, M., Potdar, S., and Sharma, V. K. (2015). Or47b-neurons promote male-mating success in *Drosophila*. *Biol Lett* 11, 20150292–5. doi:10.1098/rsbl.2015.0292.

Long, T. A. F., Pischedda, A., and Rice, W. R. (2010). Remating in *Drosophila melanogaster*: are indirect benefits condition dependent? *Evolution* 64, 2767–2774. doi:10.1111/j.1558-5646.2010.00997.x.

Lung, O., and Wolfner, M. F. (2001). Identification and characterization of the major *Drosophila melanogaster* mating plug protein. *Insect Biochem Molec* 31, 543–551. doi:10.1016/S0965-1748(00)00154-5.

Lüpold, S. (2013). Ejaculate quality and constraints in relation to sperm competition levels among eutherian mammals. *Evolution* 67, n/a–n/a. doi:10.1111/evo.12132.

M

Mack, P. D., Kapelnikov, A., Heifetz, Y., and Bender, M. (2006). Mating-responsive genes in reproductive tissues of female *Drosophila melanogaster*. *Proc Natl Acad Sci USA* 103, 10358–10363.

Mackay, T. F. C., and Huang, W. (2017). Charting the genotype-phenotype map: lessons from the *Drosophila melanogaster* Genetic Reference Panel. *WIREs Dev Biol* 52, e289–18. doi:10.1002/wdev.289.

Mackay, T. F. C., Richards, S., Stone, E. A., Barbadilla, A., Ayroles, J. F., Zhu, D., et al. (2012). The *Drosophila melanogaster* Genetic Reference Panel. *Nature* 482, 173–178. doi:10.1038/nature10811.

Manier, M. K., Belote, J. M., Berben, K. S., Novikov, D., Stuart, W. T., and Pitnick, S. (2010). Resolving mechanisms of competitve fertilization success in *Drosophila melanogaster*. *Science* 328, 354–357.

Manning, A. (1967). The control of sexual receptivity in female *Drosophila*. *Anim Behav* 15, 239–250.

Manning, L., Heckscher, E. S., Purice, M. D., Roberts, J., Bennett, A. L., Kroll, J. R., et al. (2012). A resource for manipulating gene expression and analyzing cis-regulatory modules in the *Drosophila* CNS. *Cell Rep* 2, 1002–1013. doi:10.1016/j.celrep.2012.09.009.

Markow, T. A. (1987). Behavioural and sensory basis of courtship success in *Drosophila melanogaster*. *Proc Natl Acad Sci USA* 64, 6200–6204.

Markow, T. A. (2011). “Cost” of virginity in wild *Drosophila melanogaster* females. *Ecol Evol* 1, 596–600. doi:10.1002/ece3.54.

Markow, T. A., and Hanson, S. J. (1981). Multivariate analysis of *Drosophila* courtship. *Proc Natl Acad Sci USA* 78, 430–434.

Marks, R. W., Seager, R. D., and Barr, L. G. (1988). Local ecology and multiple mating in a natural population of *Drosophila melanogaster*. *Am Nat* 131, 918–923.

doi:10.1086/284832.

Martin, J.-R., Ernst, R., and Heisenberg, M. (1998). Mushroom bodies suppress locomotor activity in *Drosophila melanogaster*. *Learn Memory*, 179–191.

McGraw, L. A., Gibson, G., Clark, A. G., and Wolfner, M. F. (2004). Genes regulated by mating, sperm, or seminal proteins in mated female *Drosophila melanogaster*. *Curr Biol* 14, 1509–1514. doi:10.1016/j.cub.2004.08.028.

Meunier, J. (2015). Social immunity and the evolution of group living in insects. *Phil Trans R Soc B* 370, 20140102–20140102. doi:10.1098/rstb.2014.0102.

Miyamoto, T., Slone, J., Song, X., and Amrein, H. (2012). A fructose receptor functions as a nutrient sensor in the *Drosophila* brain. *Cell* 151, 1113–1125. doi:10.1016/j.cell.2012.10.024.

Montell, C. (2012). *Drosophila* visual transduction. *Trend Neurosci* 35, 356–363. doi:10.1016/j.tins.2012.03.004.

Morley, E. L., Steinmann, T., Casas, J., and Robert, D. (2012). Directional cues in Drosophila melanogaster audition: structure of acoustic flow and inter-antennal velocity differences. *J Exp Biol* 215, 2405–2413. doi:10.1242/jeb.068940.

Mueller, J. L., Page, J. L., and Wolfner, M. F. (2007). An ectopic expression screen reveals the protective and toxic effects of *Drosophila* seminal fluid proteins. *Genetics* 175, 777–783. doi:10.1534/genetics.106.065318.

N

Nakagawa, S., and Cuthill, I. C. (2007). Effect size, confidence interval and statistical significance: a practical guide for biologists. *Biol Rev* 82, 591–605. doi:10.1111/j.1469-185X.2007.00027.x.

Neckameyer, W. S. (1998). Dopamine and mushroom bodies in *Drosophila*: Experience-dependent and -independent aspects of sexual Behaviour. *Learn Memory*, 157–165.

Neckameyer, W. S., and Matsuo, H. (2008). Distinct neural circuits reflect sex, sexual maturity, and reproductive status in response to stress in *Drosophila melanogaster*. *Neuroscience* 156, 841–856. doi:10.1016/j.neuroscience.2008.08.020.

Newport, M. E. A., and Gromko, M. H. (1984). The effect of experimental design on female receptivity to remating and its impact on reproductive succes in *Drosophila* melanogaster. *Evolution* 38, 1261–1272.

Nino, M., Ignatow, G., and Cai, T. (2016). Social Isolation, Strain, and Youth Violence. *Youth Violence Juv J*, 1–15. doi:10.1177/1541204016636435.

O

O'Dell, K., and Burnet, B. (1988). The effects on locomotor activity and reactivity of the *hypoactive* and *inactive* mutations of *Drosophila melanogaster*. *Heredity* 61, 199–207.

Ochando, M. D., Reyes, A., and Ayala, F. J. (1996). Multiple paternity in two natural populations (orchard and vineyard) of *Drosophila*. *Proc Natl Acad Sci USA* 93, 11769–11773.

OTousa, J. E., Baehr, W., Martin, R. L., Hirsh, J., Pak, W. L., and Applebury, M. L. (1985). The *Drosophila ninaE* gene encodes an opsin. *Cell* 40, 839–850.

Owald, D., and Waddell, S. (2015). Olfactory learning skews mushroom body output pathways to steer behavioural choice in *Drosophila*. *Curr Opin Neurobiol* 35, 178–184. doi:10.1016/j.conb.2015.10.002.

Owald, D., Felsenberg, J., Talbot, C. B., Das, G., Perisse, E., Huetteroth, W., et al. (2015). Activity of defined mushroom body output neurons underlies learned olfactory behaviour in *Drosophila*. *Neuron* 86, 417–427. doi:10.1016/j.neuron.2015.03.025.

P

Page, D. T. (2003). A function for Egf receptor signalling in expanding the developing vrain in *Drosophila*. *Curr Biol* 13, 474–482. doi:10.1016/S0960-9822(03)00094-0.

Parker, G. A., and Birkhead, T. R. (2013). Polyandry: the history of a revolution. *Phil Trans R Soc B* 368, 20120335–20120335. doi:10.1098/rstb.2012.0335.

Parker, G. A., and Pizzari, T. (2010). Sperm competition and ejaculate economics. *Biol Rev*, 897–897. doi:10.1111/j.1469-185x.2010.00140.x.

Partridge, L., and Harvey, P. H. (1988). The ecological context of life history evolution. *Science* 241, 1449–1455. doi:10.1126/science.241.4872.1449.

Patterson, J. E. H., and Ruckstuhl, K. E. (2013). Parasite infection and host group size: a meta-analytical review. *Parasitology* 140, 803–813. doi:10.1017/S0031182012002259.

Peng, J., Chen, S., Büsser, S., Liu, H., Honegger, T., and Kubli, E. (2005). Gradual release of

sperm bound sex-peptide controls female postmating behaviour in *Drosophila*. *Curr Biol* 15, 207–213. doi:10.1016/j.cub.2005.01.034.

Pfeiffer, B. D., Jenett, A., Hammonds, A. S., Ngo, T. T. B., Misra, S., Murphy, C., et al. (2008). Tools for neuroanatomy and neurogenetics in *Drosophila*. *Proc Natl Acad Sci USA* 105, 9715–9720. doi:10.1073/pnas.0803697105.

Piper, M. D. W., Blanc, E., Leitão-Gonçalves, R., Yang, M., He, X., Linford, N. J., et al. (2013). A holidic medium for *Drosophila melanogaster*. *Nat Meth* 11, 100–105. doi:10.1038/nmeth.2731.

Pitts, S., Pelser, E., Meeks, J., and Smith, D. (2016). Odorant responses and courtship behaviours influenced by at4 neurons in *Drosophila*. *PLoS ONE* 11, e0162761–15. doi:10.1371/journal.pone.0162761.

Priest, N. K., Roach, D. A., and Galloway, L. F. (2008). Cross-generational fitness benefits of mating and male seminal fluid. *Biol Lett* 4, 6–8. doi:10.1098/rsbl.2007.0473.

Pyle, D. W., and Gromko, M. H. (1981). Genetic basis for repeated mating in *Drosophila melanogaster*. *Am Nat* 117, 133–146.

Q

Qiu, Y., and Davis, R. L. (1993). Genetic dissection of the learning/memory gene *dunce* of *Drosophila melanogaster*. *Genes Dev* 7, 1447–1458.

R

Rahn, T., Leippe, M., Roeder, T., and Fedders, H. (2013). EGFR signalling in the brain is necessary for olfactory learning in *Drosophila* larvae. *Learn Mem* 20, 194–200. doi:10.1101/lm.029934.112.

Ram, K. R., and Wolfner, M. F. (2007). Sustained post-mating response in *Drosophila melanogaster* requires multiple seminal fluid proteins. *PLoS genet* 3, e238–11. doi:10.1371/journal.pgen.0030238.

Ram, K. R., and Wolfner, M. F. (2009). A network of interactions among seminal proteins underlies the long-term postmating response in *Drosophila*. *Proc Natl Acad Sci USA* 106, 15384–15389. doi:10.1073/pnas.0902923106.

Reuter, J. E., Nardine, T. M., Penton, A., Billuart, P., Scott, E. K., Usui, T., et al. (2003). A

mosaic genetic screen for genes necessary for *Drosophila* mushroom body neuronal morphogenesis. *Development* 130, 1203–1213. doi:10.1242/dev.00319.

Rexhepaj, A., Liu, H., Peng, J., Choffat, Y., and Kubli, E. (2003). The sex-peptide DUP99B is expressed in the male ejaculatory duct and in the cardia of both sexes. *Eur J Biochem* 270, 4306–4314. doi:10.1046/j.1432-1033.2003.03823.x.

Rezával, C., Pavlou, H. J., Dornan, A. J., Chan, Y.-B., Kravitz, E. A., and Goodwin, S. F. (2012). Neural circuitry underlying *Drosophila* female postmating behavioural responses. *Curr Biol*, 1–11. doi:10.1016/j.cub.2012.04.062.

Ribeiro, C. (2013). The dilemmas of the gourmet fly: the molecular and neuronal mechanisms of feeding and nutrient decision making in *Drosophila*. *Front Neurosci* 7, 1–13. doi:10.3389/fnins.2013.00012/abstract.

Ribeiro, C., and Dickson, B. J. (2010). Sex Peptide Receptor and neuronal TOR/S6K signalling modulate nutrient balancing in *Drosophila*. *Curr Biol* 20, 1000–1005. doi:10.1016/j.cub.2010.03.061.

Rice, W. R., Stewart, A. D., Morrow, E. H., Linder, J. E., Orteiza, N., and Byrne, P. G. (2006). Assessing sexual conflict in the *Drosophila melanogaster* laboratory model system. *Phil Trans R Soc B* 361, 287–299. doi:10.1098/rstb.2005.1787.

Ringo, J., Werczberger, R., Altaratz, M., and Segal, D. (1991). Female sexual receptivity is defective in juvenile hormone-deficient mutants of the *apterous* gene of *Drosophila melanogaster*. *Behav Genet* 21, 453–469.

Rohde, P. D., Gaertner, B., Ward, K., Sørensen, P., and Mackay, T. F. C. (2017). Genomic analysis of genotype-by-social environment Interaction for *Drosophila melanogaster* aggressive behaviour. *Genetics* 206, 1969–1984. doi:10.1534/genetics.117.200642.

Root, C. M., Masuyama, K., Green, D. S., Enell, L. E., Nässel, D. R., Lee, C.-H., et al. (2008). A presynaptic gain control mechanism fine-tunes olfactory behaviour. *Neuron* 59, 311–321. doi:10.1016/j.neuron.2008.07.003.

Rowe, L. (1992). Convenience polyandry in a water strider: foraging conflicts and female control of copulation frequency and guarding duration. *Anim Behav* 44, 189–202. doi:10.1016/0003-3472(92)90025-5.

Rybak, F., Sureau, G., and Aubin, T. (2002). Functional coupling of acoustic and chemical signals in the courtship behaviour of the male *Drosophila melanogaster*. *P Roy Soc B-Biol Sci* 269, 695–701. doi:10.1098/rspb.2001.1919.

S

Sakai, T., Kasuya, J., Kitamoto, T., and Aigaki, T. (2009). The *Drosophila* TRPA channel,

painless, regulates sexual receptivity in virgin females. *Genes Brain Behav* 8, 546–557. doi:10.1111/j.1601-183X.2009.00503.x.

Sakai, T., Watanabe, K., Ohashi, H., Sato, S., Inami, S., Shimada, N., et al. (2014). Insulin-producing cells regulate the sexual receptivity through the painless TRP channel in *Drosophila* virgin females. *PLoS ONE* 9, e88175–13. doi:10.1371/journal.pone.0088175.

Sakurai, A., Koganezawa, M., Yasunaga, K.-I., Emoto, K., and Yamamoto, D. (2013). Select interneuron clusters determine female sexual receptivity in *Drosophila*. *Nat Commun* 4, 1–9. doi:10.1038/ncomms2837.

Sambandan, D., Yamamoto, A., Fanara, J.-J., Mackay, T. F. C., and Anholt, R. R. H. (2006). Dynamic genetic interactions determine odour-guided behaviour in *Drosophila melanogaster*. *Genetics* 174, 1349–1363. doi:10.1534/genetics.106.060574.

Santa-Maria, I., Alaniz, M. E., Renwick, N., Cela, C., Fulga, T. A., Van Vactor, D., et al. (2015). Dysregulation of microRNA-219 promotes neurodegeneration through post-transcriptional regulation of tau. *J Clin Invest* 125, 681–686. doi:10.1172/JCI78421.

Saudan, P., Hauck, K., Soller, M., Choffat, Y., Ottiger, M., Spörri, M., et al. (2002). Ductus ejaculatorius peptide 99B (DUP99B), a novel *Drosophila melanogaster* sex-peptide pheromone. *Eur J Biochem* 269, 989–997. doi:10.1046/j.0014-2956.2001.02733.x.

Schultzhaus, J. N., and Carney, G. E. (2017). Dietary protein content alters both male and female contributions to *Drosophila melanogaster* female post-mating response traits. *J Insect Physiol* 99, 101–106. doi:10.1016/j.jinsphys.2017.04.004.

Schultzhaus, J. N., Saleem, S., Iftikhar, H., and Carney, G. E. (2017). The role of the *Drosophila* lateral horn in olfactory information processing and behavioural response. *J Insect Physiol* 98, 29–37. doi:10.1016/j.jinsphys.2016.11.007.

Schwenke, R. A., and Lazzaro, B. P. (2017). Juvenile hormone suppresses resistance to infection in mated female *Drosophila melanogaster*. *Curr Biol* 27, 596–601. doi:10.1016/j.cub.2017.01.004.

Seeley, C., and Dukas, R. (2011). Teneral matings in fruit flies: male coercion and female response. *Anim Behav* 81, 595–601. doi:10.1016/j.anbehav.2010.12.003.

Sepp, K. J., and Auld, V. J. (2003). Reciprocal interactions between neurons and glia are required for *Drosophila* peripheral nervous system developments. *J Neurosci* 23, 8221–8230.

Shohat-Ophir, G., Kaun, K. R., Azanchi, R., Mohammed, H., and Heberlein, U. (2012). Sexual deprivation increases ethanol intake in *Drosophila*. *Science* 335, 1351–1355. doi:10.1126/science.1215932.

Short, S. M., Wolfner, M. F., and Lazzaro, B. P. (2012). Female *Drosophila melanogaster* suffer reduced defense against infection due to seminal fluid components. *J Insect Physiol* 58, 1192–1201. doi:10.1016/j.jinsphys.2012.06.002.

Shorter, J., Couch, C., Huang, W., Carbone, M. A., Peiffer, J., Anholt, R. R. H., et al. (2015). Genetic architecture of natural variation in *Drosophila melanogaster* aggressive behaviour. *Proc Natl Acad Sci USA* 112, E3555–63. doi:10.1073/pnas.1510104112.

Silbering, A. F., Rytz, R., Grosjean, Y., Abuin, L., Ramdya, P., Jefferis, G. S. X. E., et al. (2011). Complementary function and integrated wiring of the evolutionarily distinct *Drosophila* olfactory subsystems. *J Neurosci* 31, 13357–13375. doi:10.1523/JNEUROSCI.2360-11.2011.

Sirot, L. K., LaFlamme, B. A., Sitnik, J. L., Rubinstein, C. D., Avila, F. W., Chow, C. Y., et al. (2009). Molecular social interactions: *Drosophila melanogaster* seminal fluid proteins as a case study. *Adv Genet* 68, 23–56. doi:10.1016/S0065-2660(09)68002-0.

Sirot, L. K., Wolfner, M. F., and Wigby, S. (2011). Protein-specific manipulation of ejaculate composition in response to female mating status in *Drosophila melanogaster*. *Proc Natl Acad Sci USA* 108, 9922–9926. doi:10.1073/pnas.1100905108.

Sirot, L. K., Wong, A., Chapman, T., and Wolfner, M. F. (2015). Sexual conflict and seminal fluid proteins: A dynamic landscape of sexual interactions. *Cold Spring Harb Perspect Biol* 7, 1–24.

Sitnik, J. L., Gligorov, D., Maeda, R. K., Karch, F., and Wolfner, M. F. (2016). The female post-mating response requires genes expressed in the secondary cells of the male accessory gland in *Drosophila melanogaster*. *Genetics* 202, 1029–1041. doi:10.1534/genetics.115.181644/-/DC1.

Smith, D. T., Clarke, N. V. E., Boone, J. M., Fricke, C., and Chapman, T. (2017). Sexual conflict over remating interval is modulated by the sex peptide pathway. *P Roy Soc B-Biol Sci* 284, 20162394–9. doi:10.1098/rspb.2016.2394.

Sokolowski, M. B. (2001). *Drosophila*: genetics meets behaviour. *Nat Rev Genet* 2, 879–890.

Spieth, H. T. (1974). Courtship behaviour in *Drosophila*. *Annu Rev Entomol* 9, 385–405.

Stafford, J. W., Lynd, K. M., Jung, A. Y., and Gordon, M. D. (2012). Integration of taste and calorie sensing in *Drosophila*. *J Neurosci* 32, 14767–14774. doi:10.1523/JNEUROSCI.1887-12.2012.

Stockinger, P., Kvitsiani, D., Rotkopf, S., Tirián, L., and Dickson, B. J. (2005). Neural circuitry that governs *Drosophila* male courtship behaviour. *Cell* 121, 795–807. doi:10.1016/j.cell.2005.04.026.

Stökl, J., Strutz, A., Dafni, A., Svatoš, A., Doubsky, J., Knaden, M., et al. (2010). A deceptive

pollination system targeting Drosophilids through olfactory mimicry of yeast. *Curr Biol* 20, 1846–1852. doi:10.1016/j.cub.2010.09.033.

Su, C.-Y., Menuz, K., Reisert, J., and Carlson, J. R. (2012). Non-synaptic inhibition between grouped neurons in an olfactory circuit. *Nature* 492, 66–71. doi:10.1038/nature11712.

Svetec, N., and Ferveur, J.-F. (2005). Social experience and pheromonal perception can change male-male interactions in *Drosophila melanogaster*. *J Exp Biol* 208, 891–898. doi:10.1242/jeb.01454.

Swarup, S., Harbison, S. T., Hahn, L. E., Morozova, T. V., Yamamoto, A., Mackay, T. F. C., et al. (2012). Extensive epistasis for olfactory behaviour, sleep and waking activity in *Drosophila melanogaster*. *Genet Res* 94, 9–20. doi:10.1017/S001667231200002X.

T

Taylor, M. L., Price, T. A. R., and Wedell, N. (2014). Polyandry in nature: a global analysis. *Trends Ecol Evol* 29, 376–383. doi:10.1016/j.tree.2014.04.005.

Team, R. C. (2015). *R: A language and environment for statistical computing*.

Terashima, J. (2004). Translating available food into the number of eggs laid by *Drosophila melanogaster*. *Genetics* 167, 1711–1719. doi:10.1534/genetics.103.024323.

Thompson, J. D. (1991). Phenotypic plasticity as a component of evolutionary change. *Trends Ecol Evol* 6, 246–249. doi:10.1016/0169-5347(91)90070-E.

Tompkins, L., Gross, A. C., Hall, J. C., Gailey, D. A., and Siegel, R. W. (1982). The role of female movement in the sexual behaviour of *Drosophila melanogaster*. *Behav Genet* 12, 295–307. doi:10.1007/BF01067849.

Toshima, N., and Tanimura, T. (2012). Taste preference for amino acids is dependent on internal nutritional state in *Drosophila* melanogaster. *J Exp Biol* 215, 2827–2832. doi:10.1242/jeb.069146.

Toshima, N., Hara, C., Scholz, C.-J., and Tanimura, T. (2014). Genetic variation in food choice behaviour of amino acid-deprived *Drosophila*. *J Insect Physiol* 69, 89–94. doi:10.1016/j.jinsphys.2014.06.019.

U

Ueda, A., and Kidokoro, Y. (2002). Aggressive behaviours of female *Drosophila melanogaster* are influenced by their social experience and food resources. *Physiol Entomol* 27, 21–28. doi:10.1046/j.1365-3032.2002.00262.x.

V

van der Goes van Naters, W. (2013). Inhibition among olfactory receptor neurons. *Front Hum Neurosci* 7, 1–5. doi:10.3389/fnhum.2013.00690/abstract.

van der Goes van Naters, W., and Carlson, J. R. (2007). Receptors and neurons for fly odours in *Drosophila*. *Curr Biol* 17, 606–612. doi:10.1016/j.cub.2007.02.043.

van Vianen, A., and Bijlsma, R. (1993). The adult component of selection in *Drosophila melanogster*: some aspects of early-remating activity of females. *Heredity* 71, 269–276.

Vargas, M. A., Luo, N., Yamaguchi, A., and Kapahi, P. (2010). A role for S6 kinase and serotonin in postmating dietary switch and balance of nutrients in *D. melanogaster*. *Curr Biol* 20, 1006–1011. doi:10.1016/j.cub.2010.04.009.

Venken, K. J. T., Simpson, J. H., and Bellen, H. J. (2011). Genetic manipulation of genes and cells in the nervous system of the fruit fly. *Neuron* 72, 202–230. doi:10.1016/j.neuron.2011.09.021.

Vosshall, L. B., and Stocker, R. F. (2007). Molecular architecture of smell and taste in *Drosophila*. *Annu. Rev. Neurosci*. 30, 505–533. doi:10.1146/annurev.neuro.30.051606.094306.

W

Wade, G. N., Schneider, J. E., and Li, H.-Y. (1996). Control of fertility by metabolic cues. *Am J Physiol* 270, E1–19.

Walker, S. J., Corrales-Carvajal, V. M., and Ribeiro, C. (2015). Postmating circuitry modulates salt taste processing to increase reproductive output in *Drosophila*. *Curr Biol* 25, 2621–2630. doi:10.1016/j.cub.2015.08.043.

Wang, L., Dankert, H., Perona, P., and Anderson, D. J. (2008). A common genetic target for environmental and heritable influences on aggressiveness in *Drosophila*. *Proc Natl Acad Sci USA* 105, 5657–5663. doi:10.1073/pnas.0801327105.

Wang, L., Han, X., Mehren, J., Hiroi, M., Billeter, J.-C., Miyamoto, T., et al. (2011). Hierarchical chemosensory regulation of male-male social interactions in *Drosophila*. *Nat Neurosci* 14, 757–762. doi:10.1038/nn.2800.

Watanabe, K., and Sakai, T. (2015). Knockout mutations of insulin-like peptide genes enhance sexual receptivity in *Drosophila* virgin females. *Genes Genet. Syst.* 90, 237–241. doi:10.1266/ggs.15-00025.

Wertheim, B., Dicke, M., and Vet, L. E. (2002a). Behavioural plasticity in support of a benefit for aggregation pheromone use in *Drosophila melanogaster*. *Entomol Exp Appl* 103, 61–71.

Wertheim, B., Marchais, J., Vet, L. E. M., and Dicke, M. (2002b). Allee effect in larval resource exploitation in *Drosophila*: an interaction among density of adults, larvae, and micro-organisms. *Ecol Entomol* 27, 608–617. doi:10.1046/j.1365-2311.2002.00449.x.

Wigby, S., and Chapman, T. (2004). Female resistance to male harm evolves in response to manipulation of sexual conflict. *Evolution* 58, 1028–1037.

Wigby, S., Sirot, L. K., Linklater, J. R., Buehner, N., Calboli, F. C. F., Bretman, A., et al. (2009). Seminal fluid protein allocation and male reproductive success. *Curr Biol* 19, 751–757. doi:10.1016/j.cub.2009.03.036.

Wigby, S., Slack, C., Gronke, S., Martinez, P., Calboli, F. C. F., Chapman, T., et al. (2011). Insulin signalling regulates remating in female *Drosophila*. *P Roy Soc B-Biol Sci* 278, 424–431. doi:10.1098/rspb.2010.1390.

Winbush, A., Reed, D., Chang, P. L., Nuzhdin, S. V., Lyons, L. C., and Arbeitman, M. N. (2012). Identification of gene expression changes associated with long-term memory of courtship rejection in *Drosophila* males. *G3-Genes Genom Genet* 2, 1437–1445. doi:10.1534/g3.112.004119.

X

Xue, L., and Noll, M. (2000). *Drosophila* female sexual behaviour induced by sterile males showing copulation complementation. *Proc Natl Acad Sci USA* 97, 3272–3275. doi:10.1073/pnas.97.7.3272.

Y

Yamamoto, D., and Kohatsu, S. (2017). What does the *fruitless* gene tell us about nature versus nurture in the sex life of *Drosophila*? *Fly* 11, 139–147.

Yamamoto, D., Sato, K., and Koganezawa, M. (2014). Neuroethology of male courtship in *Drosophila*: from the gene to behaviour. *J Comp Physiol A Neuroethol Sens Neural Behav Physiol* 200, 251–264. doi:10.1007/s00359-014-0891-5.

Yang, C. H., Belawat, P., Hafen, E., Jan, L. Y., and Jan, Y. N. (2008). *Drosophila* egg-laying site selection as a system to study simple decision-making processes. *Science* 319, 1679–1683. doi:10.1126/science.1151842.

Yang, C.-H., Rumpf, S., Xiang, Y., Gordon, M. D., Song, W., Jan, L. Y., et al. (2009). Control of the postmating behavioural switch in *Drosophila* females by internal sensory neurons. *Neuron* 61, 519–526. doi:10.1016/j.neuron.2008.12.021.

Yapici, N., Kim, Y.-J., Ribeiro, C., and Dickson, B. J. (2008). A receptor that mediates the post-mating switch in *Drosophila* reproductive behaviour. *Nature* 451, 33–37. doi:10.1038/nature06483.

Yew, J. Y., Dreisewerd, K., Luftmann, H., MUthing, J., Pohlentz, G., and Kravitz, E. A. (2009). A new male sex pheromone and novel cuticular cues for chemical communication in *Drosophila*. *Curr Biol* 19, 1245–1254. doi:10.1016/j.cub.2009.06.037.

Yin, J. C. P., Del Vecchio, M., Zhou, H., and Tully, T. (1995). CREB as a memory modulator: induced expression of a dCREB2 activator isoform enhances long-term memory in *Drosophila*. *Cell* 81, 107–115. doi:10.1016/0092-8674(95)90375-5.

Yorozu, S., Wong, A., Fischer, B. J., Dankert, H., Kernan, M. J., Kamikouchi, A., et al. (2009). Distinct sensory representations of wind and near-field sound in the *Drosophila* brain. *Nature* 457, 201–205. doi:10.1038/nature07843.

Z

Zawistowski, S., and Rollin, R. C. (1986). Inhibition of courtship and mating of *Drosophila melanogaste*r by the male-produced lipid, cis-vaccenyl acetate. *J Insect Physiol* 32, 189–192.

Zhou, C., Pan, Y., Robinett, C. C., Meissner, G. W., and Baker, B. S. (2014). Central brain neurons expressing doublesex regulate female receptivity in *Drosophila*. *Neuron* 83, 149–163. doi:10.1016/j.neuron.2014.05.038.

Zhou, L., Schnitzler, A., Agapite, J., Schwartz, L. M., Steller, H., and Nambu, J. R. (1997). Cooperative functions of the reaper and head involution defective genes in the programmed cell death of *Drosophila* central nervous system midline cells. *Proc Natl Acad Sci USA* 94, 5131–5136.

Zhu, J., Park, K.-C., and Baker, T. C. (2003). Identification of odours from overripe mango that attract vinegar flies, *Drosophila melanogaster*. *J Chem Ecol* 29, 899–909.

Zhuang, L., Sun, Y., Hu, M., Wu, C., La, X., Chen, X., et al. (2016). Or47b plays a role in *Drosophila* males' preference for younger mates. *Open Biol* 6, 160086–8. doi:10.1098/rsob.160086.

Zwarts, L., Broeck, L. V., Cappuyns, E., Ayroles, J. F., Magwire, M. M., Vulsteke, V., et al. (2015). The genetic basis of natural variation in mushroom body size in *Drosophila melanogaster*. *Nat Commun* 6, 1–11. doi:10.1038/ncomms10115.