

REFERENCES

- Abbott, D H, Saltzman, W, Schultz-Darken, N J & Tannenbaum, P L (1998) Adaptations to subordinate status in female marmoset monkeys. *Comp Biochem Physiol C Pharmacol Toxicol Endocrinol* 119: 261–74.
- Abel, R L, MacLaine, J S, Cotton, R *et al.* (2010) Functional morphology of the nasal region of a hammerhead shark. *Comp Biochem Physiol A Mol Integr Physiol* 155: 464–75.
- Ackerman, D (1990) *A Natural History of the Senses*. New York: Random House (Phoenix Pbk).
- Adams, E S & Traniello, J F A (1981) Chemical interference competition by *Monomorium minimum* (Hymenoptera, Formicidae). *Oecologia* 51: 265–70.
- Aeschlimann, P B, Haberli, M A, Reusch, T B H, Boehm, T & Milinski, M (2003) Female sticklebacks *Gasterosteus aculeatus* use self-reference to optimize MHC allele number during mate selection. *Behav Ecol Sociobiol* 54: 119–26.
- Aggio, J & Derby, C D (2011) Chemical communication in lobsters. In Breithaupt, T & Thiel, M (eds.) *Chemical Communication in Crustaceans*. pp. 239–56. New York: Springer.
- Aggleton, J P & Waskett, L (1999) The ability of odours to serve as state-dependent cues for real-world memories: can Viking smells aid the recall of Viking experiences? *Br J Psychol* 90: 1–7.
- Akino, T (2008) Chemical strategies to deal with ants: a review of mimicry, camouflage, propaganda, and phytomimesis by ants (Hymenoptera: Formicidae) and other arthropods. *Myrmecol News* 11: 173–81.
- Akino, T, Yamamura, K, Wakamura, S & Yamaoka, R (2004) Direct behavioral evidence for hydrocarbons as nestmate recognition cues in *Formica japonica* (Hymenoptera: Formicidae). *Appl Entomol Zool* 39: 381–7.
- Al Abassi, S, Birkett, M A, Pettersson, J, Pickett, J A & Woodcock, C M (1998) Ladybird beetle odour identified and found to be responsible for attraction between adults. *Cell Mol Life Sci* 54: 876–9.
- Alaux, C & Robinson, G (2007) Alarm pheromone induces immediate-early gene expression and slow behavioral response in honey bees. *J Chem Ecol* 33: 1346–50.
- Alaux, C, Le Conte, Y, Adams, H A *et al.* (2009a) Regulation of brain gene expression in honey bees by brood pheromone. *Genes Brain Behav* 8: 309–19.
- Alaux, C, Sinha, S, Hasadsri, L *et al.* (2009b) Honey bee aggression supports a link between gene regulation and behavioral evolution. *Proc Natl Acad Sci USA* 106: 15400–5.
- Alaux, C, Maisonnasse, A & Le Conte, Y (2010) Pheromones in a superorganism: from gene to social regulation. In Gerald, L (ed.) *Pheromones*. pp. 401–23. London: Academic Press.
- Alberts, A C (1990) Chemical-properties of femoral gland secretions in the desert iguana, *Dipsosaurus dorsalis*. *J Chem Ecol* 16: 13–25.
- Alberts, A C (1992) Constraints on the design of chemical communication-systems in terrestrial vertebrates. *Am Nat* 139: 62–89.
- Albone, E S (1984) *Mammalian Semiochemistry: the Investigation of Chemical Signals between Mammals*. Chichester: John Wiley.
- Alcock, J (1982) Natural selection and communication in bark beetles. *Fla Entomol* 65: 17–32.
- Alcock, J (2009) *Animal Behaviour. An Evolutionary Approach*, 9th edn. Sunderland, MA: Sinauer.
- Aldred, N & Clare, A S (2008) The adhesive strategies of cyprids and development of barnacle-resistant marine coatings. *Biofouling* 24: 351–63.
- Aldrich, J R (1995) Chemical communication in the true bugs and parasitoid exploitation. In Cardé, R T & Bell, W J (eds.) *Chemical Ecology of Insects* 2. pp. 318–63. London: Chapman and Hall.
- Aldrich, J R (1999) Predators. In Hardie, J & Minks, A K (eds.) *Pheromones of Non-lepidopteran Insects*

- associated with *Agricultural Plants*. pp. 357–81. Wallingford, Oxon: CAB International.
- Aldrich, J R, Kochansky, J R & Abrams, C B (1984) Attractant for a beneficial insect and its parasitoids: pheromone of the predatory spined soldier bug, *Podisus maculiventris* (Hemiptera: Pentatomidae). *Environ Entomol* 13: 1031–6.
- Aldrich, J R, Neal, J W, Oliver, J E & Lusby, W R (1991) Chemistry vis-a-vis maternalism in lace bugs (Heteroptera, Tingidae) – alarm pheromones and exudate defense in *Corythucha* and *Gargaphia* species. *J Chem Ecol* 17: 2307–22.
- Allan, R A, Elgar, M A & Capon, R J (1996) Exploitation of an ant chemical alarm signal by the zodariid spider *Habronestes bradleyi* Walckenaer. *Proc R Soc B* 263: 69–73.
- Allan, S A (2010) Chemical ecology of tick–host interactions. In Takken, W & Knols, B G J (eds.) *Olfaction in Vector–Host Interactions*. pp. 327. Wageningen: Wageningen Academic Publishers.
- Allee, W C (1931) *Animal Aggregations: a Study in General Sociology*. Chicago: Chicago University Press.
- Allen, C E, Zwaan, B J & Brakefield, P M (2011) Evolution of sexual dimorphism in the Lepidoptera. *Annu Rev Entomol* 56: 445–64.
- Allison, J D & Cardé, R T (eds.) (2014) *Pheromone Communication in Moths: Evolution, Behavior and Application*. Berkeley, CA: University of California Press.
- Alpizar, D, Fallas, M, Oehlschlager, A & Gonzalez, L (2012) Management of *Cosmopolites sordidus* and *Metamasius hemipterus* in banana by pheromone-based mass trapping. *J Chem Ecol* 38: 245–52.
- Aluja, M, Leskey, T C & Vincent, C (eds.) (2009a) *Biorational Tree Fruit Pest Management*. Wallingford: CABI Publishing.
- Aluja, M, Diaz-Fleischer, F, Boller, E F *et al.* (2009b) Application of feces extracts and synthetic analogues of the host marking pheromone of *Anastrepha ludens* significantly reduces fruit infestation by *A. obliqua* in tropical plum and mango backyard orchards. *J Econ Entomol* 102: 2268–78.
- Alves, H, Rouault, JD, Kondoh, Y *et al.* (2010) Evolution of cuticular hydrocarbons of Hawaiian Drosophilidae. *Behav Genet* 40: 694–705.
- Amoore, J E (1977) Specific anosmia and the concept of primary odors. *Chem Senses* 2: 267–81.
- Andersson, J, Borg-Karlson, A K & Wiklund, C (2003) Antiaphrodisiacs in pierid butterflies: a theme with variation! *J Chem Ecol* 29: 1489–99.
- Andersson, J, Borg-Karlson, A K & Wiklund, C (2004) Sexual conflict and anti-aphrodisiac titre in a polyandrous butterfly: male ejaculate tailoring and absence of female control. *Proc R Soc B* 271: 1765–70.
- Andersson, M (1994) *Sexual Selection*. Princeton: Princeton University Press.
- Andersson, M & Iwasa, Y (1996) Sexual selection. *Trends Ecol Evol* 11: 53–8.
- Andersson, M & Simmons, L W (2006) Sexual selection and mate choice. *Trends Ecol Evol* 21: 296–302.
- Andrade, M C B & Roitberg, B D (1995) Rapid response to intracolonial selection in the pea aphid (*Acyrtosiphon pisum*). *Evol Ecol* 9: 397–410.
- Anon (2008) General guidelines for authors for submission of manuscripts that contain identifications and syntheses of compounds. *J Chem Ecol* 34: 984–6.
- Anon (2009) New SPME guidelines. *J Chem Ecol* 35: 1383.
- Anon (2010) General guidelines for authors for submission of manuscripts that contain molecular biological content. *J Chem Ecol* 36: 1288–92.
- Anton, S, Dufour, M C & Gadenne, C (2007) Plasticity of olfactory-guided behaviour and its neurobiological basis: lessons from moths and locusts. *Entomol Exp Appl* 123: 1–11.
- Anton, S, Evenggaard, K, Barrozo, R B, Anderson, P & Skals, N (2011) Brief predator sound exposure elicits behavioral and neuronal long-term sensitization in the olfactory system of an insect. *Proc Natl Acad Sci USA* 108: 3401–5.
- Aoki, S (1977) *Colophina clematis* (Homoptera, Pemphigidae), an aphid species with soldiers. *Kontyu* 45: 276–82.
- Apanius, V, Penn, D, Slev, P R, Ruff, L R & Potts, W K (1997) The nature of selection on the major histocompatibility complex. *Crit Rev Immunol* 17: 179–224.
- Appelt, C W & Sorensen, P W (2007) Female goldfish signal spawning readiness by altering when and where they release a urinary pheromone. *Anim Behav* 74: 1329–38.

- Arak, A & Enquist, M (1993) Hidden preferences and the evolution of signals. *Phil Trans R Soc B* **340**: 207–13.
- Arakaki, N (1989) Alarm pheromone eliciting attack and escape responses in the sugar-cane woolly aphid, *Ceratomyces lanigera* (Homoptera, Pemphigidae). *J Ethol* **7**: 83–90.
- Arakaki, N (1990) Colony defense by first instar nymphs and dual function of alarm pheromone in the sugar cane woolly aphid, *Ceratomyces lanigera*. In Veeresh, G K, Mallik, B & Viraktamath, C A (eds.) *Social Insects and the Environment*. pp. 299–300. Bombay: Oxford University Press.
- Arakaki, N, Wakamura, S & Yasuda, T (1996) Phoretic egg parasitoid, *Telenomus euproctidis* (Hymenoptera, Scelionidae), uses sex-pheromone of tussock moth *Euproctis taiwana* (Lepidoptera, Lymantriidae) as a kairomone. *J Chem Ecol* **22**: 1079–85.
- Arakaki, N, Wakamura, S, Yasuda, T & Yamagishi, K (1997) Two regional strains of a phoretic egg parasitoid, *Telenomus euproctidis* (Hymenoptera: Scelionidae), that use different sex pheromones of two allopatric tussock moth species as kairomones. *J Chem Ecol* **23**: 153–61.
- Arakaki, N, Yamazawa, H & Wakamura, S (2011) The egg parasitoid *Telenomus euproctidis* (Hymenoptera: Scelionidae) uses sex pheromone released by immobile female tussock moth *Orgyia postica* (Lepidoptera: Lymantriidae) as kairomone. *Appl Entomol Zool* **46**: 195–200.
- Arakawa, H, Cruz, S & Deak, T (2011) From models to mechanisms: odorant communication as a key determinant of social behavior in rodents during illness-associated states. *Neurosci Biobehav Rev* **35**: 1916–28.
- Arathi, H S, Shakarad, M & Gadagkar, R (1997) Factors affecting the acceptance of alien conspecifics on nests of the primitively eusocial wasp, *Ropalidia marginata* (Hymenoptera: Vespidae). *J Insect Behav* **10**: 343–53.
- Arcese, P (1999) Effect of auxiliary males on territory ownership in the oribi and the attributes of multi-male groups. *Anim Behav* **57**: 61–71.
- Archie, E A & Theis, K R (2011) Animal behaviour meets microbial ecology. *Anim Behav* **82**: 425–36.
- Arn, H (1990) Pheromones: prophecies, economics, and the ground swell. In Ridgeway, R L, Silverstein, R M & Inscoe, M N (eds.) *Behavior-modifying Chemicals for Insect Management*. pp. 717–22. New York: Marcel Dekker.
- Arn, H & Louis, F (1997) Mating disruption in European vineyards. In Cardé, R T & Minks, A K (eds.) *Pheromone Research: New Directions*. pp. 377–82. New York: Chapman and Hall.
- Arnold, A P (2009) The organizational–activational hypothesis as the foundation for a unified theory of sexual differentiation of all mammalian tissues. *Horm Behav* **55**: 570–8.
- Arnqvist, G (2006) Sensory exploitation and sexual conflict. *Phil Trans R Soc B* **361**: 375–86.
- Arnqvist, G & Rowe, L (2005) *Sexual Conflict*. Princeton: Princeton University Press.
- Arvedlund, M, McCormick, M I, Fautin, D G & Bildsøe, M (1999) Host recognition and possible imprinting in the anemonefish *Amphiprion melanopus* (Pisces: Pomacentridae). *Mar Ecol Prog Ser* **188**: 207–18.
- Atema, J (1986) Review of sexual selection and chemical communication in the lobster, *Homarus americanus*. *Can J Fish Aquat Sci* **43**: 2283–90.
- Atema, J (1995) Chemical signals in the marine environment: dispersal, detection, and temporal signal analysis. In Eisner, T & Meinwald, J (eds.) *Chemical Ecology: the Chemistry of Biotic Interaction*. pp. 147–59. Washington, DC: National Academy of Sciences.
- Atema, J (2012) Aquatic odour dispersal fields: opportunities and limits of detection, communication, and navigation. In Brönmark, C & Hansson, L-A (eds.) *Chemical Ecology in Aquatic Systems*. pp. 1–18. Oxford: Oxford University Press.
- Atema, J & Steinbach, M A (2007) Chemical communication and social behavior of the lobster *Homarus americanus* and other decapod Crustacea. In Duffy, J E & Thiel, M (eds.) *Evolutionary Ecology of Social and Sexual Systems: Crustaceans as Model Organisms*. pp. 115–44. Oxford & New York: Oxford University Press.
- Avila, F W, Sirot, L K, Laflamme, B A, Rubinstein, C D & Wolfner, M F (2011) Insect seminal fluid proteins: identification and function. *Annu Rev Entomol* **56**: 21–40.
- Axel, R (2005) Scents and sensibility: a molecular logic of olfactory perception (Nobel Lecture). *Angew Chem Int Ed* **44**: 6111–27.

- Bagley, K R, Goodwin, T E, Rasmussen, L E L & Schulte, B A (2006) Male African elephants, *Loxodonta africana*, can distinguish oestrous status via urinary signals. *Anim Behav* 71: 1439–45.
- Bagnères, A-G & Lorenzi, M C (2010) Chemical deception/mimicry using cuticular hydrocarbons. In Blomquist, G J & Bagnères, A-G (eds.) *Insect Hydrocarbons: Biology, Biochemistry, and Chemical Ecology*. pp. 282–324. Cambridge: Cambridge University Press.
- Bagøien, E & Kiørboe, T (2005) Blind dating – mate finding in planktonic copepods. I. Tracking the pheromone trail of *Centropages typicus*. *Mar Ecol Prog Ser* 300: 105–15.
- Baker, C F, Montgomery, J C & Dennis, T E (2002) The sensory basis of olfactory search behavior in banded kokopu (*Galaxias fasciatus*). *J Comp Physiol A* 188: 553–60.
- Baker, T C (2002) Mechanism for saltational shifts in pheromone communication systems. *Proc Natl Acad Sci USA* 99: 13368–70.
- Baker, T C (2008) Balanced olfactory antagonism as a concept for understanding evolutionary shifts in moth sex pheromone blends. *J Chem Ecol* 34: 971–81.
- Baker, T C (2011) Insect pheromones: useful lessons for crustacean pheromone programs? In Breithaupt, T & Thiel, M (eds.) *Chemical Communication in Crustaceans*. pp. 531–50. New York: Springer.
- Baker, T C, Cossé, A A & Todd, J L (1998) Behavioral antagonism in the moth *Helicoverpa zea* in response to pheromone blends of three sympatric heliothine moth species is explained by one type of antennal neuron. *Ann N Y Acad Sci* 855: 511–13.
- Bakker, J, Pierman, S & Gonzalez-Martinez, D (2010) Effects of aromatase mutation (ArKO) on the sexual differentiation of kisspeptin neuronal numbers and their activation by same versus opposite sex urinary pheromones. *Horm Behav* 57: 390–5.
- Barata, E N, Hubbard, P C, Almeida, O G, Miranda, A & Canário, A V M (2007) Male urine signals social rank in the *Mozambique tilapia* (*Oreochromis mossambicus*). *BMC Biol* 5: 54.
- Barata, E N, Serrano, R M, Miranda, A, et al. (2008a) Putative pheromones from the anal glands of male blennies attract females and enhance male reproductive success. *Anim Behav* 75: 379–89.
- Barata, E N, Fine, J M, Hubbard, P C et al. (2008b) A sterol-like odorant in the urine of Mozambique tilapia males likely signals social dominance to females. *J Chem Ecol* 34: 438–49.
- Barbero, F, Bonelli, S, Thomas, J A, Balletto, E & Schonrogge, K (2009) Acoustical mimicry in a predatory social parasite of ants. *J Exp Biol* 212: 4084–90.
- Bargmann, C I (2006a) Comparative chemosensation from receptors to ecology. *Nature* 444: 295–301.
- Bargmann, C I (2006b) Chemosensation in *C. elegans*. In The *C. elegans* Research Community (ed.) *WormBook: The Online Review of C. elegans Biology [Internet]*. doi/10.1895/wormbook.1891.1123.1891. Pasadena, CA: WormBook.
- Barki, A, Jones, C & Karplus, I (2011) Chemical communication and aquaculture of decapod crustaceans: needs, problems, and possible solutions. In Breithaupt, T & Thiel, M (eds.) *Chemical Communication in Crustaceans*. pp. 485–506. New York: Springer.
- Barrozo, R B, Jarriault, D, Simeone, X et al. (2010) Mating-induced transient inhibition of responses to sex pheromone in a male moth is not mediated by octopamine or serotonin. *J Exp Biol* 213: 1100–6.
- Barth, F G, Hrncir, M & Jarau, S (2008) Signals and cues in the recruitment behavior of stingless bees (*Meliponini*). *J Comp Physiol A* 194: 313–27.
- Bartlet, R J (2010) Volatile hydrocarbon pheromones from beetles. In Blomquist, G J & Bagnères, A-G (eds.) *Insect Hydrocarbons: Biology, Biochemistry, and Chemical Ecology*. pp. 448–76. Cambridge: Cambridge University Press.
- Bashir, M & Hassanali, A (2010) Novel cross-stage solitarising effect of gregarious-phase adult desert locust (*Schistocerca gregaria* (Forskål)) pheromone on hoppers. *J Insect Physiol* 56: 640–5.
- Basil, J A, Hanlon, R T, Sheikh, S I & Atema, J (2000) Three-dimensional odor tracking by *Nautilus pompilius*. *J Exp Biol* 203: 1409–14.
- Bastir, M, Rosas, A, Gunz, P et al. (2011) Evolution of the base of the brain in highly encephalized human species. *Nat Commun* 2: 588.
- Bateman, A & Logan, D W (2010) Time to underpin Wikipedia wisdom. *Nature* 468: 765.
- Bateson, P & Mameli, M (2007) The innate and the acquired: useful clusters or a residual distinction from folk biology? *Dev Psychobiol* 49: 818–31.

- Bathellier, B, Gschwend, O & Carleton, A (2010) Temporal coding in olfaction. In Menini, A (ed.) *The Neurobiology of Olfaction*. Boca Raton, FL.: CRC Press. Available online at www.ncbi.nlm.nih.gov/books/NBK55968/.
- Bauer, R T (2011) Chemical communication in decapod shrimps: the influence of mating and social systems on the relative importance of olfactory and contact pheromones. In Breithaupt, T & Thiel, M (eds.) *Chemical Communication in Crustaceans*. pp. 277–96. New York: Springer.
- Baum, M J (2012) Contribution of pheromones processed by the main olfactory system to mate recognition in female mammals. *Front Neuroanat* 6: 20.
- Baum, M J & Kelliher, K R (2009) Complementary roles of the main and accessory olfactory systems in mammalian mate recognition. *Annu Rev Physiol* 71: 141–60.
- Baxi, K N, Dorries, K M & Eisthen, H L (2006) Is the vomeronasal system really specialized for detecting pheromones? *Trends Neurosci* 29: 1–7.
- Beale, M H, Birkett, M A, Bruce, T J A *et al.* (2006) Aphid alarm pheromone produced by transgenic plants affects aphid and parasitoid behavior. *Proc Natl Acad Sci USA* 103: 10509–13.
- Beauchamp, G K, Doty, R L, Moulton, D G & Mugford, R A (1976) The pheromone concept in mammalian chemical communication: a critique. In Doty, R L (ed.) *Mammalian Olfaction, Reproductive Processes, and Behavior*. pp. 143–60. New York: Academic Press.
- Becker, S D & Hurst, J L (2009) Female behaviour plays a critical role in controlling murine pregnancy block. *Proc R Soc B* 276: 1723–9.
- Beckers, R, Deneubourg, J L & Goss, S (1993) Modulation of trail laying in the ant *Lasius niger* (Hymenoptera, Formicidae) and its role in the collective selection of a food source. *J Insect Behav* 6: 751–9.
- Bedell, V M, Westcot, S E & Ekker, S C (2011) Lessons from morpholino-based screening in zebrafish. *Brief Funct Genomics* 10: 181–8.
- Beggs, K T & Mercer, A R (2009) Dopamine receptor activation by honey bee queen pheromone. *Curr Biol* 19: 1206–9.
- Belanger, R M & Moore, P A (2006) The use of the major chelae by reproductive male crayfish (*Orconectes rusticus*) for discrimination of female odours. *Behaviour* 143: 713–31.
- Bell, W J (1991) *Searching Behaviour. The Behavioural Ecology of Finding Resources*. London: Chapman and Hall.
- Bell, W J, Roth, L M & Nalepa, C A (2007) *Cockroaches: Ecology, Behavior, and Natural History*. Baltimore: Johns Hopkins University Press.
- Bellés, X (2010) Beyond *Drosophila*: RNAi in vivo and functional genomics in insects. *Annu Rev Entomol* 55: 111–28.
- Ben-Shahar, Y, Dudek, N L & Robinson, G E (2004) Phenotypic deconstruction reveals involvement of manganese transporter malvolio in honey bee division of labor. *J Exp Biol* 207: 3281–8.
- Ben-Shaul, Y, Katz, L C, Mooney, R & Dulac, C (2010) In vivo vomeronasal stimulation reveals sensory encoding of conspecific and allospecific cues by the mouse accessory olfactory bulb. *Proc Natl Acad Sci USA* 107: 5172–7.
- Bendesky, A & Bargmann, C I (2011) Genetic contributions to behavioural diversity at the gene–environment interface. *Nat Rev Genet* 12: 809–20.
- Bengtsson, B O & Löfstedt, C (2007) Direct indirect selection in moth pheromone evolution: population genetical simulations of asymmetric sexual interactions. *Biol J Linn Soc* 90: 117–23.
- Benoit, J B, Phillips, S A, Croxall, T J *et al.* (2009) Addition of alarm pheromone components improves the effectiveness of desiccant dusts against *Cimex lectularius*. *J Med Entomol* 46: 572–9.
- Benton, R (2011) Decision making: singin' in the brain. *Neuron* 69: 399–401.
- Benton, R, Vannice, K S, Gomez-Diaz, C & Vossell, L B (2009) Variant ionotropic glutamate receptors as chemosensory receptors in *Drosophila*. *Cell* 136: 149–62.
- Bentz, B J, Régnière, J, Fettig, C J *et al.* (2010) Climate change and bark beetles of the western United States and Canada: direct and indirect effects. *Bioscience* 60: 602–13.
- Berec, L, Angulo, E & Courchamp, F (2007) Multiple Allee effects and population management. *Trends Ecol Evol* 22: 185–91.
- Berg, H C (2004) *E. coli in Motion*. New York: Springer.
- Bergstrom, C T & Lachmann, M (1998) Signaling among relatives. III. Talk is cheap. *Proc Natl Acad Sci USA* 95: 5100.

- Bergstrom, C T, Számadó, S & Lachmann, M (2002) Separating equilibria in continuous signalling games. *Phil Trans R Soc B* 357: 1595–606.
- Bertness, M D, Leonard, G H, Levine, J M & Bruno, J F (1999) Climate-driven interactions among rocky intertidal organisms caught between a rock and a hot place. *Oecologia* 120: 446–50.
- Beydoun, H & Saftlas, A (2005) Association of human leucocyte antigen sharing with recurrent spontaneous abortions. *Tissue Antigens* 65: 123–35.
- Bhatnagar, K & Smith, T (2010) The human vomeronasal organ. Part VI: A nonchemosensory vestige in the context of major variations of the mammalian vomeronasal organ. *Curr Neurobiol* 1: 1–9.
- Billen, J (2006) Signal variety and communication in social insects. *Proc Neth Entomol Soc Meet* 17: 9–25 available at <http://tinyurl.com/billen2006>.
- Billen, J & Morgan, E D (1998) Pheromone communication in social insects: sources and secretions. In Vander Meer, R K, Breed, M D, Espelie, K E & Winston, M L (eds.) *Pheromone Communication in Social Insects: Ants, Wasps, Bees, and Termites*. pp. 3–33. Boulder, CO: Westview Press.
- Billeter, J C, Rideout, E J, Dorman, A J & Goodwin, S F (2006) Control of male sexual behavior in *Drosophila* by the sex determination pathway. *Curr Biol* 16: R766–R776.
- Billeter, J C, Atallah, J, Krupp, J J, Millar, J G & Levine, J D (2009) Specialized cells tag sexual and species identity in *Drosophila melanogaster*. *Nature* 461: 987–91.
- Birch, M C, Poppy, G M & Baker, T C (1990) Scents and eversible scent structures of male moths. *Annu Rev Entomol* 35: 25–58.
- Bisulco, S & Slotnick, B (2003) Olfactory discrimination of short chain fatty acids in rats with large bilateral lesions of the olfactory bulbs. *Chem Senses* 28: 361–70.
- Black, S & Biron, C (1982) Androstenol as a human pheromone: no effect on perceived physical attractiveness. *Behav Neural Biol* 34: 326–30.
- Blomquist, G J (2010) Structure and analysis of insect hydrocarbons. In Blomquist, G J & Bagnères, A-G (eds.) *Insect Hydrocarbons: Biology, Biochemistry, and Chemical Ecology*. pp. 19–34. Cambridge: Cambridge University Press.
- Blomquist, G J & Bagnères, A G (eds.) (2010) *Insect Hydrocarbons: Biology, Biochemistry, and Chemical Ecology*. Cambridge: Cambridge University Press.
- Blomquist, G J, Teran, R F, Aw, M *et al.* (2010) Pheromone production in bark beetles. *Insect Biochem Mol Biol* 40: 699–712.
- Blum, M S (1974) Pheromonal bases of social manifestations in insects. In Birch, M C (ed.) *Pheromones*. pp. 190–99. Amsterdam: North-Holland.
- Blum, M S (1982) Pheromonal bases of insect sociality: communications, conundrums and caveats. *Colloques de l'INRA* 7: 149–62.
- Blum, M S (1985) Alarm pheromones. In Kerkut, GA & Gilbert, LI (eds.) *Comprehensive Insect Physiology, Biochemistry and Pharmacology*. pp. 193–224. Oxford: Pergamon Press.
- Blum, M S (1996) Semiochemical parsimony in the arthropoda. *Annu Rev Entomol* 41: 353–74.
- Boake, C R B (1991) Coevolution of senders and receivers of sexual signals: genetic coupling and genetic correlations. *Trends Ecol Evol* 6: 225–7.
- Boehm, U, Zou, Z H & Buck, L B (2005) Feedback loops link odor and pheromone signaling with reproduction. *Cell* 123: 683–95.
- Bolnick, D I & Fitzpatrick, B M (2007) Sympatric speciation: models and empirical evidence. *Annu Rev Ecol Evol Syst* 38: 459–87.
- Bonabeau, E, Theraulaz, G, Deneubourg, J L, Aron, S & Camazine, S (1997) Self-organization in social insects. *Trends Ecol Evol* 12: 188–93.
- Bonabeau, E, Theraulaz, G, Deneubourg, J L *et al.* (1998) A model for the emergence of pillars, walls and royal chambers in termite nests. *Phil Trans R Soc B* 353: 1561–76.
- Bonadonna, F & Sanz-Aguilar, A (2012) Kin recognition and inbreeding avoidance in wild birds: the first evidence for individual kin-related odour recognition. *Anim Behav* 84: 509–13.
- Bond, A L (2011) Why ornithologists should embrace and contribute to Wikipedia. *Ibis* 153: 640–1.
- Bonthuis, P J, Cox, K H, Searcy, B T *et al.* (2010) Of mice and rats: key species variations in the sexual differentiation of brain and behavior. *Front Neuroendocrinol* 31: 341–58.

- Boone, C K, Six, D L & Raffa, K F (2008) The enemy of my enemy is still my enemy: competitors add to predator load of a tree-killing bark beetle. *Agric For Entomol* 10: 411–21.
- Booth, D W & Signoret, J P (1992) Olfaction and reproduction in ungulates. In Milligan, S R (ed.) *Oxford Reviews of Reproduction*. pp. 263–301. Oxford: Oxford University Press.
- Boppré, M (1990) Lepidoptera and pyrrolizidine alkaloids – exemplification of complexity in chemical ecology. *J Chem Ecol* 16: 165–85.
- Bordereau, C & Pasteels, J M (2011) Pheromones and chemical ecology of dispersal and foraging in termites. In Bignell, D E, Roisin, Y & Lo, N (eds.) *Biology of Termites: a Modern Synthesis*, 2nd edn. pp. 279–320. Dordrecht: Springer.
- Bos, D H, Williams, R N, Gopurenko, D, Bulut, Z & Dewoody, J A (2009) Condition-dependent mate choice and a reproductive disadvantage for MHC-divergent male tiger salamanders. *Mol Ecol* 18: 3307–15.
- Bos, N & d'Ettorre, P (2012) Recognition of social identity in ants. *Front Psychol* 3: 83.
- Bossert, W H & Wilson, E O (1963) The analysis of olfactory communication among animals. *J Theor Biol* 5: 443–69.
- Bourke, A F G (2011a) The validity and value of inclusive fitness theory. *Proc R Soc B* 278: 3313–20.
- Bourke, A F G (2011b) *Principles of Social Evolution*. Oxford: Oxford University Press.
- Bousquet, F, Nojima, T, Houot, B *et al.* (2012) Expression of a desaturase gene, *desat1*, in neural and nonneural tissues separately affects perception and emission of sex pheromones in *Drosophila*. *Proc Natl Acad Sci USA* 109: 249–54.
- Boydston, E E, Morelli, T L & Holekamp, K E (2001) Sex differences in territorial behavior exhibited by the spotted hyena (*Hyaenidae*, *Crocuta crocuta*). *Ethology* 107: 369–85.
- Bradbury, J W & Vehrencamp, S L (2011) *Principles of Animal Communication*, 2nd edn. Sunderland, MA: Sinauer.
- Bradshaw, J W S, Baker, R & Howse, P E (1975) Multicomponent alarm pheromones of the weaver ant. *Nature* 258: 230–1.
- Bradshaw, J W S, Baker, R & Howse, P E (1979) Multicomponent alarm pheromones in the mandibular glands of the African weaver ant, *Oecophylla longinoda*. *Physiol Entomol* 4: 15–25.
- Brandstaetter, A S & Kleineidam, C J (2011) Distributed representation of social odors indicates parallel processing in the antennal lobe of ants. *J Neurophysiol* 106: 2437–49.
- Brandstaetter, A S, Endler, A & Kleineidam, C J (2008) Nestmate recognition in ants is possible without tactile interaction. *Naturwissenschaften* 95: 601–8.
- Brandstaetter, A S, Rossler, W & Kleineidam, C J (2011) Friends and foes from an ant brain's point of view – neuronal correlates of colony odors in a social insect. *PLoS ONE* 6: e21383.
- Brashares, J S & Arcese, P (1999a) Scent marking in a territorial African antelope: I. The maintenance of borders between male oribi. *Anim Behav* 57: 1–10.
- Brashares, J S & Arcese, P (1999b) Scent marking in a territorial African antelope: II. The economics of marking with faeces. *Anim Behav* 57: 11–17.
- Brechbühl, J, Klaey, M & Broillet, M-C (2008) Grueneberg ganglion cells mediate alarm pheromone detection in mice. *Science* 321: 1092–5.
- Brechbühl, J, Luyet, G, Moine, F, Rodriguez, I & Broillet, M-C (2011) Imaging pheromone sensing in a mouse vomeronasal acute tissue slice preparation. *J Vis Exp* e3311.
- Breed, M D (1998a) Chemical cues in kin recognition: criteria for identification, experimental approaches, and the honey bee as an example. In Vander Meer, R K, Breed, M D, Espelie, K E & Winston, M L (eds.) *Pheromone Communication in Social Insects: Ants, Wasps, Bees, and Termites*. pp. 57–78. Boulder, CO: Westview Press.
- Breed, M D (1998b) Recognition pheromones of the honey bee. *Bioscience* 48: 463–70.
- Breed, M D & Buchwald, R (2009) Cue diversity and social recognition. In Gadau, J & Fewell, J H (eds.) *Organization of Insect Societies: From Genome to Sociocomplexity*. pp. 173–94. Cambridge, MA: Harvard University Press.
- Breed, M D, Stiller, T M & Moor, M J (1988) The ontogeny of kin discrimination cues in the honey bee, *Apis mellifera*. *Behav Genet* 18: 439–48.
- Breed, M D, Garry, M F, Pearce, A N *et al.* (1995) The role of wax comb in honey-bee nestmate recognition. *Anim Behav* 50: 489–96.

- Breed, M D, Perry, S & Bjostad, L B (2004a) Testing the blank slate hypothesis: why honey bee colonies accept young bees. *Insectes Soc* 51: 12–16.
- Breed, M D, Guzmán-Novoa, E & Hunt, G J (2004b) Defensive behavior of honey bees: organization, genetics, and comparisons with other bees. *Annu Rev Entomol* 49: 271–98.
- Breed, M D, Cook, C & Krasnec, M O (2012) Cleptobiosis in social insects. *Psyche* 2012 doi:10.1155/2012/484765.
- Breithaupt, T & Thiel, M (eds.) (2011) *Chemical Communication in Crustaceans*. New York: Springer.
- Breithaupt, T & Hardege, J (2012) Pheromones mediating sex and dominance in aquatic animals. In Brönmark, C & Hansson, L-A (eds.) *Chemical Ecology in Aquatic Systems*. pp. 39–56. Oxford: Oxford University Press.
- Bremner, E A, Mainland, J D, Khan, R M & Sobel, N (2003) The prevalence of androstenone anosmia. *Chem Senses* 28: 423–32.
- Brennan, P A (2009) Outstanding issues surrounding vomeronasal mechanisms of pregnancy block and individual recognition in mice. *Behav Brain Res* 200: 287–94.
- Brennan, P A (2010) Pheromones and mammalian behavior. In Menini, A (ed.) *The Neurobiology of Olfaction*. pp. 157. Boca Raton, FL: CRC Press. Available online at www.ncbi.nlm.nih.gov/books/NBK55973/.
- Brennan, P A & Kendrick, K M (2006) Mammalian social odours: attraction and individual recognition. *Phil Trans R Soc B* 361: 2061–78.
- Brennan, P A & Zufall, F (2006) Pheromonal communication in vertebrates. *Nature* 444: 308–15.
- Brenner, S (2002) Life sentences: Detective Rummage investigates. *Genome Biol* 3: 1–1013.
- Bretman, A, Westmancoat, J D, Gage, M J G & Chapman, T (2011) Males use multiple, redundant cues to detect mating rivals. *Curr Biol* 21: 617–22.
- Brisbin, I L & Austad, S N (1991) Testing the individual odour theory of canine olfaction. *Anim Behav* 42: 63–9.
- Brisbin, I L, Austad, S N & Jacobson, S K (2000) Canine detectives: the nose knows – or does it? *Science* 290: 1093.
- Brodmann, J, Twele, R, Francke, W *et al.* (2009) Orchid mimics honey bee alarm pheromone in order to attract hornets for pollination. *Curr Biol* 19: 1368–72.
- Brönmark, C & Hansson, L-A (eds.) (2012) *Chemical Ecology in Aquatic Systems*. Oxford: Oxford University Press.
- Brown, G E & Smith, R J F (1998) Acquired predator recognition in juvenile rainbow trout (*Oncorhynchus mykiss*): conditioning hatchery-reared fish to recognize chemical cues of a predator. *Can J Fish Aquat Sci* 55: 611–17.
- Brown, G E, Chivers, D P & Smith, R J F (1997) Differential learning rates of chemical versus visual cues of a northern pike by fathead minnows in a natural habitat. *Environ Biol Fishes* 49: 89–96.
- Brown, R E, Roser, B & Singh, P B (1989) Class I and class II regions of the major histocompatibility complex both contribute to individual odors in congenic inbred strains of rats. *Behav Genet* 19: 659–74.
- Bruschini, C, Cervo, R & Turillazzi, S (2010) Pheromones in social wasps. In Gerald, L (ed.) *Pheromones*. pp. 447–92. London: Academic Press.
- Buck, L B (2005) Unraveling the sense of smell (Nobel Lecture). *Angew Chem Int Ed* 44: 6128–40.
- Buck, L B & Axel, R (1991) A novel multigene family may encode odorant receptors – a molecular-basis for odor recognition. *Cell* 65: 175–87.
- Buckley, S H, Tregenza, T & Butlin, R K (2003) Transitions in cuticular composition across a hybrid zone: historical accident or environmental adaptation? *Biol J Linn Soc* 78: 193–201.
- Büda, V, Mozūraitis, R, Kutra, J & Borg-Karlson, A-K (2012) *p*-Cresol: a sex pheromone component identified from the estrous urine of mares. *J Chem Ecol* 38: 811–13.
- Buesching, C D, Stopka, P & Macdonald, D W (2003) The social function of allo-marking in the European badger (*Meles meles*). *Behaviour* 140: 965–80.
- Burgener, N, Dehnhard, M, Hofer, H & East, M L (2009) Does anal gland scent signal identity in the spotted hyaena? *Anim Behav* 77: 707–15.
- Burghardt, G M, Bartmess-LeVasseur, J N, Browning, S A *et al.* (2012) Perspectives – Minimizing observer bias in behavioral studies: a review and recommendations. *Ethology* 118: 511–17.

- Burke, R D (1984) Pheromonal control of metamorphosis in the Pacific sand dollar, *Dendraster excentricus*. *Science* 225: 442–3.
- Burkholder, W E (1982) Reproductive biology and communication among grain storage and warehouse beetles. *J Ga Entomol Soc* 17 (II. suppl.): 1–10.
- Burton, J L & Franks, N R (1985) The foraging ecology of the army ant *Eciton rapax* – an ergonomic enigma. *Ecol Entomol* 10: 131–41.
- Buschinger, A (2009) Social parasitism among ants: a review (Hymenoptera: Formicidae). *Myrmecol News* 12: 219–35.
- Butenandt, A, Beckmann, R, Stamm, D & Hecker, E (1959) Über den sexual-lockstoff des seidenspinners *Bombyx mori* – reindarstellung und konstitution. *Zeitschrift Fur Naturforschung Part B-Chemie Biochemie Biophysik Biologie Und Verwandten Gebiete* 14: 283–4.
- Butler, C (1623) *The Feminine Monarchie, Or the Historie of Bees*, 2nd edn. John Haviland. Available Google Books <http://tinyurl.com/butler-1623-feminine>.
- Butlin, R K & Ritchie, M G (1989) Genetic coupling in mate recognition systems – what is the evidence. *Biol J Linn Soc* 37: 237–46.
- Butlin, R K & Trickett, A J (1997) Can population genetic simulations help to interpret pheromone evolution? In Cardé, R T & Minks, A K (eds.) *Pheromone Research: New Directions* pp. 548–62. New York: Chapman and Hall.
- Byers, J A (1992) Optimal fractionation and bioassay plans for isolation of synergistic chemicals: the subtractive-combination method. *J Chem Ecol* 18: 1603–21.
- Byers, J A (2005) A cost of alarm pheromone production in cotton aphids, *Aphis gossypii*. *Naturwissenschaften* 92: 69–72.
- Byers, J A & Zhang, Q (2011) Chemical ecology of bark beetles in regard to search and selection of host trees. In Liu, T & Kang, L (eds.) *Recent Advances in Entomological Research: from Molecular Biology to Pest Management*. pp. 150–90. Beijing and Berlin: Higher Education Press and Springer.
- Calenbuhr, V & Deneubourg, J L (1992) A model for osmotropotactic orientation. 1. *J Theor Biol* 158: 359–93.
- Calenbuhr, V, Chretien, L, Deneubourg, J L & Detrain, C (1992) A model for osmotropotactic orientation. 2. *J Theor Biol* 158: 395–407.
- Camazine, S, Deneubourg, J-L, Franks, N R *et al.* (2001) *Self-organization in Biological Systems*. Princeton: Princeton University Press.
- Cammaerts, M C & Cammaerts, R (1980) Food recruitment strategies of the ant *Myrmica sabuleti* and *Myrmica ruginodis*. *Behav Processes* 5: 251–70.
- Campagna, S, Mardon, J, Celerier, A & Bonadonna, F (2012) Potential semiochemical molecules from birds: a practical and comprehensive compilation of the last 20 years studies. *Chem Senses* 37: 3–25.
- Campbell-Palmer, R & Rosell, F (2010) Conservation of the Eurasian beaver *Castor fiber*: an olfactory perspective. *Mammal Rev* 40: 293–312.
- Cardé, R T & Baker, T C (1984) Sexual communication with pheromones. In Bell, W J & Cardé, R T (eds.) *Chemical Ecology of Insects*. pp. 355–86. London: Chapman & Hall.
- Cardé, R T & Haynes, K F (2004) Structure of the pheromone communication channel in moths. In: Cardé, R & Millar, J G (eds.) *Advances in Insect Chemical Ecology*. pp. 283–332. Cambridge: Cambridge University Press.
- Cardé, R T & Mafra-Neto, A (1997) Mechanisms of flight of male moths to pheromone. In Cardé, R T & Minks, A K (eds.) *Pheromone Research: New Directions*. pp. 275–90. New York: Chapman and Hall.
- Cardé, R T & Minks, A K (1995) Control of moth pests by mating disruption – successes and constraints. *Annu Rev Entomol* 40: 559–85.
- Cardé, R T & Willis, M A (2008) Navigational strategies used by insects to find distant, wind-borne sources of odor. *J Chem Ecol* 34: 854–66.
- Cardé, R T, Cardé, A M & Girling, R D (2012) Observations on the flight paths of the day flying moth *Virbia lamae* during periods of mate location: do males have a strategy for contacting the pheromone plume? *J Anim Ecol* 81: 268–76.
- Cardwell, J R, Stacey, N E, Tan, E S P, McAdam, D S O & Lang, S L C (1995) Androgen increases olfactory receptor response to a vertebrate sex pheromone. *J Comp Physiol A* 176: 55–61.

- Carey, A F & Carlson, J R (2011) Insect olfaction from model systems to disease control. *Proc Natl Acad Sci USA* **108**: 12987–95.
- Carlin, N F & Hölldobler, B (1987) The kin recognition system of carpenter ants (*Camponotus* spp). 2. Larger colonies. *Behav Ecol Sociobiol* **20**: 209–17.
- Caro, S P & Balthazart, J (2010) Pheromones in birds: myth or reality? *J Comp Physiol A* **196**: 751–66.
- Carroll, J F, Mills, G D & Schmidtman, E T (1996) Field and laboratory responses of adult *Ixodes scapularis* (Acari: Ixodidae) to kairomones produced by white-tailed deer. *J Med Entomol* **33**: 640–4.
- Carson, C, Birkett, M A, Logan, J G *et al.* (2010) Novel use of stir bar sorptive extraction (SBSE) as a tool for isolation of oviposition site attractants for gravid *Culex quinquefasciatus*. *Bull Entomol Res* **100**: 1–7.
- Carter, C S & Getz, L L (1993) Monogamy and the prairie vole. *Sci Am* **268**: 100–6.
- Carter, C S & Roberts, R L (1997) The psychobiological basis of cooperative breeding in rodents. In Solomon, N G (ed.) *Cooperative Breeding in Mammals*. pp. 231–66. Cambridge: Cambridge University Press.
- Caspers, B A, Schroeder, F C, Franke, S, Streich, W J & Voigt, C C (2009) Odour-based species recognition in two sympatric species of sac-winged bats (*Saccopteryx bilineata*, *S. leptura*): combining chemical analyses, behavioural observations and odour preference tests. *Behav Ecol Sociobiol* **63**: 741–9.
- Chamero, P, Marton, T F, Logan, D W *et al.* (2007) Identification of protein pheromones that promote aggressive behaviour. *Nature* **450**: 899–902.
- Chamero, P, Leinders-Zufall, T & Zufall, F (2012) From genes to social communication: molecular sensing by the vomeronasal organ. *Trends Neurosci* **35**: 597–606.
- Chandler, D, Bailey, A S, Tatchell, G M *et al.* (2011) The development, regulation and use of biopesticides for integrated pest management. *Phil Trans R Soc B* **366**: 1987–98.
- Chapman, R F (1998) *The Insects. Structure and Function*, 4th edn. Cambridge: Cambridge University Press.
- Chapman, T (2008) The soup in my fly: evolution, form and function of seminal fluid proteins. *PLoS Biol* **6**: e179.
- Charlesworth, D & Willis, J H (2009) The genetics of inbreeding depression. *Nat Rev Genet* **10**: 783–96.
- Charra, R, Datiche, F, Casthano, A *et al.* (2012) Brain processing of the mammary pheromone in newborn rabbits. *Behav Brain Res* **226**: 179–88.
- Chemineau, P (2011) A foresight reflection on sustainable methods for controlling mammalian farm animal reproduction. *Trop Subtrop Agroecosyst* [Online], 15. Available: www.veterinaria.uady.mx/ojs/index.php/TSA/article/view/1344/639 [Accessed 6 June 2013].
- Chen, Z-F, Matsumura, K, Wang, H *et al.* (2011) Toward an understanding of the molecular mechanisms of barnacle larval settlement: a comparative transcriptomic approach. *PLoS ONE* **6**: e22913.
- Chivers, D P, Brown, G E & Ferrari, M C O (2012) The evolution of alarm substances and disturbance cues in aquatic animals. In Brönmark, C & Hansson, L-A (eds) *Chemical Ecology in Aquatic Systems*. pp. 127–39. Oxford: Oxford University Press.
- Choe, A, von Reuss, SH, Kogan, D *et al.* (2012) Ascaroside signaling is widely conserved among nematodes. *Curr Biol* **22**: 772–80.
- Choleris, E, Clipperton-Allen, A E, Phan, A & Kavaliers, M (2009) Neuroendocrinology of social information processing in rats and mice. *Front Neuroendocrinol* **30**: 442–59.
- Choleris, E, Pfaff, D W & Kavaliers, M (eds.) (2013) *Oxytocin, Vasopressin and Related Peptides in the Regulation of Behavior*. Cambridge: Cambridge University Press.
- Christensen, T A (2005) Making scents out of spatial and temporal codes in specialist and generalist olfactory networks. *Chem Senses* **30**: i283–4.
- Christensen, T A & Hildebrand, J G (2002) Pheromonal and host-odor processing in the insect antennal lobe: how different? *Curr Opin Neurobiol* **12**: 393–9.
- Christy, J H (2011) Timing of hatching and release of larvae by brachyuran crabs: patterns, adaptive significance and control. *Integr Comp Biol* **51**: 62–72.
- Chung-Davidson, Y-W, Huertas, M & Li, W (2011) A review of research in fish pheromones. In Breithaupt, T & Thiel, M (eds.) *Chemical Communication in Crustaceans*. pp. 467–82. New York: Springer.

- Clare, A S (2011) Toward a characterization of the chemical cue to barnacle gregariousness. In Breithaupt, T & Thiel, M (eds.) *Chemical Communication in Crustaceans*. pp. 431–50. New York: Springer.
- Clark, C J (2012) The role of power versus energy in courtship: what is the 'energetic cost' of a courtship display? *Anim Behav* 84: 269–77.
- Clark, J & Edexcel (2009) *Edexcel International GCSE Chemistry*. Harlow: Pearson Education. Supported by the website www.chemguide.co.uk.
- Clarke, I J (2011) Control of GnRH secretion: one step back. *Front Neuroendocrinol* 32: 367–75.
- Classen, C, Honer, D & Synott, A (1994) *Aroma. The Cultural History of Smell*. London: Routledge.
- Clavijo McCormick, A, Unsicker, S B & Gershenzon, J (2012) The specificity of herbivore-induced plant volatiles in attracting herbivore enemies. *Trends Plant Sci* 17: 303–10.
- Clegg, J M & Barlow, C A (1982) Escape behavior of the pea aphid *Acyrtosiphon pisum* (Harris) in response to alarm pheromone and vibration. *Can J Zool* 60: 2245–52.
- Clément, J L & Bagnères, A G (1998) Nestmate recognition in termites. In Vander Meer, R K, Breed, M D, Espelie, K E & Winston, M L (eds.) *Pheromone Communication in Social Insects*, pp. 126–55. Boulder, CO: Westview Press.
- Cleveland, A, Verde, E A & Lee, R W (2011) Nutritional exchange in a tropical tripartite symbiosis: direct evidence for the transfer of nutrients from anemonefish to host anemone and zooxanthellae. *Mar Biol* 158: 589–602.
- Clifford, K T, Gross, L, Johnson, K *et al.* (2003) Slime-trail tracking in the predatory snail, *Euglandina rosea*. *Behav Neurosci* 117: 1086.
- Clutton-Brock, T (2007) Sexual selection in males and females. *Science* 318: 1882–5.
- Clutton-Brock, T (2009) Structure and function in mammalian societies. *Phil Trans R Soc B* 364: 3229–42.
- Clutton-Brock, T & McAuliffe, K (2009) Female mate choice in mammals. *Q Rev Biol* 84: 3–27.
- Clyne, J D & Miesenböck, G (2009) Postcoital finesse. *Neuron* 61: 491–3.
- Clyne, P J, Warr, C G, Freeman, M R *et al.* (1999) A novel family of divergent seven-transmembrane proteins: candidate odorant receptors in *Drosophila*. *Neuron* 22: 327–38.
- Cohen, L, Rothschild, G & Mizrahi, A (2011) Multisensory integration of natural odors and sounds in the auditory cortex. *Neuron* 72: 357–69.
- Colazza, S, Peri, E, Salerno, G & Conti, E (2010) Host searching by egg parasitoids: exploitation of host chemical cues. In Consoli, F L, Parra, J R P & Zucchi, R A (eds.) *Egg Parasitoids in Agroecosystems with Emphasis on Trichogramma*. pp. 97–147. Dordrecht: Springer.
- Colledge, W H (2009) Kisspeptins and GnRH neuronal signalling. *Trends Endocrinol Metab* 20: 115–21.
- Conner, W E (ed.) (2009) *Tiger Moths and Woolly Bears: Behavior, Ecology, and Evolution of the Arctiidae*. Oxford: Oxford University Press.
- Conner, W E & Best, B A (1988) Biomechanics of the release of sex pheromone in moths: effects of body posture on local airflow. *Physiol Entomol* 13: 15–20.
- Conner, W E & Weller, S J (2004) A quest for alkaloids: the curious relationship between tiger moths and plants containing pyrrolizidine alkaloids. In Cardé, R & Millar, J G (eds.) *Advances in Insect Chemical Ecology*. pp. 248–82. Cambridge: Cambridge University Press.
- Conner, W E, Eisner, T, Vander Meer, R K, Guerrero, A & Meinwald, J (1980) Sex attractant of an arctiid moth (*Utetheisa ornatrix*): a pulsed chemical signal. *Behav Ecol Sociobiol* 7: 55–63.
- Conrad, T, Paxton, R J, Barth, F G, Francke, W & Ayasse, M (2010) Female choice in the red mason bee, *Osmia rufa* (L.) (Megachilidae). *J Exp Biol* 213: 4065–73.
- Consuegra, S & Garcia de Leaniz, C (2008) MHC-mediated mate choice increases parasite resistance in salmon. *Proc R Soc B* 275: 1397–403.
- Cook, S M, Khan, Z R & Pickett, J A (2007) The use of push–pull strategies in integrated pest management. *Annu Rev Entomol* 52: 375–400.
- Corbin, A (1996) *The Foul and the Fragrant: Odour and the Social Imagination*. London: Papermac.
- Cornwallis, C K & Uller, T (2010) Towards an evolutionary ecology of sexual traits. *Trends Ecol Evol* 25: 145–52.
- Costa-Leonardo, A M & Haifig, I (2010) Pheromones and exocrine glands in Isoptera. In Gerald, L (ed.) *Pheromones*. pp. 521–49. London: Academic Press.

- Costello, E K, Lauber, C L, Hamady, M *et al.* (2009) Bacterial community variation in human body habitats across space and time. *Science* **326**: 1694–17.
- Courchamp, F, Berec, L & Gascoigne, J (2008) *Allee Effects in Ecology and Conservation*. Oxford: Oxford University Press.
- Coureaud, G, Langlois, D, Sicard, G & Schaal, B (2004) Newborn rabbit responsiveness to the mammary pheromone is concentration-dependent. *Chem Senses* **29**: 341–50.
- Coureaud, G, Charra, R, Datiche, F *et al.* (2010) A pheromone to behave, a pheromone to learn: the rabbit mammary pheromone. *J Comp Physiol A* **196**: 779–90.
- Couvillon, M J, Caple, J P, Endors, S L *et al.* (2007) Nest-mate recognition template of guard honeybees (*Apis mellifera*) is modified by wax comb transfer. *Biol Lett* **3**: 228–30.
- Cox, J P L (2008) Hydrodynamic aspects of fish olfaction. *J R Soc Interface* **5**: 575.
- Coyne, J A & Elwyn, S (2006) Does the *desaturase-2* locus in *Drosophila melanogaster* cause adaptation and sexual isolation? *Evolution* **60**: 279–91.
- Coyne, J A & Orr, H A (2004) *Speciation*. Sunderland, MA: Sinauer.
- Craven, B A, Paterson, E G & Settles, G S (2010) The fluid dynamics of canine olfaction: unique nasal airflow patterns as an explanation of macrosmia. *J R Soc Interface* **7**: 933–43.
- Cremer, S, d'Ettorre, P, Drijfhout, F P *et al.* (2008) Imperfect chemical female mimicry in males of the ant *Cardiocondyla obscurior*. *Naturwissenschaften* **95**: 1101–5.
- Crespi, B J (2005) Social sophistry: logos and mythos in the forms of cooperation. *Ann Zool Fenn* **42**: 569–71.
- Crimaldi, J P (2012) The role of structured stirring and mixing on gamete dispersal and aggregation in broadcast spawning. *J Exp Biol* **215**: 1031–9.
- Crossland, M R, Haramura, T, Salim, A A, Capon, R J & Shine, R (2012) Exploiting intraspecific competitive mechanisms to control invasive cane toads (*Rhinella marina*). *Proc R Soc B* **279**: 3436–42.
- Crowe, J & Bradshaw, T (2010) *Chemistry for the Biosciences: the Essential Concepts*, 2nd edn. Oxford: Oxford University Press.
- Crozier, R H (1986) Genetic clonal recognition abilities in marine invertebrates must be maintained by selection for something else. *Evolution* **40**: 1100–1.
- Crozier, R H (1987) Genetic aspects of kin recognition: concepts, models, and synthesis. In Fletcher, D J C & Michener, C D (eds.) *Kin Recognition in Animals*. pp. 55–73. New York: Wiley.
- Crozier, R H, Newey, P S, Schluns, E A & Robson, S K A (2010) A masterpiece of evolution – *Oecophylla* weaver ants (Hymenoptera: Formicidae). *Myrmecol News* **13**: 57–71.
- Cummins, S F & Bowie, J H (2012) Pheromones, attractants and other chemical cues of aquatic organisms and amphibians. *Nat Prod Rep* **29**: 642–58.
- Cummins, S F & Degnan, B M (2010) Sensory sea slugs: towards decoding the molecular toolkit required for a mollusc to smell. *Commun Integr Biol* **3**: 423–6.
- Cummins, S F, Xie, F, de Vries, M R *et al.* (2007) *Aplysia* temptin – the ‘glue’ in the water-borne attractin pheromone complex. *FEBS J* **274**: 5425–37.
- Cummins, S F, Boal, J G, Buresch, K C *et al.* (2011) Extreme aggression in male squid induced by a beta-MSP-like pheromone. *Curr Biol* **21**: 322–7.
- Czaczkes, T J & Ratnieks, F L W (2012) Pheromone trails in the Brazilian ant *Pheidole oxyops*: extreme properties and dual recruitment action. *Behav Ecol Sociobiol*: 1149–56.
- Czaczkes, T J, Grüter, C, Jones, S M & Ratnieks, F L W (2012) Uncovering the complexity of ant foraging trails. *Commun Integr Biol* **5**: 78–80.
- d'Ettorre, P & Heinze, J (2005) Individual recognition in ant queens. *Curr Biol* **15**: 2170–4.
- d'Ettorre, P & Lenoir, A (2010) Nestmate recognition in ants. In Lach, L, Parr, C L & Abbott, K L (eds.) *Ant Ecology*. pp. 194–209. Oxford: Oxford University Press.
- d'Ettorre, P & Moore, A J (2008) Chemical communication and the coordination of social interactions in insects. In d'Ettorre, P & Hughes, D P (eds.) *Sociobiology of Communication: an Interdisciplinary Perspective*. pp. 81–96. Oxford: Oxford University Press.
- Dahanukar, A & Ray, A (2011) Courtship, aggression and avoidance: pheromones, receptors and neurons for social behaviors in *Drosophila*. *Fly* **5**: 58–63.

- Dalton, P, Doolittle, N & Breslin, P A S (2002) Gender-specific induction of enhanced sensitivity to odors. *Nat Neurosci* 5: 199–200.
- Dani, F R (2006) Cuticular lipids as semiochemicals in paper wasps and other social insects. *Ann Zool Fenn* 43: 500–14.
- Dani, F R, Jones, G R, Corsi, S *et al.* (2005) Nestmate recognition cues in the honey bee: differential importance of cuticular alkanes and alkenes. *Chem Senses* 30: 477–89.
- Dani, F R, Michelucci, E, Francese, S *et al.* (2011) Odorant-binding proteins and chemosensory proteins in pheromone detection and release in the silkmoth *Bombyx mori*. *Chem Senses* 36: 335–44.
- Darwin, C (1871) *The Descent of Man and Selection in Relation to Sex*. London: John Murray.
- David, C T, Kennedy, J S & Ludlow, A R (1983) Finding of a sex-pheromone source by gypsy moths released in the field. *Nature* 303: 804–6.
- Davies, N B, Krebs, J R & West, S A (2012) *An Introduction to Behavioural Ecology*, 4th edn. Chichester: Wiley-Blackwell.
- Davis, E C (2007) Investigation in the laboratory of mucous trail detection in the terrestrial pulmonate snail *Mesodon thyroidus* (Say, 1817) (Mollusca: Gastropoda: Polygyridae). *Am Malacol Bull* 22: 157–64.
- Dawkins, M S (2007) *Observing Animal Behaviour: Design and Analysis of Quantitative Data*. Oxford: Oxford University Press.
- Dawkins, R (1976) *The Selfish Gene*. Oxford: Oxford University Press.
- Dawkins, R (1982) *The Extended Phenotype*. San Francisco, CA: WH Freeman.
- de Brito-Sanchez, M G, Deisig, N, Sandoz, J C & Giurfa, M (2008) Neurobiology of olfactory communication in the honeybee. In d'Ettorre, P & Hughes, D P (eds.) *Sociobiology of Communication: an Interdisciplinary Perspective*. pp. 119–38. Oxford: Oxford University Press.
- de Bruyne, M & Baker, T C (2008) Odor detection in insects: volatile codes. *J Chem Ecol* 34: 882–97.
- de Vos, M, Cheng, W Y, Summers, H E, Raguso, R A & Jander, G (2010) Alarm pheromone habituation in *Myzus persicae* has fitness consequences and causes extensive gene expression changes. *Proc Natl Acad Sci USA* 107: 14673–8.
- DeBose, J & Nevitt, G (2008) The use of odors at different spatial scales: comparing birds with fish. *J Chem Ecol* 34: 867–81.
- Dehnhard, M (2011) Mammal semiochemicals: understanding pheromones and signature mixtures for better zoo animal husbandry and conservation. *Int Zoo Yearb* 45: 1–25.
- delBarco-Trillo, J & Ferkin, M H (2004) Male mammals respond to a risk of sperm competition conveyed by odours of conspecific males. *Nature* 431: 446–9.
- delBarco-Trillo, J, Burkert, B A, Goodwin, T E & Drea, C M (2011) Night and day: the comparative study of strepsirrhine primates reveals socioecological and phylogenetic patterns in olfactory signals. *J Evol Biol* 24: 82–98.
- delBarco-Trillo, J, Sacha, C R, Dubay, G R & Drea, C M (2012) *Eulemur*, me lemur: the evolution of scent-signal complexity in a primate clade. *Phil Trans R Soc B* 367: 1909–22.
- delBarco-Trillo, J, Harelimana, I H, Goodwin, T E & Drea, C M (2013) Chemical differences between voided and bladder urine in the aye-aye (*Daubentonia madagascariensis*): implications for olfactory communication studies. *Am J Primatol* 75: 695–702.
- Delgadillo, J A, Gelez, H, Ungerfeld, R, Hawken, P A R & Martin, G B (2009) The 'male effect' in sheep and goats – revisiting the dogmas: pheromonal communication in higher vertebrates and its implication for reproductive function. *Behav Brain Res* 200: 304–14.
- Deneubourg, J L, Goss, S, Franks, N & Pasteels, J M (1989) The blind leading the blind – modeling chemically mediated army ant raid patterns. *J Insect Behav* 2: 719–25.
- Denny, M W (1993) *Air and Water*. Princeton: Princeton University Press.
- Derby, C D & Sorensen, P W (2008) Neural processing, perception, and behavioral responses to natural chemical stimuli by fish and crustaceans. *J Chem Ecol* 34: 898–914.
- Derti, A & Roth, F P (2012) Response to “MHC-dependent mate choice in humans: Why genomic patterns from the HapMap European American data set support the hypothesis” (DOI: 10.1002/bies.201100150). *Bioessays* 34: 576–7.
- Dethier, V G (1987) Sniff, flick, and pulse: an appreciation of intermittency. *Proc Am Philos Soc* 131: 159–76.

- Detrain, C & Deneubourg, J-L (1997) Scavenging by *Pheidole pallidula*: a key for understanding decision-making systems in ants. *Anim Behav* 53: 537–47.
- Detrain, C & Deneubourg, J-L (2006) Self-organized structures in a superorganism: do ants “behave” like molecules? *Phys Life Rev* 3: 162–87.
- Deutsch, J & Murakhver, N (eds.) (2012) *They Eat That? A Cultural Encyclopedia of Weird and Exotic Food from Around the World*. Santa Barbara, CA: ABC-CLIO.
- Deutsch, J C & Nefdt, R J C (1992) Olfactory cues influence female choice in two lek-breeding antelopes. *Nature* 356: 596–8.
- Dewhirst, S Y, Pickett, J A & Hardie, J (2010) Aphid pheromones. In Gerald, L (ed.) *Pheromones*. pp. 551–74. London: Academic Press.
- Dhawale, A K, Hagiwara, A, Bhalla, U S, Murthy, V N & Albeanu, D F (2010) Non-redundant odor coding by sister mitral cells revealed by light addressable glomeruli in the mouse. *Nat Neurosci* 13: 1404–12.
- Dicke, M & Baldwin, I T (2010) The evolutionary context for herbivore-induced plant volatiles: beyond the ‘cry for help’. *Trends Plant Sci* 15: 167–75.
- Dicke, M & Sabelis, M W (1988) Infochemical terminology: based on cost-benefit analysis rather than origin of compounds? *Funct Ecol* 2: 131–9.
- Dickson, B J (2008) Wired for sex: the neurobiology of *Drosophila* mating decisions. *Science* 322: 904–9.
- Dietemann, V, Liebig, J, Hölldobler, B & Peeters, C (2005) Changes in the cuticular hydrocarbons of incipient reproductives correlate with triggering of worker policing in the bulldog ant *Myrmecia gulosa*. *Behav Ecol Sociobiol* 58: 486–96.
- Diggle, S P, Gardner, A, West, S A & Griffin, A S (2007) Evolutionary theory of bacterial quorum sensing: when is a signal not a signal? *Phil Trans R Soc B* 362: 1241–9.
- Dill, L M, Fraser, A H G & Roitberg, B D (1990) The economics of escape behavior in the pea aphid, *Acyrtosiphon pisum*. *Oecologia* 83: 473–8.
- Dillehay, T D (2003) Tracking the first Americans. *Nature* 425: 23–4.
- Dixson, A F (1998) *Primate Sexuality. Comparative Studies of the Prosimians, Monkeys, Apes, and Human Beings*. Oxford: Oxford University Press.
- Dixson, A F (2009) *Sexual Selection and the Origins of Human Mating Systems*. Oxford: Oxford University Press.
- Dixson, A F (2012) *Primate Sexuality: Comparative Studies of the Prosimians, Monkeys, Apes, and Human Beings*, 2nd edn. Oxford: Oxford University Press.
- Dixon, D L, Munday, P L & Jones, G P (2010) Ocean acidification disrupts the innate ability of fish to detect predator olfactory cues. *Ecol Lett* 13: 68–75.
- do Nascimento, R R, Morgan, E D, Billen, J *et al.* (1993) Variation with caste of the mandibular gland secretion in the leaf-cutting ant – *Atta sexdens rubropilosa*. *J Chem Ecol* 19: 907–18.
- Doall, M H, Colin, S P, Strickler, J R & Yen, J (1998) Locating a mate in 3D: the case of *Temora longicornis*. *Phil Trans R Soc B* 353: 681–9.
- Domingue, M J, Haynes, K F, Todd, J L & Baker, T C (2009) Altered olfactory receptor neuron responsiveness is correlated with a shift in behavioral response in an evolved colony of the cabbage looper moth, *Trichoplusia ni*. *J Chem Ecol* 35: 405–15.
- Doney, S C, Fabry, V J, Feely, R A & Kleypas, J A (2009) Ocean acidification: the other CO₂ problem. *Ann Rev Mar Sci* 1: 169–92.
- Doney, S C, Ruckelshaus, M, Emmett Duffy, J *et al.* (2012) Climate change impacts on marine ecosystems. *Ann Rev Mar Sci* 4: 11–37.
- Dopman, E B, Robbins, P S & Seaman, A (2010) Components of reproductive isolation between north American pheromone strains of the European corn borer. *Evolution* 64: 881–902.
- Dorries, K M, Adkins-Regan, E & Halpern, B P (1997) Sensitivity and behavioral responses to the pheromone androstenone are not mediated by the vomeronasal organ in domestic pigs. *Brain Behav Evol* 49: 53–62.
- Doty, R L (2001) Olfaction. *Annu Rev Psychol* 52: 423–52.
- Doty, R L (2009) The olfactory system and its disorders. *Semin Neurol* 29: 74–81.
- Doty, R L (2010) *The Great Pheromone Myth*. Baltimore, MD: Johns Hopkins University Press.
- Doty, R L (2012a) Olfaction in Parkinson’s disease and related disorders. *Neurobiol Dis* 46: 527–52.
- Doty, R L (2012b) Olfactory dysfunction in Parkinson disease. *Nat Rev Neurol* 8: 329–39.

- Doty, R L & Cameron, E L (2009) Sex differences and reproductive hormone influences on human odor perception. *Physiol Behav* **97**: 213–28.
- Doty, R L, Ford, M, Preti, G & Huggins, G R (1975) Changes in the intensity and pleasantness of human vaginal odors during the menstrual cycle. *Science* **190**: 1316–18.
- Doty, R L, Orndorff, M M, Leyden, J & Kligman, A (1978) Communication of gender from human axillary odors: relationship to perceived intensity and hedonicity. *Behav Biol* **23**: 373–80.
- Doucet, S, Soussignan, R, Sagot, P & Schaal, B (2009) The secretion of areolar (Montgomery's) glands from lactating women elicits selective, unconditional responses in neonates. *PLoS ONE* **4**: e7579.
- Doucet, S, Soussignan, R, Sagot, P & Schaal, B (2012) An overlooked aspect of the human breast: areolar glands in relation with breastfeeding pattern, neonatal weight gain, and the dynamics of lactation. *Early Hum Dev* **88**: 119–28.
- Døving, K B & Lastein, S (2009) The alarm reaction in fishes – odorants, modulations of responses, neural pathways. *Ann N Y Acad Sci* **1170**: 413–23.
- Drea, C M, Boulet, M, delBarco-Trillo, J *et al.* (2013) The “secret” in secretions: methodological considerations in deciphering primate olfactory communication. *Am J Primatol* **75**: 621–42.
- Dreanno, C, Kirby, R R & Clare, A S (2006a) Smelly feet are not always a bad thing: the relationship between cyprid footprint protein and the barnacle settlement pheromone. *Biol Lett* **2**: 423–5.
- Dreanno, C, Matsumura, K, Dohmae, N *et al.* (2006b) An α 2-macroglobulin-like protein is the cue to gregarious settlement of the barnacle *Balanus amphitrite*. *Proc Natl Acad Sci USA* **103**: 14396–401.
- Drickamer, L C (1992) Estrous female house mice discriminate dominant from subordinate males and sons of dominant from sons of subordinate males by odor cues. *Anim Behav* **43**: 868–70.
- Drickamer, L C (1995) Rates of urine excretion by house mouse (*Mus domesticus*) – differences by age, sex, social-status, and reproductive condition. *J Chem Ecol* **21**: 1481–93.
- Droney, D C (2003) Females lay fewer eggs for males with greater courtship success in a lekking *Drosophila*. *Anim Behav* **65**: 371–8.
- Dronnet, S, Lohou, C, Christides, J P & Bagnères, A G (2006) Cuticular hydrocarbon composition reflects genetic relationship among colonies of the introduced termite *Reticulitermes santonensis* Feytaud. *J Chem Ecol* **32**: 1027–42.
- Drury, J P (2010) Immunity and mate choice: a new outlook. *Anim Behav* **79**: 539–45.
- Duarte, A, Weissing, F J, Pen, I & Keller, L (2011) An evolutionary perspective on self-organized division of labor in social insects. *Annu Rev Ecol Evol Syst* **42**: 91–110.
- Duffy, J E & Macdonald, K S (2010) Kin structure, ecology and the evolution of social organization in shrimp: a comparative analysis. *Proc R Soc B* **277**: 575–84.
- Duistermars, B J, Chow, D M & Frye, M A (2009) Flies require bilateral sensory input to track odor gradients in flight. *Curr Biol* **19**: 1301–7.
- Dukas, R (2008) Evolutionary biology of insect learning. *Annu Rev Entomol* **53**: 145–60.
- Dulac, C & Torello, A T (2003) Molecular detection of pheromone signals in mammals: from genes to behaviour. *Nat Rev Neurosci* **4**: 551–62.
- Durand, N, Carot-Sans, G, Chertemps, T *et al.* (2010) A diversity of putative carboxylesterases are expressed in the antennae of the noctuid moth *Spodoptera littoralis*. *Insect Mol Biol* **19**: 87–97.
- Dusenbery, D B (1989) Calculated effect of pulsed pheromone release on range of attraction. *J Chem Ecol* **15**: 971–8.
- Dusenbery, D B (1992) *Sensory Ecology. How Organisms Acquire and Respond to Information*. New York: WH Freeman.
- Dusenbery, D B (2009) *Living at Micro Scale: The Unexpected Physics of Being Small*. Cambridge, MA: Harvard University Press.
- Dusenbery, D B & Snell, T W (1995) A critical body size for use of pheromones in mate location. *J Chem Ecol* **21**: 427–38.
- Dussourd, D E, Harvis, C A, Meinwald, J & Eisner, T (1991) Pheromonal advertisement of a nuptial gift by a male moth (*Utetheisa ornatrix*). *Proc Natl Acad Sci USA* **88**: 9224–7.
- Dussoutour, A & Beekman, M (2009) How to tell your mates. In Jarau, S & Hrnčir, M (eds.) *Food Exploitation by Social Insects: Ecological, Behavioral and Theoretical Approaches*. pp. 115–34. Boca Raton, FL: CRC Press.

- East, M L & Dehnhard, M (eds.) (2013) *Chemical Signals in Vertebrates 12*. New York: Springer.
- Eberhard, W G (2009) Postcopulatory sexual selection: Darwin's omission and its consequences. *Proc Natl Acad Sci USA* **106**: 10025–32.
- Edison, A S (2009) *Caenorhabditis elegans* pheromones regulate multiple complex behaviors. *Curr Opin Neurobiol* **19**: 378–88.
- Edmunds, A J F, Aluja, M, Diaz-Fleischer, F, Patrian, B & Hagmann, L (2010) Host marking pheromone (HMP) in the Mexican fruit fly *Anastrepha ludens*. *Chimia* **64**: 37–42.
- Edward, D A & Chapman, T (2011) The evolution and significance of male mate choice. *Trends Ecol Evol* **26**: 647–54.
- Eggert, A K & Müller, J K (1997) Biparental care and social evolution in burying beetles: lessons from the larder. In Choe, J C & Crespi, B J (eds.) *The Evolution of Social Behavior in Insects and Arachnids*. pp. 216–36. Cambridge: Cambridge University Press.
- Eggert, A K & Sakaluk, S K (1995) Female-coerced monogamy in burying beetles. *Behav Ecol Sociobiol* **37**: 147–53.
- Eisner, T (2003) *For Love of Insects*. Cambridge, MA: Belknap Press of Harvard University Press.
- Eisner, T & Meinwald, J (1995) Defense-mechanisms of arthropods. 129. The chemistry of sexual selection. *Proc Natl Acad Sci USA* **92**: 50–5.
- Eisner, T & Meinwald, J (2003) Alkaloid-derived pheromones and sexual selection in Lepidoptera. In Blomquist, G J & Vogt, R G (eds.) *Insect Pheromone Biochemistry and Molecular Biology: the Biosynthesis and Detection of Insect Pheromones and Plant Volatiles*. pp. 341–68. New York: Academic Press.
- Eisthen, H L (2002) Why are olfactory systems of different animals so similar? *Brain Behav Evol* **59**: 273–93.
- Eizaguirre, C & Lenz, T L (2010) Major histocompatibility complex polymorphism: dynamics and consequences of parasite-mediated local adaptation in fishes. *J Fish Biol* **77**: 2023–47.
- Eizaguirre, C, Lenz, T L, Sommerfeld, R D *et al.* (2011) Parasite diversity, patterns of MHC II variation and olfactory based mate choice in diverging three-spined stickleback ecotypes. *Evol Ecol* **25**: 605–22.
- Ekerholm, M & Hallberg, E (2005) Primer and short-range releaser pheromone properties of premolt female urine from the shore crab *Carcinus maenas*. *J Chem Ecol* **31**: 1845–64.
- El-Sayed, A M (2013) The Pherobase: database of pheromones and semiochemicals. [Online]. Available: www.pherobase.com [Accessed 6 June 2013].
- El-Sayed, A M, Suckling, D M, Wearing, C H & Byers, J A (2006) Potential of mass trapping for long-term pest management and eradication of invasive species. *J Econ Entomol* **99**: 1550–64.
- El-Sayed, A M, Suckling, D M, Byers, J A, Jang, E B & Wearing, C H (2009) Potential of “lure and kill” in long-term pest management and eradication of invasive species. *J Econ Entomol* **102**: 815–35.
- Elgar, M A & Allan, R A (2004) Predatory spider mimics acquire colony-specific cuticular hydrocarbons from their ant model prey. *Naturwissenschaften* **91**: 143–7.
- Eliyah, D, Ross, K, Haight, K, Keller, L & Liebig, J (2011) Venom alkaloid and cuticular hydrocarbon profiles are associated with social organization, queen fertility status, and queen genotype in the fire ant *Solenopsis invicta*. *J Chem Ecol* **37**: 1242–54.
- Eliyah, D, Nojima, S, Santangelo, R G *et al.* (2012) Unusual macrocyclic lactone sex pheromone of *Parcoblatta lata*, a primary food source of the endangered red-cockaded woodpecker. *Proc Natl Acad Sci USA* **109**: E490–E496.
- Elliott, J K, Mariscal, R N & Roux, K H (1994) Do anemonefishes use molecular mimicry to avoid being stung by host anemones. *J Exp Mar Biol Ecol* **179**: 99–113.
- Endler, A, Liebig, J, Schmitt, T *et al.* (2004) Surface hydrocarbons of queen eggs regulate worker reproduction in a social insect. *Proc Natl Acad Sci USA* **101**: 2945–50.
- Endler, J A & Basolo, A L (1998) Sensory ecology, receiver biases and sexual selection. *Trends Ecol Evol* **13**: 415–20.
- Eppler, G, Belcher, A M, Kuderling, I *et al.* (1993) Making sense out of scents – species-differences in scent glands, scent marking behavior and scent mark composition in the Callitrichidae. In Rylands, A B (ed.) *Marmosets and Tamarins: Systematics, Behaviour and Ecology*. pp. 123–51. Oxford: Oxford University Press.

- Espelie, K E, Gamboa, G J, Grudzien, T A & Bura, E A (1994) Cuticular hydrocarbons of the paper wasp, *Polistes fuscatus* – a search for recognition pheromones. *J Chem Ecol* 20: 1677–87.
- Estrada, C, Yildizhan, S, Schulz, S & Gilbert, L E (2010) Sex-specific chemical cues from immatures facilitate the evolution of mate guarding in *Heliconius* butterflies. *Proc R Soc B* 277: 407–13.
- Estrada, C, Schulz, S, Yildizhan, S & Gilbert, L E (2011) Sexual selection drives the evolution of antiaphrodisiac pheromones in butterflies. *Evolution* 65: 2843–54.
- Evans, C S & Goy, R W (1968) Social behaviour and reproductive cycles in captive ring-tailed lemurs (*Lemur catta*). *J Zool* 156: 181–97.
- Evans, I, Thornton, H, Chalmers, I & Glasziou, P (2011) *Testing Treatments: Better Research for Better Healthcare*, 2nd edn. London: Pinter and Martin.
- Everaerts, C, Farine, J P, Cobb, M & Ferveur, J F (2010) *Drosophila* cuticular hydrocarbons revisited: mating status alters cuticular profiles. *PLoS ONE* 5: e9607.
- Fabre, J H (1911) *Social Life in the Insect World*. Translated by B Miall. London: Fisher Unwin.
- Fang, S, Ting, C T, Lee, C R *et al.* (2009) Molecular evolution and functional diversification of fatty acid desaturases after recurrent gene duplication in *Drosophila*. *Mol Biol Evol* 26: 1447–56.
- Farbman, A I (1992) *Cell Biology of Olfaction*. Cambridge: Cambridge University Press.
- Fatouros, N E, Dicke, M, Mumm, R, Meiners, T & Hilker, M (2008) Foraging behavior of egg parasitoids exploiting chemical information. *Behav Ecol* 19: 677–89.
- Faulkes, C G & Abbott, D H (1993) Evidence that primer pheromones do not cause social suppression of reproduction in male and female naked mole-rats (*Heterocephalus glaber*). *J Reprod Fertil* 99: 225–30.
- Faulkes, C G & Bennett, N C (2009) Reproductive skew in African mole rats: behavioural and physiological mechanisms to maintain high skew. In Hager, R & Jones, C B (eds.) *Reproductive Skew: Proximate and Ultimate Causes*. pp. 369–96. Cambridge: Cambridge University Press.
- Fedina, T Y & Lewis, S M (2008) An integrative view of sexual selection in *Tribolium* flour beetles. *Biol Rev* 83: 151–71.
- Feener, D H, Jacobs, L F & Schmidt, J O (1996) Specialized parasitoid attracted to a pheromone of ants. *Anim Behav* 51: 61–6.
- Felix, M-A & Duveau, F (2012) Population dynamics and habitat sharing of natural populations of *Caenorhabditis elegans* and *C. briggsae*. *BMC Biol* 10: 59.
- Ferdenzi, C, Coureaud, G, Camos, V & Schaal, B (2008) Human awareness and uses of odor cues in everyday life: results from a questionnaire study in children. *Int J Behav Dev* 32: 422–6.
- Ferkin, M H (2011) Odor-related behavior and cognition in meadow voles, *Microtus pennsylvanicus* (Arvicolidae, Rodentia). *Folia Zool* 60: 262–76.
- Ferkin, M H & Pierce, A A (2007) Perspectives on over-marking: is it good to be on top? *J Ethol* 25: 107–16.
- Ferkin, M H, Sorokin, E S, Renfroe, M W & Johnston, R E (1994) Attractiveness of male odors to females varies directly with plasma testosterone concentration in meadow voles. *Physiol Behav* 55: 347–53.
- Ferkin, M H, Sorokin, E S, Johnston, R E & Lee, C J (1997) Attractiveness of scents varies with protein content of the diet in meadow voles. *Anim Behav* 53: 133–41.
- Ferner, M C & Weissburg, M J (2005) Slow-moving predatory gastropods track prey odors in fast and turbulent flow. *J Exp Biol* 208: 809–19.
- Ferrari, M C O, Wisenden, B D & Chivers, D P (2010) Chemical ecology of predator–prey interactions in aquatic ecosystems: a review and prospectus. *Can J Zool* 88: 698–724.
- Ferrero, D M, Lemon, J K, Fluegge, D *et al.* (2011) Detection and avoidance of a carnivore odor by prey. *Proc Natl Acad Sci USA* 108: 11235–40.
- Ferstl, R, Eggert, F, Westphal, E, Zavazava, N & MullerRuchholtz, W (1992) MHC-related odors in humans. In Doty, R L & Müller-Schwarze, D (eds.) *Chemical Signals in Vertebrates VI*. pp. 206–11. New York: Plenum Press.
- Ferveur, J-F (2005) Cuticular hydrocarbons: their evolution and roles in *Drosophila* pheromonal communication. *Behav Genet* 35: 279–95.
- Ferveur, J-F (2007) Elements of courtship behavior in *Drosophila*. In North, G & Greenspan, R J (eds.) *Invertebrate Neurobiology*. pp. 405–36. Cold Spring Harbor, NY Cold Spring Harbor Laboratory Press.

- Ferveur, J-F (2010) *Drosophila* female courtship and mating behaviors: sensory signals, genes, neural structures and evolution. *Curr Opin Neurobiol* 20: 764–9.
- Ferveur, J-F & Cobb, M (2010) Behavioral and evolutionary roles of cuticular hydrocarbons in *Diptera*. In Blomquist, G J & Bagnères, A-G (eds.) *Insect Hydrocarbons: Biology, Biochemistry, and Chemical Ecology*. pp. 325–43. Cambridge: Cambridge University Press.
- Ferveur, J-F, Cobb, M, Boukella, H & Jallon, J M (1996) World-wide variation in *Drosophila melanogaster* sex-pheromone behavioral effects, genetic bases and potential evolutionary consequences. *Genetica* 97: 73–80.
- Fiedler, K (2012) The host genera of ant-parasitic Lycaenidae butterflies: a review. *Psyche* 2012: doi:10.1155/2012/153975.
- Fine, J M & Sorensen, P W (2008) Isolation and biological activity of the multi-component sea lamprey migratory pheromone. *J Chem Ecol* 34: 1259–67.
- Fine, J M, Vrieze, L A & Sorensen, P W (2004) Evidence that petromyzontid lampreys employ a common migratory pheromone that is partially comprised of bile acids. *J Chem Ecol* 30: 2091–110.
- Fischer-Tenhagen, C, Wetterholm, L, Tenhagen, B A & Heuwieser, W (2011) Training dogs on a scent platform for oestrus detection in cows. *Appl Anim Behav Sci* 131: 63–70.
- Fischman, B J, Woodard, S H & Robinson, G E (2011) Molecular evolutionary analyses of insect societies. *Proc Natl Acad Sci USA* 108: 10847–54.
- Fisher, H S, Swaisgood, R & Fitch-Snyder, H (2003) Countermarking by male pygmy lorises (*Nycticebus pygmaeus*): do females use odor cues to select mates with high competitive ability? *Behav Ecol Sociobiol* 53: 123–30.
- Fitzgerald, T D (1995) *The Tent Caterpillars*. Ithaca, NY: Cornell University Press.
- Fitzgerald, T D & Gallagher, E M (1976) A chemical trail factor from the silk of the eastern tent caterpillar *Malacosoma americanum* (Lepidoptera: Lasiocamidae). *J Chem Ecol* 2: 564–74.
- Flanagan, K A, Webb, W & Stowers, L (2011) Analysis of male pheromones that accelerate female reproductive organ development. *PLoS ONE* 6: e16660.
- Flecke, C & Stengl, M (2009) Octopamine and tyramine modulate pheromone-sensitive olfactory sensilla of the hawkmoth *Manduca sexta* in a time-dependent manner. *J Comp Physiol A* 195: 529–45.
- Fleischer, J & Breer, H (2010) The Grueneberg ganglion: a novel sensory system in the nose. *Histol Histopathol* 25: 909–15.
- Fleischer, J, Breer, H & Strotmann, J (2009) Mammalian olfactory receptors. *Front Cell Neurosci* 3: 9.
- Fleming, A S, Steiner, M & Corter, C (1997) Cortisol, hedonics, and maternal responsiveness in human mothers. *Horm Behav* 32: 85–98.
- Folstad, I & Karter, A J (1992) Parasites, bright males, and the immunocompetence handicap. *Am Nat* 139: 602–22.
- Font, E, Barbosa, D, Sampedro, C & Carazo, P (2012) Social behavior, chemical communication, and adult neurogenesis: studies of scent mark function in *Podarcis* wall lizards. *Gen Comp Endocrinol* 177: 9–17.
- Ford, N B (1986) The role of pheromone trails in the sociobiology of snakes. In Duvall, D (ed.) *Chemical Signals in Vertebrates* 4. pp. 261–78. New York: Plenum Publishing.
- Ford, N B & Low, J R (1984) Sex pheromone source location by garter snakes: a mechanism for detection of direction in non-volatile trails. *J Chem Ecol* 10: 1193–9.
- Forseth, R R & Schroeder, F C (2011) NMR-spectroscopic analysis of mixtures: from structure to function. *Curr Opin Chem Biol* 15: 38–47.
- Forward, R B (2009) Larval biology of the crab *Rhithropanopeus harrisi* (Gould): a synthesis. *Biol Bull* 216: 243.
- Foster, K R (2010) Social behavior in microorganisms. In Székely, T, Moore, A J & Komdeur, J (eds.) *Social Behaviour: Genes, Ecology and Evolution*. pp. 331–56. Cambridge: Cambridge University Press.
- Foster, S P & Johnson, C P (2011) Signal honesty through differential quantity in the female-produced sex pheromone of the moth *Heliothis virescens*. *J Chem Ecol* 37: 717–23.
- Fourcassié, V, Dussutour, A & Deneubourg, J-L (2010) Ant traffic rules. *J Exp Biol* 213: 2357–63.
- Fraenkel, G S & Gunn, D L (1940) *The Orientation of Animals. Kineses, Taxes and Compass Reactions*. Oxford: Clarendon Press.

- Francke, D L, Harmon, J P, Harvey, C T & Ives, A R (2008) Pea aphid dropping behavior diminishes foraging efficiency of a predatory ladybeetle. *Entomol Exp Appl* 127: 118–24.
- Francke, W & Schulz, S (2010) Pheromones in terrestrial invertebrates. In Mander, L & Lui, H-W (eds.) *Comprehensive Natural Products II Chemistry and Biology*. Vol 4. pp. 153–223. Oxford: Elsevier.
- Frank, D, Beauchamp, G & Palestini, C (2010) Systematic review of the use of pheromones for treatment of undesirable behavior in cats and dogs. *J Am Vet Med Assoc* 236: 1308–16.
- Franks, N R, Gomez, N, Goss, S & Deneubourg, J L (1991) The blind leading the blind in army ant raid patterns – testing a model of self-organization (Hymenoptera, Formicidae). *J Insect Behav* 4: 583–607.
- Free, J B (1987) *Pheromones of Social Bees*. London: Chapman and Hall.
- French, J A (1997) Proximate regulation of singular breeding in callitrichid primates. In Solomon, N G & French, J A (eds.) *Cooperative Breeding in Mammals*. pp. 34–75. Cambridge: Cambridge University Press.
- Friedrich, R W (2011) Olfactory neuroscience: beyond the bulb. *Curr Biol* 21: R438 – R440.
- Frostig, R D (ed.) (2009) *In Vivo Optical Imaging of Brain Function*, 2nd edn. Boca Raton, FL: CRC Press.
- Frye, M A (2010) Multisensory systems integration for high-performance motor control in flies. *Curr Opin Neurobiol* 20: 347–52.
- Fujii, T, Ito, K, Tatematsu, M *et al.* (2011) Sex pheromone desaturase functioning in a primitive *Ostrinia* moth is cryptically conserved in congeners' genomes. *Proc Natl Acad Sci USA* 108: 7102–6.
- Funasaka, N, Yoshioka, M & Fujise, Y (2010) Features of the ocular Harderian gland in three balaenopterid species based on anatomical, histological and histochemical observations. *Mammal Study* 35: 9–15.
- Futuyama, D J (2009) *Evolution*, 2nd edn. Sunderland, MA: Sinauer.
- Gabirot, M, López, P & Martín, J (2011) Interpopulational variation in chemosensory responses to selected steroids from femoral secretions of male lizards, *Podarcis hispanica*, mirrors population differences in chemical signals. *Chemoecology* 22: 65–73.
- Gadagkar, R (2009) Interrogating an insect society. *Proc Natl Acad Sci USA* 106: 10407–14.
- Gadau, J & Fewell, J H (eds.) (2009) *Organization of Insect Societies: from Genome to Sociocomplexity*. Cambridge, MA: Harvard University Press.
- Gadau, J, Helmkamp, M, Nygaard, S *et al.* (2012) The genomic impact of 100 million years of social evolution in seven ant species. *Trends Genet* 28: 14–21.
- Gaillard, I, Rouquier, S, Pin, J P *et al.* (2002) A single olfactory receptor specifically binds a set of odorant molecules. *Eur J Neurosci* 15: 409–18.
- Galef, B G & Buckley, L L (1996) Use of foraging trails by Norway rats. *Anim Behav* 51: 765–71.
- Galizia, C G & Rössler, W (2010) Parallel olfactory systems in insects: anatomy and function. *Annu Rev Entomol* 55: 399–420.
- Galizia, C G & Vetter, R S (2004) Optical methods for analyzing odor-evoked activity in the insect brain. In Christensen, T A (ed.) *Methods in Insect Sensory Neuroscience*. pp. 345–88. Boca Raton, FL: CRC Press.
- Gamboa, G J (2004) Kin recognition in eusocial wasps. *Ann Zool Fenn* 41: 789–808.
- Gamboa, G J, Grudzien, T A, Espelie, K E & Bura, E A (1996) Kin recognition pheromones in social wasps: combining chemical and behavioural evidence. *Anim Behav* 51: 625–9.
- Gangestad, S W & Thornhill, R (1998) Menstrual cycle variation in women's preferences for the scent of symmetrical men. *Proc R Soc B* 265: 927–33.
- Gao, Q & Chess, A (1999) Identification of candidate *Drosophila* olfactory receptors from genomic DNA sequence. *Genomics* 60: 31–9.
- Gardiner, J M & Atema, J (2007) Sharks need the lateral line to locate odor sources: rheotaxis and eddy chemotaxis. *J Exp Biol* 210: 1925–34.
- Gardiner, J M & Atema, J (2010) The function of bilateral odor arrival time differences in olfactory orientation of sharks. *Curr Biol* 20: 1187–91.
- Gardner, A & West, S A (2007) Social evolution: the decline and fall of genetic kin recognition. *Curr Biol* 17: R810–R812.
- Gardner, A & West, S A (2010) Greenbeards. *Evolution* 64: 25–38.
- Garner, S R, Bortoluzzi, R N, Heath, D D & Neff, B D (2010) Sexual conflict inhibits female mate choice for major histocompatibility complex dissimilarity in Chinook salmon. *Proc R Soc B* 277: 885–94.

- Gascoigne, J, Berec, L, Gregory, S & Courchamp, F (2009) Dangerously few liaisons: a review of mate-finding Allee effects. *Popul Ecol* 51: 355–72.
- Gaskett, A C (2007) Spider sex pheromones: emission, reception, structures, and functions. *Biol Rev* 82: 26–48.
- Gaskett, A C (2011) Orchid pollination by sexual deception: pollinator perspectives. *Biol Rev* 86: 33–75.
- Gaskett, A C, Winnick, C G & Herberstein, M E (2008) Orchid sexual deceit provokes ejaculation. *Am Nat* 171: E206–E212.
- Gasparini, C & Pilastro, A (2011) Cryptic female preference for genetically unrelated males is mediated by ovarian fluid in the guppy. *Proc R Soc B* 278: 2495–501.
- Gaudry, Q, Nagel, K I & Wilson, R I (2012) Smelling on the fly: sensory cues and strategies for olfactory navigation in *Drosophila*. *Curr Opin Neurobiol* 22: 216–22.
- Gautschi, M, Natsch, A & Schröder, F (2007) Biochemistry of human axilla malodor and chemistry of deodorant ingredients. *CHIMIA* 61: 27–32.
- Gelstein, S, Yeshurun, Y, Rozenkrantz, L *et al.* (2011) Human tears contain a chemosignal. *Science* 331: 226–30.
- Gemeno, C & Schal, C (2004) Sex pheromones of cockroaches. In Cardé, R & Millar, J G (eds.) *Advances in Insect Chemical Ecology*. pp. 179–247. Cambridge: Cambridge University Press.
- Gemeno, C, Yeargan, K V & Haynes, K F (2000) Aggressive chemical mimicry by the bolas spider *Mastophora hutchinsoni*: identification and quantification of a major prey's sex pheromone components in the spider's volatile emissions. *J Chem Ecol* 26: 1235–43.
- Gemeno, C, Snook, K, Benda, N & Schal, C (2003) Behavioral and electrophysiological evidence for volatile sex pheromones in *Parcoblatta* wood cockroaches. *J Chem Ecol* 29: 37–54.
- Getty, T (2006) Sexually selected signals are not similar to sports handicaps. *Trends Ecol Evol* 21: 83–8.
- Getz, W (1991) The honey bee as a model kin recognition system. In Hepper, P G, (ed.) *Kin Recognition*. pp. 358–412. Cambridge: Cambridge University Press.
- Ghaleb, A, Atwood III, J, Morales-Montor, J & Damian, R (2006) A 3 kDa peptide is involved in the chemoattraction in vitro of the male *Schistosoma mansoni* to the female. *Microbes Infect* 8: 2367–75.
- Gibson, R W & Pickett, J A (1983) Wild potato repels aphids by release of aphid alarm pheromone. *Nature* 302: 608–9.
- Gilad, Y, Wiebel, V, Przeworski, M, Lancet, D & Paabo, S (2004) Loss of olfactory receptor genes coincides with the acquisition of full trichromatic vision in primates. *PLoS Biol* 2: 120–5.
- Gilad, Y, Wiebe, V, Przeworski, M, Lancet, D & Paabo, S (2007) Correction: Loss of olfactory receptor genes coincides with the acquisition of full trichromatic vision in primates (Vol 2, pg 120, 2004). *PLoS Biol* 5: 1383.
- Gilbert, A N (2008) *What the Nose Knows: the Science of Scent in Everyday Life*. New York: Crown.
- Gilbert, A N & Firestein, S (2002) Dollars and scents: commercial opportunities in olfaction and taste. *Nat Neurosci* 5: 1043–5.
- Gilbert, A N, Yamazaki, K, Beauchamp, G K & Thomas, L (1986) Olfactory discrimination of mouse strains (*Mus musculus*) and major histocompatibility types by humans (*Homo sapiens*). *J Comp Psychol* 100: 262–5.
- Gilley, D C, Kuzora, J M & Thom, C (2012) Hydrocarbons emitted by waggle-dancing honey bees stimulate colony foraging activity by causing experienced foragers to exploit known food sources. *Apidologie* 43: 85–94.
- Gillingham, M A F, Richardson, D S, Lovlie, H *et al.* (2009) Cryptic preference for MHC-dissimilar females in male red junglefowl, *Gallus gallus*. *Proc R Soc B* 276: 1083–92.
- Gillott, C (2003) Male accessory gland secretions: modulators of female reproductive physiology and behavior. *Annu Rev Entomol* 48: 163–84.
- Glastad, K M, Hunt, B G & Goodisman, M A D (2013) Evidence of a conserved functional role for DNA methylation in termites. *Insect Mol Biol* 22: 143–54.
- Gleason, J M, James, R A, Wicker-Thomas, C & Ritchie, M G (2009) Identification of quantitative trait loci function through analysis of multiple cuticular hydrocarbons differing between *Drosophila simulans* and *Drosophila sechellia* females. *Heredity* 103: 416–24.
- Godfray, H C J (1994) *Parasitoids: Behavioral and Evolutionary Ecology*. Princeton: Princeton University Press.
- Goldfoot, D A (1981) Olfaction, sexual-behavior, and the pheromone hypothesis in rhesus monkeys – a critique. *Am Zool* 21: 153–64.

- Goldfoot, D A, Kravetz, M A, Goy, R W & Freeman, S K (1976) Lack of effect of vaginal lavages and aliphatic acids on ejaculatory responses in rhesus monkeys. *Horm Behav* 7: 1–27.
- Gomez-Diaz, C, Reina, J H, Cambillau, C & Benton, R (2013) Ligands for pheromone-sensing neurons are not conformationally activated odorant binding proteins. *PLoS Biol* 11: e1001546.
- Gomez-Marin, A & Louis, M (2012) Active sensation during orientation behavior in the *Drosophila* larva: more sense than luck. *Curr Opin Neurobiol* 22: 208–15.
- Gomez-Marin, A, Stephens, G J & Louis, M (2011) Active sampling and decision making in *Drosophila* chemotaxis. *Nat Commun* 2: 441.
- Gorman, M L (1976) A mechanism for individual recognition by odour in *Herpestes auropunctatus*. *Anim Behav* 24: 141–6.
- Gorman, M L & Mills, M G L (1984) Scent marking strategies in hyaenas (Mammalia). *J Zool* 202: 535–47.
- Gorman, M L & Stone, R D (1990) Mutual avoidance by European moles *Talpa europaea*. In Macdonald, D W, Müller-Schwarze, D & Natynczuk, S E (eds.) *Chemical Signals in Vertebrates* 5. pp. 367–77. Oxford: Oxford Science Publications.
- Gosling, L M (1982) A reassessment of the function of scent marking in territories. *Z Tierpsychol* 60: 89–118.
- Gosling, L M (1990) Scent marking by resource holders: alternative mechanisms for advertising the cost of competition. In Macdonald, D W, Müller-Schwarze, D & Natynczuk, S E (eds.) *Chemical Signals in Vertebrates* 5. pp. 315–28. Oxford: Oxford Science Publications.
- Gosling, L M & McKay, H V (1990) Competitor assessment by scent matching – an experimental test. *Behav Ecol Sociobiol* 26: 415–20.
- Gosling, L M & Roberts, S C (2001) Scent-marking by male mammals: cheat-proof signals to competitors and mates. *Adv Study Behav* 30: 169–217.
- Gosling, L M, Atkinson, N W, Dunn, S & Collins, S A (1996) The response of subordinate male mice to scent marks varies in relation to their own competitive ability. *Anim Behav* 52: 1185–91.
- Gosling, L M, Roberts, S C, Thornton, E A & Andrew, M J (2000) Life history costs of olfactory status signalling in mice. *Behav Ecol Sociobiol* 48: 328–32.
- Gotzek, D & Ross, K G (2007) Genetic regulation of colony social organization in fire ants: an integrative overview. *Q Rev Biol* 82: 201–26.
- Gotzek, D & Ross, K G (2009) Current status of a model system: the gene *Gp-9* and its association with social organization in fire ants. *PLoS ONE* 4: e7713.
- Gould, F, Estock, M, Hillier, N K *et al.* (2010) Sexual isolation of male moths explained by a single pheromone response QTL containing four receptor genes. *Proc Natl Acad Sci USA* 107: 8660–5.
- Goulson, D (2009) The use of scent marks by foraging bumble bees. In Jarau, S & Hrncir, M (eds.) *Food Exploitation by Social Insects: Ecological, Behavioral and Theoretical Approaches*. Boca Raton, FL: CRC Press.
- Gowaty, P A, Drickamer, L C & Schmid-Holmes, S (2003) Male house mice produce fewer offspring with lower viability and poorer performance when mated with females they do not prefer. *Anim Behav* 65: 95–103.
- Gower, D B, Bird, S, Sharma, P & House, F R (1985) Axillary 5- α -androst-16-en-3-one in men and women – relationships with olfactory acuity to odorous 16-androstenes. *Experientia* 41: 1134–6.
- Gower, D B, Holland, K T, Mallet, A I, Rennie, P J & Watkins, W J (1994) Comparison of 16-androstene steroid concentrations in sterile apocrine sweat and axillary secretions – interconversions of 16-androstenes by the axillary microflora – a mechanism for axillary odor production in man. *J Steroid Biochem Mol Biol* 48: 409–18.
- Gower, D B, Mallet, A I, Watkins, W J, Wallace, L M & Calame, J P (1997) Capillary gas chromatography with chemical ionization negative ion mass spectrometry in the identification of odorous steroids formed in metabolic studies of the sulphates of androsterone, DHA and 5 α -androst-16-en-3 β -ol with human axillary bacterial isolates. *J Steroid Biochem Mol Biol* 63: 81–9.
- Grafen, A (1990a) Biological signals as handicaps. *J Theor Biol* 144: 517–46.
- Grafen, A (1990b) Do animals really recognize kin? *Anim Behav* 39: 42–54.
- Granero, A M, Sanz, J M G, Gonzalez, F J E *et al.* (2005) Chemical compounds of the foraging recruitment pheromone in bumblebees. *Naturwissenschaften* 92: 371–4.
- Grassé, P-P (1959) La reconstruction du nid et les coordinations inter-individuelles chez *Bellicositermes*

- natalensis* et *Cubitermes* sp. La théorie de la stigmergie: essai d'interprétation des termites constructeurs. *Insectes Soc* 6: 41–83.
- Grassé, P-P (1984) *Termitologia, fondation des sociétés. Construction. Tome II*. Paris: Masson.
- Grasso, D A, Sledge, M F, Le Moli, F, Mori, A & Turillazzi, S (2005) Nest-area marking with faeces: a chemical signature that allows colony-level recognition in seed harvesting ants (Hymenoptera, Formicidae). *Insectes Soc* 52: 36–44.
- Gray, S & Hurst, J L (1995) The effects of cage cleaning on aggression within groups of male laboratory mice. *Anim Behav* 49: 821–6.
- Greenberg, L (1979) Genetic component of bee odor in kin recognition. *Science* 206: 1095–7.
- Greene, M J (2010) Cuticular hydrocarbon cues in the formation and maintenance of insect social groups. In Blomquist, G J & Bagnères, A-G (eds.) *Insect Hydrocarbons: Biology, Biochemistry, and Chemical Ecology*. pp. 244–53. Cambridge: Cambridge University Press.
- Greene, M J & Gordon, D M (2003) Cuticular hydrocarbons inform task decisions. *Nature* 423: 32.
- Greenfield, M D (2002) *Signalers and Receivers: Mechanisms and Evolution of Arthropod Communication*. Oxford: Oxford University Press.
- Greenfield, M D (2006) Honesty and deception in animal signals. In Lucas, J R & Simmons, L W (eds.) *Essays in Animal Behaviour: Celebrating 50 Years of Animal Behaviour*. pp. 281–98. Burlington, MA: Academic Press.
- Grether, G F (2010) The evolution of mate preferences, sensory biases, and indicator traits. *Adv Study Behav* 41: 35–76.
- Grice, E A & Segre, J A (2011) The skin microbiome. *Nat Rev Microbiol* 9: 244–53.
- Grice, E A, Kong, H H, Conlan, S *et al.* (2009) Topographical and temporal diversity of the human skin microbiome. *Science* 324: 1190–2.
- Gries, R, Khaskin, G, Gries, G *et al.* (2002) [Z, Z]-4,7-Tridecadien-(S)-2-yl acetate: sex pheromone of douglas-fir cone gall midge, *Contarinia oregonensis*. *J Chem Ecol* 28: 2283–97.
- Griffith, L C & Ejima, A (2009) Courtship learning in *Drosophila melanogaster*: diverse plasticity of a reproductive behavior. *Learn Mem* 16: 743–50.
- Griggio, M, Biard, C, Penn, D & Hoi, H (2011) Female house sparrows “count on” male genes: experimental evidence for MHC-dependent mate preference in birds. *BMC Evol Biol* 11: 44.
- Grillet, M, Everaerts, C, Houot, B *et al.* (2012) Incipient speciation in *Drosophila melanogaster* involves chemical signals. *Scientific Reports* 2: 224.
- Gronenberg, W & Riveros, A J (2009) Social brains and behavior, past and present. In Gadau, J & Fewell, J H (eds.) *Organization of Insect Societies: from Genome to Sociocomplexity*. pp. 377–401. Cambridge, MA: Harvard University Press.
- Groot, A T, Horovitz, J L, Hamilton, J *et al.* (2006) Experimental evidence for interspecific directional selection on moth pheromone communication. *Proc Natl Acad Sci USA* 103: 5858–63.
- Groot, A T, Estock, M L, Horovitz, J L *et al.* (2009) QTL analysis of sex pheromone blend differences between two closely related moths: insights into divergence in biosynthetic pathways. *Insect Biochem Mol Biol* 39: 568–77.
- Grosjean, Y, Rytz, R, Farine, J-P *et al.* (2011) An olfactory receptor for food-derived odours promotes male courtship in *Drosophila*. *Nature* 478: 236–40.
- Grosmaître, X, Santarelli, L C, Tan, J, Luo, M & Ma, M (2007) Dual functions of mammalian olfactory sensory neurons as odor detectors and mechanical sensors. *Nat Neurosci* 10: 348–54.
- Grozinger, C M (2013) Honey bee pheromones In Graham, J (ed.) *The Hive and the Honey Bee*. Hamilton, IL: Dadant & Sons Inc.
- Grozinger, C M & Robinson, G E (2007) Pheromone-mediated gene expression in the honey bee brain. *J Comp Physiol A* 193: 461–70.
- Grozinger, C M, Sharabash, N M, Whitfield, C W & Robinson, G E (2003) Pheromone-mediated gene expression in the honey bee brain. *Proc Natl Acad Sci USA* 100: 14519–25.
- Grozinger, C M, Fischer, P & Hampton, J E (2007a) Uncoupling primer and releaser responses to pheromone in honey bees. *Naturwissenschaften* 94: 375–9.
- Grozinger, C M, Fan, Y, Hoover, S E R & Winston, M L (2007b) Genome wide analysis reveals differences in brain gene expression patterns associated with caste and reproductive status in honey bees (*Apis mellifera*). *Mol Ecol* 16: 4837–48.

- Grüter, C, Menezes, C, Imperatriz-Fonseca, V L & Ratnieks, F L W (2012) A morphologically specialized soldier caste improves colony defense in a neotropical eusocial bee. *Proc Natl Acad Sci USA* 109: 1182–6.
- Guerra Sanz, J M & Roldán Serrano, A (2008) Influence of honey bees brood pheromone on the production of triploid watermelon. In Pitrat, M, (ed.) *Cucurbitaceae 2008, Proc IXth EUCARPIA genetics & breeding Cucurbitaceae*. pp. 385–9. Avignon (France): INRA.
- Guerrieri, F J & d'Ettorre, P (2008) The mandible opening response: quantifying aggression elicited by chemical cues in ants. *J Exp Biol* 211: 1109–13.
- Guilford, T & Dawkins, M S (1991) Receiver psychology and the evolution of animal signals. *Anim Behav* 42: 1–14.
- Guilford, T & Dawkins, M S (1993) Receiver psychology and the design of animal signals. *Trends Neurosci* 16: 430–6.
- Guilford, T, Nicol, C, Rothschild, M & Moore, B P (1987) The biological roles of pyrazines – evidence for a warning odor function. *Biol J Linn Soc* 31: 113–28.
- Guo, C C, Hwang, J S & Fautin, D G (1996) Host selection by shrimps symbiotic with sea anemones: a field survey and experimental laboratory analysis. *J Exp Mar Biol Ecol* 202: 165–76.
- Gutiérrez-Castellanos, N, Martínez-Marcos, A, Martínez-García, F & Lanuza, E (2010) Chemosensory function of the amygdala. In Gerald, L (ed.) *Pheromones*. pp. 165–96. London: Academic Press.
- Haberer, W, Schmitt, T, Peschke, K, Schreier, P & Müller, J (2008) Ethyl 4-methyl heptanoate: a male-produced pheromone of *Nicrophorus vespilloides*. *J Chem Ecol* 34: 94–8.
- Hafernik, J & Saul-Gershenz, L (2000) Beetle larvae cooperate to mimic bees. *Nature* 405: 35–6.
- Haga, S, Hattori, T, Sato, T *et al.* (2010) The male mouse pheromone ESP1 enhances female sexual receptive behaviour through a specific vomeronasal receptor. *Nature* 466: 118–22.
- Hagelin, J C (2007) The citrus-like scent of crested auklets: reviewing the evidence for an avian olfactory ornament. *J Ornithol* 148: S195–S201.
- Hagelin, J C & Jones, I L (2007) Bird odors and other chemical substances: a defense mechanism or overlooked mode of intraspecific communication? *Auk* 124: 741–61.
- Hager, R & Jones, C B (eds.) (2009) *Reproductive Skew in Vertebrates: Proximate and Ultimate Causes*. Cambridge: Cambridge University Press.
- Hagman, M & Shine, R (2009) Larval alarm pheromones as a potential control for invasive cane toads (*Bufo marinus*) in tropical Australia. *Chemoecology* 19: 211–17.
- Hallem, E A & Carlson, J R (2006) Coding of odors by a receptor repertoire. *Cell* 125: 143–60.
- Halpern, M & Martínez-Marcos, A (2003) Structure and function of the vomeronasal system: an update. *Prog Neurobiol* 70: 245–318.
- Halpin, Z T (1986) Individual odors among mammals – origins and functions. *Adv Study Behav* 16: 39–70.
- Hamdani, E H & Døving, K B (2007) The functional organization of the fish olfactory system. *Prog Neurobiol* 82: 80–6.
- Hamilton, W D (1964) The genetical evolution of social behaviour. I and II. *J Theor Biol* 7: 1–32.
- Hamilton, W D (1971) Geometry for the selfish herd. *J Theor Biol* 31: 295–311.
- Hamilton, W D (1987) Kinship, recognition, disease, and intelligence: constraints of social evolution. In Itô, Y (ed.) *Animal Societies: Theories and Facts*. pp. 88–102. Tokyo: Japan Science Society Press.
- Hangartner, W (1967) Spezifität und inaktivierung des spurpheromons von *Lasius fuliginosus* Latr. und orientierung der arbeitenden in duftfeld. *ZeitverglPhysiol* 57: 103–36.
- Hanin, O, Azrielli, A, Applebaum, S W & Rafaeli, A (2012) Functional impact of silencing the *Helicoverpa armigera* sex-peptide receptor on female reproductive behaviour. *Insect Mol Biol* 21: 161–7.
- Hansson, B S & Stensmyr, M C (2011) Evolution of insect olfaction. *Neuron* 72: 698–711.
- Hanus, R, Vrkošlav, V, Hrdý, I, Cvacka, J & Sobotník, J (2010) Beyond cuticular hydrocarbons: evidence of proteinaceous secretion specific to termite kings and queens. *Proc R Soc B* 277: 995–1002.
- Hardege, J D (1999) Nereidid polychaetes as model organisms for marine chemical ecology. *Hydrobiologia* 402: 145–61.
- Hardege, J D & Terschak, J A (2011) Identification of crustacean sex pheromones. In Breithaupt, T & Thiel, M (eds.) *Chemical Communication in Crustaceans*. pp. 373–92. New York: Springer.
- Hardege, J D, Bartels-Hardege, H, Müller, C T & Beckmann, M (2004) Peptide pheromones in female *Nereis succinea*. *Peptides* 25: 1517–22.

- Hardege, J D, Rotchell, J M, Terschak, J & Greenway, G M (2011a) Analytical challenges and the development of biomarkers to measure and to monitor the effects of ocean acidification. *Trends Analyt Chem* 30: 1320–6.
- Hardege, J D, Bartels-Hardege, H, Fletcher, N *et al.* (2011b) Identification of a female sex pheromone in *Carcinus maenas*. *Mar Ecol Prog Ser* 436: 177–89.
- Hardie, J & Minks, A K (eds.) (1999) *Pheromones of Non-lepidopteran Insects associated with Agricultural Plants*. Wallingford, Oxon: CAB International.
- Hardy, S, Legagneux, V, Audic, Y & Paillard, L (2010) Reverse genetics in eukaryotes. *Biol Cell* 102: 561–80.
- Harris, M O & Foster, S P (1995) Behavior and integration. In Cardé, R T & Bell, W J (eds.) *Chemical Ecology of Insects* 2. pp. 3–46. London: Chapman and Hall.
- Hart, A C & Chao, M Y (2010) From odors to behaviors in *Caenorhabditis elegans*. In Menini, A (ed.) *The Neurobiology of Olfaction*. Boca Raton, FL: CRC Press. Available online at www.ncbi.nlm.nih.gov/books/NBK55983.
- Harter, J (1979) *Animals. 1419 Copyright-free Illustrations of Mammals etc.* New York: Dover.
- Häsemeyer, M, Yapici, N, Heberlein, U & Dickson, B J (2009) Sensory neurons in the *Drosophila* genital tract regulate female reproductive behavior. *Neuron* 61: 511–18.
- Hasin-Brumshtein, Y, Lancet, D & Olender, T (2009) Human olfaction: from genomic variation to phenotypic diversity. *Trends Genet* 25: 178–84.
- Hassanali, A, Njagi, P G N & Bashir, M O (2005) Chemical ecology of locusts and related acridids. *Annu Rev Entomol* 50: 223–45.
- Hassanali, A, Nyandat, E, Obenchain, F A, Otieno, D A & Galun, R (1989) Humidity effects on response of *Argas persicus* (Oken) to guanine, an assembly pheromone of ticks. *J Chem Ecol* 15: 791–3.
- Haupt, S S, Sakurai, T, Namiki, S, Kazawa, T & Kanzaki, R (2010) Olfactory information processing in moths. In Menini, A (ed.) *The Neurobiology of Olfaction*. Boca Raton, FL: CRC Press. Available online at www.ncbi.nlm.nih.gov/books/NBK55976/.
- Havlíček, J & Roberts, S C (2009) MHC-correlated mate choice in humans: a review. *Psychoneuroendocrinology* 34: 497–512.
- Havlíček, J, Dvůráková, R, Bartoš, L & Flegr, J (2006) Non advertized does not mean concealed: body odour changes across the human menstrual cycle. *Ethology* 112: 81–90.
- Havlíček, J, Murray, A K, Saxton, T K & Roberts, S C (2010) Current issues in the study of androstenes in human chemosignaling. In Gerald, L (ed.) *Pheromones*. pp. 47–81. London: Academic Press.
- Hawken, P & Martin, G (2012) Sociosexual stimuli and gonadotropin-releasing hormone/luteinizing hormone secretion in sheep and goats. *Domest Anim Endocrinol* 43: 85–94.
- Hawkes, C H & Doty, R L (2009) *The Neurology of Olfaction*. Cambridge: Cambridge University Press.
- Hawkins, R D, Hon, G C & Ren, B (2010) Next-generation genomics: an integrative approach. *Nat Rev Genet* 11: 476–86.
- Hay, M E (2009) Marine chemical ecology: chemical signals and cues structure marine populations, communities, and ecosystems. *Ann Rev Mar Sci* 1: 193–212.
- Hayden, S, Bekaert, M, Crider, T A *et al.* (2010) Ecological adaptation determines functional mammalian olfactory subgenomes. *Genome Res* 20: 1–9.
- Hayes, R A, Richardson, B J & Wyllie, S G (2003) To fix or not to fix: the role of 2-phenoxyethanol in rabbit, *Oryctolagus cuniculus*, chin gland secretion. *J Chem Ecol* 29: 1051–64.
- Haynes, K F & Millar, J G (eds.) (1998) *Methods in Chemical Ecology. Volume 2. Bioassay Methods*. London: Chapman & Hall.
- Haynes, K F, Gemenio, C, Yeargan, K V, Millar, J G & Johnson, K M (2002) Aggressive mimicry of moth pheromones by a bolas spider: how does this specialist predator attract more than one species of prey? *Chemoecology* 12: 99–105.
- He, J, Ma, L M, Kim, S, Nakai, J & Yu, C R (2008) Encoding gender and individual information in the mouse vomeronasal organ. *Science* 320: 535–8.
- Hebets, E A & Papaj, D R (2005) Complex signal function: developing a framework of testable hypotheses. *Behav Ecol Sociobiol* 57: 197–214.

- Hedin, P A, Hardee, D D, Thompson, A C & Gueldner, R C (1974) An assessment of the lifetime biosynthesis potential of the male boll weevil. *J Insect Physiol* **20**: 1707–12.
- Hedrick, P W (1999) Balancing selection and MHC. *Genetica* **104**: 207–14.
- Hedrick, P W & Loeschcke, V (1996) MHC and mate selection in humans? *Trends Ecol Evol* **11**: 24.
- Hefetz, A (2007) The evolution of hydrocarbon pheromone parsimony in ants (Hymenoptera: Formicidae) – interplay of colony odor uniformity and odor idiosyncrasy. *Myrmecol News* **10**: 59–68.
- Hefetz, A, Bergström, G & Tengo, J (1986) Species, individual and kin specific blends in Dufour's gland secretions of halictine bees – chemical evidence. *J Chem Ecol* **12**: 197–208.
- Heinze, J & d'Ettorre, P (2009) Honest and dishonest communication in social Hymenoptera. *J Exp Biol* **212**: 1775–9.
- Helanterä, H, Lee, Y R, Drijfhout, F P & Martin, S J (2011) Genetic diversity, colony chemical phenotype, and nest mate recognition in the ant *Formica fusca*. *Behav Ecol* **22**: 710–16.
- Helgason, A, Palsson, S & Guthbjartsson, D F (2008) An association between the kinship and fertility of human couples. *Science* **319**: 813.
- Hendrichs, J, Katsoyannos, B I, Wornoayporn, V & Hendrichs, M A (1994) Odor-mediated foraging by yellowjacket wasps (Hymenoptera, Vespidae) – predation on leks of pheromone-calling Mediterranean fruit-fly males (Diptera, Tephritidae). *Oecologia* **99**: 88–94.
- Hendrichs, M A & Hendrichs, J (1998) Perfumed to be killed: interception of Mediterranean fruit fly (Diptera: Tephritidae) sexual signaling by predatory foraging wasps (Hymenoptera: Vespidae). *Ann Entomol Soc Am* **91**: 228–34.
- Hensch, T K (2004) Critical period regulation. *Annu Rev Neurosci* **27**: 549–79.
- Hepper, P G & Wells, D L (2005) How many footsteps do dogs need to determine the direction of an odour trail? *Chem Senses* **30**: 291–8.
- Herb, B R, Wolschin, F, Hansen, K D *et al.* (2012) Reversible switching between epigenetic states in honeybee behavioral subcastes. *Nat Neurosci.* **15**: 1371–3.
- Herz, R S (2007) *The Scent of Desire: Discovering our Enigmatic Sense of Smell*. New York: William Morrow/HarperCollins.
- Herz, R S (2009a) Aromatherapy facts and fictions: a scientific analysis of olfactory effects on mood, physiology and behavior. *Int J Neurosci* **119**: 263–90.
- Herz, R S (2009b) Symposium overview. Basic processes in human olfactory cognition: current findings and future directions. *Ann N Y Acad Sci* **1170**: 313–17.
- Herz, R S (2011) Perfume. In Gottfried, J A (ed.) *Neurobiology of Sensation and Reward*. Boca Raton, FL: CRC Press. Available from: www.ncbi.nlm.nih.gov/books/NBK92802.
- Herz, R S (2012) Odor memory and the special role of associative learning. In Zucco, G M, Schaal, B & Herz, R S (eds.) *Olfactory Cognition: from Perception and Memory to Environmental Odours and Neuroscience*. pp. 95–114. Amsterdam: John Benjamins.
- Hesselschwerdt, J, Tschärner, S, Necker, J & Wantzen, K (2009) A local gammarid uses kairomones to avoid predation by the invasive crustaceans *Dikergammarus villosus* and *Orconectes limosus*. *Biol Invasions* **11**: 2133–40.
- Hettyey, A, Hegyi, G, Puurtinen, M *et al.* (2010) Mate choice for genetic benefits: time to put the pieces together. *Ethology* **116**: 1–9.
- Heuskin, S, Verheggen, F, Haubruge, E, Wathélet, J P & Lognay, G (2011) The use of semiochemical slow-release devices in integrated pest management strategies. *Biotechnol Agron Soc Environ* **15**: 459–70.
- Hildebrand, J G & Shepherd, G M (1997) Mechanisms of olfactory discrimination: converging evidence for common principles across phyla. *Annu Rev Neurosci* **20**: 595–631.
- Hill, G E (2011) Condition-dependent traits as signals of the functionality of vital cellular processes. *Ecol Lett* **14**: 625–34.
- Hillier, N K & Vickers, N J (2011) Hairpencil volatiles influence interspecific courtship and mating between two related moth species. *J Chem Ecol* **37**: 1127–36.
- Himuro, C, Yokoi, T & Matsuura, K (2011) Queen-specific volatile in a higher termite *Nasutitermes takasagoensis* (Isoptera: Termitidae). *J Insect Physiol* **57**: 962–5.

- Hine, E, McGuigan, K & Blows, M W (2011) Natural selection stops the evolution of male attractiveness. *Proc Natl Acad Sci USA* **108**: 3659–64.
- Hobbs, N J & Ferkin, M H (2011) Dietary protein content affects the response of meadow voles, *Microtus pennsylvanicus*, to over-marks. *Acta Ethol* **14**: 57–64.
- Hoffmeister, T S & Roitberg, B D (2002) Evolutionary ecology of oviposition marking pheromones. In Hilker, M & Meiners, T (eds.) *Chemoeecology of Insect Eggs and Egg Deposition*. pp. 319–47. Berlin: Blackwell.
- Hofstetter, R W, Gaylord, M L, Martinson, S & Wagner, M R (2012) Attraction to monoterpenes and beetle-produced compounds by syntopic *Ips* and *Dendroctonus* bark beetles and their predators. *Agric For Entomol* **14**: 207–15.
- Höglund, J & Alatalo, R V (1995) *Leks*. Princeton: Princeton University Press.
- Holekamp, K E & Dloniak, S M (2010) Intraspecific variation in the behavioral ecology of a tropical carnivore, the spotted hyena. *Adv Study Behav* **42**: 189–229.
- Holland, B & Rice, W R (1998) Chase-away sexual selection: antagonistic seduction versus resistance. *Evolution* **52**: 1–7.
- Hölldobler, B & Carlin, N F (1987) Anonymity and specificity in the chemical communication signals of social insects. *J Comp Physiol A* **161**: 567–81.
- Hölldobler, B & Wilson, E O (1977) Weaver ants. *Sci Am* **237**: 146–54.
- Hölldobler, B & Wilson, E O (1978) The multiple recruitment systems of the African weaver ant *Oecophylla longinoda* (Latreille) (Hymenoptera: Formicidae). *Behav Ecol Sociobiol* **3**: 19–60.
- Hölldobler, B & Wilson, E O (1990) *The Ants*. Berlin: Springer.
- Hölldobler, B & Wilson, E O (1994) *Journey to the Ants. A Story of Scientific Exploration*. Cambridge, MA: Harvard University Press.
- Hölldobler, B & Wilson, E O (2009) *The Superorganism: the Beauty, Elegance, and Strangeness of Insect Societies*. New York: W.W. Norton.
- Hölldobler, B, Stanton, R C & Markl, H (1978) Recruitment and food-retrieving behavior in *Novomessor* (Formicidae, Hymenoptera). I. Chemical signals. *Behav Ecol Sociobiol* **4**: 163–81.
- Holman, L (2010) Queen pheromones: the chemical crown governing insect social life. *Commun Integr Biol* **3**: 558–60.
- Holman, L, Dreier, S & d'Ettorre, P (2010a) Selfish strategies and honest signalling: reproductive conflicts in ant queen associations. *Proc R Soc B* **277**: 2007–15.
- Holman, L, Jørgensen, C, Nielsen, J & d'Ettorre, P (2010b) Identification of an ant queen pheromone regulating worker sterility. *Proc R Soc B* **277**: 3793–800.
- Holmes, W G (1986) Identification of paternal half-siblings by captive Belding ground-squirrels. *Anim Behav* **34**: 321–7.
- Holmes, W G (2004) The early history of Hamiltonian-based research on kin recognition. *Ann Zool Fenn* **41**: 691–711.
- Holmes, W G & Sherman, P W (1982) The ontogeny of kin recognition in 2 species of ground-squirrels. *Am Zool* **22**: 491–517.
- Hong, W S, Chen, S X, Zhang, Q Y & Zheng, W Y (2006) Sex organ extracts and artificial hormonal compounds as sex pheromones to attract broodfish and to induce spawning of Chinese black sleeper (*Bostrichthys sinensis* Lacépède). *Aquac Res* **37**: 529–34.
- Hoover, S E R, Keeling, C I, Winston, M L & Slessor, K N (2003) The effect of queen pheromones on worker honey bee ovary development. *Naturwissenschaften* **90**: 477–80.
- Hoover, S E R, Oldroyd, B P, Wossler, T C & Winston, M L (2005) Anarchistic queen honey bees have normal queen mandibular pheromones. *Insectes Soc* **52**: 6–10.
- Horne, T J & Ylönen, H (1998) Heritabilities of dominance-related traits in male bank voles (*Clethrionomys glareolus*). *Evolution* **52**: 894–9.
- Horner, A J, Nickles, S P, Weissburg, M J & Derby, C D (2006) Source and specificity of chemical cues mediating shelter preference of Caribbean spiny lobsters (*Panulirus argus*). *Biol Bull* **211**: 128–39.
- Horner, A J, Weissburg, M J & Derby, C D (2008) The olfactory pathway mediates sheltering behavior of Caribbean spiny lobsters, *Panulirus argus*, to conspecific urine signals. *J Comp Physiol A* **194**: 243–53.
- Hosken, D J, Stockley, P, Tregenza, T & Wedell, N (2009) Monogamy and the battle of the sexes. *Annu Rev Entomol* **54**: 361–78.

- Houck, L D (2009) Pheromone communication in amphibians and reptiles. *Annu Rev Physiol* **71**: 161–76.
- House, P K, Vyas, A & Sapolsky, R (2011) Predator cat odors activate sexual arousal pathways in brains of *Toxoplasma gondii* infected rats. *PLoS ONE* **6**: e23277.
- Hovestadt, T, Thomas, J A, Mitesser, O, Elmes, G W & Schönrogge, K (2012) Unexpected benefit of a social parasite for a key fitness component of its ant host. *Am Nat* **179**: 110–23.
- Howard, L O & Fiske, W F (1911) *The Importation into the United States of the Parasites of the Gipsy Moth and the Brown-tail Moth. Bulletin 91*. Washington, DC: US Department of Agriculture, Bureau of Entomology.
- Howard, R W & Akre, R D (1995) Propaganda, crypsis, and slave-making. In Cardé, R T & Bell, W J (eds.) *Chemical Ecology of Insects* 2. pp. 364–424. London: Chapman and Hall.
- Howard, R W & Blomquist, G J (2005) Ecological, behavioral, and biochemical aspects of insect hydrocarbons. *Annu Rev Entomol* **50**: 371–93.
- Howard, R W, McDaniel, C A & Blomquist, G J (1980) Chemical mimicry as an integrating mechanism: cuticular hydrocarbons of a termitophile and its host. *Science* **210**: 431–3.
- Howard, S & Hughes, B M (2008) Expectancies, not aroma, explain impact of lavender aromatherapy on psychophysiological indices of relaxation in young healthy women. *Br J Health Psychol* **13**: 603–17.
- Howe, N R & Harris, L G (1978) Transfer of the sea anemone pheromone, anthopleurine, by the nudibranch *Aedidia papillosa*. *J Chem Ecol* **4**: 551–61.
- Howe, N R & Sheik, Y M (1975) Anthopleurine: a sea anemone alarm pheromone. *Science* **189**: 386–8.
- Howse, P E, Stevens, I D R & Jones, O T (1998) *Insect Pheromones and their Use in Pest Management*. London: Chapman & Hall.
- Hu, P J (2007) Dauer. In The *C. elegans* Research Community (ed.) *WormBook: The Online Review of C. elegans Biology [Internet]*. doi/10.1895/wormbook.1891.1144.1891. Pasadena, CA: WormBook.
- Hudson, R (1993) Olfactory imprinting. *Curr Opin Neurobiol* **3**: 548–52.
- Hughes, M (1996) The function of concurrent signals: visual and chemical communication in snapping shrimp. *Anim Behav* **52**: 247–57.
- Huigens, M E, Pashalidou, F G, Qian, M H *et al.* (2009) Hitch-hiking parasitic wasp learns to exploit butterfly antiaphrodisiac. *Proc Natl Acad Sci USA* **106**: 820.
- Huigens, M E, de Swart, E & Mumm, R (2011) Risk of egg parasitoid attraction depends on anti-aphrodisiac titre in the large cabbage white butterfly *Pieris brassicae*. *J Chem Ecol* **37**: 364–7.
- Human Microbiome Project Consortium (2012) Structure, function and diversity of the healthy human microbiome. *Nature* **486**: 207–14.
- Hunter, J R & Hasler, A D (1965) Spawning association of the redbfin shiner *Notropis umbratilis* and the green sunfish *Lepomis cyanellus*. *Copeia* **1965**: 265–81.
- Hurd, P L (1995) Communication in discrete action-response games. *J Theor Biol* **174**: 217–22.
- Hurd, P L (1997) Is signalling of fighting ability costlier for weaker individuals? *J Theor Biol* **184**: 83–8.
- Hurst, J L (1993) The priming effects of urine substrate marks on interactions between male house mice, *Mus musculus domesticus* Schwarz and Schwarz. *Anim Behav* **45**: 55–81.
- Hurst, J L (2009) Female recognition and assessment of males through scent. *Behav Brain Res* **200**: 295–303.
- Hurst, J L & Beynon, R J (2004) Scent wars: the chemobiology of competitive signalling in mice. *Bioessays* **26**: 1288–98.
- Hurst, J L & Beynon, R J (2008) Chemical communication in societies of rodents. In d'Ettorre, P & Hughes, DP (eds.) *Sociobiology of Communication: an Interdisciplinary Perspective*. pp. 97–117. Oxford: Oxford University Press.
- Hurst, J L & Beynon, R J (2013) Rodent urinary proteins used in scent communication. In East, M L & Dehnhard, M (eds.) *Chemical Signals in Vertebrates* 12. pp. 117–33. New York: Springer.
- Hurst, J L, Beynon, R J, Roberts, S C & Wyatt, T D (eds.) (2008) *Chemical Signals in Vertebrates* 11. New York: Springer.
- Hutchison, L V & Wenzel, B M (1980) Olfactory guidance in procellariiforms. *Condor* **82**: 314–19.
- Iino, Y & Yoshida, K (2009) Parallel use of two behavioral mechanisms for chemotaxis in *Caenorhabditis elegans*. *J Neurosci* **29**: 5370–80.

- Imai, T, Sakano, H & Vosshall, L B (2010) Topographic mapping – the olfactory system. *Cold Spring Harb Perspect Biol* 2: a001776.
- Inoshita, T, Martin, J R, Marion-Poll, F & Ferveur, J F (2011) Peripheral, central and behavioral responses to the cuticular pheromone bouquet in *Drosophila melanogaster* males. *PLoS ONE* 6: e19770.
- Ishida, Y & Leal, W S (2005) Rapid inactivation of a moth pheromone. *Proc Natl Acad Sci USA* 102: 14075–9.
- Isogai, Y, Si, S, Pont-Lezica, L *et al.* (2011) Molecular organization of vomeronasal chemoreception. *Nature* 478: 241–5.
- Ivy, T M, Weddle, C B & Sakaluk, S K (2005) Females use self-referent cues to avoid mating with previous mates. *Proc R Soc B* 272: 2475–8.
- Iyengar, V K & Eisner, T (1999a) Heritability of body mass, a sexually selected trait, in an arctiid moth (*Utetheisa ornatrix*). *Proc Natl Acad Sci USA* 96: 9169–71.
- Iyengar, V K & Eisner, T (1999b) Female choice increases offspring fitness in an arctiid moth (*Utetheisa ornatrix*). *Proc Natl Acad Sci USA* 96: 15013–16.
- Iyengar, V K, Reeve, H K & Eisner, T (2002) Paternal inheritance of a female moth's mating preference. *Nature* 419: 830–2.
- Izard, M K (1983) Pheromones and reproduction in domestic animals. In Vandenberg, J G (ed.) *Pheromones and Reproduction in Mammals*. pp. 253–85. New York: Academic Press.
- Jackson, D E & Ratnieks, F L W (2006) Communication in ants. *Curr Biol* 16: R570–R574.
- Jackson, D E, Holcombe, M & Ratnieks, F L W (2004) Trail geometry gives polarity to ant foraging networks. *Nature* 432: 907–9.
- Jackson, D E, Martin, S J, Holcombe, M & Ratnieks, F L W (2006) Longevity and detection of persistent foraging trails in Pharaoh's ants, *Monomorium pharaonis* (L.). *Anim Behav* 71: 351–9.
- Jackson, D E, Martin, S J, Ratnieks, F L W & Holcombe, M (2007) Spatial and temporal variation in pheromone composition of ant foraging trails. *Behav Ecol* 18: 444–50.
- Jacob, S & McClintock, M K (2000) Psychological state and mood effects of steroidal chemosignals in women and men. *Horm Behav* 37: 57–78.
- Jallon, J M & David, J R (1987) Variations in cuticular hydrocarbons among the 8 species of the *Drosophila melanogaster* subgroup. *Evolution* 41: 294–302.
- James, A, Plank, M J & Edwards, A M (2011) Assessing Lévy walks as models of animal foraging. *J R Soc Interface* 8: 1233–47.
- James, A, Casey, J, Hyliands, D & Mycock, G (2004) Fatty acid metabolism by cutaneous bacteria and its role in axillary malodour. *World J Microbiol Biotechnol* 20: 787–93.
- Jarau, S (2009) Chemical communication during food exploitation in stingless bees. In Jarau, S & Hrncir, M (eds.) *Food Exploitation by Social Insects: Ecological, Behavioral and Theoretical Approaches*. pp. 223–49. Boca Raton, FL: CRC Press.
- Jarau, S, Schulz, C M, Hrncir, M *et al.* (2006) Hexyl decanoate, the first trail pheromone compound identified in a stingless bee, *Trigona recursa*. *J Chem Ecol* 32: 1555–64.
- Jarriault, D, Barrozo, R B, Pinto, C J D *et al.* (2009) Age-dependent plasticity of sex pheromone response in the moth, *Agrotis ipsilon*: combined effects of octopamine and juvenile hormone. *Horm Behav* 56: 185–91.
- Jeanson, R, Dussutour, A & Fourcassie, V (2012) Key factors for the emergence of collective decision in invertebrates. *Front Neurosci* 6: 121.
- Jefferis, G S X E & Livet, J (2012) Sparse and combinatorial neuron labelling. *Curr Opin Neurobiol* 22: 101–10.
- Jefferis, G S X E, Potter, C J, Chan, A I *et al.* (2007) Comprehensive maps of *Drosophila* higher olfactory centers: spatially segregated fruit and pheromone representation. *Cell* 128: 1187–203.
- Jenkins, S R, Marshall, D & Frascchetti, S (2009) Settlement and recruitment. In Whal, M (ed.) *Marine Hard Bottom Communities: Patterns, Dynamics, Diversity, and Change*. pp. 177–90. Dordrecht: Springer.
- Jeong, S, Rokas, A & Carroll, S B (2006) Regulation of body pigmentation by the Abdominal-B Hox protein and its gain and loss in *Drosophila* evolution. *Cell* 125: 1387–99.
- Johansson, B G & Jones, T M (2007) The role of chemical communication in mate choice. *Biol Rev* 82: 265–89.
- John, L, Aguilar, I, Ayasse, M & Jarau, S (2012) Nest-specific composition of the trail pheromone of the

- stingless bee *Trigona corvina* within populations. *Insectes Soc* 59: 527–32.
- Johnson, M E & Atema, J (2005) The olfactory pathway for individual recognition in the American lobster *Homarus americanus*. *J Exp Biol* 208: 2865–72.
- Johnson, N S & Li, W M (2010) Understanding behavioral responses of fish to pheromones in natural freshwater environments. *J Comp Physiol A* 196: 701–11.
- Johnson, N S, Yun, S S, Thompson, H T, Brant, C O & Li, W (2009) A synthesized pheromone induces upstream movement in female sea lamprey and summons them into traps. *Proc Natl Acad Sci USA* 106: 1021–6.
- Johnson, N S, Yun, S S, Buchinger, T J & Li, W (2012) Multiple functions of a multi-component mating pheromone in sea lamprey *Petromyzon marinus*. *J Fish Biol* 80: 538–54.
- Johnston, C E (1994) Nest association in fishes – evidence for mutualism. *Behav Ecol Sociobiol* 35: 379–83.
- Johnston, R E (1998) Pheromones, the vomeronasal system, and communication – from hormonal responses to individual recognition. *Ann N Y Acad Sci* 855: 333–48.
- Johnston, R E (2003) Chemical communication in rodents: from pheromones to individual recognition. *J Mammal* 84: 1141–62.
- Johnston, R E (2005) Communication by mosaic signals: individual recognition and underlying neural mechanisms. In Mason, R T, LeMaster, M P & Müller-Schwarze, D (eds.) *Chemical Signals in Vertebrates* 10. pp. 269–82. New York, NY: Springer.
- Johnston, R E (2008) Individual odors and social communication: individual recognition, kin recognition, and scent over-marking. *Adv Study Behav* 38: 439–505.
- Johnston, R E & Jernigan, P (1994) Golden hamsters recognize individuals, not just individual scents. *Anim Behav* 48: 129–36.
- Johnston, R E & Rasmussen, K (1984) Individual recognition of female hamsters by males: role of chemical cues and of the olfactory and vomeronasal systems. *Physiol Behav* 33: 95–104.
- Johnston, R E & Robinson, T A (1993) Cross-species discrimination of individual odors by hamsters (Muridae: *Mesocricetus auratus*, *Phodopus campbelli*). *Ethology* 94: 317–25.
- Johnston, R E, Derzie, A, Chiang, G, Jernigan, P & Lee, H C (1993) Individual scent signatures in golden hamsters: evidence for specialization of function. *Anim Behav* 45: 1061–70.
- Jones, A G & Ratterman, N L (2009) Mate choice and sexual selection: what have we learned since Darwin? *Proc Natl Acad Sci USA* 106: 10001–8.
- Jones, T M, Quinnell, R J & Balmford, A (1998) Fisherian flies: benefits of female choice in a lekking sandfly. *Proc R Soc B* 265: 1651–7.
- Jordan, N R, Mwanguhya, F, Furrer, R D *et al.* (2011) Scent marking in wild banded mongooses: 2. Intrasexual overmarking and competition between males. *Anim Behav* 81: 43–50.
- Judd, T M & Sherman, P W (1996) Naked mole-rats recruit colony mates to food sources. *Anim Behav* 52: 957–69.
- Jumper, G Y & Baird, R C (1991) Location by olfaction – a model and application to the mating problem in the deep-sea hatchetfish *Argyropelecus hemigymnus*. *Am Nat* 138: 1431–58.
- Jurenka, R A, Haynes, K F, Adlof, R O, Bengtsson, M & Roelofs, W L (1994) Sex-pheromone component ratio in the cabbage-looper moth altered by a mutation affecting the fatty-acid chain-shortening reactions in the pheromone biosynthetic-pathway. *Insect Biochem Mol Biol* 24: 373–81.
- Kaib, M (1999) Termites. In Hardie, J & Minks, A K (eds.) *Pheromones of Non-lepidopteran Insects Associated with Agricultural Plants*. pp. 329–53. Wallingford: CAB International.
- Kaib, M, Husseneder, C, Epplen, C, Epplen, J T & Brandl, R (1996) Kin-biased foraging in a termite. *Proc R Soc B* 263: 1527–32.
- Kaib, M, Jmhasly, P, Wilfert, L *et al.* (2004) Cuticular hydrocarbons and aggression in the termite *Macrotermes subhyalinus*. *J Chem Ecol* 30: 365–85.
- Kaissling, K-E (1987) *R. H. Wright Lectures on Insect Olfaction* Burnaby, BC, Canada: Simon Fraser University.
- Kaissling, K-E (1998) Olfactory transduction in moths: I. Generation of receptor potentials and nerve impulses. In Taddei-Ferretti, C & Musio, C (eds.) *From Structure to Information in Sensory Systems*. pp. 93–112. Singapore: World Scientific.

- Kaissling, K-E (2009a) Olfactory perireceptor and receptor events in moths: a kinetic model revised. *J Comp Physiol A* 195: 895–922.
- Kaissling, K-E (2009b) The sensitivity of the insect nose: the example of *Bombyx mori*. In Gutiérrez, A & Marco, S (eds.) *Biologically Inspired Signal Processing for Chemical Sensing*. pp. 45–52. Berlin: Springer.
- Kaitz, M, Good, A, Rokem, A M & Eidelman, A I (1987) Mothers' recognition of their newborns by olfactory cues. *Dev Psychobiol* 20: 587–91.
- Kalbe, M, Eizaguirre, C, Dankert, I *et al.* (2009) Lifetime reproductive success is maximized with optimal major histocompatibility complex diversity. *Proc R Soc B* 276: 925–34.
- Kalberer, N M, Reisenman, C E & Hildebrand, J G (2010) Male moths bearing transplanted female antennae express characteristically female behaviour and central neural activity. *J Exp Biol* 213: 1272–80.
- Kamakura, M (2011) Royalactin induces queen differentiation in honeybees. *Nature* 473: 478–83.
- Kamio, M & Derby, C D (2011) Approaches to a molecular identification of sex pheromones in blue crabs. In Breithaupt, T & Thiel, M (eds.) *Chemical Communication in Crustaceans*. pp. 393–412. New York: Springer.
- Kamio, M, Reidenbach, M A & Derby, C D (2008) To paddle or not: context dependent courtship display by male blue crabs, *Callinectes sapidus*. *J Exp Biol* 211: 1243.
- Kanaujia, S & Kaissling, K E (1985) Interactions of pheromone with moth antennae – adsorption, desorption and transport. *J Insect Physiol* 31: 71–81.
- Kaneshiro, K Y (1989) The dynamics of sexual selection and founder effects in species formation. In Giddings, L V, Kaneshiro, K Y & Anderson, W W (eds.) *Genetics, Speciation, and the Founder Principle*. pp. 279–96. Oxford: Oxford University Press.
- Kaneshiro, K Y (2006) Dynamics of sexual selection in the Hawaiian Drosophilidae: a paradigm for evolutionary change. *Proc Hawaiian Entomol Soc* 38: 1–19.
- Kaneshiro, K Y & Boake, C R B (1987) Sexual selection and speciation – issues raised by Hawaiian *Drosophila*. *Trends Ecol Evol* 2: 207–12.
- Karlson, P & Lüscher, M (1959) 'Pheromones': a new term for a class of biologically active substances. *Nature* 183: 55–6.
- Karpati, Z, Dekker, T & Hansson, B S (2008) Reversed functional topology in the antennal lobe of the male European corn borer. *J Exp Biol* 211: 2841–8.
- Karpati, Z, Olsson, S, Hansson, B S & Dekker, T (2010) Inheritance of central neuroanatomy and physiology related to pheromone preference in the male European corn borer. *BMC Evol Biol* 10: 286.
- Kasparov, S (2011) The many facets of optogenetics. *Exp Physiol* 96: 1–3.
- Kathrin, S (2012) Just follow your nose: homing by olfactory cues in ants. *Curr Opin Neurobiol* 22: 231–5.
- Kato, A & Touhara, K (2009) Mammalian olfactory receptors: pharmacology, G protein coupling and desensitization. *Cell Mol Life Sci* 66: 3743–53.
- Kaupp, U B (2010) Olfactory signalling in vertebrates and insects: differences and commonalities. *Nat Rev Neurosci* 11: 188–200.
- Kausrud, K L, Gregoire, J C, Skarpaas, O *et al.* (2011) Trees wanted – dead or alive! Host selection and population dynamics in tree-killing bark beetles. *PLoS ONE* 6: e18274.
- Kavaliers, M, Choleris, E & Pfaff, D W (2005) Genes, odours and the recognition of parasitized individuals by rodents. *Trends Parasitol* 21: 423–9.
- Kay, L M, Beshel, J, Brea, J *et al.* (2009) Olfactory oscillations: the what, how and what for. *Trends Neurosci* 32: 207–14.
- Keeling, C I, Plettner, E & Slessor, K N (2004) Hymenopteran semiochemicals. *Top Curr Chem* 239: 133–77.
- Keil, T A (1992) Fine structure of a developing insect olfactory organ: morphogenesis of the silkworm antenna. *Microsc Res Tech* 22: 351–71.
- Keller, A & Vosshall, L B (2007) Influence of odorant receptor repertoire on odor perception in humans and fruit flies. *Proc Natl Acad Sci USA* 104: 5614–19.
- Keller, A, Zhuang, H Y, Chi, Q Y, Vosshall, L B & Matsunami, H (2007) Genetic variation in a human odorant receptor alters odour perception. *Nature* 449: 468–73.
- Keller, L & Nonacs, P (1993) The role of queen pheromones in social insects – queen control or queen signal. *Anim Behav* 45: 787–94.
- Keller, L & Reeve, H K (1994) Partitioning of reproduction in animal societies. *Trends Ecol Evol* 9: 98–102.

- Keller, L & Surette, M G (2006) Communication in bacteria: an ecological and evolutionary perspective. *Nat Rev Microbiol* 4: 249–58.
- Keller, M, Baum, M J, Brock, O, Brennan, P A & Bakker, J (2009) The main and the accessory olfactory systems interact in the control of mate recognition and sexual behavior. *Behav Brain Res* 200: 268–76.
- Kelliher, K R, Spehr, M, Li, X H, Zufall, F & Leinders-Zufall, T (2006) Pheromonal recognition memory induced by TRPC2-independent vomeronasal sensing. *Eur J Neurosci* 23: 3385–90.
- Kelly, C A, Norbutus, A J, Lagalante, A F & Iyengar, V K (2012) Male courtship pheromones as indicators of genetic quality in an arctiid moth (*Utetheisa ornatrix*). *Behav Ecol* 23: 1009–14.
- Kelly, C D & Jennions, M D (2011) Sexual selection and sperm quantity: meta-analyses of strategic ejaculation. *Biol Rev* 86: 863–84.
- Kelly, D R (1996) When is a butterfly like an elephant? *Chem Biol* 3: 595–602.
- Kempnaers, B (2007) Mate choice and genetic quality: a review of the heterozygosity theory. *Adv Study Behav* 37: 189–278.
- Kendrick, K M, DaCosta, A P C, Broad, K D *et al.* (1997) Neural control of maternal behaviour and olfactory recognition of offspring. *Brain Res Bull* 44: 383–95.
- Kennedy, J S (1986) Some current issues in orientation to odour sources. In Payne, T L, Birch, M C & Kennedy, C E J (eds.) *Mechanisms in Insect Olfaction*. pp. 1–25. New York: Oxford University Press.
- Kennedy, J S (1992) *The New Anthropomorphism*. Cambridge: Cambridge University Press.
- Kepecs, A, Uchida, N & Mainen, Z F (2006) The sniff as a unit of olfactory processing. *Chem Senses* 31: 167–79.
- Kerr, J N D & Nimmerjahn, A (2012) Functional imaging in freely moving animals. *Curr Opin Neurobiol* 22: 45–53.
- Khan, Z R, Midega, C A O, Pittchar, J, Bruce, T J A & Pickett, J A (2012) ‘Push–pull’ revisited: the process of successful deployment of a chemical ecology based pest management tool. In Gurr, G M, Wratten, S D, Snyder, W E & Read, D M Y (eds.) *Biodiversity and Insect Pests*. pp. 259–75. Chichester: John Wiley.
- Kiemnec-Tyburczy, K M, Woodley, S K, Feldhoff, P W, Feldhoff, R C & Houck, L D (2011) Dermal application of courtship pheromones does not influence receptivity in female red-legged salamanders (*Plethodon shermani*). *J Herpetol* 45: 169–73.
- Kikuta, S, Sato, K, Kashiwadani, H *et al.* (2010) Neurons in the anterior olfactory nucleus pars externa detect right or left localization of odor sources. *Proc Natl Acad Sci USA* 107: 12363–8.
- Kilner, R M & Langmore, N E (2011) Cuckoos versus hosts in insects and birds: adaptations, counter-adaptations and outcomes. *Biol Rev* 86: 836–52.
- Kjørboe, T (2011) What makes pelagic copepods so successful? *J Plankton Res* 33: 677.
- Kirkendall, L R, Kent, D S & Raffa, K A (1997) Interactions among males, females and offspring in bark and ambrosia beetles: the significance of living in tunnels for the evolution of social behavior. In Choe, J C & Crespi, B J (eds.) *The Evolution of Social Behavior in Insects and Arachnids*. pp. 181–215. Cambridge: Cambridge University Press.
- Kjaer, I & Hansen, B F (1996) The human vomeronasal organ: prenatal developmental stages and distribution of luteinizing hormone-releasing hormone. *Eur J Oral Sci* 104: 34–40.
- Klarica, J, Bittner, L, Pallua, J *et al.* (2011) Near-infrared imaging spectroscopy as a tool to discriminate two cryptic *Tetramorium* ant species. *J Chem Ecol* 37: 549–52.
- Kleineidam, C J & Rossler, W (2009) Adaptations in the olfactory system of social Hymenoptera. In Gadau, J & Fewell, J H (eds.) *Organization of Insect Societies: from Genome to Sociocomplexity*. pp. 195–219. Cambridge, MA: Harvard University Press.
- Kleineidam, C J, Rössler, W, Hölldobler, B & Roces, F (2007) Perceptual differences in trail-following leaf-cutting ants relate to body size. *J Insect Physiol* 53: 1233–41.
- Kloppenburg, P & Mercer, A (2008) Serotonin modulation of moth central olfactory neurons. *Annu Rev Entomol* 53: 179–90.
- Knaapila, A, Zhu, G, Medland, S E *et al.* (2012) A genome-wide study on the perception of the odorants androstenone and galaxolide. *Chem Senses* 37: 541–52.
- Knöpfel, T & Boyden, E S (eds.) (2012) *Optogenetics: Tools for Controlling and Monitoring Neuronal Activity*. Amsterdam: Elsevier.

- Kobayakawa, K, Kobayakawa, R, Matsumoto, H *et al.* (2007) Innate versus learned odour processing in the mouse olfactory bulb. *Nature* **450**: 503–8.
- Kocher, S & Grozinger, C (2011) Cooperation, conflict, and the evolution of queen pheromones. *J Chem Ecol* **37**: 1263–75.
- Kock, D, Ruther, J & Sauer, K P (2007) A male sex pheromone in a scorpionfly. *J Chem Ecol* **33**: 1249–56.
- Koehl, M A R (2006) The fluid mechanics of arthropod sniffing in turbulent odor plumes. *Chem Senses* **31**: 93–105.
- Koehl, M A R (2011) Hydrodynamics of sniffing by crustaceans. In Breithaupt, T & Thiel, M (eds.) *Chemical Communication in Crustaceans*. pp. 85–102. New York: Springer.
- Koene, J M & ter Maat, A (2001) “Allohormones”: a class of bioactive substances favoured by sexual selection. *J Comp Physiol A* **187**: 323–6.
- Koene, J M & ter Maat, A (2002) The distinction between pheromones and allohormones – reply. *J Comp Physiol A* **188**: 163–4.
- Kohatsu, S, Koganezawa, M & Yamamoto, D (2011) Female contact activates male-specific interneurons that trigger stereotypic courtship behavior in *Drosophila*. *Neuron* **69**: 498–508.
- Kohoutová, D, Rubešová, A & Havlíček, J (2012) Shaving of axillary hair has only a transient effect on perceived body odor pleasantness. *Behav Ecol Sociobiol* **66**: 569–81.
- Koivula, M & Viitala, J (1999) Rough-legged buzzards use vole scent marks to assess hunting areas. *J Avian Biol* **30**: 329–32.
- Kokko, H (2005) Treat 'em mean, keep 'em (sometimes) keen: evolution of female preferences for dominant and coercive males. *Evol Ecol* **19**: 123–35.
- Kokko, H & Rankin, D J (2006) Lonely hearts or sex in the city? Density-dependent effects in mating systems. *Phil Trans R Soc B* **361**: 319–34.
- Kokko, H & Wong, B B M (2007) What determines sex roles in mate searching? *Evolution* **61**: 1162–75.
- Kokko, H, Jennions, M D & Brooks, R (2006) Unifying and testing models of sexual selection. *Annu Rev Ecol Evol Syst* **37**: 43–66.
- Kolliker, M, Chuckalovcak, J P, Haynes, K F & Brodie, E D (2006) Maternal food provisioning in relation to condition-dependent offspring odours in burrower bugs (*Sehirus cinctus*). *Proc R Soc B* **273**: 1523–8.
- Korb, J & Hartfelder, K (2008) Life history and development a framework for understanding developmental plasticity in lower termites. *Biol Rev* **83**: 295–313.
- Korb, J, Weil, T, Hoffmann, K, Foster, K R & Rehli, M (2009) A gene necessary for reproductive suppression in termites. *Science* **324**: 758.
- Kotiaho, J S (2001) Costs of sexual traits: a mismatch between theoretical considerations and empirical evidence. *Biol Rev* **76**: 365–76.
- Kou, R, Chang, H W, Chen, S C & Ho, H Y (2009) Suppression pheromone and cockroach rank formation. *Naturwissenschaften* **96**: 691–701.
- Kozak, G M, Head, M L & Boughman, J W (2011) Sexual imprinting on ecologically divergent traits leads to sexual isolation in sticklebacks. *Proc R Soc B* **278**: 2604–10.
- Krause, E T, Krüger, O, Kohlmeier, P & Caspers, B A (2012) Olfactory kin recognition in a songbird. *Biol Lett* **8**: 327–9.
- Krautwurst, D (2008) Human olfactory receptor families and their odorants. *Chemistry & Biodiversity* **5**: 842–52.
- Kreher, S A, Mathew, D, Kim, J & Carlson, J R (2008) Translation of sensory input into behavioral output via an olfactory system. *Neuron* **59**: 110–24.
- Kristoffersen, L, Hansson, B S, Anderbrant, O & Larsson, M C (2008) Agglomerular hemipteran antennal lobes – basic neuroanatomy of a small nose. *Chem Senses* **33**: 771–8.
- Kroiss, J, Lechner, K & Strohm, E (2010) Male territoriality and mating system in the European beewolf *Philanthus triangulum* F. (Hymenoptera: Crabronidae): evidence for a “hotspot” lek polygyny. *J Ethol* **28**: 295–304.
- Kronauer, D J C & Pierce, N E (2011) Myrmecophiles. *Curr Biol* **21**: R208–R209.
- Kronforst, M R, Young, L G, Kapan, D D *et al.* (2006) Linkage of butterfly mate preference and wing color preference cue at the genomic location of wingless. *Proc Natl Acad Sci USA* **103**: 6575–80.
- Kruuk, H (1972) *The Spotted Hyena. A Study of Predation and Social Behavior*. Chicago: Chicago University Press.
- Kruuk, H (1989) *The Social Badger. Ecology and Behaviour of a Group-living Carnivore (Meles meles)*. Oxford: Oxford University Press.

- Kruuk, H, Gorman, M & Leitch, A (1984) Scent-marking with the subcaudal gland by the European badger, *Meles meles* L. *Anim Behav* 32: 899–907.
- Kubli, E & Bopp, D (2012) Sexual behavior: how sex peptide flips the postmating switch of female flies. *Curr Biol* 22: R520–R522.
- Kuebler, L S, Kelber, C & Kleineidam, C J (2010) Distinct antennal lobe phenotypes in the leaf-cutting ant (*Atta vollenweideri*). *J Comp Neurol* 518: 352–65.
- Kunert, G, Otto, S, Röse, U, Gershenzon, J & Weisser, W (2005) Alarm pheromone mediates production of winged dispersal morphs in aphids. *Ecol Lett* 8: 596–603.
- Kwak, J & Preti, G (2011) Volatile disease biomarkers in breath: a critique. *Curr Pharm Biotechnol* 12: 1067–74.
- Kwak, J, Opiekun, M C, Matsumura, K *et al.* (2009) Major histocompatibility complex-regulated odortypes: peptide-free urinary volatile signals. *Physiol Behav* 96: 184–8.
- Kwak, J, Willse, A, Preti, G, Yamazaki, K & Beauchamp, GK (2010) In search of the chemical basis for MHC odortypes. *Proc R Soc B* 277: 2417–25.
- Labows, J N & Preti, G (1992) Human semiochemicals. In Van Toller, S & Dodd, G H (eds.) *Fragrance: the Psychology and Biology of Perfume*. pp. 69–90. London: Elsevier Science.
- Lacey, E A & Sherman, P W (2005) Redefining eusociality: concepts, goals and levels of analysis. *Ann Zool Fenn* 42: 573–77.
- Lachmann, M, Szamado, S & Bergstrom, C T (2001) Cost and conflict in animal signals and human language. *Proc Natl Acad Sci USA* 98: 13189.
- Lamunyon, C W & Eisner, T (1993) Postcopulatory sexual selection in an arctiid moth (*Utetheisa ornatrix*). *Proc Natl Acad Sci USA* 90: 4689–92.
- Lamunyon, C W & Eisner, T (1994) Spermatophore size as determinant of paternity in an arctiid moth (*Utetheisa ornatrix*). *Proc Natl Acad Sci USA* 91: 7081–4.
- Landolt, P J (1997) Sex attractant and aggregation pheromones of male phytophagous insects. *Am Entomol* 43: 12–22.
- Landolt, P J, Reed, H C & Heath, R R (1992) Attraction of female papaya fruit-fly (Diptera, Tephritidae) to male pheromone and host fruit. *Environ Entomol* 21: 1154–9.
- Landolt, P J, Molina, O H, Heath, R R *et al.* (1996) Starvation of cabbage looper moths (Lepidoptera: Noctuidae) increases attraction to male pheromone. *Ann Entomol Soc Am* 89: 459–65.
- LaPorte, J (2002) Must signals handicap? *Monist* 85: 86–104.
- Larsson, M C & Svensson, G P (2009) Pheromone monitoring of rare and threatened insects: exploiting a pheromone-kairomone system to estimate prey and predator abundance. *Conserv Biol* 23: 1516–25.
- Laska, M (2004) Olfactory discrimination ability of human subjects for enantiomers with an isopropenyl group at the chiral center. *Chem Senses* 29: 143–52.
- Laska, M, Genzel, D & Wieser, A (2005) The number of functional olfactory receptor genes and the relative size of olfactory brain structures are poor predictors of olfactory discrimination performance with enantiomers. *Chem Senses* 30: 171–5.
- Lassance, J-M (2010) Journey in the *Ostrinia* world: from pest to model in chemical ecology. *J Chem Ecol* 36: 1155–69.
- Lassance, J-M & Löfstedt, C (2009) Concerted evolution of male and female display traits in the European corn borer, *Ostrinia nubilalis*. *BMC Biol* 7: 10.
- Lassance, J-M, Groot, A T, Liénard, M A *et al.* (2010) Allelic variation in a fatty-acyl reductase gene causes divergence in moth sex pheromones. *Nature* 466: 486–9.
- Lassance, J-M, Bogdanowicz, S M, Wanner, K W, Löfstedt, C & Harrison, R G (2011) Gene genealogies reveal differentiation at sex pheromone olfactory receptor loci in pheromone strains of the European corn borer, *Ostrinia nubilalis*. *Evolution* 65: 1583–93.
- Lassance, J-M, Liénard, M A, Antony, B, *et al.* (2013) Functional consequences of sequence variation in the pheromone biosynthetic gene *pgFAR* for *Ostrinia* moths. *Proc Natl Acad Sci USA* 110: 3967–72.
- Lastein, S, Hamdani, E H & Døving, K B (2014) Olfactory discrimination of pheromones. In Sorensen, P W & Wisenden, B D (eds.) *Fish Pheromones and Related Conspecific Chemical Cues*. Chichester: Wiley-Blackwell.
- Laughlin, J D, Ha, T S, Jones, D N M & Smith, D P (2008) Activation of pheromone-sensitive neurons is mediated by conformational activation of pheromone-binding protein. *Cell* 133: 1255–65.
- Laurence, B R & Pickett, J A (1985) An oviposition attractant pheromone in *Culex quinquefasciatus* Say (Diptera: Culicidae). *Bull Entomol Res* 75: 283–90.

- Laurent, R & Chaix, R (2012) HapMap European American genotypes are compatible with the hypothesis of MHC-dependent mate choice (response to DOI 10.1002/bies.201200023, Derti and Roth). *Bioessays* **34**: 871–2.
- Lawniczak, M K N, Barnes, A I, Linklater, J R *et al.* (2007) Mating and immunity in invertebrates. *Trends Ecol Evol* **22**: 48–55.
- Lawson, L P, Vander Meer, R K & Shoemaker, D (2012a) Male reproductive fitness and queen polyandry are linked to variation in the supergene Gp-9 in the fire ant *Solenopsis invicta*. *Proc R Soc B* **279**: 3217–22.
- Lawson, M J, Craven, B A, Paterson, E G & Settles, G S (2012b) A computational study of odorant transport and deposition in the canine nasal cavity: implications for olfaction. *Chem Senses* **37**: 553–66.
- Le Conte, Y & Hefetz, A (2008) Primer pheromones in social Hymenoptera. *Annu Rev Entomol* **53**: 523–42.
- Le Roux, A, Cherry, M I & Manser, M B (2008) The effects of population density and sociality on scent marking in the yellow mongoose. *J Zool* **275**: 33–40.
- Leal, W S (1999) Scarab beetles. In Hardie, J & Minks, A K (eds.) *Pheromones of Non-lepidopteran Insects Associated with Agricultural Plants*. pp. 51–68. Wallingford, Oxon: CAB International.
- Leal, W S (2005) Pheromone reception. In Schulz, S (ed.) *Chemistry of Pheromones and Other Semiochemicals II*. pp. 1–36. Berlin: Springer.
- Leal, W S (2013) Odorant reception in insects: roles of receptors, binding proteins, and degrading enzymes. *Annu Rev Entomol* **58**: 373–91.
- Leal, W S & Ishida, Y (2008) GP-9s are ubiquitous proteins unlikely involved in olfactory mediation of social organization in the red imported fire ant, *Solenopsis invicta*. *PLoS ONE* **3**: e3762.
- Leal, W S, Chen, A M, Ishida, Y *et al.* (2005) Kinetics and molecular properties of pheromone binding and release. *Proc Natl Acad Sci USA* **102**: 5386–91.
- Leary, G P, Allen, J E, Bunger, P L *et al.* (2012) Single mutation to a sex pheromone receptor provides adaptive specificity between closely related moth species. *Proc Natl Acad Sci USA* **109**: 14081–6.
- Lehner, P N (1996) *Handbook of Ethological Methods*, 2nd edn. Cambridge: Cambridge University Press.
- Leinders-Zufall, T, Lane, A P, Puche, A C *et al.* (2000) Ultrasensitive pheromone detection by mammalian vomeronasal neurons. *Nature* **405**: 792–6.
- Leinders-Zufall, T, Brennan, P, Widmayer, P *et al.* (2004) MHC Class I peptides as chemosensory signals in the vomeronasal organ. *Science* **306**: 1033–7.
- Leinders-Zufall, T, Ishii, T, Mombaerts, P, Zufall, F & Boehm, T (2009) Structural requirements for the activation of vomeronasal sensory neurons by MHC peptides. *Nat Neurosci* **12**: 1551–8.
- Lelito, J, Myrick, A & Baker, T (2008) Interspecific pheromone plume interference among sympatric heliothine moths: a wind tunnel test using live, calling females. *J Chem Ecol* **34**: 725–33.
- Lenochova, P & Havlíček, J (2008) Human body odour individuality. In Hurst, J L, Beynon, R J, Roberts, S C & Wyatt, T D (eds.) *Chemical Signals in Vertebrates 11*. pp. 189–98. New York: Springer.
- Lenoir, A, d'Ettorre, P, Errard, C & Hefetz, A (2001) Chemical ecology and social parasitism in ants. *Annu Rev Entomol* **46**: 573–99.
- Leonhardt, S D, Brandstaetter, A S & Kleineidam, C J (2007) Reformation process of the neuronal template for nestmate-recognition cues in the carpenter ant *Camponotus floridanus*. *J Comp Physiol A* **193**: 993–1000.
- Levesque, H M, Scaffidi, D, Polkinghorne, C N & Sorensen, P W (2011) A multi-component species identifying pheromone in the goldfish. *J Chem Ecol* **37**: 219–27.
- Levinson, A & Levinson, H (1995) Reflections on structure and function of pheromone glands in storage insect species. *Anz Schädlingsk, Pflanzen, Umweltschutz* **68**: 99–118.
- Levitan, D R & McGovern, T M (2005) The Allee effect in the sea. In Norse, E A & Crowder, L B (eds.) *Marine Conservation Biology: the Science of Maintaining the Sea's Biodiversity*. pp. 47–57. Washington DC: Island Press.
- Lévy, F & Keller, M (2008) Neurobiology of maternal behavior in sheep. *Adv Study Behav* **38**: 399–437.
- Lévy, F & Keller, M (2009) Olfactory mediation of maternal behavior in selected mammalian species. *Behav Brain Res* **200**: 336–45.
- Lévy, F, Porter, R H, Kendrick, K M, Keverne, E B & Romeyer, A (1996) Physiological, sensory, and experiential factors of parental care in sheep. *Adv Study Behav* **25**: 385–422.
- Lewis, S M & Austad, S N (1994) Sexual selection in flour beetles – the relationship between sperm precedence and male olfactory attractiveness. *Behav Ecol* **5**: 219–24.

- Leypold, B G, Yu, C R, Leinders-Zufall, T *et al.* (2002) Altered sexual and social behaviors in TRP2 mutant mice. *Proc Natl Acad Sci USA* **99**: 6376–81.
- Li, Q, Korzan, W J, Ferrero, D M *et al.* (2013) Synchronous evolution of an odor biosynthesis pathway and behavioral response. *Curr Biol* **23**: 11–20.
- Liberles, S D & Buck, L B (2006) A second class of chemosensory receptors in the olfactory epithelium. *Nature* **442**: 645–50.
- Liberles, S D, Horowitz, L F, Kuang, D H *et al.* (2009) Formyl peptide receptors are candidate chemosensory receptors in the vomeronasal organ. *Proc Natl Acad Sci USA* **106**: 9842–7.
- Lichtman, J W, Livet, J & Sanes, J R (2008) A technicolour approach to the connectome. *Nat Rev Neurosci* **9**: 417–22.
- Liebig, J, Eliyahu, D & Brent, C S (2009) Cuticular hydrocarbon profiles indicate reproductive status in the termite *Zootermopsis nevadensis*. *Behav Ecol Sociobiol* **63**: 1799–807.
- Liebig, J (2010) Hydrocarbon profiles indicate fertility and dominance status in ant, bee, and wasp colonies. In Blomquist, G J & Bagnères, A-G (eds.) *Insect Hydrocarbons: Biology, Biochemistry, and Chemical Ecology*. pp. 254–81. Cambridge: Cambridge University Press.
- Liénard, M A, Strandh, M, Hedenström, E, Johansson, T & Löfstedt, C (2008) Key biosynthetic gene subfamily recruited for pheromone production prior to the extensive radiation of Lepidoptera. *BMC Evol Biol* **8**: 270.
- Liénard, M A, Hagstrom, A K, Lassance, J-M & Löfstedt, C (2010) Evolution of multicomponent pheromone signals in small ermine moths involves a single fatty-acyl reductase gene. *Proc Natl Acad Sci USA* **107**: 10955–60.
- Lihoreau, M & Rivault, C (2009) Kin recognition via cuticular hydrocarbons shapes cockroach social life. *Behav Ecol* **20**: 46–53.
- Lihoreau, M, Zimmer, C & Rivault, C (2008) Mutual mate choice: when it pays both sexes to avoid inbreeding. *PLoS ONE* **3**: e3365.
- Lihoreau, M, Costa, J & Rivault, C (2012) The social biology of domiciliary cockroaches: colony structure, kin recognition and collective decisions. *Insectes Soc* **59**: 445–52.
- Lim, H & Sorensen, P W (2012) Common carp implanted with prostaglandin F2 α release a sex pheromone complex that attracts conspecific males in both the laboratory and field. *J Chem Ecol* **38**: 127–34.
- Liman, E R & Innan, H (2003) Relaxed selective pressure on an essential component of pheromone transduction in primate evolution. *Proc Natl Acad Sci USA* **100**: 3328–32.
- Lin, C P (2006) Social behaviour and life history of membracine treehoppers. *J Nat Hist* **40**: 1887–907.
- Lin, D Y, Zhang, S Z, Block, E & Katz, L C (2005) Encoding social signals in the mouse main olfactory bulb. *Nature* **434**: 470–7.
- Lin, D Y, Shea, S D & Katz, L C (2006) Representation of natural stimuli in the rodent main olfactory bulb. *Neuron* **50**: 937–49.
- Lindauer, M & Kerr, W E (1958) Die gegenseitige Verständigung bei den stachellosen Bienen. *J Comp Physiol A* **41**: 405–34.
- Lindsay, S M (2009) Ecology and biology of chemoreception in polychaetes. *Zoosymposia* **2**: 339–67.
- Linn, C E & Roelofs, W L (1989) Response specificity of male moths to multicomponent pheromones. *Chem Senses* **14**: 421–37.
- Linn, C E, Campbell, M G & Roelofs, W L (1987) Pheromone components and active spaces: what do moths smell and where do they smell it? *Science* **237**: 650–2.
- Linn, C E, O'Connor, M & Roelofs, W (2003) Silent genes and rare males: a fresh look at pheromone blend response specificity in the European corn borer moth, *Ostrinia nubilalis*. *J Insect Sci* **3**: 15.
- Liu, S, Zhao, B & Bonjour, E (2011) Host marking and host discrimination in phytophagous insects. In Liu, T & Kang, L (eds.) *Recent Advances in Entomological Research: from Molecular Biology to Pest Management*. pp. 73–85. Beijing and Berlin: Higher Education Press and Springer.
- Liu, Y B & Haynes, K F (1992) Filamentous nature of pheromone plumes protects integrity of signal from background chemical noise in cabbage-looper moth, *Trichoplusia ni*. *J Chem Ecol* **18**: 299–307.
- Lledo, P M, Alonso, M & Grubb, M S (2006) Adult neurogenesis and functional plasticity in neuronal circuits. *Nat Rev Neurosci* **7**: 179–93.
- Locatello, L, Mazzoldi, C & Rasotto, M (2002) Ejaculate of sneaker males is pheromonally inconspicuous in the

- black goby, *Gobius niger* (Teleostei, Gobiidae). *J Exp Zool* 293: 601–5.
- Lockery, S R (2011) The computational worm: spatial orientation and its neuronal basis in *C. elegans*. *Curr Opin Neurobiol* 21: 782–90.
- Löfstedt, C (1990) Population variation and genetic control of pheromone communication systems in moths. *Entomol Exp Appl* 54: 199–218.
- Löfstedt, C (1993) Moth pheromone genetics and evolution. *Phil Trans R Soc B* 340: 167–77.
- Löfstedt, C, Vickers, N J, Roelofs, W L & Baker, T C (1989) Diet related courtship success in the oriental fruit moth, *Grapholita molesta* (Tortricidae). *Oikos* 55: 402–8.
- Löfstedt, C, Herrebout, W M & Menken, S B J (1991) Sex pheromones and their potential role in the evolution of reproductive isolation in small ermine moths (Yponomeutidae). *Chemoecology* 2: 20–8.
- Logan, D W, Marton, T F & Stowers, L (2008) Species specificity in major urinary proteins by parallel evolution. *PLoS ONE* 3: e3280.
- Logan, D W, Sandal, M, Gardner, P P, Manske, M & Bateman, A (2010) Ten simple rules for editing Wikipedia. *PLoS Comput Biol* 6: e1000941.
- Logan, D W, Brunet, J L, Webb *et al.* (2012) Learned recognition of maternal signature odors mediates the first suckling episode in mice. *Curr Biol* 22: 1998–2007.
- Lois, C & Groves, J O (2012) Genetics in non-genetic model systems. *Curr Opin Neurobiol* 22: 79–85.
- Lopez, F, Acosta, F J & Serrano, J M (1994) Guerrilla vs phalanx strategies of resource capture – growth and structural plasticity in the trunk trail system of the harvester ant *Messor barbarus*. *J Anim Ecol* 63: 127–38.
- Lorenzi, M C (2006) The result of an arms race: the chemical strategies of *Polistes* social parasites. *Ann Zool Fenn* 43: 550–63.
- Louis, M, Huber, T, Benton, R, Sakmar, T P & Vosshall, L B (2008) Bilateral olfactory sensory input enhances chemotaxis behavior. *Nat Neurosci* 11: 187–99.
- Lu, B, LaMora, A, Sun, Y, Welsh, M J & Ben-Shahar, Y (2012) ppk23-Dependent chemosensory functions contribute to courtship behavior in *Drosophila melanogaster*. *PLoS Genet* 8: e1002587.
- Luehring, M A, Wagner, C M & Li, W M (2011) The efficacy of two synthesized sea lamprey sex pheromone components as a trap lure when placed in direct competition with natural male odors. *Biol Invasions* 13: 1589–97.
- Lundström, J N & Olsson, M J (2010) Functional neuronal processing of human body odors. In Gerald, L (ed.) *Pheromones*. pp. 1–23. London: Academic Press.
- Lundström, J N, Gordon, A R, Alden, E C, Boesveldt, S & Albrecht, J (2010) Methods for building an inexpensive computer-controlled olfactometer for temporally-precise experiments. *Int J Psychophysiol* 78: 179–89.
- Lürling, M (2012) Infodisruption: pollutants interfering with the natural chemical information conveyance in aquatic systems. In Brönmark, C & Hansson, L-A (eds.) *Chemical Ecology in Aquatic Systems*. pp. 250–71. Oxford: Oxford University Press.
- Lyko, F, Foret, S, Kucharski, R *et al.* (2010) The honeybee epigenomes: differential methylation of brain DNA in queens and workers. *PLoS Biol* 8: e1000506.
- Ma, M (2010) Multiple olfactory subsystems convey various sensory signals. In Menini, A (ed.) *The Neurobiology of Olfaction*. Boca Raton, FL: CRC Press. Available online at www.ncbi.nlm.nih.gov/books/NBK55971.
- Ma, W D, Miao, Z S & Novotny, M V (1999) Induction of estrus in grouped female mice (*Mus domesticus*) by synthetic analogues of preputial gland constituents. *Chem Senses* 24: 289–93.
- Macbeth, A H, Edds, J S & Young, W S (2009) Housing conditions and stimulus females: a robust social discrimination task for studying male rodent social recognition. *Nat Protoc* 4: 1574–81.
- Macdonald, D W (1985a) The rodents IV: suborder Hystricomorpha. In Brown, R E & Macdonald, D W (eds.) *Social Odours in Mammals*. pp. 480–506. Oxford: Oxford University Press.
- Macdonald, D W (1985b) The carnivores: order Carnivora. In Brown, R E & Macdonald, D W (eds.) *Social Odours in Mammals*. pp. 619–722. Oxford: Oxford University Press.
- Madsen, T, Shine, R, Loman, J & Håkansson, T (1992) Why do female adders copulate so frequently? *Nature* 355: 440–1.
- Maeno, K & Tanaka, S (2012) Adult female desert locusts require contact chemicals and light for progeny gregarization. *Physiol Entomol* 37: 109–18.

- Magro, A, Ducamp, C, Ramon-Portugal, F *et al.* (2010) Oviposition deterring infochemicals in ladybirds: the role of phylogeny. *Evol Ecol* **24**: 251–71.
- Mainland, J & Sobel, N (2006) The sniff is part of the olfactory percept. *Chem Senses* **31**: 181–96.
- Maisonnasse, A, Lenoir, J C, Beslay, D, Crauser, D & Le Conte, Y (2010) E- β -ocimene, a volatile brood pheromone involved in social regulation in the honey bee colony (*Apis mellifera*). *PLoS ONE* **5**: e13531.
- Malka, O, Karunker, I, Yeheskel, A, Morin, S & Hefetz, A (2009) The gene road to royalty – differential expression of hydroxylating genes in the mandibular glands of the honeybee. *FEBS J* **276**: 5481–90.
- Mallet, J (2008) Hybridization, ecological races and the nature of species: empirical evidence for the ease of speciation. *Phil Trans R Soc B* **363**: 2971–86.
- Malnic, B, Hirono, J, Sato, T & Buck, L B (1999) Combinatorial receptor codes for odors. *Cell* **96**: 713–23.
- Malnic, B, Gonzalez-Kristeller, D C & Gutiyama, L M (2010) Odorant receptors. In Menini, A (ed.) *The Neurobiology of Olfaction*. Boca Raton, FL: CRC Press. Available online at www.ncbi.nlm.nih.gov/books/NBK55985.
- Mameli, M & Bateson, P (2011) An evaluation of the concept of innateness. *Phil Trans R Soc B* **366**: 436–43.
- Manning, A & Dawkins, M S (1998) *An Introduction to Animal Behaviour*, 5th edn. Cambridge: Cambridge University Press.
- Manoli, D S, Meissner, G W & Baker, B S (2006) Blueprints for behavior: genetic specification of neural circuitry for innate behaviors. *Trends Neurosci* **29**: 444–51.
- Mardon, J, Saunders, S M, Anderson, M J, Couchoux, C & Bonadonna, F (2010) Species, gender, and identity: cracking petrels' sociochemical code. *Chem Senses* **35**: 309–21.
- Maresh, A, Gil, D R, Whitman, M C & Greer, C A (2008) Principles of glomerular organization in the human olfactory bulb – implications for odor processing. *PLoS ONE* **3**: e2640.
- Martin, A, Saathoff, M, Kuhn, F *et al.* (2010a) A functional ABCC11 allele is essential in the biochemical formation of human axillary odor. *J Invest Dermatol* **130**: 529–40.
- Martin, G B, Milton, J T B, Davidson, R H *et al.* (2004) Natural methods for increasing reproductive efficiency in small ruminants. *Anim Reprod Sci* **82**: 231–45.
- Martin, H (1965) Osmotropotaxis in the honey-bee. *Nature* **208**: 59–63.
- Martin, J & López, P (2008) Female sensory bias may allow honest chemical signaling by male Iberian rock lizards. *Behav Ecol Sociobiol* **62**: 1927–34.
- Martin, J & López, P (2010a) Condition-dependent pheromone signaling by male rock lizards: more oily scents are more attractive. *Chem Senses* **35**: 253–62.
- Martin, J & López, P (2010b) Pheromones and reproduction in reptiles. In Norris, D O & Lopez, K H (eds.) *Hormones and Reproduction of Vertebrates*. pp. 141–67. San Diego, CA: Academic Press.
- Martin, J A & Wang, Z (2011) Next-generation transcriptome assembly. *Nat Rev Genet* **12**: 671–82.
- Martin, J P, Beyerlein, A, Dacks, AM *et al.* (2011a) The neurobiology of insect olfaction: Sensory processing in a comparative context. *Prog Neurobiol* **95**: 427–47.
- Martin, P & Bateson, P (2007) *Measuring Behaviour. An Introductory Guide*, 3rd edn. Cambridge: Cambridge University Press.
- Martin, S J & Drijfhout, F P (2009a) Nestmate and task cues are influenced and encoded differently within ant cuticular hydrocarbon profiles. *J Chem Ecol* **35**: 368–74.
- Martin, S J & Drijfhout, F P (2009b) A review of ant cuticular hydrocarbons. *J Chem Ecol* **35**: 1151–61.
- Martin, S J, Châline, N G, Ratnieks, F L W & Jones, G R (2005) Searching for the egg-marking signal in honeybees. *J Negat Results* **2**: 1–9.
- Martin, S J, Helanterä, H & Drijfhout, F P (2008a) Evolution of species specific cuticular hydrocarbon patterns in *Formica* ants. *Biol J Linn Soc* **95**: 131–40.
- Martin, S J, Helanterä, H & Drijfhout, F P (2008b) Colony-specific hydrocarbons identify nest mates in two species of *Formica* ant. *J Chem Ecol* **34**: 1072–80.
- Martin, S J, Vitikainen, E, Helanterä, H & Drijfhout, F P (2008c) Chemical basis of nest-mate discrimination in the ant *Formica exsecta*. *Proc R Soc B* **275**: 1271–78.
- Martin, S J, Carruthers, J M, Williams, P H & Drijfhout, F P (2010b) Host specific social parasites (*Psithyrus*) indicate chemical recognition system in bumblebees. *J Chem Ecol* **36**: 855–63.

- Martin, S J, Helanterä, H & Drijfhout, F P (2011b) Is parasite pressure a driver of chemical cue diversity in ants? *Proc R Soc B* **278**: 496–503.
- Martins, Y, Preti, G, Crabtree, C R *et al.* (2005) Preference for human body odors is influenced by gender and sexual orientation. *Psychol Sci* **16**: 694–701.
- Mas, F & Kölliker, M (2008) Maternal care and offspring begging in social insects: chemical signalling, hormonal regulation and evolution. *Anim Behav* **76**: 1121–31.
- Mason, R T (1993) Chemical ecology of the red-sided garter snake, *Thamnophis sirtalis parietalis*. *Brain Behav Evol* **41**: 261–8.
- Mason, R T & Parker, M R (2010) Social behavior and pheromonal communication in reptiles. *J Comp Physiol A* **196**: 729–49.
- Mateo, J M (2004) Recognition systems and biological organization: the perception component of social recognition. *Ann Zool Fenn* **41**: 729–45.
- Mateo, J M (2009) The causal role of odours in the development of recognition templates and social preferences. *Anim Behav* **77**: 115–21.
- Mateo, J M (2010) Self-referent phenotype matching and long-term maintenance of kin recognition. *Anim Behav* **80**: 929–35.
- Mateo, J M & Johnston, R E (2000) Kin recognition and the ‘armpit effect’: evidence of self-referent phenotype matching. *Proc R Soc B* **267**: 695–700.
- Mateo, J M & Johnston, R E (2003) Kin recognition by self-referent phenotype matching: weighing the evidence. *Anim Cogn* **6**: 73–6.
- Mathis, K A & Philpott, S M (2012) Current understanding and future prospects of host selection, acceptance, discrimination, and regulation of phorid fly parasitoids that attack ants. *Psyche* 2012: doi:10.1155/2012/895424.
- Mathuru, A S, Kibat, C, Cheong, W F *et al.* (2012) Chondroitin fragments are odorants that trigger fear behavior in fish. *Curr Biol* **22**: 538–44.
- Matsui, A, Go, Y & Niimura, Y (2010) Degeneration of olfactory receptor gene repertoires in primates: no direct link to full trichromatic vision. *Mol Biol Evol* **27**: 1192–200.
- Matsumura, K, Nagano, M & Fusetani, N (1998) Purification of a larval settlement-inducing protein complex (SIPC) of the barnacle, *Balanus amphitrite*. *J Exp Zool* **281**: 12–20.
- Matsuo, T, Sugaya, S, Yasukawa, J, Aigaki, T & Fuyama, Y (2007) Odorant-binding proteins OBP57d and OBP57e affect taste perception and host-plant preference in *Drosophila sechellia*. *PLoS Biol* **5**: e118.
- Matsuura, K (2012) Multifunctional queen pheromone and maintenance of reproductive harmony in termite colonies. *J Chem Ecol* **38**: 746–54.
- Matsuura, K, Himuro, C, Yokoi, T *et al.* (2010) Identification of a pheromone regulating caste differentiation in termites. *Proc Natl Acad Sci USA* **107**: 12963–8.
- Maynard Smith, J (1991) Honest signalling: the Philip Sidney game. *Anim Behav* **42**: 1034–5.
- Maynard Smith, J & Harper, D (1995) Animal signals: models and terminology. *J Theor Biol* **177**: 305–11.
- Maynard Smith, J & Harper, D (2003) *Animal Signals*. Oxford: Oxford University Press.
- Mays, H L & Hill, G E (2004) Choosing mates: good genes versus genes that are a good fit. *Trends Ecol Evol* **19**: 554–9.
- McAllister, M K & Roitberg, B D (1987) Adaptive suicidal behaviour in pea aphids. *Nature* **328**: 797–9.
- McBurney, D H, Shoup, M L & Streeter, S A (2006) Olfactory comfort: smelling a partner’s clothing during periods of separation. *J Appl Soc Psychol* **36**: 2325–35.
- McClintock, M K (1971) Menstrual synchrony and suppression. *Nature* **229**: 244–5.
- McDonald, R A, Delahay, R J, Carter, S P, Smith, G C & Cheeseman, C L (2008) Perturbing implications of wildlife ecology for disease control. *Trends Ecol Evol* **23**: 53–6.
- McGlone, J J & Morrow, J L (1988) Reduction of pig agonistic behavior by androstenone. *J Anim Sci* **66**: 880–4.
- McGrath, P T, Xu, Y F, Ailion, M *et al.* (2011) Parallel evolution of domesticated *Caenorhabditis* species targets pheromone receptor genes. *Nature* **477**: 321–5.
- McGraw, L A & Young, L J (2010) The prairie vole: an emerging model organism for understanding the social brain. *Trends Neurosci* **33**: 103–9.
- McNeil, J N (1992) Evolutionary perspectives and insect pest control: an attractive blend for the deployment of semiochemicals in management systems. In Roitberg, B D & Isman, M B (eds.) *Insect Chemical Ecology: an Evolutionary Approach*. pp. 334–52. New York: Chapman and Hall.

- McRae, J F, Mainland, J D, Jaeger, S R *et al.* (2012) Genetic variation in the odorant receptor OR2J3 is associated with the ability to detect the “grassy” smelling odor, cis-3-hexen-1-ol. *Chem Senses* **37**: 585–93.
- Mead, K S & Caldwell, R (2011) Mantis shrimp: olfactory apparatus and chemosensory behavior. In Breithaupt, T & Thiel, M (eds.) *Chemical Communication in Crustaceans*. pp. 219–38. New York: Springer.
- Mead, K S, Koehl, M A R & O'Donnell, M J (1999) Stomatopod sniffing: the scaling of chemosensory sensillae and flicking behavior with body size. *J Exp Mar Biol Ecol* **241**: 235–61.
- Meaney, M J (2001) Nature, nurture, and the disunity of knowledge. *Ann N Y Acad Sci* **935**: 50–61.
- Mebs, D (2009) Chemical biology of the mutualistic relationships of sea anemones with fish and crustaceans. *Toxicon* **54**: 1071–4.
- Meckley, T D, Wagner, C M & Luehring, M A (2012) Field evaluation of larval odor and mixtures of synthetic pheromone components for attracting migrating sea lampreys in rivers. *J Chem Ecol* **38**: 1062–9.
- Meinwald, J (2003) Understanding the chemistry of chemical communication: are we there yet? *Proc Natl Acad Sci USA* **100**: 14514–16.
- Meinwald, J (2009) The chemistry of biotic interactions in perspective: small molecules take center stage. *J Org Chem* **74**: 1813–25.
- Mellon, D (2012) Smelling, feeling, tasting and touching: behavioral and neural integration of antennular chemosensory and mechanosensory inputs in the crayfish. *J Exp Biol* **215**: 2163–72.
- Melo, A & González-Mariscal, G (2010) Communication by olfactory signals in rabbits: its role in reproduction. In Gerald, L (ed.) *Pheromones*. pp. 351–71. London: Academic Press.
- Menashe, I, Man, O, Lancet, D & Gilad, Y (2003) Different noses for different people. *Nat Genet* **34**: 143–4.
- Menashe, I, Abaffy, T, Hasin, Y *et al.* (2007) Genetic elucidation of human hyperosmia to isovaleric acid. *PLoS Biol* **5**: e284.
- Menini, A (ed.) (2010) *The Neurobiology of Olfaction*. Boca Raton, FL: CRC Press. Available online at www.ncbi.nlm.nih.gov/books/NBK55980.
- Mercier, A & Hamel, J F (2010) Synchronized breeding events in sympatric marine invertebrates: role of behavior and fine temporal windows in maintaining reproductive isolation. *Behav Ecol Sociobiol* **64**: 1749–65.
- Meredith, M (1998) Vomeronasal, olfactory, hormonal convergence in the brain – cooperation or coincidence? *Ann N Y Acad Sci* **855**: 349–61.
- Meredith, M (2001) Human vomeronasal organ function: a critical review of best and worst cases. *Chem Senses* **26**: 433–45.
- Meyer, S L F, Johnson, G, Dimock, M, Fahey, J W & Huettel, R N (1997) Field efficacy of *Verticillium lecanii*, sex pheromone, and pheromone analogs as potential management agents for soybean cyst nematode. *J Nematol* **29**: 282–8.
- Michael, R P & Keverne, E B (1970) Primate sex pheromones of vaginal origin. *Nature* **225**: 84–5.
- Miesenböck, G (2009) The optogenetic catechism. *Science* **326**: 395–9.
- Miklos, G L G & Maleszka, R (2011) Epigenomic communication systems in humans and honey bees: from molecules to behavior. *Horm Behav* **59**: 399–406.
- Milinski, M (2006) The major histocompatibility complex, sexual selection, and mate choice. *Annu Rev Ecol Evol Syst* **37**: 159–86.
- Milinski, M & Wedekind, C (2001) Evidence for MHC-correlated perfume preferences in humans. *Behav Ecol* **12**: 140–9.
- Milinski, M, Griffiths, S, Wegner, K M *et al.* (2005) Mate choice decisions of stickleback females predictably modified by MHC peptide ligands. *Proc Natl Acad Sci USA* **102**: 4414–18.
- Millar, J G & Haynes, K F (eds.) (1998) *Methods in Chemical Ecology. Volume 1. Chemical Methods*. London: Chapman & Hall.
- Miller, E J, Eldridge, M D B & Herbert, C A (2010a) Dominance and paternity in the tammar wallaby. In Coulson, G M & Eldridge, M D B (eds.) *Macropods: Biology of Kangaroos, Wallabies and Rat-kangaroos*. pp. 77–86. Collingwood, VIC: CSIRO Publishing.
- Miller, J R, McGhee, P S, Siegert, P Y *et al.* (2010b) General principles of attraction and competitive attraction as revealed by large-cage studies of moths responding to sex pheromone. *Proc Natl Acad Sci USA* **107**: 22–7.
- Mills, M G L, Gorman, M L & Mills, M E J (1980) The scent marking behaviour of the brown hyaena, *Hyaena brunea*. *S Afr J Zool* **15**: 240–8.

- Minks, A K & Cardé, R T (1988) Disruption of pheromone communication in moths – is the natural blend really most efficacious. *Entomol Exp Appl* **49**: 25–36.
- Mitchell, M D, McCormick, M I, Ferrari, M C O & Chivers, D P (2011) Coral reef fish rapidly learn to identify multiple unknown predators upon recruitment to the reef. *PLoS ONE* **6**: e15764.
- Miura, T & Scharf, M (2011) Molecular basis underlying caste differentiation in termites. In Bignell, D, Roisin, Y & Lo, N (eds.) *Biology of Termites: a Modern Synthesis*, 2nd edn., pp. 211–53. Dordrecht: Springer.
- Mizuno, K (2011) Infantile olfactory learning. In Preedy, V R, Watson, R R & Martin, C R (eds.) *Handbook of Behavior, Food and Nutrition*. pp. 119–32. New York: Springer.
- Mochizuki, F, Fukumoto, T, Noguchi, H *et al.* (2002) Resistance to a mating disruptant composed of (Z)-11-tetradecenyl acetate in the smaller tea tortrix, *Adoxophyes honmai* (Yasuda) (Lepidoptera: Tortricidae). *Appl Entomol Zool* **37**: 299–304.
- Mochizuki, F, Noguchi, H, Sugie, H, Tabata, J & Kainoh, Y (2008) Sex pheromone communication from a population resistant to mating disruptant of the smaller tea tortrix, *Adoxophyes honmai* Yasuda (Lepidoptera: Tortricidae). *Appl Entomol Zool* **43**: 293–8.
- Molet, M, Chittka, L & Raine, N E (2009) Potential application of the bumblebee foraging recruitment pheromone for commercial greenhouse pollination. *Apidologie* **40**: 608–16.
- Møller, A P & Thornhill, R (1998) Bilateral symmetry and sexual selection: a meta-analysis. *Am Nat* **151**: 174–92.
- Mombaerts, P (2004) Genes and ligands for odorant, vomeronasal and taste receptors. *Nat Rev Neurosci* **5**: 263–78.
- Mombaerts, P (2006) Axonal wiring in the mouse olfactory system. *Annu Rev Cell Dev Biol* **22**: 713–37.
- Monaco, E L, Tallamy, D W & Johnson, R K (1998) Chemical mediation of egg dumping in the lace bug *Gargaphia solani* Heidemann (Heteroptera: Tingidae). *Anim Behav* **56**: 1491–5.
- Mondor, E B & Roitberg, B D (2004) Inclusive fitness benefits of scent-marking predators. *Proc R Soc B* **271**: S341.
- Monnin, T & Peeters, C (1999) Dominance hierarchy and reproductive conflicts among subordinates in a monogynous queenless ant. *Behav Ecol* **10**: 323–32.
- Monnin, T, Malosse, C & Peeters, C (1998) Solid-phase microextraction and cuticular hydrocarbon differences related to reproductive activity in queenless ant *Dinoponera quadricaps*. *J Chem Ecol* **24**: 473–90.
- Montagna, W & Parakkal, P F (1974) *The Structure and Function of Skin*. New York: Academic Press.
- Montell, C (2009) A taste of the *Drosophila* gustatory receptors. *Curr Opin Neurobiol* **19**: 345–53.
- Montgomery, J C, Diebel, C, Halstead, M B D & Downer, J (1999) Olfactory search tracks in the Antarctic fish *Trematomus bernacchii*. *Polar Biol* **21**: 151–4.
- Montgomery, J C, Carton, G, Voigt, R, Baker, C & Diebel, C (2000) Sensory processing of water currents by fishes. *Phil Trans R Soc B* **355**: 1325.
- MontiBloch, L, JenningsWhite, C & Berliner, D L (1998) The human vomeronasal system – a review. *Ann N Y Acad Sci* **855**: 373–89.
- Moore, A J & Moore, P J (1999) Balancing sexual selection through opposing mate choice and male competition. *Proc R Soc B* **266**: 711–16.
- Moore, A J, Reagan, N L & Haynes, K F (1995) Conditional signaling strategies – effects of ontogeny, social experience and social-status on the pheromonal signal of male cockroaches. *Anim Behav* **50**: 191–202.
- Moore, B P, Brown, W V & Rothschild, M (1990) Methylalkylpyrazines in aposematic insects, their host plants and mimics. *Chemoecology* **1**: 43–51.
- Moore, P J, Reagan-Wallin, N L, Haynes, K F & Moore, A J (1997) Odour conveys status on cockroaches. *Nature* **389**: 25.
- Moreno-Rueda, G (2007) Is there empirical evidence for the cost of begging? *J Ethol* **25**: 215–22.
- Morgan, E D (2008) Chemical sorcery for sociality: exocrine secretions of ants (Hymenoptera: Formicidae). *Myrmecol News* **11**: 79–90.
- Morgan, E D (2009) Trail pheromones of ants. *Physiol Entomol* **34**: 1–17.
- Mori, K (2007) Significance of chirality in pheromone science. *Biorg Med Chem* **15**: 7505–23.
- Mori, K & Sakano, H (2011) How is the olfactory map formed and interpreted in the mammalian brain? *Annu Rev Neurosci* **34**: 467–99.

- Morris, N M & Udry, R J (1978) Pheromonal influences on human sexual behavior: an experimental search. *J Biosoc Sci* 10: 147–57.
- Moser, E & McCulloch, M (2010) Canine scent detection of human cancers: a review of methods and accuracy. *J Vet Behav* 5: 145–52.
- Mucignat-Caretta, C, Caretta, A & Cavaggioni, A (1995) Acceleration of puberty onset in female mice by male urinary proteins. *J Physiol* 486: 517–22.
- Mucignat-Caretta, C, Redaelli, M & Caretta, A (2012) One nose, one brain: contribution of the main and accessory olfactory system to chemosensation. *Front Neuroanat* 6: 46.
- Muenz, T, Maisonnasse, A, Plettner, E, Le Conte, Y & Rössler, W (2012) Sensory reception of the primer pheromone ethyl oleate. *Naturwissenschaften* 99: 421–5.
- Müller, C A & Manser, M B (2007) 'Nasty neighbours' rather than 'dear enemies' in a social carnivore. *Proc R Soc B* 274: 959.
- Müller-Schwarze, D (2006) *Chemical Ecology of Vertebrates*. Cambridge: Cambridge University Press.
- Müller-Schwarze, D, Altieri, R & Porter, N (1984) Alert odor from skin gland in deer. *J Chem Ecol* 10: 1707–29.
- Munger, S D, Leinders-Zufall, T & Zufall, F (2009) Subsystem organization of the mammalian sense of smell. *Annu Rev Physiol* 71: 115–40.
- Murata, K, Wakabayashi, Y, Sakamoto, K *et al.* (2011) Effects of brief exposure of male pheromone on multiple-unit activity at close proximity to kisspeptin neurons in the goat arcuate nucleus. *J Reprod Dev* 57: 197–202.
- Murlis, J, Elkinton, JS & Cardé, R T (1992) Odor plumes and how insects use them. *Annu Rev Entomol* 37: 505–32.
- Mylonas, C C, Fostier, A & Zanuy, S (2010) Broodstock management and hormonal manipulations of fish reproduction. *Gen Comp Endocrinol* 165: 516–34.
- Nakada, T, Toyoda, F, Iwata, T *et al.* (2007) Isolation, characterization and bioactivity of a region-specific pheromone, [Val8]sodefrin from the newt *Cynops pyrrhogaster*. *Peptides* 28: 774–80.
- Nakagawa, T & Vosshall, L B (2009) Controversy and consensus: noncanonical signaling mechanisms in the insect olfactory system. *Curr Opin Neurobiol* 19: 284–92.
- Nakagawa, T, Pellegrino, M, Sato, K, Vosshall, L B & Touhara, K (2012) Amino acid residues contributing to function of the heteromeric insect olfactory receptor complex. *PLoS ONE* 7: e32372.
- Nash, D R & Boomsma, J J (2008) Communication between hosts and social parasites. In d'Ettorre, P & Hughes, D P (eds.) *Sociobiology of Communication: An Interdisciplinary Perspective*. pp. 55–79. Oxford: Oxford University Press.
- Nash, D R, Als, T D, Maile, R, Jones, G R & Boomsma, J J (2008) A mosaic of chemical coevolution in a large blue butterfly. *Science* 319: 88–90.
- Natsch, A, Kuhn, F & Tiercy, JM (2010) Lack of evidence for HLA-linked patterns of odorous carboxylic acids released from glutamine conjugates secreted in the human axilla. *J Chem Ecol* 36: 837–46.
- Nault, L R (1973) Alarm pheromones help aphids escape predators. *Ohio Report* 58: 16–17.
- Nault, L R, Montgomery, M E & Bowers, W S (1976) Ant-aphid association: role of aphid alarm pheromone. *Science* 192: 1349–51.
- Naumann, K, Winston, M L, Slessor, K N, Prestwich, G D & Latli, B (1992) Intra-nest transmission of aromatic honey-bee queen mandibular gland pheromone components – movement as a unit. *Can Entomol* 124: 917–34.
- Naumann, K, Winston, M L & Slessor, K N (1993) Movement of honey bee (*Apis mellifera* L.) queen mandibular gland pheromone in populous and unpopulous colonies. *J Insect Behav* 6: 211–23.
- Nehring, V, Evison, S E F, Santorelli, L A, d'Ettorre, P & Hughes, W O H (2011) Kin-informative recognition cues in ants. *Proc R Soc B* 278: 1942–8.
- Nehring, V, Wyatt, T D & d'Ettorre, P (2014) Noise in chemical communication. In H Brumm (ed.) *Animal Communication and Noise. Animal Signals and Communication*, Vol. 2. New York: Springer.
- Nei, M, Niimura, Y & Nozawa, M (2008) The evolution of animal chemosensory receptor gene repertoires: roles of chance and necessity. *Nat Rev Genet* 9: 951–63.
- Nevitt, G A (2008) Sensory ecology on the high seas: the odor world of the procellariiform seabirds. *J Exp Biol* 211: 1706–13.
- Nevitt, G A, Losekoot, M & Weimerskirch, H (2008) Evidence for olfactory search in wandering albatross, *Diomedea exulans*. *Proc Natl Acad Sci USA* 105: 4576–81.

- Newcomb, R D, Xia, M B & Reed, D R (2012) Heritable differences in chemosensory ability among humans. *Flavour* 1: 9.
- Newey, P S, Robson, S K A & Crozier, R H (2008) Near-infrared spectroscopy as a tool in behavioural ecology: a case study of the weaver ant, *Oecophylla smaragdina*. *Anim Behav* 76: 1727–33.
- Newey, P S, Robson, S K A & Crozier, R H (2010) Weaver ants *Oecophylla smaragdina* encounter nasty neighbors rather than dear enemies. *Ecology* 91: 2366–72.
- Nicholson, J K & Lindon, J C (2008) Systems biology: metabonomics. *Nature* 455: 1054–6.
- Nie, Y, Swaisgood, R R, Zhang, Z *et al.* (2012) Giant panda scent-marking strategies in the wild: role of season, sex and marking surface. *Anim Behav* 84: 39–44.
- Nieberding, C M, de Vos, H, Schneider, M V *et al.* (2008) The male sex pheromone of the butterfly *Bicyclus anynana*: towards an evolutionary analysis. *PLoS ONE* 3: e2751.
- Nieh, J C, Contrera, F A L & Nogueira-Neto, P (2003) Pulsed mass recruitment by a stingless bee, *Trigona hyalinata*. *Proc R Soc B* 270: 2191.
- Nieh, J C, Contrera, F A L, Yoon, R R, Barreto, L S & Imperatriz-Fonseca, V L (2004) Polarized short odor-trail recruitment communication by a stingless bee, *Trigona spinipes*. *Behav Ecol Sociobiol* 56: 435–48.
- Nixon, A, Mallet, A I & Gower, D B (1988) Simultaneous quantification of 5 odorous steroids (16-androstenes) in the axillary hair of men. *J Steroid Biochem Mol Biol* 29: 505–10.
- Nodari, F, Hsu, F F, Fu, X Y *et al.* (2008) Sulfated steroids as natural ligands of mouse pheromone-sensing neurons. *J Neurosci* 28: 6407–18.
- Noldus, L P J J, Potting, R P J & Barendregt, H E (1991) Moth sex-pheromone adsorption to leaf surface – bridge in time for chemical spies. *Physiol Entomol* 16: 329–44.
- Nonacs, P & Hager, R (2011) The past, present and future of reproductive skew theory and experiments. *Biol Rev* 86: 271–98.
- Nordlund, D A & Lewis, W J (1976) Terminology of chemical releasing stimuli in intraspecific and interspecific interactions. *J Chem Ecol* 2: 211–20.
- Novil, P & Schluter, D (2011) The genes underlying the process of speciation. *Trends Ecol Evol* 26: 160–7.
- Novotny, M V (2003) Pheromones, binding proteins and receptor responses in rodents. *Biochem Soc Trans* 31: 117–22.
- Novotny, M V, Harvey, S, Jemiolo, B & Alberts, J (1985) Synthetic pheromones that promote inter-male aggression in mice. *Proc Natl Acad Sci USA* 82: 2059–61.
- Novotny, M V, Xie, T M, Harvey, S *et al.* (1995) Stereoselectivity in mammalian chemical communication – male-mouse pheromones. *Experientia* 51: 738–43.
- Novotny, M V, Ma, W, Zidek, L & Daev, E (1999a) Recent biochemical insights into puberty acceleration, estrus induction and puberty delay in the house mouse. In Johnston, R E, Müller-Schwarze, D & Sorensen, P W (eds.) *Advances in Chemical Signals in Vertebrates*. pp. 99–116. New York: Kluwer Academic/Plenum Press.
- Novotny, M V, Ma, W D, Wiesler, D & Zidek, L (1999b) Positive identification of the puberty-accelerating pheromone of the house mouse: the volatile ligands associating with the major urinary protein. *Proc R Soc B* 266: 2017–22.
- Nufio, C R & Papaj, D R (2001) Host marking behavior in phytophagous insects and parasitoids. *Entomol Exp Appl* 99: 273–93.
- Nyby, J G (2009) Adult house mouse (*Mus musculus*) ultrasonic calls: hormonal and pheromonal regulation. In Brudzynski, S M (ed.) *Handbook of Mammalian Vocalization*. pp. 303–10. Oxford: Academic Press.
- O'Riain, M J & Jarvis, J U M (1997) Colony member recognition and xenophobia in the naked mole-rat. *Anim Behav* 53: 487–98.
- Ober, C (1999) Studies of HLA, fertility and mate choice in a human isolate. *Hum Reprod Update* 5: 103–7.
- Ober, C, Weitkamp, L R, Cox, N *et al.* (1997) HLA and mate choice in humans. *Am J Hum Genet* 61: 497–504.
- Obin, M S & Vander Meer, R K (1989) Nestmate recognition in fire ants (*Solenopsis invicta* Buren) – do queens label workers? *Ethology* 80: 255–64.
- Oboti, L, Schellino, R, Giachino, C *et al.* (2011) Newborn interneurons in the accessory olfactory bulb promote mate recognition in female mice. *Front Neurosci* 5: 10.3389/fnins.2011.00113.

- Oehlschlager, A C, Chinchilla, C, Castillo, G & Gonzalez, L (2002) Control of red ring disease by mass trapping of *Rhynchophorus palmarum* (Coleoptera: Curculionidae). *Fla Entomol* 85: 507–13.
- Olender, T & Lancet, D (2012) Evolutionary grass roots for odor recognition. *Chem Senses* 37: 581–4.
- Olender, T, Waszak, S, Viavant, M *et al.* (2012) Personal receptor repertoires: olfaction as a model. *BMC Genomics* 13: 414.
- Olsén, K H (2011) Effects of pollutants on olfactory mediated behaviors in fish and crustaceans. In Breithaupt, T & Thiel, M (eds.) *Chemical Communication in Crustaceans*. pp. 507–29. New York: Springer.
- Olsson, M & Shine, R (1998) Chemosensory mate recognition may facilitate prolonged mate guarding by male snow skinks, *Niveoscincus microlepidotus*. *Behav Ecol Sociobiol* 43: 359–63.
- Olsson, P & Laska, M (2010) Human male superiority in olfactory sensitivity to the sperm attractant odorant bourgeonal. *Chem Senses* 35: 427–32.
- Olsson, S B, Kesevan, S, Groot, A T *et al.* (2010) *Ostrinia* revisited: evidence for sex linkage in European corn borer *Ostrinia nubilalis* (Hubner) pheromone reception. *BMC Evol Biol* 10: 285.
- Ono, M, Igarashi, T, Ohno, E & Sasaki, M (1995) Unusual thermal defence by a honeybee against mass attack by hornets. *Nature* 377: 334–6.
- Ophir, A G, Schrader, S B & Gillooly, J F (2010) Energetic cost of calling: general constraints and species-specific differences. *J Evol Biol* 23: 1564–9.
- Oppelt, A, Spitzenfeil, N, Kroiss, J & Heinze, J (2008) The significance of intercolonial variation of cuticular hydrocarbons for inbreeding avoidance in ant sexuals. *Anim Behav* 76: 1029–34.
- Ortiz, C O, Etchberger, J F, Posy, S L *et al.* (2006) Searching for neuronal left/right asymmetry: genome wide analysis of nematode receptor-type guanylyl cyclases. *Genetics* 173: 131–49.
- Ouyang, G, Vuckovic, D & Pawliszyn, J (2011) Nondestructive sampling of living systems using in vivo solid-phase microextraction. *Chem Rev* 111: 2784–814.
- Owens, I P F, Rowe, C & Thomas, A L R (1999) Sexual selection, speciation and imprinting: separating the sheep from the goats. *Trends Ecol Evol* 14: 131–2.
- Oyarzun, F X & Strathmann, R R (2011) Plasticity of hatching and the duration of planktonic development in marine invertebrates. *Integr Comp Biol* 51: 81–90.
- Ozaki, M, Wada-Katsumata, A, Fujikawa, K *et al.* (2005) Ant nestmate and non-nestmate discrimination by a chemosensory sensillum. *Science* 309: 311–14.
- Ozsolak, F & Milos, P M (2010) RNA sequencing: advances, challenges and opportunities. *Nat Rev Genet* 12: 87–98.
- Page, J L, Dickman, B D, Webster, D R & Weissburg, M J (2011) Staying the course: chemical signal spatial properties and concentration mediate cross-stream motion in turbulent plumes. *J Exp Biol* 214: 1513–22.
- Page, R E, Rueppell, O & Amdam, G V (2012) Genetics of reproduction and regulation of honeybee (*Apis mellifera* L.) social behavior. *Annu Rev Genet* 46: 97–119.
- Pain, F, L'Heureux, B & Gurden, H (2011) Visualizing odor representation in the brain: a review of imaging techniques for the mapping of sensory activity in the olfactory glomeruli. *Cell Mol Life Sci* 68: 2689–709.
- Palmer, A R (2000) Quasireplication and the contract of error: lessons from sex ratios, heritabilities and fluctuating asymmetry. *Annu Rev Ecol Syst* 31: 441–80.
- Palmer, C A, Watts, R A, Gregg, R G *et al.* (2005) Lineage-specific differences in evolutionary mode in a salamander courtship pheromone. *Mol Biol Evol* 22: 2243–56.
- Palmer, C A, Watts, R A, Houck, L D, Picard, A L & Arnold, S J (2007a) Evolutionary replacement of components in a salamander pheromone signaling complex: more evidence for phenotypic-molecular decoupling. *Evolution* 61: 202–15.
- Palmer, C A, Hollis, D M, Watts, R A *et al.* (2007b) Plethodontid modulating factor, a hypervariable salamander courtship pheromone in the three-finger protein superfamily. *FEBS J* 274: 2300–10.
- Palmer, C A, Watts, R A, Hastings, A P, Houck, L D & Arnold, S J (2010) Rapid evolution of plethodontid modulating factor, a hypervariable salamander courtship pheromone, is driven by positive selection. *J Mol Evol* 70: 427–40.
- Pankiw, T (2004) Brood pheromone regulates foraging activity of honey bees (Hymenoptera: Apidae). *J Econ Entomol* 97: 748–51.

- Parker, G A & Pizzari, T (2010) Sperm competition and ejaculate economics. *Biol Rev* **85**: 897–934.
- Parker, M R & Mason, R T (2012) How to make a sexy snake: estrogen activation of female sex pheromone in male red-sided garter snakes. *J Exp Biol* **215**: 723–30.
- Parker, M R, Young, B A & Kardong, K V (2008) The forked tongue and edge detection in snakes *Crotalus oreganus*: an experimental test. *J Comp Psychol* **122**: 35–40.
- Partan, S R & Marler, P (2005) Issues in the classification of multimodal communication signals. *Am Nat* **166**: 231–45.
- Pasteels, J M (2007) Chemical defence, offence and alliance in ants–aphids–ladybirds relationships. *Popul Ecol* **49**: 5–14.
- Pasteels, J M, Deneubourg, J L & Goss, S (1987) Self-organization mechanisms in ant societies (I): trail recruitment to newly discovered food sources. *Experimentia Supplementum* **54**: 155–75.
- Paterson, S & Pemberton, J M (1997) No evidence for major histocompatibility complex-dependent mating patterns in a free-living ruminant population. *Proc R Soc B* **264**: 1813–19.
- Peakall, R (1990) Responses of male *Zaspilothynnus trilobatus* Turner wasps to females and the sexually deceptive orchid it pollinates. *Funct Ecol* **4**: 159–68.
- Peakall, R, Ebert, D, Poldy, J *et al.* (2010) Pollinator specificity, floral odour chemistry and the phylogeny of Australian sexually deceptive *Chiloglottis* orchids: implications for pollinator-driven speciation. *New Phytol* **188**: 437–50.
- Peele, P, Salazar, I, Mimmack, M, Keverne, E B & Brennan, P A (2003) Low molecular weight constituents of male mouse urine mediate the pregnancy block effect and convey information about the identity of the mating male. *Eur J Neurosci* **18**: 622–8.
- Peeters, C & Liebig, J (2009) Fertility signaling as a general mechanism of regulating reproductive division of labor in ants. In Gadau, J & Fewell, J H (eds.) *Organization of Insect Societies: From Genome to Sociocomplexity*. pp. 220–42. Cambridge, MA: Harvard University Press.
- Peeters, C, Monnin, T & Malosse, C (1999) Cuticular hydrocarbons correlated with reproductive status in a queenless ant. *Proc R Soc B* **266**: 1323–7.
- Pelosi, P (1996) Perireceptor events in olfaction. *J Neurobiol* **30**: 3–19.
- Pelosi, P, Zhou, J, Ban, L & Calvello, M (2006) Soluble proteins in insect chemical communication. *Cell Mol Life Sci* **63**: 1658–76.
- Pener, M P & Simpson, S J (2009) Locust phase polyphenism: an update. *Adv Insect Physiol* **36**: 1–272.
- Penn, D J (2002) The scent of genetic compatibility: sexual selection and the major histocompatibility complex. *Ethology* **108**: 1–21.
- Penn, D J & Frommen, J G (2010) Kin recognition: an overview of conceptual issues, mechanisms and evolutionary theory. In Kappeler, P M (ed.) *Animal Behaviour: Evolution and Mechanisms*. pp. 55–85. Heidelberg: Springer.
- Penn, D J & Ilmonen, P (2005) Major histocompatibility complex (MHC). eLS. Chichester: John Wiley DOI: 10.1038/npg.els.0003986.
- Penn, D J & Potts, W K (1998a) How do major histocompatibility complex genes influence odor and mating preferences? *Adv Immunol* **69**: 411–36.
- Penn, D J & Potts, W K (1998b) MHC-disassortative mating preferences reversed by cross-fostering. *Proc R Soc B* **265**: 1299–306.
- Penn, D J & Potts, W K (1998c) Chemical signals and parasite-mediated sexual selection. *Trends Ecol Evol* **13**: 391–6.
- Penn, D J, Oberzaucher, E, Grammer, K *et al.* (2007) Individual and gender fingerprints in human body odour. *J R Soc Interface* **4**: 331–40.
- Pereira, R, Sivinski, J & Teal, P E A (2010a) Influence of a juvenile hormone analog and dietary protein on male *Anastrepha suspensa* (Diptera: Tephritidae) sexual success. *J Econ Entomol* **103**: 40–6.
- Pereira, R, Sivinski, J, Teal, P & Brockmann, J (2010b) Enhancing male sexual success in a lekking fly (*Anastrepha suspensa* Diptera: Tephritidae) through a juvenile hormone analog has no effect on adult mortality. *J Insect Physiol* **56**: 1552–7.
- Pernal, S F, Baird, D S, Birmingham, A L *et al.* (2005) Semiochemicals influencing the host-finding behaviour of *Varroa destructor*. *Exp Appl Acarol* **37**: 1–26.
- Petrulis, A (2009) Neural mechanisms of individual and sexual recognition in Syrian hamsters (*Mesocricetus auratus*): pheromonal communication in higher vertebrates and its implication for reproductive function. *Behav Brain Res* **200**: 260–7.

- Pettis, J, Pankiw, T & Plettner, E (1999) Bees. In Hardie, J & Minks, A K (eds.) *Pheromones of Non-lepidopteran Insects Associated with Agricultural Plants*. pp. 429–50. Wallingford, Oxon: CAB International.
- Pettis, R J, Erickson, B W, Forward, R B & Rittschof, D (1993) Superpotent synthetic tripeptide mimics of the mud-crab pumping pheromone. *Int J Pept Protein Res* 42: 312–19.
- Pfennig, D W & Sherman, P W (1995) Kin recognition. *Sci Am* 272: 98–103.
- Pham-Delègue, M, Trouiller, J, Caillaud, C, Roger, B & Masson, C (1993) Effect of queen pheromone on worker bees of different ages: behavioural and electrophysiological responses. *Apidologie* 24: 267–81.
- Phelan, P L (1992) Evolution of sex pheromones and the role of asymmetric tracking. In Roitberg, B D & Isman, M B (eds.) *Insect Chemical Ecology: an Evolutionary Approach*. pp. 245–64. New York: Chapman and Hall.
- Phelan, P L (1997) Evolution of mate-signalling in moths: phylogenetic considerations and predictions from the asymmetric tracking hypothesis. In Choe, J C & Crespi, B J (eds.) *The Evolution of Mating Systems in Insects and Arachnids*. pp. 240–56. Cambridge: Cambridge University Press.
- Phelan, P L & Baker, T C (1986) Male-size-related courtship success and intersexual selection in the tobacco moth, *Ephesia elutella*. *Experientia* 42: 1291–3.
- Phelan, P L & Baker, T C (1987) Evolution of male pheromones in moths – reproductive isolation through sexual selection. *Science* 235: 205–7.
- Phillips, T W & Throne, J E (2010) Biorational approaches to managing stored-product insects. *Annu Rev Entomol* 55: 375–97.
- Pickett, J A, Wadhams, L J, Woodcock, C M & Hardie, J (1992) The chemical ecology of aphids. *Annu Rev Entomol* 37: 67–90.
- Pickett, J A, Birkett, M A, Dewhurst, S Y *et al.* (2010) Chemical ecology of animal and human pathogen vectors in a changing global climate. *J Chem Ecol* 36: 113–21.
- Pierce, N E, Braby, M F, Heath, A *et al.* (2002) The ecology and evolution of ant association in the Lycaenidae (Lepidoptera). *Annu Rev Entomol* 47: 733–71.
- Piertney, S B & Oliver, M K (2006) The evolutionary ecology of the major histocompatibility complex. *Heredity* 96: 7–21.
- Pike, N & Foster, W A (2008) The ecology of altruism in a clonal insect. In Korb, J & Heinze, J (eds.) *Ecology of Social Evolution*. pp. 37–56. Berlin: Springer.
- Pilkington, L J, Messelink, G, van Lenteren, J C & Le Mottee, K (2010) “Protected biological control” – biological pest management in the greenhouse industry. *Biol Control* 52: 216–20.
- Pizzari, T & Bonduriansky, R (2010) Sexual behaviour: conflict, cooperation and co-evolution. In Székely, T, Moore, A & Komdeur, J (eds.) *Social Behaviour: Genes, Ecology and Evolution*. pp. 230–66. Cambridge: Cambridge University Press.
- Pizzari, T & Snook, R R (2004) Sexual conflict and sexual selection: measuring antagonistic coevolution. *Evolution* 58: 1389–93.
- Pizzolon, M, Giacomello, E, Marri, L *et al.* (2010) When fathers make the difference: efficacy of male sexually selected antimicrobial glands in enhancing fish hatching success. *Funct Ecol* 24: 141–8.
- Plenderleith, M, Oosterhout, C, Robinson, R L & Turner, G F (2005) Female preference for conspecific males based on olfactory cues in a Lake Malawi cichlid fish. *Biol Lett* 1: 411–14.
- Plettner, E, Slessor, K N, Winston, M L & Oliver, J E (1996) Caste-selective pheromone biosynthesis in honeybees. *Science* 271: 1851–3.
- Podjasek, J O, Bosnjak, L M, Brooker, D J & Mondor, E B (2005) Alarm pheromone induces a transgenerational wing polyphenism in the pea aphid, *Acyrtosiphon pisum*. *Can J Zool* 83: 1138–41.
- Poiani, A (2006) Complexity of seminal fluid: a review. *Behav Ecol Sociobiol* 60: 289–310.
- Polak, M (2008) The developmental instability-sexual selection hypothesis: a general evaluation and case study. *Evol Biol* 35: 208–30.
- Porat, D & Chadwick-Furman, N (2004) Effects of anemonefish on giant sea anemones: expansion behavior, growth, and survival. *Hydrobiologia* 530: 513–20.
- Porter, J, Craven, B, Khan, R M *et al.* (2007) Mechanisms of scent-tracking in humans. *Nat Neurosci* 10: 27–9.
- Porter, M L, Blasic, J R, Bok, M J *et al.* (2012) Shedding new light on opsin evolution. *Proc R Soc B* 279: 3–14.

- Porter, R H & Blaustein, A R (1989) Mechanisms and ecological correlates of kin recognition. *Sci Prog* **73**: 53–66.
- Porter, R H & Winberg, J (1999) Unique salience of maternal breast odors for newborn infants. *Neurosci Biobehav Rev* **23**: 439–49.
- Porter, R H, Tepper, V J & White, D M (1981) Experiential influences on the development of huddling preferences and sibling recognition in spiny mice. *Dev Psychobiol* **14**: 375–82.
- Porter, R H, Cernoch, J M & McLaughlin, F J (1983) Maternal recognition of neonates through olfactory cues. *Physiol Behav* **30**: 151–4.
- Porter, R H, Balogh, R D, Cernoch, J M & Franchi, C (1986) Recognition of kin through characteristic body odors. *Chem Senses* **11**: 389–95.
- Porter, R H, McFadyen-Ketchum, S A & King, G A (1989) Underlying bases of recognition signatures in spiny mice, *Acomys cahirinus*. *Anim Behav* **37**: 638–44.
- Poth, D, Wollenberg, K C, Vences, M & Schulz, S (2012) Volatile amphibian pheromones: macrolides from mantellid frogs from Madagascar. *Angew Chem Int Ed* **51**: 2187–90.
- Poulin, G B (2011) A guide to using RNAi and other nucleotide-based technologies. *Brief Funct Genomics* **10**: 173–4.
- Prehn-Kristensen, A, Wiesner, C, Bergmann, T O *et al.* (2009) Induction of empathy by the smell of anxiety. *PLoS ONE* **4**: e5987.
- Prestwich, K N & Walter, T J (1981) Energetics of singing in crickets: effect of temperature in three trilling species (Orthoptera: Gryllidae). *J Comp Physiol B* **143**: 199–212.
- Preti, G & Leyden, J J (2010) Genetic influences on human body odor: from genes to the axillae. *J Invest Dermatol* **130**: 344–6.
- Preti, G & Wysocki, C J (1999) Human pheromones: releasers or primers, fact or myth. In Johnston, R E, Müller-Schwarze, D & Sorensen, P W (eds.) *Advances in Chemical Signals in Vertebrates*. pp. 315–32. New York: Kluwer Academic/Plenum Press.
- Preti, G, Wysocki, C J, Barnhart, K T, Sondheimer, S J & Leyden, J J (2003) Male axillary extracts contain pheromones that affect pulsatile secretion of luteinizing hormone and mood in women recipients. *Biol Reprod* **68**: 2107–13.
- Pungalija, C, Srinivasan, J, Fox, B *et al.* (2009) A shortcut to identifying small molecule signals that regulate behavior and development in *Caenorhabditis elegans*. *Proc Natl Acad Sci USA* **106**: 7708–13.
- Puurtinen, M, Ketola, T & Kotiaho, J S (2009) The good-genes and compatible-genes benefits of mate choice. *Am Nat* **174**: 741–52.
- Queller, D C & Strassmann, J E (2010) Evolution of complex societies. In Westneat, D F & Fox, C W (eds.) *Evolutionary Behavioral Ecology*. pp. 327–40. New York: Oxford University Press.
- Quental, T B, Patten, M M & Pierce, N E (2007) Host plant specialization driven by sexual selection. *Am Nat* **169**: 830–6.
- Quinet, Y & Pasteels, J M (1996) Spatial specialization of the foragers and foraging strategy in *Lasius fuliginosus* (Latreille) (Hymenoptera, Formicidae). *Insectes Soc* **43**: 333–46.
- Qvarnström, A & Forsgren, E (1998) Should females prefer dominant males? *Trends Ecol Evol* **13**: 498–501.
- Raffa, K F (2001) Mixed messages across multiple trophic levels: the ecology of bark beetle chemical communication systems. *Chemoecology* **11**: 49–65.
- Raffa, K F & Dahlsten, D L (1995) Differential responses among natural enemies and prey to bark beetle pheromones. *Oecologia* **102**: 17–23.
- Raffa, K F, Phillips, T W & Salom, S M (1993) Strategies and mechanisms of host colonization by bark beetles. In Schowalter, T D (ed.) *Beetle-Pathogens Interactions in Conifer Forests*. pp. 103–28. London: Academic Press.
- Raffa, K F, Hobson, K R, LaFontaine, S & Aukema, B H (2007) Can chemical communication be cryptic? Adaptations by herbivores to natural enemies exploiting prey semiochemistry. *Oecologia* **153**: 1009–19.
- Rajan, R, Clement, J P & Bhalla, U S (2006) Rats smell in stereo. *Science* **311**: 666–70.
- Ramdaya, P & Benton, R (2010) Evolving olfactory systems on the fly. *Trends Genet* **26**: 307–16.
- Ramírez, S R, Eltz, T, Fujiwara, M K *et al.* (2011) Asynchronous diversification in a specialized plant-pollinator mutualism. *Science* **333**: 1742–6.

- Ramm, S A, McDonald, L, Hurst, J L, Beynon, R J & Stockley, P (2009) Comparative proteomics reveals evidence for evolutionary diversification of rodent seminal fluid and its functional significance in sperm competition. *Mol Biol Evol* 26: 189–98.
- Rantala, M J & Marcinkowska, U M (2011) The role of sexual imprinting and the Westermarck effect in mate choice in humans. *Behav Ecol Sociobiol* 65: 859–73.
- Rasa, O A E (1973) Marking behaviour and its social significance in the African dwarf mongoose, *Helogale undulata rufula*. *Z Tierpsychol* 32: 293–318.
- Rasmussen, H B, Ganswindt, A, Douglas-Hamilton, I & Vollrath, F (2008) Endocrine and behavioral changes in male African elephants: linking hormone changes to sexual state and reproductive tactics. *Horm Behav* 54: 539–48.
- Rasmussen, L E L, Lee, T D, Zhang, A J, Roelofs, W L & Daves, G D (1997) Purification, identification, concentration and bioactivity of (Z)-7-dodecen-1-yl acetate: sex pheromone of the female Asian elephant, *Elephas maximus*. *Chem Senses* 22: 417–37.
- Rasmussen, L E L, Lazar, J & Greenwood, DR (2003) Olfactory adventures of elephantine pheromones. *Biochem Soc Trans* 31: 137–41.
- Rasmussen, L E L, Krishnamurthy, V & Sukumar, R (2005) Behavioural and chemical confirmation of the preovulatory pheromone, (Z)-7-dodecenyl acetate, in wild Asian elephants: its relationship to musth. *Behaviour* 142: 351–96.
- Ratnieks, F L W & Wenseleers, T (2005) Policing insect societies. *Science* 307: 54–6.
- Ratnieks, F L W & Wenseleers, T (2008) Altruism in insect societies and beyond: voluntary or enforced? *Trends Ecol Evol* 23: 45–52.
- Ratnieks, F L W, Foster, K R & Wenseleers, T (2006) Conflict resolution in insect societies. *Annu Rev Entomol* 51: 581–608.
- Rechav, Y, Norval, R A I, Tannock, J & Colborne, J (1978) Attraction of the tick *Ixodes neitzi* to twigs marked by the klipspringer antelope. *Nature* 275: 310–11.
- Reddy, G V P & Guerrero, A (2004) Interactions of insect pheromones and plant semiochemicals. *Trends Plant Sci* 9: 253–61.
- Reddy, G V P & Guerrero, A (2010) New pheromones and insect control strategies. In Gerald, L, (ed.) *Pheromones*. pp. 493–519. London: Academic Press.
- Reeve, H K & Sherman, P W (1993) Adaptation and the goals of evolutionary research. *Q Rev Biol* 68: 1–32.
- Regnier, F E & Wilson, E O (1969) The alarm-defense system of the ant *Lasius alienus*. *J Insect Physiol* 15: 893–8.
- Regnier, F E & Wilson, E O (1971) Chemical communication and 'propaganda' in slave-maker ants. *Science* 172: 267–9.
- Reichle, C, Aguilar, I, Ayasse, M *et al.* (2013) Learnt information in species-specific 'trail pheromone' communication in stingless bees. *Anim Behav* 85: 225–32.
- Reidenbach, M A & Koehl, M A R (2011) The spatial and temporal patterns of odors sampled by lobsters and crabs in a turbulent plume. *J Exp Biol* 214: 3138–53.
- Reinhard, J & Kaib, M (1995) Interaction of pheromones during food exploitation by the termite *Schedorhinotermes lamanianus*. *Physiol Entomol* 20: 266–72.
- Reinhard, J, Lacey, M J, Ibarra, F *et al.* (2002) Hydroquinone: a general phagostimulating pheromone in termites. *J Chem Ecol* 28: 1–14.
- Reisert, J & Restrepo, D (2009) Molecular tuning of odorant receptors and its implication for odor signal processing. *Chem Senses* 34: 535–45.
- Rekwot, P I, Ogwu, D, Oyedipe, E O & Sekoni, V O (2001) The role of pheromones and biostimulation in animal reproduction. *Anim Reprod Sci* 65: 157–70.
- Restrepo, D, Lin, W H, Salcedo, E, Yarnazaki, K & Beauchamp, G (2006) Odortypes and MHC peptides: complementary chemosignals of MHC haplotype? *Trends Neurosci* 29: 604–9.
- Restrepo, D, Doucette, W, Whitesell, J D, McTavish, T S & Salcedo, E (2009) From the top down: flexible reading of a fragmented odor map. *Trends Neurosci* 32: 525–31.
- Rettenmeyer, C W (1963) Behavioral studies of army ants. *Univ Kans Sci Bull* 44: 281–465.
- Rettenmeyer, C W, Rettenmeyer, M, Joseph, J & Berghoff, S (2011) The largest animal association centered on one species: the army ant *Eciton burchellii* and its more than 300 associates. *Insectes Soc* 58: 281–92.

- Reusch, T B H, Haberli, M A, Aeschlimann, P B & Milinski, M (2001) Female sticklebacks count alleles in a strategy of sexual selection explaining MHC polymorphism. *Nature* 414: 300–2.
- Reynolds, A M (2010) Bridging the gulf between correlated random walks and Lévy walks: autocorrelation as a source of Lévy walk movement patterns. *J R Soc Interface* 7: 1753–8.
- Reynolds, A M, Reynolds, D R, Smith, A D, Svensson, G P & Löfstedt, C (2007) Appetitive flight patterns of male *Agrotis segetum* moths over landscape scales. *J Theor Biol* 245: 141–9.
- Rezával, C, Pavlou, H J, Dornan, A J *et al.* (2012) Neural circuitry underlying *Drosophila* female postmating behavioral responses. *Curr Biol* 22: 1155–65.
- Richgels, P K & Rollmann, S M (2012) Genetic variation in odorant receptors contributes to variation in olfactory behavior in a natural population of *Drosophila melanogaster*. *Chem Senses* 37: 229–40.
- Richter, S H, Garner, J P & Wurbel, H (2009) Environmental standardization: cure or cause of poor reproducibility in animal experiments? *Nat Meth* 6: 257–61.
- Richter, S H, Garner, J P, Zipser, B *et al.* (2011) Effect of population heterogenization on the reproducibility of mouse behavior: a multi-laboratory study. *PLoS ONE* 6: e16461.
- Ritchie, M G (2007) Sexual selection and speciation. *Annu Rev Ecol Evol Syst* 38: 79–102.
- Rittschof, D (2009) Future trends in antifouling research. In Hellio, C & Yebra, D (eds.) *Advances in Marine Antifouling Coatings and Technologies*. pp. 725–48. Cambridge/Boca Raton, FL: Woodhead/CRC Press.
- Rittschof, D & Cohen, J H (2004) Crustacean peptide and peptide-like pheromones and kairomones. *Peptides* 25: 1503–16.
- Rivière, S, Challet, L, Fluegge, D, Spehr, M & Rodriguez, I (2009) Formyl peptide receptor-like proteins are a novel family of vomeronasal chemosensors. *Nature* 459: 574–7.
- Roberts, M L, Buchanan, K L & Evans, M R (2004) Testing the immunocompetence handicap hypothesis: a review of the evidence. *Anim Behav* 68: 227–39.
- Roberts, R L, Zullo, A, Gustafson, E A & Carter, C S (1996) Perinatal steroid treatments alter alloparental and affiliative behavior in prairie voles. *Horm Behav* 30: 576–82.
- Roberts, R L, Williams, J R, Wang, A K & Carter, C S (1998) Cooperative breeding and monogamy in prairie voles: influence of the sire and geographical variation. *Anim Behav* 55: 1131–40.
- Roberts, S A, Davidson, A J, McLean, L, Beynon, R J & Hurst, J L (2012) Pheromonal induction of spatial learning in mice. *Science* 338: 1462–5.
- Roberts, S A, Simpson, D M, Armstrong, S D *et al.* (2010) Darcin: a male pheromone that stimulates female memory and sexual attraction to an individual male's odour. *BMC Biol* 8: 75.
- Roberts, S C (2007) Scent marking. In Wolff, J O & Sherman, P W (eds.) *Rodent Societies: an Ecological and Evolutionary Perspective*. pp. 255–67. Chicago: Chicago University Press.
- Roberts, S C (2012) On the relationship between scent-marking and territoriality in callitrichid primates. *Int J Primatol* 33: 749–61.
- Roberts, S C & Gosling, L M (2003) Genetic similarity and quality interact in mate choice decisions by female mice. *Nat Genet* 35: 103–6.
- Roberts, S C & Gosling, L M (2004) Manipulation of olfactory signaling and mate choice for conservation breeding: a case study of harvest mice. *Conserv Biol* 18: 548–56.
- Roberts, S C & Lowen, C (1997) Optimal patterns of scent marks in klipspringer (*Oreotragus oreotragus*) territories. *J Zool* 243: 565–78.
- Roberts, S C, Gosling, L M, Spector, T D *et al.* (2005) Body odor similarity in noncohabiting twins. *Chem Senses* 30: 651–6.
- Roberts, S C, Gosling, L M, Carter, V & Petrie, M (2008) MHC-correlated odour preferences in humans and the use of oral contraceptives. *Proc R Soc B* 275: 2715–22.
- Robertson, H M & Wanner, K W (2006) The chemoreceptor superfamily in the honey bee, *Apis mellifera*: expansion of the odorant, but not gustatory, receptor family. *Genome Res* 16: 1395.
- Robinette, S L, Brutschweiler, R, Schroeder, F C & Edison, A S (2011) NMR in metabolomics and natural products research: two sides of the same coin. *Acc Chem Res* 45: 288–97.
- Robinson, E J H (2009) Physiology as a caste-defining feature. *Insectes Soc* 56: 1–6.

- Robinson, E J H, Jackson, D E, Holcombe, M & Ratnieks, F L W (2005a) 'No entry' signal in ant foraging. *Nature* **438**: 442.
- Robinson, G E, Grozinger, C M & Whitfield, C W (2005b) Sociogenomics: social life in molecular terms. *Nat Rev Genet* **6**: 257–70.
- Rodriguez, I, Greer, C A, Mok, M Y & Mombaerts, P (2000) A putative pheromone receptor gene expressed in human olfactory mucosa. *Nat Genet* **26**: 18–19.
- Rodriguez-Saona, C R & Stelinski, L L (2009) Behavior-modifying strategies in IPM: theory and practice. In Peshwin, R & Dhawan, A K (eds.) *Integrated Pest Management: Innovation-Development Process*. pp. 263–315. Dordrecht: Springer.
- Roelofs, W L & Rooney, A P (2003) Molecular genetics and evolution of pheromone biosynthesis in Lepidoptera. *Proc Natl Acad Sci USA* **100**: 9179–84.
- Roelofs, W L, Liu, W T, Hao, G X *et al.* (2002) Evolution of moth sex pheromones via ancestral genes. *Proc Natl Acad Sci USA* **99**: 13621–6.
- Roessingh, P, Peterson, S C & Fitzgerald, T D (1988) The sensory basis of trail following in some lepidopterous larvae – contact chemoreception. *Physiol Entomol* **13**: 219–24.
- Roitberg, B D & Prokopy, R J (1981) Experience required for pheromone recognition by the apple maggot fly. *Nature* **292**: 540–1.
- Roitberg, B D, Lauzon, C R, Opp, S B & Papaj, D (2009) Functional and behavioural ecology of tree-fruit pests: the four Fs of fruit flies (Diptera: Tephritidae). In Aluja, M, Leskey, T C & Vincent, C (eds.) *Biorational Tree Fruit Pest Management*. pp. 56–84. Wallingford: CABI Publishing.
- Rollmann, S M, Wang, P, Date, P *et al.* (2010) Odorant receptor polymorphisms and natural variation in olfactory behavior in *Drosophila melanogaster*. *Genetics* **186**: 687–97.
- Romantshik, O, Porter, R, Tillmann, V & Varendi, H (2007) Preliminary evidence of a sensitive period for olfactory learning by human newborns. *Acta Paediatr* **96**: 372–6.
- Romeyer, A, Porter, R H, Poindron, P *et al.* (1993) Recognition of dizygotic and monozygotic twin lambs by ewes. *Behaviour* **127**: 119–39.
- Roper, T J (2010) *Badger*. London: Collins.
- Roper, T J, Conradt, L, Butler, J *et al.* (1993) Territorial marking with faeces in badgers (*Meles meles*) – a comparison of boundary and hinterland latrine use. *Behaviour* **127**: 289–307.
- Roulston, T H, Buczkowski, G & Silverman, J (2003) Nestmate discrimination in ants: effect of bioassay on aggressive behavior. *Insectes Soc* **50**: 151–9.
- Roux, O, Martin, J M, Ghomsi, N T & Dejean, A (2009) A non-lethal water-based removal-reapplication technique for behavioral analysis of cuticular compounds of ants. *J Chem Ecol* **35**: 904–12.
- Rowley, A F, Vogan, C L, Taylor, G W & Clare, A S (2005) Prostaglandins in non-insectan invertebrates: recent insights and unsolved problems. *J Exp Biol* **208**: 3–14.
- Roy, S, Macleod, I & Moore, N (2006) The use of scent glands to improve the efficiency of mink (*Mustela vison*) captures in the Outer Hebrides. *N Z J Zool* **33**: 267–71.
- Russell, E M (1985) The metatherians: order Marsupialia. In Brown, R E & Macdonald, D W (eds.) *Social Odours in Mammals*. pp. 45–104. Oxford: Oxford University Press.
- Russo, C A, Takezaki, N & Nei, M (1995) Molecular phylogeny and divergence times of drosophilid species. *Mol Biol Evol* **12**: 391–404.
- Ruta, V, Datta, S R, Vasconcelos, M L *et al.* (2010) A dimorphic pheromone circuit in *Drosophila* from sensory input to descending output. *Nature* **468**: 686–90.
- Ruther, J & Steidle, J L M (2002) "Allohormones": a new class of bioactive substances or old wine in new skins? *J Comp Physiol A* **188**: 161–2.
- Ruxton, G D & Schaefer, H M (2011) Resolving current disagreements and ambiguities in the terminology of animal communication. *J Evol Biol* **24**: 2574–85.
- Ruxton, G D & Sherratt, T N (2006) Aggregation, defence and warning signals: the evolutionary relationship. *Proc R Soc B* **273**: 2417.
- Ryan, M J (1998) Sexual selection, receiver biases, and the evolution of sex differences. *Science* **281**: 1999–2003.
- Ryan, M J, Bernal, X E & Rand, A S (2010) Female mate choice and the potential for ornament evolution in túngara frogs *Physalaemus pustulosus*. *Curr Zool* **56**: 343–57.

- Sachs, B D (1999) Airborne aphrodisiac odor from estrous rats: implication for pheromonal classification. In Johnston, R E, Müller-Schwarze, D & Sorensen, P W (eds.) *Advances in Chemical Signals in Vertebrates*. pp. 333–42. New York: Kluwer Academic/Plenum Press.
- Sacks, O (1987) *The Man who Mistook his Wife for a Hat*. London: Duckworth.
- Sakai, R, Fukuzawa, M, Nakano, R, Tatsuki, S & Ishikawa, Y (2009) Alternative suppression of transcription from two desaturase genes is the key for species-specific sex pheromone biosynthesis in two *Ostrinia* moths. *Insect Biochem Mol Biol* 39: 62–7.
- Sakai, T, Nakagawa, Y, Takahashi, J, Iwabuchi, K & Ishii, K (1984) Isolation and identification of the male sex pheromone of the grape borer *Xylotrechus pyrrhoderus* Bates (Coleoptera: Cerambycidae). *Chem Lett* 1984: 263–4.
- Saleh, N, Scott, A, Bryning, G & Chittka, L (2007) Distinguishing signals and cues: bumblebees use general footprints to generate adaptive behaviour at flowers and nest. *Arthropod Plant Interact* 1: 119–27.
- Saltzman, W, Digby, L J & Abbott, D H (2009) Reproductive skew in female common marmosets: what can proximate mechanisms tell us about ultimate causes? *Proc R Soc B* 276: 389–99.
- Sanchez-Andrade, G & Kendrick, K M (2009) The main olfactory system and social learning in mammals: pheromonal communication in higher vertebrates and its implication for reproductive function. *Behav Brain Res* 200: 323–35.
- Sanchez-Gracia, A, Vieira, F G & Rozas, J (2009) Molecular evolution of the major chemosensory gene families in insects. *Heredity* 103: 208–16.
- Sandoz, J-C (2011) Behavioural and neurophysiological study of olfactory perception and learning in honeybees. *Front Syst Neurosci* 5: 98.
- Sandoz, J-C (2012) Olfaction in honey bees: from molecules to behavior honeybee neurobiology and behavior. In Galizia, C G, Eisenhardt, D & Giurfa, M (eds.) *Honeybee Neurobiology and Behavior*. pp. 235–52. Dordrecht: Springer.
- Sandoz, J-C, Deisig, N, de Brito Sanchez, M G & Giurfa, M (2007) Understanding the logics of pheromone processing in the honeybee brain: from labeled-lines to across-fiber patterns. *Front Behav Neurosci* 1: 5.
- Saraiva, J L, Gonçalves, D M & Oliveira, R F (2010) Environmental modulation of androgen levels and secondary sex characters in two populations of the peacock blenny *Salaria pavo*. *Horm Behav* 57: 192–7.
- Saul-Gershenz, L & Millar, J (2006) Phoretic nest parasites use sexual deception to obtain transport to their host's nest. *Proc Natl Acad Sci USA* 103: 14039.
- Savarit, F, Sureau, G, Cobb, M & Ferveur, J F (1999) Genetic elimination of known pheromones reveals the fundamental chemical bases of mating and isolation in *Drosophila*. *Proc Natl Acad Sci USA* 96: 9015–20.
- Savic, I, Berglund, H, Gulyas, B & Roland, P (2001) Smelling of odorous sex hormone-like compounds causes sex-differentiated hypothalamic activations in humans. *Neuron* 31: 661–8.
- Schaal, B (1988) Olfaction in infants and children – developmental and functional perspectives. *Chem Senses* 13: 145–90.
- Schaal, B (2009) Social chemosignal. In Binder, M D, Hirokawa, N & Windhorst, U (eds.) *Encyclopedia of Neuroscience*. pp. 3756–9. Berlin: Springer.
- Schaal, B (2012) Emerging chemosensory preferences. Another playground for the innate-acquired dichotomy in human cognition. In Zucco, G M, Schaal, B & Herz, R S (eds.) *Olfactory Cognition. From Perception and Memory to Environmental Odours and Neuroscience*. pp. 237–68. Amsterdam: John Benjamins.
- Schaal, B & Porter, R H (1991) Microsmatic humans revisited – the generation and perception of chemical signals. *Adv Study Behav* 20: 135–99.
- Schaal, B, Montagner, H, Hertling, E *et al.* (1980) Les stimulations olfactives dans les relations entre l'enfant et la mère. *Reprod Nutr Dev* 20: 843–58.
- Schaal, B, Coureaud, G, Langlois, D *et al.* (2003) Chemical and behavioural characterization of the rabbit mammary pheromone. *Nature* 424: 68–72.
- Schaal, B, Hummel, T & Soussignan, R (2004) Olfaction in the fetal and premature infant: functional status and clinical implications. *Clin Perinatol* 31: 261–85.
- Schaal, B, Doucet, S, Sagot, P, Hertling, E & Soussignan, R (2006) Human breast areolae as scent organs: morphological data and possible involvement in maternal–neonatal coadaptation. *Dev Psychobiol* 48: 100–10.

- Schaal, B, Coureaud, G, Doucet, S *et al.* (2009) Mammary olfactory signalisation in females and odor processing in neonates: ways evolved by rabbits and humans. *Behav Brain Res* 200: 346–58.
- Schaefer, A T & Claridge-Chang, A (2012) The surveillance state of behavioral automation. *Curr Opin Neurobiol* 22: 170–6.
- Schaefer, M L, Yamazaki, K, Osada, K, Restrepo, D & Beauchamp, G K (2002) Olfactory fingerprints for major histocompatibility complex-determined body odors II: relationship among odor maps, genetics, odor composition, and behavior. *J Neurosci* 22: 9513–21.
- Schank, J (2006) Do human menstrual-cycle pheromones exist? *Hum Nat* 17: 448–70.
- Schellinck, H M, Rooney, E & Brown, R E (1995) Odors of individuality of germ-free mice are not discriminated by rats in a habituation–dishabituation procedure. *Physiol Behav* 57: 1005–8.
- Schellinck, H M, Cyr, D P & Brown, R E (2010) How many ways can mouse behavioral experiments go wrong? Confounding variables in mouse models of neurodegenerative diseases and how to control them. *Adv Study Behav* 41: 255–366.
- Schiestl, F P, Ayasse, M, Paulus, H F *et al.* (1999) Orchid pollination by sexual swindle. *Nature* 399: 421–2.
- Schiestl, F P, Peakall, R, Mant, J G *et al.* (2003) The chemistry of sexual deception in an orchid–wasp pollination system. *Science* 302: 437–8.
- Schilling, B, Kaiser, R, Natsch, A & Gautschi, M (2010) Investigation of odors in the fragrance industry. *Chemoecology* 20: 135–47.
- Schlechter-Helas, J, Schmitt, T & Peschke, K (2011) A contact anti-aphrodisiac pheromone supplied by the spermatophore in the rove beetle *Aleochara curtula*: mode of transfer and evolutionary significance. *Naturwissenschaften* 98: 855–62.
- Schmidt, J O (1998) Mass action in honey bees: alarm, swarming and role of releaser pheromones. In Vander Meer, R K, Breed, M D, Espelie, K E & Winston, M L (eds.) *Pheromone Communication in Social Insects: Ants, Wasps, Bees, and Termites*. pp. 257–92. Boulder, CO: Westview Press.
- Schmidt, M & Mellon, D (2011) Neuronal processing of chemical information in crustaceans. In Breithaupt, T & Thiel, M (eds.) *Chemical Communication in Crustaceans*. pp. 123–47. New York: Springer.
- Schneider, D (1999) Insect pheromone research: some history and 45 years of personal recollections. *IOBC-WPRS Bull* 22. Available at <http://phero.net/iobc/dachau/bulletin99/schneider.pdf> [Accessed 21 January 2013].
- Schöne, H (1984) *Spatial Orientation: the Spatial Control of Behavior in Animals and Man*. Princeton: Princeton University Press.
- Schönrogge, K, Gardner, M G, Elmes, G *et al.* (2006) Host propagation permits extreme local adaptation in a social parasite of ants. *Ecol Lett* 9: 1032–40.
- Schoon, G A A (1997) Scent identifications by dogs (*Canis familiaris*): a new experimental design. *Behaviour* 134: 531–50.
- Schulte, B A (1998) Scent marking and responses to male castor fluid by beavers. *J Mammal* 79: 191–203.
- Schulz, S (2004) Semiochemistry of spiders. In Cardé, R & Millar, J G (eds.) *Advances in Insect Chemical Ecology*. pp. 110–50. Cambridge: Cambridge University Press.
- Schulz, S (2009) Alkaloid-derived male courtship pheromones. In Conner, W E (ed.) *Tiger Moths and Woolly Bears: Behavior, Ecology, and Evolution of the Arctiidae*. pp. 145–54. Oxford: Oxford University Press.
- Schulz, S, Estrada, C, Yildizhan, S, Boppré, M & Gilbert, L E (2008) An antiaphrodisiac in *Heliconius melpomene* butterflies. *J Chem Ecol* 34: 82–93.
- Schwander, T, Lo, N, Beekman, M, Oldroyd, B P & Keller, L (2010) Nature versus nurture in social insect caste differentiation. *Trends Ecol Evol* 25: 275–82.
- Schwarz, M P, Richards, M H & Danforth, B N (2007) Changing paradigms in insect social evolution: insights from halictine and allodapine bees. *Annu Rev Entomol* 52: 127–50.
- Schwende, F J, Wiesler, D, Jorgenson, J W, Carmack, M & Novotny, M (1986) Urinary volatile constituents of the house mouse, *Mus musculus*, and their endocrine dependency. *J Chem Ecol* 12: 277–96.
- Schwenk, K (1994) Why snakes have forked tongues. *Science* 263: 1573–7.
- Scordato, E S & Drea, C M (2007) Scents and sensibility: information content of olfactory signals in the ring-tailed lemur, *Lemur catta*. *Anim Behav* 73: 301–14.

- Searcy, W A & Nowicki, S (2005) *The Evolution of Animal Communication: Reliability and Deception in Signalling Systems*. Princeton: Princeton University Press.
- Seeley, T D (1979) Queen substance dispersal by messenger workers in honey bee colonies. *Behav Ecol Sociobiol* 5: 391–415.
- Seeley, T D (1985) *Honeybee Ecology: a Study of Adaptation in Social Life*. Princeton: Princeton University Press.
- Seeley, T D (1995) *The Wisdom of the Hive. The Social Physiology of Honey Bee Colonies*. Cambridge, MA: Harvard University Press.
- Seeley, T D (2002) When is self-organization used in biological systems? *Biol Bull* 202: 314–18.
- Seeley, T D (2010) *Honeybee Democracy*. Princeton: Princeton University Press.
- Seenivasagan, T & Vijayaraghavan, R (2010) Oviposition pheromones in haematophagous insects. In Gerald, L (ed.) *Pheromones*. pp. 597–630. London: Academic Press.
- Serguera, C, Triaca, V, Kelly-Barrett, J, Al Banchaabouchi, M & Minichiello, L (2008) Increased dopamine after mating impairs olfaction and prevents odor interference with pregnancy. *Nat Neurosci* 11: 949–56.
- Serrano, R, Barata, E, Birkett, M *et al.* (2008) Behavioral and olfactory responses of female *Salaria pavo* (Pisces: Blenniidae) to a putative multi-component male pheromone. *J Chem Ecol* 34: 647–58.
- Serrão, E A & Havenhand, J (2009) Fertilization strategies. In Whal, M (ed.) *Marine Hard Bottom Communities: Patterns, Dynamics, Diversity, and Change*. pp. 149–64. Dordrecht: Springer.
- Setchell, J M & Huchard, E (2010) The hidden benefits of sex: evidence for MHC-associated mate choice in primate societies. *Bioessays* 32: 940–8.
- Setchell, J M, Kendal, J & Tyniec, P (2011) Do non-human primates synchronise their menstrual cycles? A test in mandrills. *Psychoneuroendocrinology* 36: 51–9.
- Settle, R H, Sommerville, B A, McCormick, J & Broom, D M (1994) Human scent matching using specially trained dogs. *Anim Behav* 48: 1443–8.
- Seybold, S J, Huber, D, Lee, J, Graves, A & Bohlmann, J (2006) Pine monoterpenes and pine bark beetles: a marriage of convenience for defense and chemical communication. *Phytochem Rev* 5: 143–78.
- Shanbhag, S R, Müller, B & Steinbrecht, R A (1999) Atlas of olfactory organs of *Drosophila melanogaster*: 1. Types, external organization, innervation and distribution of olfactory sensilla. *Int J Insect Morphol Embryol* 28: 377–97.
- Sharma, K, Vander Meer, R K & Fadamiro, H Y (2011) Phorid fly, *Pseudacteon tricuspidis*, response to alkylpyrazine analogs of a fire ant, *Solenopsis invicta*, alarm pheromone. *J Insect Physiol* 57: 939–44.
- Sheehan, M J & Tibbetts, E A (2011) Specialized face learning is associated with individual recognition in paper wasps. *Science* 334: 1272–5.
- Shelley, W B, Hurley, H J & Nichols, A C (1953) Axillary odour: experimental study of the role of bacteria, apocrine sweat, and deodorants. *Arch Derm Syphilol* 68: 430–46.
- Shelly, T E & Kennelly, S S (2007) Settlement patterns of Mediterranean fruit flies in the tree canopy: an experimental analysis. *J Insect Behav* 20: 453–72.
- Shelly, T E, Edu, J & Pahio, E (2007) Condition-dependent mating success in male fruit flies: ingestion of a pheromone precursor compensates for a low-quality diet. *J Insect Behav* 20: 347–65.
- Shelly, T W & Whittier, T S (1997) Lek behavior of insects. In Choe, J C & Crespi, B J (eds.) *The Evolution of Mating Systems in Insects and Arachnids*. pp. 273–93. Cambridge: Cambridge University Press.
- Shepherd, G M (2004) The human sense of smell: are we better than we think? *PLoS Biol* 2: 572–5.
- Shepherd, G M (2005) Outline of a theory of olfactory processing and its relevance to humans. *Chem Senses* 30: I3–I5.
- Shepherd, G M (2006) Smell images and the flavour system in the human brain. *Nature* 444: 316–21.
- Shepherd, G M (2010) New perspectives on olfactory processing and human smell. In Menini, A (ed.) *The Neurobiology of Olfaction*. Boca Raton, FL: CRC Press. Available online at www.ncbi.nlm.nih.gov/books/NBK55977.
- Shepherd, G M (2012) *Neurogastronomy: How the Brain Creates Flavor and Why it Matters*. New York: Columbia University Press.
- Sherborne, A L, Thom, M D, Paterson, S *et al.* (2007) The basis of inbreeding avoidance in house mice. *Curr Biol* 17: 2061–6.

- Sherman, P W, Lacey, E A, Reeve, H K & Keller, L (1995) The eusociality continuum. *Behav Ecol* 6: 102–8.
- Sherman, P W, Reeve, H K & Pfennig, D W (1997) Recognition systems. In Krebs, J R & Davies, N B (eds.) *Behavioural Ecology: an Evolutionary Approach*, 4th edn., pp. 69–96. Oxford: Blackwell Science.
- Shine, R & Mason, R T (2012) An airborne sex pheromone in snakes. *Biol Lett* 8: 183–5.
- Shirangi, T R, Dufour, H D, Williams, T M & Carroll, S B (2009) Rapid evolution of sex pheromone-producing enzyme expression in *Drosophila*. *PLoS Biol* 7: e1000168.
- Shirasu, M & Touhara, K (2011) The scent of disease: volatile organic compounds of the human body related to disease and disorder. *J Biochem* 150: 257–66.
- Shuster, S M (2009) Sexual selection and mating systems. *Proc Natl Acad Sci USA* 106: 10009–16.
- Shuster, S M (2010) Alternative mating strategies. In Westneat, D F & Fox, C W (eds.) *Evolutionary Behavioral Ecology*. pp. 434–50. New York: Oxford University Press.
- Siefkes, M J, Scott, A P, Zielinski, B, Yun, S S & Li, W (2003) Male sea lampreys, *Petromyzon marinus* L., excrete a sex pheromone from gill epithelia. *Biol Reprod* 69: 125–32.
- Silbering, A F & Benton, R (2010) Ionotropic and metabotropic mechanisms in chemoreception: ‘chance or design’? *EMBO Rep* 11: 173–9.
- Silbering, A F, Rytz, R, Grosjean, Y *et al.* (2011) Complementary function and integrated wiring of the evolutionarily distinct *Drosophila* olfactory subsystems. *J Neurosci* 31: 13357–75.
- Siljander, E, Penman, D, Harlan, H & Gries, G (2007) Evidence for male- and juvenile-specific contact pheromones of the common bed bug *Cimex lectularius*. *Entomol Exp Appl* 125: 215–19.
- Siljander, E, Gries, R, Khaskin, G & Gries, G (2008) Identification of the airborne aggregation pheromone of the common bed bug, *Cimex lectularius*. *J Chem Ecol* 34: 708–18.
- Sillén-Tullberg, B & Møller, A P (1993) The relationship between concealed ovulation and mating systems in anthropoid primates – a phylogenetic analysis. *Am Nat* 141: 1–25.
- Sillero-Zubiri, C & Macdonald, D W (1998) Scent-marking and territorial behaviour of Ethiopian wolves *Canis simensis*. *J Zool* 245: 351–61.
- Silverstein, R M (1990) Practical use of pheromones and other behavior-modifying compounds: overview. In Ridgeway, R L, Silverstein, R M & Inscoe, M N (eds.) *Behavior-modifying Chemicals for Insect Management*. pp. 1–8. New York: Marcel Dekker.
- Simerly, R B (2002) Wired for reproduction: organization and development of sexually dimorphic circuits in the mammalian forebrain. *Annu Rev Neurosci* 25: 507–36.
- Simpson, S J, Sword, G A & Lo, N (2011) Polyphenism in insects. *Curr Biol* 21: R738–R749.
- Singer, A G, Beauchamp, G K & Yamazaki, K (1997) Volatile signals of the major histocompatibility complex in male mouse urine. *Proc Natl Acad Sci USA* 94: 2210–14.
- Singh, D & Bronstad, P M (2001) Female body odour is a potential cue to ovulation. *Proc R Soc B* 268: 797–801.
- Sirugue, D, Bonnard, O, LeQuere, J L, Farine, J P & Brossut, R (1992) 2-Methylthiazolidine and 4-ethylguaiacol, male sex-pheromone components of the cockroach *Nauphoeta cinerea* (Dictyoptera, Blaberidae) – a reinvestigation. *J Chem Ecol* 18: 2261–76.
- Slatyer, R A, Mautz, B S, Backwell, P R Y & Jennions, M D (2012) Estimating genetic benefits of polyandry from experimental studies: a meta-analysis. *Biol Rev* 87: 1–33.
- Slessor, K N, Winston, M L & Le Conte, Y (2005) Pheromone communication in the honeybee (*Apis mellifera* L.). *J Chem Ecol* 31: 2731–45.
- Sliwa, A & Richardson, P R K (1998) Responses of aardwolves, *Proteles cristatus*, Sparrman 1783, to translocated scent marks. *Anim Behav* 56: 137–46.
- Slonim, D K & Yanai, I (2009) Getting started in gene expression microarray analysis. *PLoS Comput Biol* 5: e1000543.
- Smadja, C & Butlin, R K (2009) On the scent of speciation: the chemosensory system and its role in premating isolation. *Heredity* 102: 77–97.
- Smadja, C & Ganem, G (2008) Divergence of odorant signals within and between the two European subspecies of the house mouse. *Behav Ecol* 19: 223–30.

- Smallegange, R C, Verhulst, N O & Takken, W (2011) Sweaty skin: an invitation to bite? *Trends Parasitol* 27: 143–8.
- Smith, A A, Hölldobler, B & Liebig, J (2012) Queen-specific signals and worker punishment in the ant *Aphaenogaster cockerelli*: the role of the Dufour's gland. *Anim Behav* 83: 587–93.
- Smith, B H & Breed, M D (1995) The chemical basis for nest-mate recognition and mate discrimination in social insects. In Cardé, R T & Bell, W J (eds.) *Chemical Ecology of Insects* 2. pp. 287–317. London: Chapman and Hall.
- Smith, C R, Tóth, A L, Suarez, A V & Robinson, G E (2008) Genetic and genomic analyses of the division of labour in insect societies. *Nat Rev Genet* 9: 735–48.
- Smith, J L, Cork, A, Hall, D R & Hodges, R J (1996) Investigation of the effect of female larger grain borer, *Prostephanus truncatus* (Horn) (Coleoptera: Bostrichidae), and their residues on the production of aggregation pheromone by males. *J Stored Prod Res* 32: 171–81.
- Snell, T W (2011a) A review of the molecular mechanisms of monogonont rotifer reproduction. *Hydrobiologia* 662: 89–97.
- Snell, T W (2011b) Contact chemoreception and its role in zooplankton mate recognition. In Breithaupt, T & Thiel, M (eds.) *Chemical Communication in Crustaceans*. pp. 451–66. New York: Springer.
- Šobotník, J, Jirosová, A & Hanus, R (2010) Chemical warfare in termites. *J Insect Physiol* 56: 1012–21.
- Šobotník, J, Bourguignon, T, Hanus, R *et al.* (2012) Explosive backpacks in old termite workers. *Science* 337: 436.
- Soini, H A, Bruce, K E, Wiesler, D *et al.* (2005) Stir bar sorptive extraction: a new quantitative and comprehensive sampling technique for determination of chemical signal profiles from biological media. *J Chem Ecol* 31: 377–92.
- Solomon, N G & Getz, L L (1997) Examination of alternative hypotheses for cooperative breeding in rodents. In Solomon, N G & French, J A (eds.) *Cooperative Breeding in Mammals*. pp. 199–230. Cambridge: Cambridge University Press.
- Solomon, N G & Keane, B (2007) Reproductive strategies in female rodents. In Wolff, J O & Shermann, P W (eds.) *Rodent Societies: an Ecological and Evolutionary Perspective*. pp. 42–56. Chicago: Chicago University Press.
- Sonenshine, D E (2004) Pheromones and other semiochemicals of ticks and their use in tick control. *Parasitology* 129: S405–S425.
- Sonenshine, D E (2006) Tick pheromones and their use in tick control. *Annu Rev Entomol* 51: 557–80.
- Soo, M L M & Stevenson, R J (2007) The moralisation of body odor. *Mankind Q* 47: 25–56.
- Sorensen, P W & Hoyer, T R (2007) A critical review of the discovery and application of a migratory pheromone in an invasive fish, the sea lamprey *Petromyzon marinus* L. *J Fish Biol* 71: 100–14.
- Sorensen, P W & Wisenden, B D (eds) (2014) *Fish Pheromones and Related Conspecific Chemical Cues*. Chichester: Wiley Blackwell.
- Sorensen, P W, Christensen, T A & Stacey, N E (1998) Discrimination of pheromonal cues in fish: emerging parallels with insects. *Curr Opin Neurobiol* 8: 458–67.
- Sorensen, P W, Pinillos, M & Scott, A P (2005) Sexually mature male goldfish release large quantities of androstenedione into the water where it functions as a pheromone. *Gen Comp Endocrinol* 140: 164–75.
- Soucy, E R, Albeanu, D F, Fantana, A L, Murthy, V N & Meister, M (2009) Precision and diversity in an odor map on the olfactory bulb. *Nat Neurosci* 12: 210–20.
- Soussignan, R, Schaal, B, Marlier, L & Jiang, T (1997) Facial and autonomic responses to biological and artificial olfactory stimuli in human neonates: re-examining early hedonic discrimination of odors. *Physiol Behav* 62: 745–58.
- South, A & Lewis, S M (2011) The influence of male ejaculate quantity on female fitness: a meta-analysis. *Biol Rev* 86: 299–309.
- South, S H, House, C M, Moore, A J, Simpson, S J & Hunt, J (2011) Male cockroaches prefer a high carbohydrate diet that makes them more attractive to females: implications for the study of condition dependence. *Evolution* 65: 1594–606.
- Spannhoff, A, Kim, Y K, Noel, J *et al.* (2011) Histone deacetylase inhibitor activity in royal jelly might facilitate caste switching in bees. *EMBO Rep* 12: 238–43.

- Spehr, M & Munger, S D (2009) Olfactory receptors: G protein-coupled receptors and beyond. *J Neurochem* 109: 1570–83.
- Spehr, M, Spehr, J, Ukhanov, K *et al.* (2006a) Parallel processing of social signals by the mammalian main and accessory olfactory systems. *Cell Mol Life Sci* 63: 1476–84.
- Spehr, M, Kelliher, K R, Li, X H *et al.* (2006b) Essential role of the main olfactory system in social recognition of major histocompatibility complex peptide ligands. *J Neurosci* 26: 1961–70.
- Sreng, L (1990) Seducin, male sex-pheromone of the cockroach *Nauphoeta cinerea* – isolation, identification, and bioassay. *J Chem Ecol* 16: 2899–912.
- Srinivasan, J, Kaplan, F, Ajredini, R *et al.* (2008) A blend of small molecules regulates both mating and development in *Caenorhabditis elegans*. *Nature* 454: 1115–18.
- Srinivasan, J, von Reuss, S H, Bose, N *et al.* (2012) A modular library of small molecule signals regulates social behaviors in *Caenorhabditis elegans*. *PLoS Biol* 10: e1001237.
- Stacey, N E & Sorensen, P W (2006) Reproductive pheromones. In Sloman, KA, Wilson, RW & Balshine, S (eds.) *Fish Physiology, Volume 24: Behaviour and Physiology of Fish*. pp. 359–412. Amsterdam: Academic Press, Elsevier.
- Stacey, N E & Sorensen, P W (2009) Fish hormonal pheromones. In Pfaff, D W, Arnold, A P, Fahrbach, S E, Etgen, A M & Rubin, R T (eds.) *Hormones, Brain and Behavior*, 2nd edn., pp. 639–81. San Diego, CA: Academic Press.
- Stacey, N E & Sorensen, P W (2011) Hormonal pheromones. In Farrell, A P (ed.) *Encyclopedia of Fish Physiology: From Genome to Environment*. pp. 1553–62. San Diego, CA: Academic Press.
- Stadler, B & Dixon, A F G (2005) Ecology and evolution of aphid-ant interactions. *Annu Rev Ecol Evol Syst* 36: 345–72.
- Stamps, J (1994) Territorial behavior – testing the assumptions. *Adv Study Behav* 23: 173–232.
- Stapley, J, Reger, J, Feulner, P G D *et al.* (2010) Adaptation genomics: the next generation. *Trends Ecol Evol* 25: 705–12.
- Steel, E & Keverne, E B (1985) Effect of female odor on male hamsters mediated by the vomeronasal organ. *Physiol Behav* 35: 195–200.
- Steiger, S, Franz, R, Eggert, A K & Muller, J K (2008a) The Coolidge effect, individual recognition and selection for distinctive cuticular signatures in a burying beetle. *Proc R Soc B* 275: 1831–8.
- Steiger, S, Schmitt, T & Schaefer, H M (2011) The origin and dynamic evolution of chemical information transfer. *Proc R Soc B* 278: 970–9.
- Steiger, S S, Fidler, A E, Valcu, M & Kempenaers, B (2008b) Avian olfactory receptor gene repertoires: evidence for a well-developed sense of smell in birds? *Proc R Soc B* 275: 2309–17.
- Stein, B E & Meredith, M A (1993) *The Merging of the Senses*. Cambridge, MA: MIT Press.
- Stern, D L & Foster, W A (1996) The evolution of soldiers in aphids. *Biol Rev* 71: 27–79.
- Stern, K & McClintock, M K (1998) Regulation of ovulation by human pheromones. *Nature* 392: 177–9.
- Stevenson, R J (2010) An initial evaluation of the functions of human olfaction. *Chem Senses* 35: 3–20.
- Stoddard, P K & Salazar, V L (2011) Energetic cost of communication. *J Exp Biol* 214: 200–5.
- Stoddart, D M (1990) *The Scented Ape. The Biology and Culture of Human Odour*. Cambridge: Cambridge University Press.
- Stoeffler, M, Tolasch, T & Steidle, J L M (2011) Three beetles – three concepts. Different defensive strategies of congeneric myrmecophilous beetles. *Behav Ecol Sociobiol* 65: 1605–13.
- Stöckl, J, Brodmann, J, Dafni, A, Ayasse, M & Hansson, B S (2011) Smells like aphids: orchid flowers mimic aphid alarm pheromones to attract hoverflies for pollination. *Proc R Soc B* 278: 1216–22.
- Storer, A J, Wainhouse, D & Speight, M R (1997) The effect of larval aggregation behaviour on larval growth of the spruce bark beetle *Dendroctonus micans*. *Ecol Entomol* 22: 109–15.
- Störtkuhl, K F & Fiala, A (2011) The smell of blue light: a new approach towards understanding an olfactory neuronal network. *Front Neurosci* 5: 72.
- Stowers, L, Holy, T E, Meister, M, Dulac, C & Koentges, G (2002) Loss of sex discrimination and male-male aggression in mice deficient for TRP2. *Science* 295: 1493–500.
- Strausfeld, N J (2009) Brain organization and the origin of insects: an assessment. *Proc R Soc B* 276: 1929–37.

- Strausfeld, N J & Hildebrand, J G (1999) Olfactory systems: common design, uncommon origins? *Curr Opin Neurobiol* 9: 634–9.
- Stuart, A M (1969) Social behavior and communication. In Krishna, K (ed.) *The Biology of Termites*. pp. 193–232. New York: Academic Press.
- Sturgis, S J & Gordon, D M (2012) Nestmate recognition in ants (Hymenoptera: Formicidae): a review. *Myrmecol News* 16: 101–10.
- Su, C Y, Menuz, K & Carlson, J R (2009) Olfactory perception: receptors, cells, and circuits. *Cell* 139: 45–59.
- Su, C Y, Martelli, C, Emonet, T & Carlson, J R (2011) Temporal coding of odor mixtures in an olfactory receptor neuron. *Proc Natl Acad Sci USA* 108: 5075–80.
- Suckling, D M, Peck, R W, Stringer, L D, Snook, K & Banko, P C (2010) Trail pheromone disruption of Argentine ant trail formation and foraging. *J Chem Ecol* 36: 122–8.
- Suckling, D M, Woods, B, Mitchell, V J *et al.* (2011) Mobile mating disruption of light-brown apple moths using pheromone-treated sterile Mediterranean fruit flies. *Pest Manag Sci* 67: 1004–14.
- Suckling, D M, Tobin, P C, McCullough, D G & Herms, D A (2012a) Combining tactics to exploit Allee effects for eradication of alien insect populations. *J Econ Entomol* 105: 1–13.
- Suckling, D M, Stringer, L D, Corn, J E *et al.* (2012b) Aerosol delivery of trail pheromone disrupts the foraging of the red imported fire ant, *Solenopsis invicta*. *Pest Manag Sci* 68: 1572–8.
- Sugahara, M & Sakamoto, F (2009) Heat and carbon dioxide generated by honeybees jointly act to kill hornets. *Naturwissenschaften* 96: 1133–6.
- Sullivan, T P & Crump, D (1984) Influence of mustelid scent gland compounds on suppression of feeding by snowshoe hares (*Lepus americanus*). *J Chem Ecol* 10: 903–19.
- Sumpter, D J T (2006) The principles of collective animal behaviour. *Phil Trans R Soc B* 361: 5–22.
- Sumpter, D J T (2010) *Collective Animal Behavior*. Princeton: Princeton University Press.
- Sumpter, D J T, Mann, R P & Perna, A (2012) The modelling cycle for collective animal behaviour. *Interface Focus* 2: 764–73.
- Sun, L X & Müller-Schwarze, D (1997) Sibling recognition in the beaver: a field test for phenotype matching. *Anim Behav* 54: 493–502.
- Sun, L X & Müller-Schwarze, D (1998) Beaver response to recurrent alien scents: scent fence or scent match? *Anim Behav* 55: 1529–36.
- Sun, L X & Müller-Schwarze, D (1999) Chemical signals in the beaver: one species, two secretions, many functions? In Johnston, R E, Müller-Schwarze, D & Sorensen, P W (eds.) *Advances in Chemical Signals in Vertebrates*. pp. 281–8. New York: Kluwer Academic/Plenum Press.
- Sunamura, E, Suzuki, S, Nishisue, K *et al.* (2011) Combined use of a synthetic trail pheromone and insecticidal bait provides effective control of an invasive ant. *Pest Manag Sci* 67: 1230–6.
- Sundberg, H, Døving, K, Novikov, S & Ursin, H (1982) A method for studying responses and habituation to odors in rats. *Behav Neural Biol* 34: 113–19.
- Süskind, P (1986) *Perfume. The Story of a Murderer*. London: Hamish Hamilton. Translated by J E Woods.
- Swaigood, R & Schulte, B (2010) Applying knowledge of mammalian social organization, mating systems, and communication to management. In Kleiman, D, Thompson, K & Baer, C (eds.) *Wild Mammals in Captivity: Principles and Techniques for Zoo Management*, 2nd edn., pp. 329–43. Chicago: University of Chicago Press.
- Swaney, W T & Keverne, E B (2011) Genomic imprinting and sexual experience-dependent learning in the mouse. In Clelland, J D (ed.) *Genomics, Proteomics, and the Nervous System*. pp. 195–225. New York: Springer.
- Swaney, W T, Curley, J P, Champagne, F A & Keverne, E B (2007) Genomic imprinting mediates sexual experience-dependent olfactory learning in male mice. *Proc Natl Acad Sci USA* 104: 6084–9.
- Swann, J, Fabre-Nys, C & Barton, R (2009) Hormonal and pheromonal modulation of the extended amygdala: implications for social behavior. In Pfaff, D W, Arnold, A P, Fahrbach, S E, Etgen, A M & Rubin, R T (eds.) *Hormones, Brain and Behavior*. pp. 441–72. San Diego: Academic Press.
- Symonds, M R E & Elgar, M A (2008) The evolution of pheromone diversity. *Trends Ecol Evol* 23: 220–8.

- Symonds, M R E, Johnson, T L & Elgar, M A (2012) Pheromone production, male abundance, body size, and the evolution of elaborate antennae in moths. *Ecol Evol* 2: 227–46.
- Számadó, S (1999) The validity of the handicap principle in discrete action–response games. *J Theor Biol* 198: 593–602.
- Számadó, S (2003) Threat displays are not handicaps. *J Theor Biol* 221: 327–48.
- Számadó, S (2008) How threat displays work: species-specific fighting techniques, weaponry and proximity risk. *Anim Behav* 76: 1455–63.
- Számadó, S (2011a) The rise and fall of handicap principle: a commentary on the “Modelling and the fall and rise of the handicap principle”. *Biol Philos* 27: 279–86.
- Számadó, S (2011b) The cost of honesty and the fallacy of the handicap principle. *Anim Behav* 81: 3–10.
- Székely, T, Moore, A & Komdeur, J (eds.) (2010) *Social Behaviour: Genes, Ecology and Evolution*. Cambridge: Cambridge University Press.
- Taborsky, M, Oliveira, R F & Brockmann, H J (2008) The evolution of alternative reproductive tactics: concepts and questions. In Oliveira, R F, Taborsky, M & Brockmann, H J (eds.) *Alternative Reproductive Tactics: an Integrative Approach* pp. 1–22. Cambridge: Cambridge University Press.
- Tallamy, D W (2005) Egg dumping in insects. *Annu Rev Entomol* 50: 347–70.
- Tallamy, D W & Denno, R F (1982) Maternal care in *Gargaphia solani* (Hemiptera: Tingidae). *Anim Behav* 29: 771–8.
- Tarver, M R, Zhou, X G & Scharf, M E (2010) Socio-environmental and endocrine influences on developmental and caste-regulatory gene expression in the eusocial termite *Reticulitermes flavipes*. *BMC Mol Biol* 11: 28.
- Teal, P E A, Gomez-Simuta, Y & Proveaux, A T (2000) Mating experience and juvenile hormone enhance sexual signaling and mating in male caribbean fruit flies. *Proc Natl Acad Sci USA* 97: 3708–12.
- Temeles, E J (1994) The role of neighbours in territorial systems: when are they ‘dear enemies?’. *Anim Behav* 47: 339–50.
- ten Cate, C, Verzijden, M N & Etman, E (2006) Sexual imprinting can induce sexual preferences for exaggerated parental traits. *Curr Biol* 16: 1128–32.
- Theis, K R, Schmidt, T M & Holekamp, K E (2012) Evidence for a bacterial mechanism for group-specific social odors among hyenas. *Sci Rep* 2.
- Theisen, B, Zeiske, E, Silver, W L, Marui, T & Caprio, J (1991) Morphological and physiological studies on the olfactory organ of the striped eel catfish, *Plotosus lineatus*. *Mar Biol* 110: 127–35.
- Thesen, A, Steen, J B & Døving, K B (1993) Behavior of dogs during olfactory tracking. *J Exp Biol* 180: 247–51.
- Thewissen, J, George, J, Rosa, C & Kishida, T (2011) Olfaction and brain size in the bowhead whale (*Balaena mysticetus*). *Mar Mamm Sci* 27: 282–94.
- Thistle, R, Cameron, P, Ghorayshi, A, Dennison, L & Scott, K (2012) Contact chemoreceptors mediate male–male repulsion and male–female attraction during *Drosophila* courtship. *Cell* 149: 1140–51.
- Thom, C, Gilley, D C, Hooper, J & Esch, H E (2007) The scent of the waggle dance. *PLoS Biol* 5: e228.
- Thom, M D & Hurst, J L (2004) Individual recognition by scent. *Ann Zool Fenn* 41: 765–87.
- Thom, M D, Stockley, P, Jury, F *et al.* (2008) The direct assessment of genetic heterozygosity through scent in the mouse. *Curr Biol* 18: 619–23.
- Thomas, J A, Knapp, J J, Akino, T *et al.* (2002) Insect communication: parasitoid secretions provoke ant warfare. *Nature* 417: 505–6.
- Thomas, J A, Schönrogge, K & Elmes, G W (2005) Specializations and host associations of social parasites of ants. In Fellowes, M D E, Holloway, G J & Rolff, J (eds.) *Insect Evolutionary Ecology*. pp. 479–518. Wallingford: CABI.
- Thomas, J H (1993) Chemosensory regulation of development in *C. elegans*. *Bioessays* 15: 791–7.
- Thomas, M L (2011) Detection of female mating status using chemical signals and cues. *Biol Rev* 86: 1–13.
- Thomas, M L & Simmons, L W (2009) Male-derived cuticular hydrocarbons signal sperm competition intensity and affect ejaculate expenditure in crickets. *Proc R Soc B* 276: 383–8.
- Thomas, M L & Simmons, L W (2011) Crickets detect the genetic similarity of mating partners via cuticular hydrocarbons. *J Evol Biol* 24: 1793–800.
- Thompson, G J, Kucharski, R, Maleszka, R & Oldroyd, B P (2006) Towards a molecular definition of worker sterility: differential gene expression and reproductive plasticity in honey bees. *Insect Mol Biol* 15: 537–644.

- Thompson, J N (2009) The coevolving web of life. *Am Nat* 173: 125–40.
- Thornhill, R (1979) Male pair formation pheromones in *Panorpa* scorpionflies (Mecoptera: Panorpidae). *Environ Entomol* 8: 886–9.
- Thornhill, R & Alcock, J (1983) *The Evolution of Insect Mating Systems*. Cambridge, MA: Harvard University Press.
- Thoss, M, Ilmonen, P, Musolf, K & Penn, D J (2011) Major histocompatibility complex heterozygosity enhances reproductive success. *Mol Ecol* 20: 1546–57.
- Thysen, B, Elliott, W H & Katzman, P A (1968) Identification of estra-1, 3, 5 (10), 16-tetraen-3-ol (estratetraenol) from the urine of pregnant women. *Steroids* 11: 73–87.
- Tibbetts, E A (2004) Complex social behaviour can select for variability in visual features: a case study in *Polistes* wasps. *Proc R Soc B* 271: 1955–60.
- Tibbetts, E A & Dale, J (2007) Individual recognition: it is good to be different. *Trends Ecol Evol* 22: 529–37.
- Tinbergen, N (1952) “Derived” activities; their causation, biological significance, origin, and emancipation during evolution. *Q Rev Biol* 27: 1–32.
- Tirindelli, R, Dibattista, M, Pifferi, S & Menini, A (2009) From pheromones to behavior. *Physiol Rev* 89: 921–56.
- Toda, H, Zhao, X & Dickson, B J (2012) The *Drosophila* female aphrodisiac pheromone activates ppk23+ sensory neurons to elicit male courtship behavior. *Cell Reports* 1: 599–607.
- Todrank, J, Heth, G & Restrepo, D (2011) Effects of in utero odorant exposure on neuroanatomical development of the olfactory bulb and odour preferences. *Proc R Soc B* 278: 1949–55.
- Tompkins, L, McRobert, S P & Kaneshiro, K Y (1993) Chemical communication in Hawaiian *Drosophila*. *Evolution* 47: 1407–19.
- Toonen, R & Pawlik, J (2001) Foundations of gregariousness: a dispersal polymorphism among the planktonic larvae of a marine invertebrate. *Evolution* 55: 2439–54.
- Tóth, A L & Robinson, G E (2007) Evo-devo and the evolution of social behavior. *Trends Genet* 23: 334–41.
- Touhara, K (ed.) (2013) *Pheromone Signaling: Methods and Protocols*. New York, NY: Humana Press (Springer).
- Touhara, K & Vosshall, L B (2009) Sensing odorants and pheromones with chemosensory receptors. *Annu Rev Physiol* 71: 307–32.
- Toyoda, F, Yamamoto, K, Iwata, T *et al.* (2004) Peptide pheromones in newts. *Peptides* 25: 1531–6.
- Trabalon, M & Bagnères, A-G (2010) Contact recognition pheromones in spiders and scorpions. In Blomquist, G J & Bagnères, A-G (eds.) *Insect Hydrocarbons: Biology, Biochemistry, and Chemical Ecology*. pp. 344–74. Cambridge: Cambridge University Press.
- Traniello, J F A & Robson, S K (1995) Trail and territorial communication in insects. In Cardé, R T & Bell, W J (eds.) *Chemical Ecology of Insects* 2. pp. 241–86. London: Chapman and Hall.
- Trematerra, P (2012) Advances in the use of pheromones for stored-product protection. *J Pest Sci* 85: 285–99.
- Troccaz, M, Borchard, G, Vuilleumier, C *et al.* (2009) Gender-specific differences between the concentrations of nonvolatile (R)/(S)-3-methyl-3-sulfanylhexasan-1-ol and (R)/(S)-3-hydroxy-3-methyl-hexanoic acid odor precursors in axillary secretions. *Chem Senses* 34: 203–10.
- Trumble, J T (1997) Integrating pheromones into vegetable crop production. In Cardé, R T & Minks, A K (eds.) *Pheromone Research: New Directions*. pp. 397–410. New York: Chapman and Hall.
- Tsutsui, N D (2004) Scents of self: the expression component of self/non-self recognition systems. *Ann Zool Fenn* 41: 713–27.
- Tumlinson, J H, Silverstein, R M, Moser, J C, Brownlee, R G & Ruth, J M (1971) Identification of the trail pheromone of a leaf-cutting ant, *Atta texana*. *Nature* 234: 348–9.
- Ungerfeld, R (2007) Socio-sexual signalling and gonadal function: opportunities for reproductive management in domestic ruminants. *Soc Reprod Fertil Suppl* 64: 207–21.
- Vahed, K (2007) All that glitters is not gold: sensory bias, sexual conflict and nuptial feeding in insects and spiders. *Ethology* 113: 105–27.
- van der Pers, J N C & Minks, A K (1997) Measuring pheromone dispersion in the field with the single sensillum recording technique. In Cardé, R T & Minks, A K (eds.) *Pheromone Research: New Directions*. pp. 359–71. New York: Chapman and Hall.

- van Djiken, M J, van Stratum, P & van Alphen, J J M (1992) Recognition of individual-specific marked parasitized hosts by the solitary parasitoid *Epidinocarsis lopezi*. *Behav Ecol Sociobiol* 30: 77–82.
- Van Dongen, S (2011) Associations between asymmetry and human attractiveness: possible direct effects of asymmetry and signatures of publication bias. *Ann Hum Biol* 38: 317–23.
- van Lenteren, J C (ed.) (2012) *IOBC Internet Book of Biological Control*, 6th edn. Wageningen, the Netherlands: Available from: www.iobc-global.org/publications_iobc_internet_book_of_biological_control.html.
- van Wilgenburg, E, Symonds, M R E & Elgar, M A (2011) Evolution of cuticular hydrocarbon diversity in ants. *J Evol Biol* 24: 1188–98.
- van Wilgenburg, E, Felden, A, Choe, D H *et al.* (2012) Learning and discrimination of cuticular hydrocarbons in a social insect. *Biol Lett* 8: 17–20.
- van Zweden, J S & d'Ettorre, P (2010) Nestmate recognition in social insects and the role of hydrocarbons. In Blomquist, G J & Bagnères, A-G (eds.) *Insect Hydrocarbons: Biology, Biochemistry, and Chemical Ecology*. pp. 222–43. Cambridge: Cambridge University Press.
- van Zweden, J S, Brask, J B, Christensen, J H *et al.* (2010) Blending of heritable recognition cues among ant nestmates creates distinct colony gestalt odours but prevents within-colony nepotism. *J Evol Biol* 23: 1498–508.
- van Zweden, J S, Gruter, C, Jones, S M & Ratnieks, F L (2011) Hovering guards of the stingless bee *Tetragonisca angustula* increase colony defensive perimeter as shown by intra- and inter-specific comparisons. *Behav Ecol Sociobiol* 65: 1277–82.
- Vander Meer, R K & Alonso, L E (1998) Pheromone directed behavior in ants. In Vander Meer, R K, Breed, M D, Espelie, K E & Winston, M L (eds.) *Pheromone Communication in Social Insects: Ants, Wasps, Bees, and Termites*. pp. 159–92. Boulder, CO: Westview Press.
- Vander Meer, R K & Morel, L (1998) Nestmate recognition in ants. In Vander Meer, R K, Breed, M D, Espelie, K E & Winston, M L (eds.) *Pheromone Communication in Social Insects: Ants, Wasps, Bees, and Termites*. pp. 79–103. Boulder, CO: Westview Press.
- Vargo, E L (1992) Mutual pheromonal inhibition among queens in polygyne colonies of the fire ant *Solenopsis invicta*. *Behav Ecol Sociobiol* 31: 205–10.
- Vargo, E L (1998) Primer pheromones in ants. In Vander Meer, R K, Breed, M D, Espelie, K E & Winston, M L (eds.) *Pheromone Communication in Social Insects: Ants, Wasps, Bees, and Termites*. pp. 293–313. Boulder, CO: Westview Press.
- Vargo, E L & Husseneder, C (2009) Biology of subterranean termites: insights from molecular studies of Reticulitermes and Coptotermes. *Annu Rev Entomol* 54: 379–403.
- Vaziri, A & Emiliani, V (2012) Reshaping the optical dimension in optogenetics. *Curr Opin Neurobiol* 22: 128–37.
- Venkataraman, A B, Swarnalatha, V B, Nair, P & Gadagkar, R (1988) The mechanism of nestmate discrimination in the tropical social wasp *Ropalidia marginata* and its implications for the evolution of sociality. *Behav Ecol Sociobiol* 23: 271–9.
- Vereecken, N J & McNeil, J N (2010) Cheaters and liars: chemical mimicry at its finest. *Can J Zool* 88: 725–52.
- Vereecken, N J & Schiestl, F P (2008) The evolution of imperfect floral mimicry. *Proc Natl Acad Sci USA* 105: 7484–8.
- Vergoz, V, McQuillan, H J, Geddes, L H *et al.* (2009) Peripheral modulation of worker bee responses to queen mandibular pheromone. *Proc Natl Acad Sci USA* 106: 20930–5.
- Verzijden, M N & Rosenthal, G G (2011) Effects of sensory modality on learned mate preferences in female swordtails. *Anim Behav* 82: 557–62.
- Verzijden, M N, ten Cate, C, Servedio, M R *et al.* (2012) The impact of learning on sexual selection and speciation. *Trends Ecol Evol* 27: 511–19.
- Via, S (2009) Natural selection in action during speciation. *Proc Natl Acad Sci USA* 106: 9939–46.
- Vickers, N J (2000) Mechanisms of animal navigation in odor plumes. *Biol Bull* 198: 203–12.
- Vickers, N J (2006) Winging it: moth flight behavior and responses of olfactory neurons are shaped by pheromone plume dynamics. *Chem Senses* 31: 155–66.
- Vickers, N J & Baker, T C (1991) The effects of unilateral antennectomy on the flight behavior of male

- Heliothis virescens* in a pheromone plume. *Physiol Entomol* 16: 497–506.
- Vickers, N J, Christensen, T A & Hildebrand, J G (1998) Integrating behavior with neurobiology: odor-mediated moth flight and olfactory discrimination by glomerular arrays. *Integr Biol* 1: 224–30.
- Viitala, J, Korpimäki, E, Palokangas, P & Koivula, M (1995) Attraction of kestrels to vole scent marks visible in ultraviolet-light. *Nature* 373: 425–7.
- Vogel, S (1983) How much air flows through a silkworm's antenna? *J Insect Physiol* 29: 597–602.
- Vogel, S (1994) *Life in Moving Fluids: the Physical Biology of Flow*, 2nd edn. (1996 paperback printing) Princeton: Princeton University Press.
- Voigt, C C, Caspers, B & Speck, S (2005) Bats, bacteria, and bat smell: sex-specific diversity of microbes in a sexually selected scent organ. *J Mammal* 86: 745–9.
- Vosshall, L B & Hansson, B S (2011) A unified nomenclature system for the insect olfactory coreceptor. *Chem Senses* 36: 497–8.
- Vosshall, L B & Stocker, R E (2007) Molecular architecture of smell and taste in *Drosophila*. *Annu Rev Neurosci* 30: 505–33.
- Vosshall, L B, Amrein, H, Morozov, P S, Rzhetsky, A & Axel, R (1999) A spatial map of olfactory receptor expression in the *Drosophila* antenna. *Cell* 96: 725–36.
- Vrieze, L A, Bergstedt, R A & Sorensen, P W (2011) Olfactory-mediated stream-finding behavior of migratory adult sea lamprey (*Petromyzon marinus*). *Can J Fish Aquat Sci* 68: 523–33.
- Vyas, A (2013) Parasite-augmented mate choice and reduction in innate fear in rats infected by *Toxoplasma gondii*. *J Exp Biol* 216: 120–6.
- Wabnitz, P A, Bowie, J H, Tyler, M J, Wallace, J C & Smith, B P (1999) Aquatic sex pheromone from a male tree frog. *Nature* 401: 444–5.
- Wachowiak, M (2010) Active sensing in olfaction. In Menini, A, (ed.) *The Neurobiology of Olfaction*. Boca Raton, FL: CRC Press. Available online at www.ncbi.nlm.nih.gov/books/NBK55978.
- Wagner, C M, Jones, M L, Twohey, M B & Sorensen, P W (2006) A field test verifies that pheromones can be useful for sea lamprey (*Petromyzon marinus*) control in the Great Lakes. *Can J Fish Aquat Sci* 63: 475–9.
- Waldman, B, Frumhoff, P C & Sherman, P W (1988) Problems of kin recognition. *Trends Ecol Evol* 3: 8–13.
- Walker, D B, Walker, J C, Cavnar, P J *et al.* (2006) Naturalistic quantification of canine olfactory sensitivity. *Appl Anim Behav Sci* 97: 241–54.
- Walker, J C, Hall, S B, Walker, D B *et al.* (2003) Human odor detectability: new methodology used to determine threshold and variation. *Chem Senses* 28: 817–26.
- Wang, J, Ross, K & Keller, L (2008a) Genome-wide expression patterns and the genetic architecture of a fundamental social trait. *PLoS Genet* 4: e1000127.
- Wang, L M, Han, X Q, Mehren, J *et al.* (2011) Hierarchical chemosensory regulation of male-male social interactions in *Drosophila*. *Nat Neurosci* 14: 757–62.
- Wang, S P, Sato, K, Giurfa, M & Zhang, S W (2008b) Processing of sting pheromone and its components in the antennal lobe of the worker honeybee. *J Insect Physiol* 54: 833–41.
- Wang, Y, Kocher, S D, Linksvayer, T A *et al.* (2012) Regulation of behaviorally associated gene networks in worker honey bee ovaries. *J Exp Biol* 215: 124–34.
- Wanner, K W, Nichols, A S, Walden, K K O *et al.* (2007) A honey bee odorant receptor for the queen substance 9-oxo-2-decanoic acid. *Proc Natl Acad Sci USA* 104: 14383.
- Watelet, J B, Strolin-Benedetti, M & Whomsley, R (2009) Defence mechanisms of olfactory neuro-epithelium: mucosa regeneration, metabolising enzymes and transporters. *B-Ent* 5: Suppl. 13, 21–37.
- Watson, P J (1986) Transmission of a female sex pheromone thwarted by males in the spider *Linyphia litigiosa* Keyserling (Linyphiidae). *Science* 233: 219–21.
- Webb, B, Harrison, R R & Willis, M A (2004) Sensorimotor control of navigation in arthropod and artificial systems. *Arthropod Struct Dev* 33: 301–29.
- Webster, D R & Weissburg, M J (2001) Chemosensory guidance cues in a turbulent chemical odor plume. *Limnol Oceanogr* 46: 1034–47.
- Webster, D R & Weissburg, M J (2009) The hydrodynamics of chemical cues among aquatic organisms. *Annu Rev Fluid Mech* 41: 73–90.
- Wedekind, C & Furi, S (1997) Body odour preferences in men and women: do they aim for specific MHC

- combinations or simply heterozygosity? *Proc R Soc B* 264: 1471–9.
- Wedekind, C, Seebeck, T, Bettens, F & Paepke, A J (1995) MHC-dependent mate preferences in humans. *Proc R Soc B* 260: 245–9.
- Wedell, N (2005) Female receptivity in butterflies and moths. *J Exp Biol* 208: 3433–40.
- Weeks, E N I, Birkett, M A, Cameron, M M, Pickett, J A & Logan, J G (2011) Semiochemicals of the common bed bug, *Cimex lectularius* L. (Hemiptera: Cimicidae), and their potential for use in monitoring and control. *Pest Manag Sci* 67: 10–20.
- Wegner, K M, Kalbe, M, Kurtz, J, Reusch, T B H & Milinski, M (2003) Parasite selection for immunogenetic optimality. *Science* 301: 1343.
- Weil, T, Hoffmann, K, Kroiss, J, Strohm, E & Korb, J (2009) Scent of a queen: cuticular hydrocarbons specific for female reproductives in lower termites. *Naturwissenschaften* 96: 315–19.
- Weiner, S A & Toth, A L (2012) Epigenetics in social insects: a new direction for understanding the evolution of castes. *Genetics Research International* 2012: 11 doi:10.1155/2012/609810.
- Weissburg, M J (2000) The fluid dynamical context of chemosensory behavior. *Biol Bull* 198: 188–202.
- Weissburg, M J (2011) Waterborne chemical communication: stimulus dispersal dynamics and orientation strategies in crustaceans. In Breithaupt, T & Thiel, M (eds.) *Chemical Communication in Crustaceans*. pp. 63–83. New York: Springer.
- Weissburg, M J, Doall, M H & Yen, J (1998) Following the invisible trail: kinematic analysis of mate-tracking in the copepod *Temora longicornis*. *Phil Trans R Soc B* 353: 701–12.
- Wells, M J & Buckley, S K L (1972) Snails and trails. *Anim Behav* 20: 345–55.
- Welsh, R G & Müller-Schwarze, D (1989) Experimental habitat scenting inhibits colonization by beaver, *Castor canadensis*. *J Chem Ecol* 15: 887–93.
- Wenhold, B A & Rasa, O A E (1994) Territorial marking in the yellow mongoose *Cynictis penicillata* – sexual advertisement for subordinates. *Z Saugetierkd* 59: 129–38.
- Wenseleers, T, Billen, J & Hefetz, A (2002) Territorial marking in the desert ant *Cataglyphis niger*: does it pay to play bourgeois? *J Insect Behav* 15: 85–93.
- Wertheim, B, Van Baalen, E J A, Dicke, M & Vet, L E M (2005) Pheromone-mediated aggregation in non-social arthropods: an evolutionary ecological perspective. *Annu Rev Entomol* 50: 321–46.
- West, S A & Gardner, A (2010) Altruism, spite, and greenbeards. *Science* 327: 1341–4.
- White, A M, Swaisgood, R R & Zhang, H (2002) The highs and lows of chemical communication in giant pandas (*Ailuropoda melanoleuca*): effect of scent deposition height on signal discrimination. *Behav Ecol Sociobiol* 51: 519–29.
- White, T L (2009) A second look at the structure of human-olfactory memory. *Ann N Y Acad Sci* 1170: 338–42.
- Whitfield, C W, Cziko, A M & Robinson, G E (2003) Gene expression profiles in the brain predict behavior in individual honey bees. *Science* 302: 296–9.
- Whitman, M C & Greer, C A (2009) Adult neurogenesis and the olfactory system. *Prog Neurobiol* 89: 162–75.
- Whittaker, D J, Soini, H A, Atwell, J W (2010) Songbird chemosignals: volatile compounds in preen gland secretions vary among individuals, sexes, and populations. *Behav Ecol* 21: 608–14.
- Whittier, T S & Kaneshiro, K Y (1995) Intersexual selection in the Mediterranean fruit-fly – does female choice enhance fitness. *Evolution* 49: 990–6.
- Whittier, T S, Nam, F Y, Shelly, T E & Kaneshiro, K Y (1994) Male courtship success and female discrimination in the Mediterranean fruit-fly (Diptera, Tephritidae). *J Insect Behav* 7: 159–70.
- Wicker-Thomas, C (2007) Pheromonal communication involved in courtship behavior in *Diptera*. *J Insect Physiol* 53: 1089–100.
- Wilburn, D B, Bowen, K E, Gregg, R G *et al.* (2012) Proteomic and UTR analyses of a rapidly evolving hypervariable family of vertebrate pheromones. *Evolution* 66: 2227–39.
- Wiley, C, Ellison, C K & Shaw, K L (2011) Widespread genetic linkage of mating signals and preferences in the Hawaiian cricket *Laupala*. *Proc R Soc B* 279: 1203–9.
- Wiley, R H (2013) Specificity and multiplicity in the recognition of individuals: implications for the evolution of social behaviour. *Biol Rev* 88: 179–95.
- Wilke, K, Martin, A, Terstegen, L & Biel, S (2007) A short history of sweat gland biology. *Int J Cosmet Sci* 29: 169–80.

- Willis, M A (2008a) Chemical plume tracking behavior in animals and mobile robots. *Navigation* 55: 127–35.
- Willis, M A (2008b) Odor plumes and animal orientation. In Firestein, S & Beauchamp, G (eds.) *Olfaction and Taste*. pp. 771–81. San Diego: Academic Press.
- Willis, M A & Avondet, J L (2005) Odor-modulated orientation in walking male cockroaches *Periplaneta americana*, and the effects of odor plumes of different structure. *J Exp Biol* 208: 721–35.
- Wilms, J & Eltz, T (2008) Foraging scent marks of bumblebees: footprint cues rather than pheromone signals. *Naturwissenschaften* 95: 149–53.
- Wilson, A D & Baietto, M (2011) Advances in electronic-nose technologies developed for biomedical applications. *Sensors* 11: 1105–76.
- Wilson, D A & Stevenson, R J (2006) *Learning to Smell: Olfactory Perception from Neurobiology to Behavior*. Baltimore, MD: Johns Hopkins University Press.
- Wilson, E O (1962) Chemical communication among workers of the fire ant *Solenopsis savissima* (Fr. Smith). 1: the organization of mass foraging. *Anim Behav* 10: 134–47.
- Wilson, E O (1970) Chemical communication within animal species. In Sondheimer, E, (ed.) *Chemical Ecology*. pp. 133–55. New York: Academic Press.
- Wilson, E O (1971) *The Insect Societies*. Cambridge, MA: Belknap Press.
- Wilson, E O & Bossert, W H (1963) Chemical communication among animals. *Recent Prog Horm Res* 19: 673–716.
- Wilson, M (2008) *Bacteriology of Humans: an Ecological Perspective*. Oxford: Blackwell.
- Wilson, R I & Mainen, Z F (2006) Early events in olfactory processing. *Annu Rev Neurosci* 29: 163–201.
- Winston, M L (1987) *The Biology of the Honey Bee*. Cambridge, MA: Harvard University Press.
- Winston, M L (1997) *Nature Wars: People vs. Pests*. Cambridge, MA: Harvard University Press.
- Winston, M L & Slessor, K N (1998) Honey bee primer pheromones and colony organization: gaps in our knowledge. *Apidologie* 29: 81–95.
- Wisenden, B D (1999) Alloparental care in fishes. *Rev Fish Biol Fish* 9: 45–70.
- Wisenden, B D (2014) Chemical cues that indicate risk of predation. In Sorensen, P W & Wisenden, B D (eds.) *Fish Pheromones and Related Conspecific Chemical Cues*. Chichester: Wiley-Blackwell.
- Wittmann, D, Radtke, R, Zeil, J, Luebke, G & Francke, W (1990) Robber bees (*Lestrimelitta limao*) and their host: chemical and visual cues in nest defense by *Trigona angustula* (Apidae: Meliponinae). *J Chem Ecol* 16: 631–42.
- Witzgall, P, Kirsch, P & Cork, A (2010) Sex pheromones and their impact on pest management. *J Chem Ecol* 36: 80–100.
- Wolff, J O (2003) Laboratory studies with rodents: facts or artifacts? *Bioscience* 53: 421–7.
- Wolff, J O & Sherman, P W (eds.) (2007) *Rodent Societies: an Ecological and Evolutionary Perspective*. Chicago: Chicago University Press.
- Wolff, J O, Dunlap, A S & Ritchhart, E (2001) Adult female prairie voles and meadow voles do not suppress reproduction in their daughters. *Behav Processes* 55: 157–62.
- Wolfner, M F (2009) Battle and ballet: molecular interactions between the sexes in *Drosophila*. *J Hered* 100: 399–410.
- Wood, D L (1982) The role of pheromones, kairomones, and allomones in the host selection and colonization behavior of bark beetles. *Annu Rev Entomol* 27: 411–46.
- Woodard, S H, Fischman, B J, Venkat, A *et al.* (2011) Genes involved in convergent evolution of eusociality in bees. *Proc Natl Acad Sci USA* 108: 7472–7.
- Woodley, S K (2010) Pheromonal communication in amphibians. *J Comp Physiol A* 196: 713–27.
- Workman, J & Weyer, L (2012) *Practical Guide and Spectral Atlas for Interpretive Near-infrared Spectroscopy*, 2nd edn. Boca Raton, FL: CRC Press.
- Wu, M V & Shah, N M (2011) Control of masculinization of the brain and behavior. *Curr Opin Neurobiol* 21: 116–23.
- Wurm, Y, Wang, J & Keller, L (2010) Changes in reproductive roles are associated with changes in gene expression in fire ant queens. *Mol Ecol* 19: 1200–11.
- Wyatt, T D (1997) Putting pheromones to work: paths forward for direct control. In Cardé, R T & Minks, A K (eds.) *Pheromone Research: New Directions*. pp. 445–59. New York: Chapman and Hall.

- Wyatt, T D (2003) *Pheromones and Animal Behaviour: Communication by Smell and Taste*. Cambridge: Cambridge University Press.
- Wyatt, T D (2005) Pheromones: convergence and contrasts in insects and vertebrates. In Mason, R T, LeMaster, M P & Müller-Schwarze, D (eds.) *Chemical Signals in Vertebrates 10*. pp. 7–20. New York: Springer.
- Wyatt, T D (2009) Fifty years of pheromones. *Nature* **457**: 262–3.
- Wyatt, T D (2010) Pheromones and signature mixtures: defining species-wide signals and variable cues for identity in both invertebrates and vertebrates. *J Comp Physiol A* **196**: 685–700.
- Wyatt, T D (2011) Pheromones and behavior. In Breithaupt, T & Thiel, M (eds.) *Chemical Communication in Crustaceans*. pp. 23–38. New York: Springer.
- Wynn, E, Sanchez-Andrade, G, Carss, K & Logan, D (2012) Genomic variation in the vomeronasal receptor gene repertoires of inbred mice. *BMC Genomics* **13**: 415.
- Wysocki, C J & Beauchamp, G K (1984) Ability to smell androstenone is genetically determined. *Proc Natl Acad Sci USA* **81**: 4899–902.
- Wysocki, C J & Preti, G. (2009) Human pheromones: what's purported, what's supported. *A Sense of Smell Institute White Paper* [Online]. Available: www.senseofsmell.org/research/C.Wysocki-White-Paper-Human_Pheromones.pdf [Accessed 29 Oct 2012].
- Wysocki, C J, Dorries, K M & Beauchamp, G K (1989) Ability to perceive androstenone can be acquired by ostensibly anosmic people. *Proc Natl Acad Sci USA* **86**: 7976–8.
- Xu, F Q, Schaefer, M, Kida, I *et al.* (2005) Simultaneous activation of mouse main and accessory olfactory bulbs by odors or pheromones. *J Comp Neurol* **489**: 491–500.
- Xu, S, Schlüter, P M & Schiestl, F P (2012) Pollinator-driven speciation in sexually deceptive orchids. *Int J Ecol* **2012**: doi:10.1155/2012/285081.
- Xu, Y, Gong, F, Dixon, SJ *et al.* (2007) Application of dissimilarity indices, principal coordinates analysis, and rank tests to peak tables in metabolomics of the gas chromatography/mass spectrometry of human sweat. *Anal Chem* **79**: 5633–41.
- Xue, B Y, Rooney, A P, Kajikawa, M, Okada, N & Roelofs, W L (2007) Novel sex pheromone desaturases in the genomes of corn borers generated through gene duplication and retroposon fusion. *Proc Natl Acad Sci USA* **104**: 4467–72.
- Yamagata, N, Fujiwara-Tsuji, N, Yamaoka, R & Mizunami, M (2005) Pheromone communication and the mushroom body of the ant, *Camponotus obscuripes* (Hymenoptera : Formicidae). *Naturwissenschaften* **92**: 532–6.
- Yamagata, N, Nishino, H & Mizunami, M (2006) Pheromone-sensitive glomeruli in the primary olfactory centre of ants. *Proc R Soc B* **273**: 2219–25.
- Yamagata, N, Nishino, H & Mizunami, M (2007) Neural pathways for the processing of alarm pheromone in the ant brain. *J Comp Neurol* **505**: 424–42.
- Yamamoto, M E, Araújo, A, de Sousa, M B C & Arruda, M d F (2010) Social organization in *Callithrix jacchus*: cooperation and competition. *Adv Study Behav* **42**: 259–73.
- Yamamoto, Y & Matsuura, K (2011) Queen pheromone regulates egg production in a termite. *Biol Lett* **7**: 727–9.
- Yamazaki, K & Beauchamp, G K (2007) Genetic basis for MHC-dependent mate choice. *Adv Genet* **59**: 129–45.
- Yamazaki, K, Beauchamp, G K, Wysocki, C J *et al.* (1983) Recognition of H-2 types in relation to the blocking of pregnancy in mice. *Science* **221**: 186–8.
- Yambe, H, Kitamura, S, Kamio, M *et al.* (2006) L-Kynurenine, an amino acid identified as a sex pheromone in the urine of ovulated female masu salmon. *Proc Natl Acad Sci USA* **103**: 15370–4.
- Yang, C H, Rumpf, S, Xiang, Y *et al.* (2009) Control of the postmating behavioral switch in *Drosophila* females by internal sensory neurons. *Neuron* **61**: 519–26.
- Yang, Z & Schank, J (2006) Women do not synchronize their menstrual cycles. *Hum Nat* **17**: 434–47.
- Yarmolinsky, D A, Zuker, C S & Ryba, N J P (2009) Common sense about taste: from mammals to insects. *Cell* **139**: 234–44.
- Yeagan, K V & Quate, L W (1997) Adult male bolas spiders retain juvenile hunting tactics. *Oecologia* **112**: 572–6.
- Yen, J & Lasley, R (2011) Chemical communication between copepods: finding the mate in a fluid environment. In

- Breithaupt, T & Thiel, M (eds.) *Chemical Communication in Crustaceans*. pp. 177–97. New York: Springer.
- Yen, J, Weissburg, M J & Doall, M H (1998) The fluid physics of signal perception by mate-tracking copepods. *Phil Trans R Soc B* 353: 787–804.
- Yew, J Y, Dreisewerd, K, Luftmann, H *et al.* (2009) A new male sex pheromone and novel cuticular cues for chemical communication in *Drosophila*. *Curr Biol* 19: 1245–54.
- Yew, J Y, Soltwisch, J, Pirkel, A & Dreisewerd, K (2011) Direct laser desorption ionization of endogenous and exogenous compounds from insect cuticles: practical and methodologic aspects. *J Am Soc Mass Spectrom* 22: 1273–84.
- Yizhar, O, Fenno, L E, Davidson, T J, Mogri, M & Deisseroth, K (2011) Optogenetics in neural systems. *Neuron* 71: 9–34.
- Yoder, J A & Grojean, N C (1997) Group influence on water conservation in the giant Madagascar hissing-cockroach, *Gromphadorhina portentosa* (Dictyoptera: Blaberidae). *Physiol Entomol* 22: 79–82.
- Yoon, H Y, Enquist, L W & Dulac, C (2005) Olfactory inputs to hypothalamic neurons controlling reproduction and fertility. *Cell* 123: 669–82.
- Yoshiura, K, Kinoshita, A, Ishida, T *et al.* (2006) A SNP in the ABCC11 gene is the determinant of human earwax type. *Nat Genet* 38: 324–30.
- Young, A J (2009) The causes of physiological suppression in vertebrate societies: a synthesis. In Hager, R & Jones, C B (eds.) *Reproductive Skew in Vertebrates: Proximate and Ultimate Causes*. pp. 397–436. Cambridge: Cambridge University Press.
- Zahavi, A (1975) Mate selection: a selection for a handicap. *J Theor Biol* 53: 205–14.
- Zahavi, A (2008) The handicap principle and signalling in collaborative systems. In d'Ettorre, P & Hughes, D P (eds.) *Sociobiology of Communication: an Interdisciplinary Perspective*. pp. 1–9. Oxford: Oxford University Press.
- Zahavi, A & Zahavi, A (1997) *The Handicap Principle. A Missing Piece of Darwin's Puzzle*. Oxford: Oxford University Press.
- Zala, S M & Penn, DJ (2004) Abnormal behaviours induced by chemical pollution: a review of the evidence and new challenges. *Anim Behav* 68: 649–64.
- Zala, S M, Potts, W K & Penn, D J (2004) Scent-marking displays provide honest signals of health and infection. *Behav Ecol* 15: 338–44.
- Zampiga, E, Gaibani, G, Csermely, D, Frey, H & Hoi, H (2006) Innate and learned aspects of vole urine UV-reflectance use in the hunting behaviour of the common kestrel *Falco tinnunculus*. *J Avian Biol* 37: 318–22.
- Zanen, P O, Sabelis, M W, Buonaccorsi, J P & Cardé, R T (1994) Search strategies of fruit-flies in steady and shifting winds in the absence of food odors. *Physiol Entomol* 19: 335–41.
- Zavazava, N & Eggert, F (1997) MHC and behavior. *Immunol Today* 18: 8–10.
- Zayed, A & Robinson, G E (2012) Understanding the relationship between brain gene expression and social behavior: lessons from the honey bee. *Annu Rev Genet* 46: 591–615.
- Zeng, X N, Leyden, J J, Lawley, H J *et al.* (1991) Analysis of characteristic odors from human male axillae. *J Chem Ecol* 17: 1469–92.
- Zhang, J-X, Zuo, M X & Sun, L (2009) The volatile composition of uropygial glands contains information about sex, individual, and species in Bengalese finches, *Lonchura striata*. *Curr Zool* 55: 357–65.
- Zhang, J-X, Wei, W, Zhang, J-H & Yang, W-H (2010) Uropygial gland-secreted alkanols contribute to olfactory sex signals in budgerigars. *Chem Senses* 35: 375–82.
- Zhang, X M & Firestein, S (2002) The olfactory receptor gene superfamily of the mouse. *Nat Neurosci* 5: 124–33.
- Zhang, X M & Firestein, S (2009) Genomics of olfactory receptors. *Results Probl Cell Differ* 47: 239–55.
- Zhao, C H, Löfstedt, C & Wang, X Y (1990) Sex-pheromone biosynthesis in the Asian corn-borer *Ostrinia furnacalis* (H) – biosynthesis of (E)-12-tetradecenyl and (Z)-12-tetradecenyl acetate involves delta-14 desaturation. *Arch Insect Biochem Physiol* 15: 57–65.
- Zhou, J-J (2010) Odorant-binding proteins in insects. In Gerald, L (ed.) *Pheromones*. pp. 241–72. London: Academic Press.
- Zhou, W & Chen, D (2008) Encoding human sexual chemosensory cues in the orbitofrontal and fusiform cortices. *J Neurosci* 28: 14416.

- Zhuang, J J & Hunter, C P (2011) RNA interference in *Caenorhabditis elegans*: uptake, mechanism, and regulation. *Parasitology* **139**: 560–73.
- Zimmer-Faust, R K, Finelli, C M, Pentcheff, N D & Wethey, D S (1995) Odor plumes and animal navigation in turbulent water-flow – a field-study. *Biol Bull* **188**: 111–16.
- Zimmermann, Y, Ramírez, S & Eltz, T (2009) Chemical niche differentiation among sympatric species of orchid bees. *Ecology* **90**: 2994–3008.
- Zou, D J, Chesler, A & Firestein, S (2009) How the olfactory bulb got its glomeruli: a just so story? *Nat Rev Neurosci* **10**: 611–18.
- Zube, C, Kleineidam, C J, Kirschner, S, Neef, J & Rossler, W (2008) Organization of the olfactory pathway and odor processing in the antennal lobe of the ant *Camponotus floridanus*. *J Comp Neurol* **506**: 425–41.
- Zuk, M & Kolluru, G R (1998) Exploitation of sexual signals by predators and parasitoids. *Q Rev Biol* **73**: 415–38.