

Update of Tables in the Review "Chiral Methyl-branched Pheromones"

Original Tables: *Natural Product Reports*, 2015, **32**: 1007-1041

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Lists of non-terpene semiochemicals with a methyl-branched structure identified from Arthropod and their syntheses

Table 1. Hydrocarbon: Pheromones and related compounds identified from insects.^{a, b}

Table 2. Primary alcohols and their derivatives (aldehydes and esters): Pheromones and related compounds identified from insects, mites, and spiders.^{a, b}

Table 3. Secondary alcohols and their esters: Pheromones and related compounds identified from insects and mites.^a

Table 4. Ketones: Pheromones and related compounds identified from insects, spiders, and mites.^{a, b}

Table 5. Carboxylic acids and their derivatives: Pheromones and allomones identified from insects and spiders.^{a, b}

Table 6. Dihydropyrans and spiroacetals: Pheromones and allomones identified from insects.^a

Table 7. Dioxabicyclo and dioxatricyclo compounds (cyclic acetals): Pheromones and allomones identified from insects.^a

Table 8. Chiral synthons (S1 – S14) for enantioselective syntheses of methyl-branched pheromones.

Table 9. Syntheses of methyl-branched pheromones applying an enantioselective organic or biochemical reaction (R-1 – R-5).

Table 10. Coupling reactions of two chiral blocks (R-6 – R-11) for the syntheses of dimethyl pheromones.

References

^a Refer to the following database for the chemical structure and IUPAC name of each compound;

https://lepipheromone.sakura.ne.jp/pdb_top.html

^b Some achiral compounds are included.

Table 1. Hydrocarbons: Pheromones and related compounds identified from insects.^a

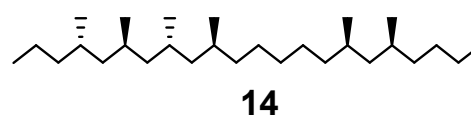
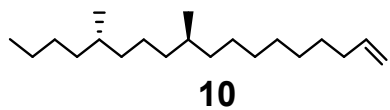
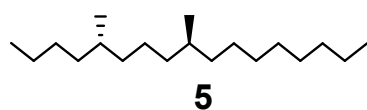
Pheromone		Insect			Reference ^e	
Structure	Configuration ^b	Group ^c	Species ^d	Identification	Stereoselective synthesis	
C ₅	Δ1,Me2,Me3-5:H	?	B24 [Heteroptera]	<i>Tessaratomya papillosa</i>	554 [09]	
C ₈	E2,Me3,E4,Me5,E6-8:H	achiral	B17 [Coleoptera]	<i>Colopterus truncatus</i>	521 (00)	
C ₉	E2,E4,Me4,E6,Me6-9:H	achiral	B17 [Coleoptera]	<i>Colopterus truncatus</i>	521 (00)	
	E2,Me3,E4,Et5,E6-9:H	achiral	B17 [Coleoptera]	(1) <i>Carpophilus freeman</i> , (2) <i>Carpophilus davidsoni</i>	(1) 515 (90), (2) 519 (94)	
C ₁₀	E2,Me3,E4,Me5,E6,Me7,E8-10:H	achiral	B17 [Coleoptera]	(1) <i>Carpophilus hemipterus</i> , (2) <i>Carpophilus brachypterus</i> , (3) <i>Colopterus truncatus</i>	(1) 514 (90), 516 (92), (2) 624 (95), (3) 521 (00)	
	E3,Me4,E5,Et6,E7-10:H	achiral	B17 [Coleoptera]	(1) <i>Carpophilus mutilates</i> , (2) <i>Carpophilus davidsoni</i>	(1) 517 (93), (2) 519 (94)	
	E2,Me3,E4,Me5,E6,Et7,E8-10:H	achiral	B17 [Coleoptera]	(1) <i>Carpophilus hemipterus</i> , (2) <i>Carpophilus brachypterus</i>	(1) 516 (92), (2) 624 (95)	
C ₁₁	Me2-11:H	achiral	B16 [Isoptera]	<i>Amitermes dentatus</i>	500 (15)	
	Me3-11:H	?	B31 [Hymenoptera]	<i>Camponotus intrepidus</i>	730 [73]	
	E2,Me3,E4,Me5,E6,Me7,E8-11:H	achiral	B17 [Coleoptera]	(1) <i>Carpophilus hemipterus</i> , (2) <i>Carpophilus davidsoni</i> , (3) <i>Carpophilus obsoletus</i> , (4) <i>Carpophilus brachypterus</i>	(1) 514 (90), 516 (92), (2) 519 (94), (3) 623 (94), (4) 624 (95)	
	E3,E5,Et5,E7,Me7-11:H	achiral	B17 [Coleoptera]	<i>Carpophilus mutilatus</i>	517 (93)	
	E2,Me3,E4,Me5,E6,Et7,E8-11:H	achiral	B17 [Coleoptera]	(1) <i>Carpophilus freemani</i> , (2) <i>Carpophilus hemipterus</i> , (3) <i>Carpophilus davidsoni</i> , (4) <i>Carpophilus lugubris</i>	(1) 515 (90), (2) 516 (92), (3) 519 (94), (4) 624 (95)	
C ₁₂	Me6-12:H	?	B31 [Hymenoptera]	<i>Pogonomyrmex barbatus</i> , <i>Pogonomyrmex rugosus</i>	731 [73]	

	Me3,Me5-12:H	?	B31	[Hymenoptera]	<i>Pogonomyrmex barbatus</i> , <i>Pogonomyrmex rugosus</i>	731 [73]	
	E3,Me4,E5,Et6,E7,Et8,E9-12:H	achiral	B17	[Coleoptera]	(1) <i>Carpophilus antiquus</i> , (2) <i>Carpophilus dimidiatus</i>	(1) 518 (93), (2) 520 (95)	
C ₁₃	Me3-13:H	?	B31	[Hymenoptera]	<i>Camponotus intrepidus</i>	730 [73]	
	Me5-13:H	?	B31	[Hymenoptera]	<i>Pogonomyrmex barbatus</i>	731 [73]	
	E3,E5,Et5,E7,Et7,E9,Me9-13:H	achiral	B17	[Coleoptera]	<i>Carpophilus dimidiatus</i>	520 (95)	
	Δ2,Δ4,Me4, Me6,Me8,Me10-13:H (1) + primary alcohol (35)	2E,4E,syn,syn	B1	[Hymenoptera]	<i>Trichogramma turkestanica</i>	15 [05], 16 (14)	16 (14)
	E2,E4,Me4, Me6,E8,Me8, Me10-13:H	2E,4E,8E,6S, 10S	B12	[Hymenoptera]	<i>Tetrastichus planipennisi</i>	442 (20)	442 (20)
C ₁₄	Me3,Me7-14:H	?	A	Lyonetiidae	<i>Leucoptera sinuella</i>	522 [20]	
C ₁₅	Me7-15:H	?	A	Lyonetiidae	<i>Leucoptera sinuella</i>	522 [20]	
	Me3,Me7-15:H	?	A	Lyonetiidae	<i>Leucoptera sinuella</i>	522 [20]	
	Me5,Me9-15:H (2)	5S,9R	A	Lyonetiidae	<i>Perileucoptera coffeella</i>	17 [88], 18 (09)	19 (03), 20 (08)
C ₁₆	Me3-16:H	?	B31	[Hymenoptera]	<i>Camponotus intrepidus</i>	730 [73]	
C ₁₇	Me2-17:H	achiral	A	Erebidae	<i>Holomelina aurantiaca</i> , <i>Holomelina immaculate</i> <i>Isia isabella</i>	524 (71)	
				B18	[Coleoptera]	<i>Phyllophaga opaca</i>	525 (88) 526 (19)
	Me2,Me5-17:H (3)	S	A	Geometridae	<i>Lambdina fiscellaria</i>	21 (91)	22 (93)
	Me3,Me13-17:H (4)	3S,13R	A	Geometridae	<i>Nepytia freemani</i>	23 [93], 24 (95)	24 (95)
	Me5,Me9-17:H (5)	5S,9S	A	Lyonetiidae	<i>Leucoptera scitella</i> #1	25 [87], 26 (89)	27 (91), 28 (99), 29 (00), 30 (05), 31 (09), 32 (12), 655 (13), 683 (23)
	Me5,Me11-17:H (6)	5R,11S	A	Geometridae	<i>Lambdina fiscellaria</i>	33 [93], 34 (93)	35 (96), 695 (23)
	Me7-17:H (7)	S	A	Erebidae	<i>Anomis texana</i>	36 (93)	22 (93), 37 (00)

		S	A	Geometridae	<i>Lambdina fiscellaria</i>	33 [93]	38 (99), 40 (01), 695 (23)
	Me7,Me11-17:H (8)	7S,11R	A	Geometridae	<i>Lambdina athasaria</i> #2 <i>Lambdina pellucidaria</i> #3	39 [94], 40 (01) 41 [98], 40 (01)	38 (99), 42 (02), 43 (04), 44 (07)
C ₁₈	Δ1,Me14-18:H (9) (= Me5,Δ17-18:H)	S	A	Lyonetiidae	<i>Lyonetia clerkella</i>	45 [84], 46 (85)	47 (85), 638 (85), 48 (95), 49 (13), 663 (13), 664 (20), 602 (21), 628 (22)
	Δ1,Me10,Me14-18:H (10) (= Me5,Me9,Δ17-18:H)	10S,14S	A	Lyonetiidae	<i>Lyonetia prunifoliella</i>	50 [97], 51 (02)	28 (99), 52 (00), 31 (09), 53 (14), 54 (14), 683 (23)
C ₁₉	Me9-19:H (11)	S	A	Erebidae	<i>Alabama argillacea</i>	36 (93)	55 (03), 56 (13)
	Me3,Me7-19:H		B15	[Diptera]	<i>Agromyza frontella</i>	501 [88]	
C ₂₁	Δ6,Me13-21:H (12)	6Z,13S	A	Erebidae	<i>Scoliopteryx libatrix</i>	57 [00], 58 (03)	58 (03)
	Me5,Me9,Me17-21:H (13)	?	B2	[Heteroptera]	<i>Phthia picta</i>	59 [12]	
C ₂₂	Me2-22:H	achiral	B19	[Diptera]	<i>Culicoides melleus</i>	537 (78)	
			B20	[Coleoptera]	<i>Chrysochus cobaltinus</i>	538 (07)	
			B13	[Coleoptera]	<i>Anoplophora glabripennis</i>	539 (14)	
C ₂₂	Me4,Me6,Me8,Me10,Me16,Me18-22:H (14) + Me4,Me6,Me8,Me10,Me16-22:H (15)	4S,6R,8R,10S, 16R,18S [α] _D (+10.7),	B3	[Coleoptera]	<i>Antitrogus parvulus</i>	60 [03], 61 [05], 62 (07)	62 (07), 63 (07), 64 (08) 65 (12), 658 (14)
C ₂₃	Me3-23:H	?	B22	[Coleoptera]	<i>Agrilus planipennis</i>	555 [09]	
	Me7-23:H (16)	?	B4	[Thysanoptera]	<i>Frankliniella occidentalis</i>	66 [13]	740 (24)
	Me11-23:H (17)	SR	B5	Gelechiidae	<i>Anarsia lineatella</i>	67 (05)	67 (05)
C ₂₅	Me3-25:H (18) + Me3-27:H + Me3-29:H	?	B6	[Hymenoptera]	<i>Camponotus floridanus</i>	68 [04], 69 [14]	
	Me3-25:H (18)	?	B13	[Coleoptera]	<i>Xylotrechus colonus</i>	447 [03]	
	Me3-25:H (18) + Me3,Me13-25:H	?	B13	[Coleoptera]	<i>Semanotus japonicus</i>	627 [93]	
	Me5,Me11-25:H (19)	?	B7	Pyralidae	<i>Galleria mellonella</i>	70 [14]	656 (15)

	Me7-25:H	R	B8	[Coleoptera]	<i>Neoclytus acuminatus</i>	71 [08], 348 (15)	
	Me9-25:H	?	B13	[Coleoptera]	<i>Xylotrechus colonus</i>	447 [03]	
		?	B22		<i>Agrilus planipennis</i>	708 [09]	709 (23)
C ₂₆	Me2-26:H	achiral	B13	[Coleoptera]	<i>Mallodon dasystemus</i>	546 (10)	
C ₂₇	Me7-27:H (20)	R	B8	[Coleoptera]	<i>Neoclytus acuminatus</i> #4	71 [08], 348 (15)	72 (13)
	Me5-27:H + Me5,M17-27:H	S, 5R,17S	B11	[Hymenoptera]	<i>Ooencyrtus kuvanae</i>	347 (12)	348 (12)
	Me9-27:H	?	B13	[Coleoptera]	<i>Anoplophora malasiaca</i>	690 [00], 691 [23]	
		R	B8		<i>Neoclytus acuminatus</i>	71 [08], 348 (15)	
		?	B27		<i>Gastrophysa atrocyanea</i>	579 [06]	
	Me11-27:H	?	B27	[Coleoptera]	<i>Gastrophysa atrocyanea</i>	579 [06]	
		S	B13		<i>Tetropium fuscum, Tetropium cinnamopterum</i>	547 (11)	547 (11), 643 (22)
	Me13-27:H	?	B23	[Homoptera]	<i>Cacopsylla pyricola</i>	556 [09]	557 (01), 558 (11), 559 (21)
C ₂₈	Me2-28:H	achiral	B14	[Diptera]	<i>Drosophila arizonae, Drosophila mojavensis, Drosophila navojoa</i>	448 (01)	
			B13	[Coleoptera]	<i>Mallodon dasystemus</i>	546 (10)	
C ₂₉	Me3-29:H	?	B21	[Hymenoptera]	<i>Dibrachys cavus</i>	543 [11]	
	Me9-29:H	?	B13	[Coleoptera]	<i>Anoplophora malasiaca</i>	690 [00], 691 [23]	
		?	B27		<i>Gastrophysa atrocyanea</i>	579 [06]	
	Me11-29:H	?	B27	[Coleoptera]	<i>Gastrophysa atrocyanea</i>	579 [06]	
	Z7,Me15-29:H + Me3,Me7,Me11-29:H etc.	?	B10	[Hymenoptera]	<i>Eurytoma maslovskii</i>		349 [16]
	Me5,Me17-29:H	?	B13	[Coleoptera]	<i>Callidiellum rufipenne</i>	560 [09]	
C ₃₁	Me3-31:H	?	B21	[Hymenoptera]	<i>Dibrachys cavus</i>	543 [11]	
	Δ1,Me13-31:H	?	B30	[Diptera]	<i>Stomoxys calcitrans</i>	713 [79]	
	Me3,Me7,Me11-31:H	?	B32	[Hymenoptera]	<i>Atta colombica</i>	367 [70]	
	Me3,Me7,Me11,Me15-31:H	?	B25	[Diptera]	<i>Glossina brevipalpis</i>	573 [88]	
C ₃₂	Me4,Me8,Me12-32:H	?	B32	[Hymenoptera]	<i>Atta colombica</i>	367 [70]	

C ₃₃	Me15-33:H (21)	?	B9	[Diptera]	<i>Stomoxys calcitrans</i> #4	73 [75], 74 [77]	75 (84), 76 (87)
	Δ1,Me13-33:H	?	B30	[Diptera]	<i>Stomoxys calcitrans</i>	713 [79]	
	Me15,Me19-33:H	?	B9	[Diptera]	<i>Stomoxys calcitrans</i>	73 [75], 74 [77]	75 (84)
					<i>Glossina austeni</i>	707 [80]	
	Δ1,Me13,Me17-33:H	13S,17R	B26	[Diptera]	<i>Glossina austeni</i>	576 [00], 578 (05)	577 (01)
	Δ1,Me19,Me23-33:H	?	B28	[Diptera]	<i>Glossina morsitans</i>	629 [91]	
	Me3,Me7,Me11-33:H	?	B32	[Hymenoptera]	<i>Atta colombica</i>	367 [70]	
C ₃₄	Me4,Me8,Me12-34:H	?	B32	[Hymenoptera]	<i>Atta colombica</i>	367 [70]	
C ₃₅	Z8,Me21-35:H	R	B13	[Coleoptera]	<i>Psacotheta hilari</i>	548 [96], 549 (97)	550 (98), 551 (99), 552 (21)
	Me13,Me17-35:H	?	B29	[Phasmatodea]	<i>Diapheromera femorata</i>	710 [81]	
	Me13,Me23-35:H	13R,23S	B26	[Diptera]	<i>Glossina pallidipes</i>	570 [84], 571 (85), 572 [86]	569 (83)
	Δ1,Me13,Me17-35:H	13S,17R	B26	[Diptera]	<i>Glossina austeni</i>	576 [00], 578 (05)	577 (01)
	Me11,Me15,Me19,Me23-35:H	?	B25	[Diptera]	<i>Glossina palpalis</i>	573 [88]	
C ₃₇	Me11,Me23-37:H	?	B26	[Diptera]	<i>Glossina tachinoides</i>	573 [88], 575 [98]	574 [94]
	Me13,Me25-37:H	?	B26	[Diptera]	<i>Glossina tachinoides</i>	573 [88], 575 [98]	574 [94]
	Me17,Me21-37:H	?	B25	[Diptera]	<i>Glossina morsitans</i>	567 [78], 572 [86]	567 [78], 587 [80]
	Me15,Me19,Me23-37:H	?	B26	[Diptera]	<i>Glossina morsitans</i>	567 [78], 572 [86]	567 [78], 568 [80]



^a Compounds are arranged in order of length of the main chains. A, sex pheromones of female moths; B1, sex pheromone from females of a parasitoid wasp; B2, sex pheromone from males of a true bug; B3, cuticular hydrocarbon from females of a scarab beetle; B4, sex pheromone from males of a thrip; B5, scent in body scales of female moths; B6, queen pheromone from several social insects; B7, sex pheromone from males of a moth; B8, cuticular hydrocarbon from females of a longhorn beetle; B9, sex pheromone from females of a fly; B10, cuticular hydrocarbons from females of a wasp; B11, sex pheromone from males of a parasitoid wasp; B12, sex pheromone from females of a wasp; B13, sex pheromone from females of a longhorn beetle; B14, sex pheromone from females of a fruit fly; B15, sex

pheromone from females of a leaf-minor fly; B16, trail pheromone from a termite; B17, aggregation pheromone from males of a sap beetle; B18, sex pheromone (?) from a scarab beetle; B19, sex pheromone from females of a biting midge; B20, sex pheromone (?) from a leaf midge; B21, sex pheromone from females of a parasitoid wasp; B22, sex pheromone from females of a jewel beetle; B23, sex pheromone from females of a psylla; B24, alarm pheromone of a true bug; B25, cuticular hydrocarbon from females of a tsetse fly; B26, sex pheromone from females of a tsetse fly; B27, sex pheromone from females of a leaf beetle; B28, anti-aphrodisiac pheromone from males of a tsetse fly; B29, cuticular hydrocarbon from females of a stick insect; B30, sex pheromone from females of a stable fly; B31, gland secretion of ant; B32, cuticular hydrocarbon from an ant.

^b Configurations of moth pheromones were mainly assigned by biological activity (field evaluation of synthetic isomers).

^c Family in Lepidoptera or [order of other insects].

^d Also identified from *Lyonetia prunifoliella* (#1); *Lambdina pellucidaria*. (#2); *Lambdina athasaria* (#3); and several species in Coleoptera and Hymenoptera (#4).

^e (Year of publication, 19XX or 20XX). [] indicates year when the publication was reported before determination of the absolute configuration.

Table 2. Primary alcohols and their derivatives (aldehydes and esters): Pheromones and related compounds identified from insects, mites, and spiders. ^a

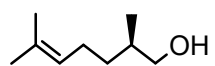
Pheromone			Insecta and [Arachnida]		Reference ^e	
Structure [Trivial name]	Configuration and analytical method ^b	Function (Producer)	Order ^c	Species ^d	Identifi- cation	Stereoselective synthesis
C ₃ Me1-3:OAc	?	aggregation (M)	Coleo.	<i>Strategus aloeus</i> (scarab beetle)	449 [00]	
C ₄ Me2-4:OH (22)	R GC* #A	aggregation (M)	Coleo.	(1) <i>Phymatodes lecontei</i> , (2) <i>Phymatodes amoenus</i> , <i>Phymatodes varius</i> , <i>Phymatodes lengi</i> , (3) <i>Phymatodes pusillus</i> , (4) <i>Pyrrhidium sanguineum</i> , <i>Phymatodes alni</i> (longhorn beetle)	(1) 77 (07) (2) 531 (15) (3) 532 [18] (4) 533 (19)	77 (07)
Me2-4:OH (22)	S	aggregation (M)	Coleo.	<i>Megacyllene acuta</i> (longhorn beetle)	523 (18)	
Me2-4:OH (22)	?	primer (queen)	Iso.	<i>Reticulitermes speratus</i> (termite)	441 [10]	
Me2-4:OH (22) + Me4-7:OH (23)	S R GC* #B	sex (F)	Hetero.	<i>Triatoma brasiliensis</i> (assassin bug)	78 (09)	78 (09)
Me2-4:OCOPr	S	(1) gland secretion, (2) aggregation (F)	Hetero.	(1) <i>Megalotomus quinquespinosus</i> (2) <i>Alydus eurinus</i> (broad-headed bug)	(1) 605 [75] (2) 606 (00)	
E2,Me2-4:OCOPr	?	aggregation (F)	Hetero.	<i>Alydus eurinus</i> (broad-headed bug)	606 [00]	
C ₅ Me2-5:OH	R	aggregation (M)	Coleo.	<i>Sphaerion inerme</i> (longhorn beetle)	734 (24)	
Me2-5:OCOR (stearate etc.) (24)	S HPLC* #C		[Astigmata]	<i>Sancassania shanghaiensis</i>	79 (01)	79 (01)

	+ Me2,Me4-6:OCOR (stearate etc.) (25)					(acarid mite)		
C ₆	Me2-6:OH (26)	S	GC* #D	(mandibular gland)	Hymeno.	<i>Cataglyphis bicolor</i> (ant) #1	80 [92], 81 (96)	81 (96)
	E2,Me2,E4,Me4-6:OH	achiral		allomone ?	[Opiliones]	<i>Leiobunum leiopenis</i> , <i>Leiobunum calcar</i> (spider: harvestman)	686 (77)	
C ₇	Me2,Δ5,Me6-7:OH (27) + Ald derivative	R	GC* #E	sex (F)	[Astigmata]	<i>Tyreophagus</i> sp (acarid mite)	82 (09)	82 (09)
	E2,Me2,E4,Me4-7:OH	achiral		allomone ?	[Opiliones]	<i>Leiobunum leiopenis</i> , (spider: harvestman)	686 (77)	
C ₈	Me7-8:OCOR (COR = Me7-8)	achiral		sex (F)	Coleo.	<i>Elater ferrugineus</i> <i>Agriotes ferrugineipennis</i> (click beetle)	460 (07) 631 (22)	
	Me7-8:OCOR (COR = Z4-10)	achiral		sex (F)	Coleo.	<i>Elater ferrugineus</i> (click beetle)	460 (07)	
C ₉	Me4-9:OH (28)	R	HPLC #F	sex (F)	Coleo.	<i>Tenebrio molitor</i> (mealworm)	83 [86], 84 (89),	84 (89), 85 (03), 86 (10), 659 (15), 660 (16), 661 [17], 662 [18], 513 (20)
C ₁₀	E2,Me2-10:Ald	achiral		gland secretion	Hymeno.	<i>Apterostigma dentigerum</i> (ant)	451 (17)	E2,Me2-10:Ald
	Me2,Me8-10:OCOEt	2S,10S		sex (F)	Hymeno.	<i>Eurytoma maslovskii</i> (wasp)	431 (20)	
	Me4,Me5-10:Ald	?		aggregation (M)	Coleo.	<i>Tribolium castaneum</i> (darkling beetle)	635 [91]	
	Me4,Me8-10:Ald (29) [tribolure]	4R,8R		aggregation	Coleo.	(1)(2) <i>Tribolium castaneum</i> (1)(4) <i>Tribolium confusum</i> , (3)(4) <i>Tribolium freemani</i> , (4) <i>Tribolium madens</i> (flour beetle) #2	(1) 87 [81], (2) 88 (83), 428 (83), 711 (84), 89 (11), (3)	90 (83), 91 (85), 92 (88), 93 (02), 94 (06), 95 (06), 96 (11), 670(15), 671 (19), 672 (20)
		mixture	HPLC #J					

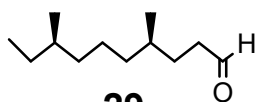
								647 (87), (4) 474 [02]	
C ₁₁	Me ₄ ,Me ₆ -11:Ald	?		sex (M), trail	Isoptera	<i>Hodotermopsis sjoestedti</i> (termite)		502 [11]	
	Me ₂ ,Me ₄ ,Me ₆ ,Me ₈ -11:OH [prieskanol]	2 <i>R</i> ,4 <i>R</i> ,6 <i>R</i> , 8 <i>R</i>	NMR	sex (F)	Homo.	<i>Margarodes prieskaensis</i> (scale)		350 (17)	350 (17)
C ₁₂	Me ₁₀ -12:OH	?		sex (M)	Cole.	<i>Compsibidion graphicum</i> , <i>C.</i> <i>sommeri</i> (longhorn beetle)		667 [20]	667 [20]
	Me ₁₀ -12:OAc (30)	<i>R</i>		sex (F)	Lepido.	<i>Adoxophyes honmai</i> (leafroller moth)		97 [79], 98 (83)	99 (79), 100 (85), 48 (95), 101 (98), 102 (01), 103 (14)
	Me ₁₀ -12:Ald	?		sex (M)	Cole.	<i>Eburodacrys vittata</i> <i>E. assimilis</i> , <i>E. lenkoi</i> , etc. (longhorn beetle)		351 [16] 667 [20]	667 [20]
	Me ₃ ,Δ ₆ ,Et ₇ ,Δ ₁₀ ,Me ₁₁ -12:Ald (31) + C ₁₁ analogue (32)	3 <i>S</i> ,6 <i>E</i>	GC* #G	sex (F)	Coleo.	<i>Callosobruchus rhodesianus</i> (seed beetle)		104 (10), 105 (10)	104 (10)
	Me ₃ ,Δ ₆ ,Me ₇ ,Δ ₁₀ ,Me ₁₁ -12:OH (33) [2,3-dihydrofarnesol] + Ald derivative	3 <i>S</i> ,6 <i>E</i>	GC* #H	marking (M)	Hymeno.	<i>Bombus terrestris</i> (bumblebee) #3		432 (70), 106 (04)	106 (04)
	Me ₃ ,Me ₅ ,Me ₉ -12:Ald (34) [stylopsal]	3 <i>R</i> ,5 <i>R</i> ,9 <i>R</i>		sex (F)	Strepsi.	<i>Stylops melittae</i> <i>S. muelleri</i> (twisted-wing parasite)		107 (12) 108 [12], 109 (13)	107 (12) 109 (13)
	Me ₄ ,Me ₆ -12:Ald	?		sex (M), trail	Iso.	<i>Zootermopsis nevadensis</i> , <i>Z. angusticollis</i> (termite)		352 [10]	353 [11]
	Me ₂ ,Me ₁₀ -12:OCOEt	2 <i>S</i> ,10 <i>R</i>		sex (F)	Hymeno.	<i>Eurytoma maslovskii</i> (wasp)		431 (20)	
C ₁₃	Me ₁₁ -13:Ald	?		sex (F)	Coleo.	<i>Eburodacrys dubitata</i> , <i>E.</i> <i>assimilis</i> , <i>E. flexuosa</i> , etc.		667 [20]	667 [20]

						(longhorn beetle)		
	$\Delta 2, \Delta 4, \text{Me}4, \text{Me}6, \text{Me}8, \text{Me}10-13:\text{OH}$ (35)	<i>2E, 4E, syn, syn</i>		sex (F)	Hymeno.	<i>Trichogramma turkestanica</i> (parasitoid wasp)	15 [05], 16 (14)	110 (14)
	$\text{Me}3, \text{Me}4, \Delta 6, \text{Me}7, \Delta 10, \text{Me}11-13:\text{Ald}$ (36) [faranal]	<i>3S, 4R, 6E, 10Z</i>	NMR #I	trail	Hymeno.	<i>Monomorium pharaonis</i> (ant)	111 (77), 429 (80)	111 (77), 429 (80), 112 (95), 113 (10), 354 (88), 355 (19)
	$\text{Me}3, \text{Me}5, \Delta 7, \text{Me}9, \Delta 11, \text{Me}11-13:\text{Ald}$ [peckidienal]	<i>3R, 5S, 9R 7E, 11E</i>	GC* #J	sex (F)	Strepsi.	<i>Xenos peckii</i> (twisted-wing parasite)	356 [15], 357 (16)	357 (16)
C ₁₄	$\text{Me}6, \text{Me}10, \text{Me}13-14:\text{OH}$ (37)	?		aggregation (M)	Hetero.	<i>Stiretrus anchorage</i> (stink bug)	114 [86], 115 [89]	
	$\text{Me}6, \text{Me}10, \text{Me}13-14:\text{OCOC}_4\text{H}_9$?		gland secretion (M)	Hetero.	(1) <i>Perillus bioculatus</i> , <i>Oplomus severus</i> (2) <i>Eocanthecona furcellata</i> (stink bug)	(1) 114 [86] (2) 589 [03], 590 [05]	
	$\text{Me}2, \text{Me}4, \text{Me}8, \text{Me}13-14:\text{OH}$	<i>2R, 4R, 8R</i>		sex (M)	Hetero.	<i>Pellaea stictica</i> (stink bug)	536 [15], 630 (22)	630 (22)
C ₁₅	$\text{Me}10, \text{Me}14-15:\text{OCO}i\text{Pr}$ (38)	<i>R</i>		sex (F)	Lepido.	<i>Arna pseudoconspersa</i> , <i>Artaxa subflava</i> (tussock moth)	116 [94], 117 (96), 118 (07)	119 (95), 358 (88), 359 (17), 360 (18), 739, (24)
C ₁₆	$\text{Z}8, \text{Me}14-16:\text{OH}$ (39)	<i>R</i>	$[\alpha]_D (-)$	sex (F)	Coleo.	<i>Trogoderma inclusum</i> (hide beetle)	120 [69], 122 (74)	122 (74)
	$\text{E}8, \text{Me}14-16:\text{OH}$?		sex (F)	Coleo.	<i>Trogoderma glabrum</i> (hide beetle)	511 [75]	
	$\text{Z}8, \text{Me}14-16:\text{Ald}$ (40) [trogodermal]	<i>R</i>		sex (F)	Coleo.	<i>Trogoderma granarium</i> (hide beetle) #4	123 [76], 121 (80), 726 (80)	125 (78), 126 (82), 103 (14)
		<i>S</i>					714 (78), 715 (79)	124 (77)
	$\text{E}8, \text{Me}14-16:\text{Ald}$ [trogodermal]	<i>R</i>		sex (F)	Coleo.	<i>Trogoderma granarium</i> (hide beetle) #5	123 [76], 121 (80), 726 (80)	126 (82)

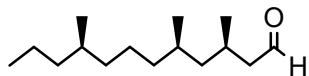
		S			714 (78), 715 (79)	124 (77)
C ₂₉	Me12,Me20-29:OMe	?	species recognition	[Araneae] <i>Tetragnatha extensa</i> (long jawed spider)	540 [21]	
	Me8,Me14,Me20-29:OMe	?	species recognition	[Araneae] <i>Tetragnatha extensa</i> (long jawed spider)	540 [21]	



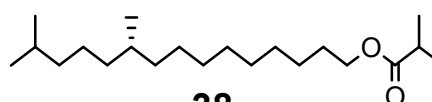
27



29



34



38

^a Compounds are arranged in order of length of the main chains.

^b GC* and HPLC* indicate analyses with the following enantioselective columns; #A, Cyclodex-B; #B, CycloSil-B (30% heptakis (2,3-di-*O*-methyl-6-*O*-*t*-butyl dimethylsilyl)- β -cyclodextrin in DB-1701); #C, Shiseido Ceramospher chiral RU-1 S-5; #D, octakis(6-*O*-methyl-2,3-di-*O*-phenyl)- γ -cyclodextrin; #E, CP-cyclodextrin- β -2,3,6-M-19; #G, β -DEX 225; #H, heptakis(2,3-di-*O*-acetyl-6-*O*-TBDMS)- β -cyclodextrin. #F: Analysis after oxidation and derivatization with (*R*)-1-phenylethylamine. #I: The coupling constant ($J_{3,4} = 4$ Hz) indicates *syn* configuration. #J: Chirasil-DEX CB

^c Coleo. = Coleoptera, Hetero. = Heteroptera, Hymeno. = Hymenoptera, Lepido. = Lepidoptera, Strepsi. = Strepsiptera.

^d Also identified from *Cataglyphis diehlii*, *C. savignyi*, and *C. viaticus* (#1); *Tribolium audax*, *T. brevicornis*, and *T. destructor* (#2); *Bombus impatiens* and *B. jonellus* (#3); *Trogoderma glabrum*, *T. inclusum* and *T. variabile* (#4). and *Trogoderma glabrum* (#5)

^e (Year of publication, 19XX or 20XX). [] indicates year when the publication was reported before determination of the absolute configuration.

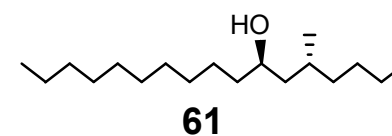
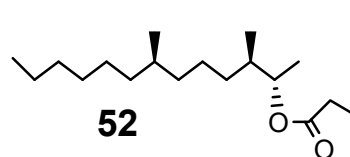
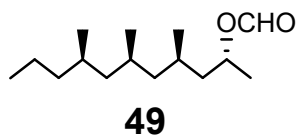
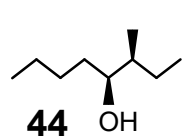
Table 3. Secondary alcohols and their esters: Pheromones and related compounds identified from insects and mites. ^a

Pheromone			Insecta and [Arachnida]		Reference ^e	
Structure [Trivial name]	Configuration and analytical method ^b	Function (Producer)	Order ^c	Species ^d	Identifi- cation	Stereoselective synthesis
C ₃ (NMe ₂) ₁ ,Me ₂ -3:2-OH	achiral	aggregation	Dictyo..	<i>Blattella germanica</i> (cockroach)	634 (90)	
C ₅ Me ₃ -5:2-OH	?	gland secretion	Hymeno.	<i>Crematogaster nigriceps</i> (ant)	603 [02]	
C ₆ Me ₃ -6:2-OH	?	gland secretion	Hymeno.	<i>Pseudomyrmex nigrocincta</i> (ant)	588 [05]	
Me ₃ ,Me ₅ -6:2-OH (41)	?	sex	Hetero.	<i>Triatoma dimidiata</i> (assassin bug)	127 [13]	
Me ₄ -6:3-OH (42) + Me ₄ -6:3-one (64)	3 <i>R</i> ,4 <i>S</i> GC #A		Hymeno.	<i>Tetramorium impurum</i> (ant)	128 (81)	129 (00)
C ₇ Me ₂ -7:4-OH	?	aggregation (M)	Coleo.	<i>Metamasius hemipterus</i> <i>Rhabdoscelus obscurus</i> (weevil) <i>Scyphophorus acupunctatus</i> (bark beetle)	433 [97] 465 [00] 561 [03], 562 [08]	
Me ₄ -7:3-OH (43) (= Me ₄ -7:5-OH)	3 <i>S</i> ,4 <i>S</i> GC* #C	aggregation	Coleo.	(1) <i>Scolytus multistriatus</i> , <i>S. amygdali</i> , (2) <i>S. scolytus</i> (3) <i>Scolytus laevis</i> (bark beetle)	(1) 131 [75], 132 (77). 133 (04) (2) 362 [77], 697 [83] (3) 669 (10)	133 (04), 361 (17)
	3 <i>R</i> ,4 <i>S</i> GC* #B	trail	Hymeno.	<i>Leptogenys diminuta</i>	130 (88), 444 [00]	361 (17)
	?	gland secretion		<i>Paraponera clavata</i>	618 [84]	

		?		alarm		<i>Ooceraea biroi</i> (ant)	689 [23]	
		?		allomone ?	[Opiliones]	<i>Leiobunum townsendi</i> (spider: harvestman)	687 [85]	
	E4,Me4-7:3-OH	?		allomone ?	[Opiliones]	<i>Leiobunum townsendi</i> (spider: harvestman)	687 [85]	
	Me4-7:3-OR (= Me4-7:5-OR)	?		gland secretion	Hymeno.	<i>Leptogenys diminuta</i> (ant)	444 [00]	
	Me6-7:2-OH	?		alarm ?	Hetero.	<i>Triatoma phyllosoma</i> , <i>T.</i> <i>longipennis</i> , <i>T. pallidipennis</i>	733 [18]	
	E2,Me6-7:4-OH [rhynchophorol]	S		aggregation (M)	Coleo.	<i>Rhynchophorus palmarum</i> , <i>Rhabdoscelus obscurus</i> (weevil)	467 (92) 465 [00]	467 (92), 580 (92)
C ₈	Me7-8:2-OH	achiral		allomone ?	[Opiliones]	<i>Gonyleptes horridus</i> (spider: harvestman)	716 (23)	
	Me2-8:4-OH	S		aggregation (M)	Coleo.	<i>Metamasius hemipterus</i> <i>Rhabdoscelus obscurus</i> <i>Sphenophorus levis</i> (weevil) <i>Scyphophorus acupunctatus</i> (bark beetle)	433 [97] 465 [00] 466 (03) 561 [03], 562 [08]	
	Me3-8:4-OH (44) (= Me6-8:5-OH) [phoenicol]	3S,4S	GC* #D	aggregation (M)	Coleo.	<i>Rhynchophorus phoenicis</i> (weevil) #1	134 [93], 135 (94)	136 (93), 135 (94), 137 (99), 138 (11)
	Me5-8:4-OH (45) (= Me4-8:5-OH) [cruentol]	4S,5S	GC* #D	aggregation (M)	Coleo.	<i>Rhynchophorus cruentatus</i> (weevil)	139 [94], 135 (94)	135 (94), 137 (99), 636 (14)
C ₉	Me4-9:5-OH (46) [ferrugineol]	4S,5S	GC* #D	aggregation (M)	Coleo.	(1) <i>Rhynchophorus ferrugineus</i> , (2) <i>Metamasius hemipterus</i> (weevil) #2	(1) 140 [93], 141 (95), (2) 433 (97)	142 (93), 137 (99), 138 (11), 636 (14), 665 [17], 666 [21]
	E6,Me7-9:3-OAc [quadrilure]	3R		aggregation (M)	Coleo.	<i>Cathartus quadricollis</i> (flat bark beetle)	646 (88)	
C ₁₀	Me8-10:2-OCOEt (47)	2R,8R		sex (F)	Coleo.	<i>Diabrotica virgifera</i>	143 [82],	145 (84), 146 (85),

					(leaf beetle)	144 (84)	147 (86), 225 (02), 363 (90), 364 (18), 657 [15]
		2 <i>S</i> ,8 <i>R</i>			<i>Diabrotica longicornis</i> (leaf beetle)	649 (86)	
C ₁₁	Me4,Me6,Δ7,Me8,Δ9-11:5-OH (48)	4 <i>R</i> *,5 <i>R</i> *,6 <i>S</i> *, 7 <i>E</i> ,9 <i>E</i> #a		gland secretion	Dictyo. <i>Cryptocercus punctulatus</i> (cockroach) #3	148 [91]	149 (90)
	Me4,Me6,Me8-11:2-OFo (49) [lardolure]	2 <i>R</i> ,4 <i>R</i> ,6 <i>R</i> ,8 <i>R</i>		aggregation	[Astigmata] <i>Lardoglyphus konoii</i> (acarid mite)	150 [82], 151 (86), 152 (94)	153 (86), 154 (90), 155 (95), 156 (96), 157 (05), 158 (12)
	Me3,Me9-11:2-OCOEt (50)	2 <i>S</i> ,3 <i>R</i> ,9 <i>S</i>		sex (F)	Hymeno. <i>Diprion nipponica</i> (sawfly)	159 (98), 160 (02)	
C ₁₂	Me3,Me9-12:6-OH	?		trail	Hymeno. <i>Leptogenys peuqueti</i> (ant)	443 [97]	
C ₁₃	Me4,Me10-13:7-OH	4 <i>R</i> ,10 <i>R</i>		trail	Hymeno. <i>Leptogenys peuqueti</i> (ant)	443 (97)	
	Me3,Me7-13:2-OAc (51) + Me3,Me7-13:2-OCOEt (52) <Me3,Me7-13:2-OH> ^f	2 <i>S</i> ,3 <i>R</i> ,7 <i>R</i> 2 <i>S</i> ,3 <i>R</i> ,7 <i>R</i> GC #A		sex (F)	Hymeno. <i>Diprion pini</i> (sawfly) #4	161 (95), 162 (11)	163 (04), 164 (06)
	Me3,Me7,Me9-13:2-OAc (53) <Me3,Me7,Me9-13:2-OH> ^f	2 <i>S</i> ,3 <i>R</i> ,7 <i>R</i> ,9 <i>S</i> GC* #E		sex (F)	Hymeno. <i>Macrodiprion nemoralis</i> (sawfly)	165 (00)	166 (11)
	Me3,Me7,Me11-13:2-OCOEt (54) <Me3,Me7,Me11-13:2-OH> ^f	2 <i>S</i> ,3 <i>S</i> ,7 <i>S</i> ,11 <i>R</i>		sex (F)	Hymeno. <i>Microdiprion pallipes</i> (sawfly)	167 [98], 168 (03)	169 (99), 170 (04)
C ₁₄	Me3,Me7-14:2-OCOEt (55)	2 <i>S</i> ,3 <i>R</i> ,7 <i>R</i>		sex (F)	Hymeno. <i>Gilpinia pallida</i> (sawfly)	171 (06)	171 (06), 365 (13), 366 (14)
	Me4-14:7-OAc + Me4-14:7-OH	? ?		trail	Hymeno. <i>Leptogenys peuqueti</i> (ant)	443 [97]	
C ₁₅	Me3,Me7-15:2-OAc (56) [diprionyl acetate] <Me3,Me7-15:2-OH> ^f (58)	2 <i>S</i> ,3 <i>S</i> ,7 <i>S</i> GC #A		sex (F)	Hymeno. (1)(2) <i>Neodiprion lecontei</i> , (1)(3)(5)(6) <i>N. sertifer</i> , (3) <i>N. nannulus</i> , <i>N. sertifer</i> , (4) <i>N. pinetum</i> (sawfly) #5	(1) 172 [76], (2) 614 [79] (3) 475 (87). (4) 476 (88), (5) 173 (00),	174 (81), 175 (01), 176 (04), 367 (07), 177 (12), 178 (12), 645 (22)

							(6) 162 (11)
	Me3,Me7-15:2-OCOEt (57)		sex (F)	Hymeno.	<i>Diprion similis</i>		172 [76], 174 (81), 175 (01),
	<Me3,Me7-15:2-OH> ^f (58)	2R,3R,7R					701 (80) 176 (04), 177 (12),
		2S,3R,7R	GC #A				702 (82), 178 (12), 367 (07),
		2S,3S,7S			<i>Neodiprion sertifer</i>		476 (88) 503 [82]
					(sawfly)		173 (00),
	<Me3-15:2-OH> ^f (59)	2S,3R	GC* #E	sex (F)	Hymeno.	<i>Gilpinia frutetorum</i>	162 (11)
	<Me3,Me7-15:2-OH> ^f (58)	2S,3R,7R				(sawfly) #6	179 (09) 179 (09)
	Me6,Me10,Me14-15:2-OH (60)	2R,6R,10R	sex (F)	Lepido.	(1) <i>Corcyra cephalonica</i> ,		(1) 180 [87], 182 (00), 183 (11)
					(2) <i>Aphomia sociella</i>		181 (91),
					(pyralid moth)		(2) 368 (12)
C ₁₇	Me5-17:7-OH (61)	5R,7R	sex (F)	Lepido.	<i>Miltchrista calamine</i>		184 (11) 185 (14), 615 (22)
					(lichen moth)		
C ₂₉	Me19-29:6-OAc (62)	6R,19R	HPLC #F	sex (F)	Diptera	<i>Cochliomyia hominivorax</i>	186 [93], 189 (04), 190 (04)
	+ Me15-29:7-OAc (63)	7R,15SR				(blowfly)	187 [07],
							188 (09)



^a Compounds are arranged in order of length of the main chains.

^b #A, Analyzed after derivatization with (*S*)-2-acetoxypropionyl chloride. GC* indicates analyses with the following enantioselective columns; #B, Mn(II)-bis[3-heptafluorobutyryl-(1*R*)-camphorate] in methylsilicone OV-101; #C, Lipodex G, octakis-(2,3-di-*O*-pentyl-6-*O*-methyl)- γ -cyclodextrin; #D, Cyclodex-B; #E, XE-60-(*S*)-valine-(*S*)-2-phenylethylamide. #G, Synthetic alcohol intermediates were analyzed after derivatization with (1*R*,2*R*)-2-(2,3-anthracenedicarboximido)cyclohexanecarboxylic acid.

^c Coleo. = Coleoptera, Dictyo. = Dictyoptera, Hymeno. = Hymenoptera, Lepido. = Lepidoptera.

^d Also identified from *Rhynchophorus cruentatus* (#1); *Rhynchophorus bilineatus*, *R. vulneratus*, *Dynamis borassi*, and *Metamasius hemipterus* (#2); *Cryptocercus kyebangensis* (#3); *Diprion jingyuanensis* (#4); *Neodiprion pratti* and *N. taedae* (#5); and *Gilpinia socia* (#6).

^e (Year of publication, 19XX or 20XX). [] indicates year when the publication was reported before determination of the absolute configuration.

^f Identification of alcohols as biosynthetic precursors.

Table 4. Ketones: Pheromones and related compounds identified from insects, spiders, and mites. ^a

Pheromone			Insecta and [Arachnida]		Reference ^e		
Structure [Trivial name]	Configuration and analytical method ^b	Function (Producer)	Order ^c	Species ^d	Identifi- cation	Stereoselective synthesis	
C ₅ Me4-5:4-OH, 2-one	achiral	alarm	Hymeno.	<i>Tapinoma simrothi</i> (ant)	564 (83)		
		sex (M) ?	Hetero.	<i>Halobates hawaiiensis</i> (water strider)	566 (01)		
C ₆ Me3-6:2-one	?	alarm	Hetero.	<i>Dipetalogaster maximus</i> <i>Triatoma phyllosoma</i> , <i>T.</i> <i>longipennis</i> , <i>T. pallidipenni</i> (assassin bug)	696 [83] 733 [18]		
		gland secretion	Hymeno.	<i>Pseudomyrmex spinicola</i> , <i>P.</i> <i>nigrocincta</i> (ant)	588 [05]		
		alarm	Hymeno.	<i>Polyrhachis vicina</i> (ant)	427 [19]		
Me4-6:3-one (64)	S ? ?	alarm	Hymeno.	<i>Manica mutica</i> (ant) #1	191 [72], 192 (92)	129 (00)	
		allomone	Coleoptera	<i>Staphylinus olens</i> . (rove beetle)	712 [75]		
		allomone	[Opiliones]	<i>Leiobunum nigripalpi</i> (spider: harvestman)	686 [77]		
E4,Me4-6:3-one	achiral	allomone	[Opiliones]	<i>Leiobunum nigripalpi</i> (spider: harvestman)	686 (77)		
Δ1,Me4-6:3-one	? ? ?	allomone ?	Coleo.	<i>Amarygmus tristis</i>	703 [82]		
					<i>Byrsax macleayi</i>	704 [92]	
			[Opiliones].		<i>Gonyleptes curvicornis</i> , <i>Parampheres</i> sp.	544 [05]	

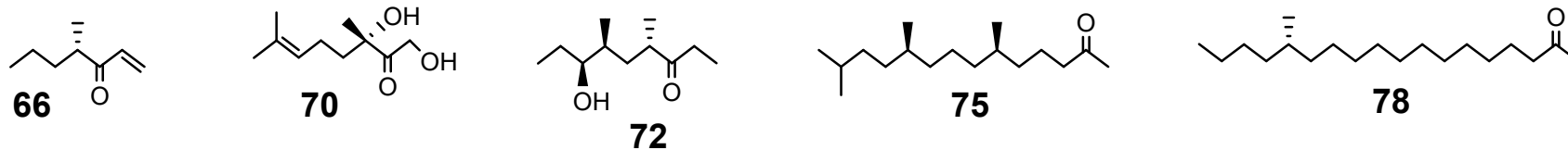
		<i>R</i>				<i>Gonyleptes saprophilus</i> , <i>Acanthogonyleptes pulche</i> (spider: harvestman)	545 (13)	
$\Delta 1, \text{Me}5\text{-}6\text{:}3\text{-one}$	achiral		allomone ?	[Opiliones]		<i>Neosadocus maximus</i> , <i>Zortalia inscripta</i> <i>Sodreana lprevosti</i> , <i>S. barbiellini</i> (spider: harvestman)	544 (05) 545 (13)	
$\text{Me}3, \text{Me}4\text{-}6\text{:}2\text{-one}$?		alarm ?	Hymeno.		<i>Apterostigma pilosum</i> (ant)	499 [17]	
C_7 $\text{Me}2\text{-}7\text{:}4\text{-one}$	achiral		alarm	Hymeno.		<i>Tapinoma simrothi</i> (ant)	564 (83)	
			aggregation (M)	Coleo.		<i>Halobates hawaiiensis</i> <i>Scyphophorus acupunctatus</i> (bark beetle)	565 (07) 561 (08)	
$\text{Me}4\text{-}7\text{:}3\text{-one}$ (65)	<i>S</i>	$[\alpha]_D (+)$	alarm	Hymeno.		<i>Atta texana</i>	193 (74),	198 (74)
	?					<i>A. colombica</i> , <i>A. cephalotes</i>	499 [17]	
	?					<i>Ooceraea biroi</i> (ant) #2	689 [23]	
	<i>S</i>	GC* #A	trail			<i>Aphaenogaster cockerelli</i> , <i>A. albisetosus</i> (ant)	194 (95)	
	<i>S</i>		allomone			<i>Dasymutilla occidentalis</i> (wasp, velvet ant) #4	196 (80)	
	?		gland secretion			<i>Paraponera clavata</i> (ant)	618 [84]	
	<i>S</i>		aggregation ?	Coleo..		<i>Scolytus scolytus</i> , <i>S. multistriatus</i> (bark beetle)	697 (83)	
	?		allomone ?			<i>Ocypus similis</i> , <i>O. olens</i> (rove beetle)	698 [90]	
	<i>S</i>	GC* #B	sex (F)	Tricho.		<i>Potamophylax latipennis</i> (caddis fly) #3	195 (01)	

	S		allomone	[Opiliones]	<i>Leiobunum vittatum</i> <i>Leiobunum formosum</i> , <i>Leiobunum speciosum</i> , <i>Leiobunum ventricosum</i> <i>Hadrobunus maculosus</i> <i>Leiobunum townsendi</i> (spider: harvestman)	197 (71) 687 [71] 685 [76] 688 [85]	
Δ 1,Me4-7:3-one (66) [chichimol ketone]	S	$[\alpha]_D$ (+)	allomone	Phasmatodea	<i>Agathemera elegans</i> (walking stick)	199 (06)	200 (09)
	?		allomone ?	[Opiliones]	<i>Gonyleptes horridus</i> , <i>Gonyleptes curvicornis</i> (harvestman)	716 [23]	
Δ 4,Me4-7:3-one	achiral		gland secretion	Hymeno.	<i>Leptanilla</i> sp, <i>Atta laevigata</i> (ant)	612 (98)	
						613 (99)	
Δ 2,Me6-7:4-one	achiral		aggregation (M)	Coleo.	<i>Metamasius spinolae</i> (bark beetle)	565 (07)	
Me2-7:2-OH, 4-one	achiral		aggregation (M)	Coleo.	<i>Metamasius spinolae</i> (bark beetle)	565 (07)	
Me4-7:5-OH, 3-one (67) [sitophilone, sitophilure]	4 <i>S</i> ,5 <i>R</i>		aggregation	Coleo.	<i>Sitophilus oryzae</i> (weevil) #5 <i>Rhinostomus barbirostris</i> (weevil)	201 [84], 507 [85], 202 (87)	203 (86), 204 (88), 205 (06)
						369 (18)	
	4 <i>S</i> ,5 <i>S</i>		aggregation	Coleo.	<i>Sitona discoideus</i> (weevil)	509 (13)	
Me4-7:3-one, 5-one	achiral		aggregation	Coleo.	<i>Sitona lineatus</i> <i>Sitona discoideus</i> (weevil)	508 (84)	
						509 (13)	
Me3,Me6-7:2-one, 4-one	?		sex (F)	Diptera	<i>Megaselia halterata</i> (humpbacked fly)	510 [82]	

C ₈	Me2-8:4-one	achiral		aggregation (M)	Coleo.	<i>Scyphophorus acupunctatus</i> (bark beetle)	561 (08)	
	Me3,Me5-8:2-one	?		alarm?	Hymeno.	<i>Apterostigma pilosum</i>	499 [17]	
	E4,Me4,Me6-8:3-one (68) [manicone]	S	GC* #C	alarm	Hymeno.	<i>Manica mutica</i> , <i>M. bradleyi</i> <i>M. rubida</i> (ant) #1	191 [72] 206 (88)	206 (88)
	Me4,E6,Me6-8:3-one	?		allomone	[Opiliones]	<i>Leiobunum calcar</i> (spider: harvestman)	685 [76], 686 [77]	
	Me6-8:3-one (69)	?		alarm gland secretion	Hymeno.	<i>Crematogaster ashmeadi</i> <i>Myrmica scabrinodis</i> (ant) #6	207 [72] 717 [78], 718 [78]	208 (88), 209 (10), 210 (13), 477 [15]
	Me7-8:4-one	achiral		gland secretion	Hymeno.	<i>Andrena clarkella</i> , <i>A. fucata</i> (mining bee)	727, (76)	
	E6,Me6-8:3-one, 8-OH	achiral		aggregation (M)	Coleo.	<i>Oulema melanopus</i> (leaf beetle)	446 (02), 596 (03)	446 (02)
	Me3,Δ6,Me7-8:1-OH,3-OH,2-one ^f (70)	S	GC* #D	aggregation (M)	Coleo.	<i>Leptinotarsa decemlineata</i> (leaf beetle)	211 (02), 430 (02)	212 (05), 213 (09), 214 (13), 215 (14)
C ₉	Me3-9:2-one	?		gland secretion	Hymeno.	<i>Apterostigma dentigerum</i> (ant)	451 [17]	
	Me8-9:2-one	achiral		sex (F)	[Araneae]	<i>Agelenopsis aperta</i> (spider)	468 (01)	
	Me6-9:3-one	?		sex (F)	Tricho.	<i>Hesperophylax occidentalis</i> (caddis fly)	604 [96]	675 [18]
	Me4-9:5-one [ferruginone]	?		aggregation (M)	Coleo.	<i>Rhynchophorus ferrugineus</i> , <i>R. vulneratus</i> (weevil)	607 [93]	665 [17], 676 [18], 666 [21]
	Me4,Δ7,Me8-9:2-one	?		alarm	Hymeno.	<i>Vespa velutina</i> (wasp)	743 [17], 744 [23]	
	Me4,Me6-9:3-one (71) + C8 derivatives	4S,6S	GC* #B	sex (F)	Tricho.	<i>Potamophylax latipennis</i> (caddis fly) #3	195 (01)	195 (01)

	Me4,E6,Me6-9:3-one	?		allomone	[Opiliones]	<i>Leiobunum longipes</i> (spider: harvestman)	685 [76]	
	Me4,Me6-9:7-OH,3-one (72) [serricornin]	4 <i>S</i> ,6 <i>S</i> ,7 <i>S</i>		sex (F)	Coleo.	<i>Lasioderma serricorne</i> (deathwatch beetle)	216 [79], 639 (82), 217 (84), 218 (01)	639 (82), 640 (85), 219 (85), 220 (11), 678 (20)
C ₁₀	Me2-10:5-one	achiral		gland secretion	Hymeno.	<i>Andrena clarkella</i> , <i>A. fucata</i> (mining bee)	727, (76)	
	E2,Me5,E6,Me7,E8-10:4-one	<i>R</i>		sex (F)	Homo.	<i>Matsucoccus josephi</i> (scale)	491 [93], 492 (95)	493 [93], 494 (94), 486 [95], 487 [95], 489 [97], 490 (00)
	E2,Me5,Z6,Me7,E8-10:4-one	<i>R</i>		sex (F)	Homo.	<i>Matsucoccus josephi</i> (scale)	491 [93], 492 (95)	
	Me4,Me6,Me8-10:2-one (73) [chortolure]	4 <i>R</i> ,6 <i>R</i> ,8 <i>R</i>	GC* #E	aggregation (F &M)	[Astigmata]	<i>Chortoglyphus arcuatus</i> (storage mite)	221 (04)	221 (04)
C ₁₁	Me4,Me6,E7,Me8,E9-11:3-one [graphisurone]	4 <i>R</i> ,6 <i>S</i>		aggregation (M)	Coleo.	<i>Graphisurus fasciatus</i> , <i>Eutrypanus dorsalis</i> (longhorn beetle)	737 (24)	737 (24)
C ₁₂	Me3,Me7,E8,Me9,E10-12:6-one	3 <i>S</i> ,7 <i>R</i>		sex (F)	Homo.	<i>Matsucoccus feytaudi</i> (scale)	497 [90], 498 (94)	495 (91), 496 (93), 494 (94), 486 [95], 487 [95], 489 [97], 490 (00)
	Me3,Me7,Z8,Me9,E10-12:6-one	?		sex (F)	Homo.	<i>Matsucoccus feytaudi</i> (scale)	497 [90], 498 (94)	487 [95]
C ₁₃	Me10-13:2-one (74)	<i>R</i>		sex (F)	Coleo.	<i>Diabrotica undecimpunctata</i> (leaf beetle)	222 (83)	223 (83), 224 (85), 225 (02), 226 (03), 55 (03), 227 (09), 228 (12), 657 [15], 673 (16)
	E2,E4,Me4,Me6,Me10,Me12-13: 7-one [matsuone]	6 <i>R</i> ,10 <i>R</i>		sex (F)	Homo.	(1)(2) <i>Matsucoccus matsumurae</i> (1)(2)(3) <i>M. thunbergiana</i>	(1) 478 [89], (2) 479 [91],	482 (91), 483 (93), 484 (93), 485 (95),

							(1)(2)(4) <i>M. resinosae</i> (scale)	(3) 480 (94), (4) 481 (95)	481 (95), 486 [95], 487 [95], 488 (96), 489 [97], 490 (00), 677 [19]
C ₁₄	Me6,Me10,Me13-14:2-one [pallantione]	(75)	6R,10S	GC* #F	sex (M)	Hetero.	<i>Pallantia macunaima</i> (stink bug)	229 (13)	230 (13), 370 (18)
	dimer of Δ1,Me5-6:3-one		?		allomone ?	[Opiliones].	<i>Sodreana lprevosti</i> , <i>Sodreana barbiellini</i>	545 [13]	
							<i>Gonyleptes horridus</i> , <i>Gonyleptes curvicornis</i> (spider: harvestman)	716 [23]	
	dimer of Δ1,Me4-6:3-one		?		allomone ?	[Opiliones].	<i>Gonyleptes saprophilus</i> <i>Gonyleptes horridus</i> , <i>Gonyleptes curvicornis</i> (spider: harvestman)	545 [13] 716 [23]	
C ₁₅	Me6,Me12-15:2-one	(76)	6R,12R		sex (F)	Coleo.	<i>Diabrotica balteata</i> (leaf beetle)	231 [87], 232 (91)	233 (88), 234 (95), 225 (02), 674 (15), 729 (24)
	Me6,Me10, Me14-15:2-one (+ Me6,Me10, Me14-15:2-OH)		6R,10R	GC* #I	sex (M)	Lepido.	<i>Bicyclus anynana</i> (butterfly) #7	371 [08], 372 (15)	372 (15)
					sex (F)	Lepido.	<i>Aphomia sociella</i> (pyralid moth)	368 (12)	
C ₁₈	Me6-18:2-one (77) + Me14-18:2-one (78) + Me6,Me14-18:2-one (79)		S S	HPLC* #G	sex (F)	Lepido.	<i>Lyclene dharmia</i> (lichen moth)	235 [07], 236 (10)	237 (09), 238 (12), 738 (24)
C ₂₇	Me3,Me11-27:2-one (81) + Me3,Me11-27:2-one, 27-OH		3S,11S		sex (F)	Dictyo.	<i>Blattella germanica</i> (cockroach)	243 (04) 725 [08]	242 (08)
C ₂₉	Me3,Me11-29:2-one (80) + Me3,Me11-29:2-one, 29-OH		3S,11S	ORD #H	sex (F)	Dictyo.	<i>Blattella germanica</i> (cockroach)	239 [74], 240 (79) 723 [76], 725 [08]	241 (81), 242 (08) 724 [77]



^a Compounds are arranged in order of length of the main chains.

^b GC* and HPLC* indicate analyses with the following enantioselective columns; #A, 6-*O*-methyl-2,3-di-*O*-pentyl- γ -cyclodextrin; #B, 60% octakis-(6-*O*-methyl-2,3-di-*O*-pentyl)- γ -cyclodextrin in OV1701, #C, FSCC coated with OV-1 containing 1% nickel(II) bis[3-(heptafluorobutyryl)-(1*R*)-camphorate]; #D, Chiraldex™ B-DM; #E, heptakis(2,6-di-*O*-dimethyl-3-*O*-pentyl)- β -cyclodextrin; #F, β -DEX 325 (2,3-di-*O*-methyl-6-*O*-TBDMS- β -cyclodextrin, after LiAlH₄ reduction); #G, Chiralpak AD-H. #H: ORD measurement and NMR analysis with a chiral shift reagent; #I: Analyzed as (*S*)-2-acetoxypropionyl ester after reduction to alcohol.

^c Coleo. = Coleoptera, Dictyo. = Dictyoptera, Hymeno. = Hymenoptera, Lepido. = Lepidoptera, Tricho. = Trichoptera.

^d Also identified from mandibular glands of *Manica bradleyi* and a head of *Tetramorium impurum* (#1, see Table 3); several species in *Atta*, *Aphaenogaster*, *Pseudomyrmex*, *Pogonomyrmex*, and *Sericomyrmex* (#2); *Potamophylax cingulatus* and *Glyphotaelius pellucidus* (#3); several species in Hymenoptera and Coleoptera (#4); *Sitophilus zeamais* (#5); several species in Hymenoptera and Trichoptera (#6); and several species in *Bicyclus* (#7).

^e (Year of publication, 19XX or 20XX). [] indicates year when the publication was reported before determination of the absolute configuration.

^f 1,3-Dihydroxy-3,7-dimethyl-6-octen-2-one

Table 5. Carboxylic acids and their derivatives: Pheromones and allomones identified from insects and spiders. ^a

Pheromone			Insecta		Reference ^e	
Structure [trivial name]	Configuration and analytical method ^b	Function (Producer)	Order ^c	Species ^d	Identifi- cation	Stereoselective synthesis
C ₃ Me2-3:acid	achiral	allomone ? aggregation alarm ? aggregation	Lepido.	<i>Graphium doson</i> , <i>G.</i> <i>sarpedon</i> (butterfly)	610 (80)	
			Hetero.	<i>Rhodnius prolixus</i> <i>Triatoma phyllosoma</i> , <i>T.</i> <i>longipennis</i> , <i>T. pallidipennis</i> (assassin bug)	445 (02) 733 (18)	
			[Ixodida]	<i>Amblyomma hebraeum</i> (tick)	611 (02)	
			Lepido.	<i>Graphium doson</i> , <i>G.</i> <i>sarpedon</i> <i>Parnassius glacialis</i> <i>Chilasa epycides</i> , <i>Papilio</i> <i>demoleus</i> , <i>P. macilentus</i> , <i>P.</i> <i>troilus</i> (butterfly)	610 (80) 616 (95) 617 (06)	
Me2-3:Me ester	achiral	allomone ?	Lepido.	<i>Graphium doson</i> , <i>G.</i> <i>sarpedon</i> <i>Parnassius glacialis</i> <i>Chilasa epycides</i> , <i>Papilio</i> <i>demoleus</i> , <i>P. macilentus</i> , <i>P.</i> <i>troilus</i> (butterfly)	610 (80) 616 (95) 617 (06)	
C ₄ Me2-4:acid	?	allomone	Lepido.	<i>Papilio machaon</i> , <i>P. protenor</i> (butterfly)	461 [65] 462 [80]	
			Coleo.	<i>Oodes vicarious</i> (ground beetle)	463 [82]	
			Thysano.	<i>Varshneyia pasaniae</i> (thrips)	464 [88]	
			Coleo.	<i>Chrysomela lapponica</i> <i>C. mainensis</i> , <i>C. walshi</i> (leaf beetle)	608 [97] 609 [99]	
Z2,Me2-4:acid [angelic acid]	achiral	allomone ?	Coleo.	<i>Pterostichus subsulcatus</i>	637 (89)	

					<i>Carabus violaceus</i> (ground beetle)	706 (20)	
Me2,E2-4:acid [tiglic acid]	achiral	allomone ?	Coleo.	<i>Carabus yaconinus</i>	599 (85)		
				<i>C. montivagus, C. caelatus</i>	706 (20)		
				<i>Pterostichus subsulcatus</i>	637 (89)		
				<i>P. californicus</i> (ground beetle)	601 (07)		
				<i>Trachypachus slevini</i> (false ground beetle)	600 (04)		
E2,Me2-4:Et ester [ethyl tiglate]	achiral	aggregation (M)	Diptera	<i>Drosophila virilis</i>	597 (85)		
				<i>D. americana, D. lummei, D. novamexicana</i>	684 (86)		
				<i>D. hydei</i>	648 (87)		
				<i>D. borealis, D. littoralis</i> (fruit fly)	598 (88)		
E2,Me2-4:iPr ester [isopropyl tiglate]	achiral	aggregation (M)	Diptera	<i>Drosophila hydei</i> (fruit fly)	648 (87)		
E2,Me2-4:E2-6-OH ester	achiral	gland secretion	Hetero.	<i>Pachylis laticornis</i> (true bug)	705 (82)		
Et2-4:2-OH, β -lactone	2 <i>S</i> ,3 <i>S</i>	sex (M)	Lepido.	<i>Idea leuconoe</i> (butterfly)	469 [96], 470 (02)		
iPro2-4:2-OH, β -lactone [viridifloric β -lactone]	2 <i>S</i> ,3 <i>S</i>	sex (M)	Lepido.	<i>Idea leuconoe</i> (butterfly)	469 [96], 470 (02)		
NH22,Me3-4:Me ester [L-valine methyl ester]	<i>S</i>	sex (F)	Coleo.	<i>Phyllophaga anxia, P. georgiana</i> (scarab beetle)	458 (97), 471 (09)		
Me2-4:Me2-4-OH ester	?	aggregation (M)	Hetero.	<i>Clavigralla elongate</i> (true bug)	742 [24]		
Me2-4:Me2-4-NH2 amide	2 <i>S</i> ,2' <i>S</i>	sex (F)	Coleo.	<i>Migdolus fryanus</i> (longhorn beetle)	472 (94)	641 (01), 642 (22)	
(CHOHCH3)2,Me3-4: γ -lactone	2 <i>S</i> ,3 <i>R</i> ,1' <i>S</i>	sex (M) ?	Lepido.	<i>Hymenitis dercetis</i>	529 [76]		

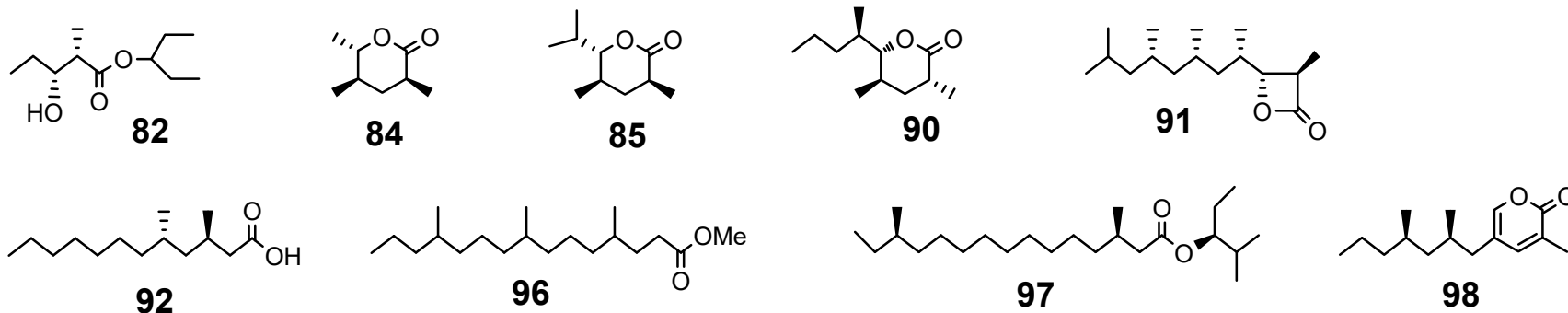
	[ithomiolide A]				<i>Ceratinia tutia</i>	530 (04)	
					<i>Ithomia salapia</i> (butterfly)	668 [20]	
	Ac2,Me3-4:γ-lactone [ithomiolide B]	2 <i>S</i> ,3 <i>R</i>	sex (M) ?	Lepido.	<i>Prittwitzia hymaenea</i>	722 (92)	
					<i>Episcada clausina</i> (butterfly)	530 (04)	
C ₅	Me2-5:acid	?	allomone ?	(Geophilo morpha)	<i>Clinopodes flavidus</i> (centipede)	735 [24]	
	Me2-5:3-OH, Et-Pr ester ^f (82) [sitophilate]	2 <i>S</i> ,3 <i>R</i>	NMR #A	aggregation (M)	Coleo. <i>Sitophilus granaries</i> (weevil)	244 (87), 245 (89)	246 (89), 247 (89), 248 (96), 249 (01), 250 (07), 251 (12), 252 (13)
	E2,(C ₂ H ₄ OH) ₃ ,Me4-5:Me ester	achiral	sex (M)	Coleo.	<i>Diaprepes abbreviates</i> (weevil)	542 (12)	
	NH ₂ ,Me3-5:Me ester [L-isoleucine methyl ester]	2 <i>S</i> ,3 <i>S</i>	sex (F)	Coleo.	<i>Holotrichia parallela</i>	457 (92)	
					<i>Phyllophaga anxia</i>	458 (97)	
					<i>Phyllophaga elenans</i> (scarab beetle)	459 (03)	
	HCONH ₂ ,Me3-5:Me ester [N-formyl L-isoleucine methyl ester]	2 <i>S</i> ,3 <i>S</i>	sex (F)	Coleo.	<i>Phyllophaga elenans</i> (scarab beetle)	459 (03)	
	MeCONH ₂ ,Me3-5:Me ester [N-acetyl L-isoleucine methyl ester]	2 <i>S</i> ,3 <i>S</i>	sex (F)	Coleo.	<i>Phyllophaga elenans</i> (scarab beetle)	459 (03)	
	NH ₂ ,Me4-5:Me ester [L-leucine methyl ester]	<i>S</i>	sex (F)	Coleo.	<i>Phyllophaga lanceolata</i> (scarab beetle)	473 (03)	
	E2,Me2-5:iPr ester [trunc-call 1]	achiral	aggregation (M)	Coleo.	<i>Prostephanus truncates</i> (auger beetle)	581 (91), 582 (91), 583 (04)	
	E2,Me2-5:Me1-4-OH ester [dominicalure 1]	<i>S</i>	aggregation (M)	Coleo.	<i>Rhyzopertha dominica</i> (auger beetle)	584 [81], 585 (81), 586 [83], 692 [03], 693 [22]	644 (22)
	E2,Me2,Me4-5:iPr ester [trunc-cal 2]	achiral	aggregation (M)	Coleo.	<i>Prostephanus truncates</i> (auger beetle)	582, (91), 583, (04)	

	E2,Me2,Me4-5:Me1-4-OH ester [dominicalure 2]	S		aggregation (M)	Coleo.	<i>Rhyzopertha dominica</i> (auger beetle)	584 [81], 585 (81), 586 [83], 692 [03], 693 [22]	644 (22)
C ₆	Me2-6:acid	?		alarm ?	Hetero.	<i>Triatoma phyllosoma</i> , <i>T.</i> <i>longipennis</i> , <i>T. pallidipennis</i> (assassin bug)	733 [18]	
	Me4-6: <i>n</i> -Bu ester (83)	S		aggregation	Hetero.	<i>Neomegalotomus parvus</i> (broad-headed bug)	253 (12)	
	Z3,Me4,Δ5-6:acid	achiral		marking (M) ?	Diptera	<i>Urophora cardui</i> , <i>U. stylata</i> (fruit fly)	633 (90)	
	Δ2,Me2,Me4-6:acid	?		allomone?	Hymeno.	<i>Myrmecocystus christineae</i> , <i>M. colei</i> , <i>M. depilis</i> . <i>M.</i> <i>romaine</i> , <i>M. semirufus</i> , <i>M.</i> <i>wheeleri</i> (ant)	450 [89]	
	Me4,Δ5-6:γ-lactone [lavender lactone]	S		sex (M) ?	Lepido.	<i>Celastrina argiolus</i> (butterfly)	541 (13)	
	Me2-6:δ-lactone	2 <i>R</i> *,5 <i>S</i> *		gland secretion (M)	Hymeno.	<i>Bombus griseocollis</i> (carpenter bee)	591 [76]	592 (78)
	Me2,Me4-6:δ-lactone ^g (84)	2 <i>S</i> ,4 <i>R</i> ,5 <i>S</i>		trail	Hymeno.	(1)(2) <i>Camponotus</i> <i>herculeanus</i> , (2)(4) <i>C. socius</i> , (2) <i>C. ligniperdus</i> , <i>C. vagus</i> , <i>C. pennsylvanicus</i> , (3) <i>C.</i> <i>modoc</i> , (5) <i>C. kaura</i> (ant)	(1) 254 [95], 255 (99) (2) 255 (99), (3) 434 (19), (4) 435 (01), (5) 436 [01]	
C ₇	Me2,Me4,Me6-7:δ-lactone ^h (85)	2 <i>S</i> ,4 <i>R</i> ,5 <i>S</i>		sex (F)	Hymeno.	<i>Macrocentrus grandii</i> (parasitoid wasp)	256 [93], 257 (94)	258 (93), 259 (96), 260 (11), 373 (19)
	Me3-7:acid (86)	R	GC* #B	sex (M)	Coleo.	<i>Kheper nigroaeneus</i> (scarab)	261 (02)	261 (02), 680 (15), 675 [18]
	Me4-7:Et ester (88)	?		aggregation	Coleo.	<i>Oryctes rhinoceros</i>	263 [95]	

		(M)		(scarab)		
				<i>Nicrophorus vespilloides</i>	437 [08],	
				(burying beetle) #1	374 [17]	
	3-hydroxy-3-methoxycarbonyl-2-methylpentanedioic acid dimethyl ester [trimethyl methylcitrate]	2R,3S	sex (F)	[Araneae] <i>Argiope bruennichi</i>	527 (10)	
				(spider)		
C ₈	Me4-8:acid		aggregation (M)	Coleo. <i>Oryctes monoceros</i>	264 [94]	679 [13]
		R		<i>Oryctes rhinoceros</i>	263 [95],	
					625 (22)	660 (16), 682 (21), 625 (22)
				<i>Oryctes elegans</i>	534 [04]	
				<i>Oryctes agamemnon</i>	535 [15]	
				(scarab)		
	Me4-8:Et ester (89) [oryctelure]		aggregation (M)	Coleo. <i>Oryctes monoceros</i>	264 [94]	
		S		<i>Oryctes rhinoceros</i>	263 (95)	263 (95), 665 [17], 681 (18)
		R			625 (22)	665 [17], 625 (22)
				<i>Oryctes elegans</i>	534 [04]	
				<i>Oryctes Agamemnon</i>	535 [15]	
				(scarab)		
	E4,Me7-8:iPr ester	achiral	sex (F)	Homo. <i>Crisicoccus azalea</i>	632 (22)	
				(mealybug)		
	Me2-8:acid, 8-acid [2-methylsuberic acid]	?	secretion (F)	Coleo. <i>Callosobruchus rhodesianus</i>	728 [17]	
				(seed beetle)		
	Me3-8:acid, 8-acid [3-methylsuberic acid]	?	secretion (F)	Coleo. <i>Callosobruchus rhodesianus</i>	728 [17]	
				(seed beetle)		
	Me2,Me4,Me6-8:δ-lactone	?	trail	Hymeno. <i>Camponotus atriceps</i>	452 [96]	
				<i>Camponotus castaneus</i>	453 [03]	
				(ant)		
C ₉	E4,Me7-9:Et ester	S	sex (F)	Homo. <i>Crisicoccus azalea</i>	632 [22],	741 (24)
				(mealybug)	741 (24)	
	E4,Me7-9:iPr ester	S	sex (F)	Homo. <i>Crisicoccus azalea</i>	632 [22],	741 (24)
				(mealybug)	741 (24)	

	Me2,Me4,Me6-9: δ -lactone ⁱ (90) [invictolide]	2 <i>R</i> ,4 <i>R</i> ,5 <i>S</i> , 6 <i>R</i>		queen recognition	Hymeno.	<i>Solenopsis invicta</i> (ant)	265 [83], 266 (86)	266 (86), 267 (86), 268 (87), 269 (96), 270 (12)
	Z2,Me2,Z4,Me4,Me6-9: δ -lactone			aggregation (M)	Coleo.	<i>Rosalia alpina</i> (longhorn beetle)	528 [17]	
C ₁₀	Me9-10:Me7-8-OH ester	achiral		sex (F)	Coleo.	<i>Ectinus aterrimus</i> (click beetle)	563 (08)	563 (08)
C ₁₁	Me2,Me4,Me6,Me8,Me10-11: β -lactone ^j (91) [vittatalactone]	2 <i>R</i> ,3 <i>R</i> ,4 <i>S</i> , 6 <i>S</i> ,8 <i>S</i>	NMR #A	aggregation (M)	Coleo.	<i>Acalymma vittatum</i> (leaf beetle)	271 [05]	272 (09), 273 (10), 274 (11), 275 (11), 276 (12)
	Me2,Me8-11:Me2-11-OH ester + Me2,Me8-11:Me2,Me8-11-OH ester + others	? ?		cuticular lipid (F)	[Aranea e]	<i>Argyrodes elevatus</i> (spider)	375 [16]	375 [16]
C ₁₂	Me3,Me5-12:acid (92)	3 <i>R</i> ,5 <i>S</i>		sex (F)	Coleo.	<i>Prionus californicus</i> (longhorn beetle)	277 [09], 278 (11), 279 (11)	278 (11)
	Me3, Δ 6,Me7, Δ 10,Me11-12:Me ester (93) [methyl 2,3-dihydrofarnesoate]	3 <i>R</i> ,6 <i>E</i>	GC #C	sex (M)	Hetero.	<i>Chlorochroa ligata</i> (stink bug) #2	280 [01], 281 (01)	281 (01)
C ₁₃	Me2-13:11-OH ester	?		cuticular lipid (M)	[Aranea e]	<i>Argyrodes elevatus</i> (spider)	375 [16]	375 [16]
C ₁₅	Me4,Me8,Me12-15:Me ester (96)	?		sex (M)	Hetero.	<i>Edessa meditabunda</i> (stink bug)	285 [12]	504 (20)
	Me3,Me13-15:Et-Me-Pr ester ^k (97)	3 <i>R</i> ,13 <i>R</i> ,3' <i>S</i>		sex (F)	Lepido.	<i>Clania variegata</i> (bagworm moth)	286 [06], 287 (10)	288 (09), 287 (10), 289 (13), 376 (17), 732 (24)
	Me2,Me14-15:Glu amide	2 <i>R</i> [(<i>S</i>)-L-Glu]		marking	Diptera	<i>Ceratitis rosa</i> (fruit fly)	699 (03), 700 (10)	700 (10), 721 (23)
C ₇₊₅	Me2,Me4-7: α -pyrone ^l (98) [supellapyrone]	2 <i>R</i> ,4 <i>R</i>	GC* #D	sex (F)	Dictyo.	<i>Supella longipalpa</i> (cockroach)	290 [93], 291 (95)	292 (95), 293 (01)
C ₁₆	Z8,Me14-16:Me ester	?		sex (F)	Coleo.	<i>Trogoderma inclusum</i> (hide beetle)	120 [69], 512 [77]	122 (74)
	E8,Me14-16:Me ester	?		sex (F)	Coleo.	<i>Trogoderma glabrum</i> (hide beetle)	511 [75]	
C ₁₇	Me2,Me4-17:13-OH ester	2 <i>R</i> ,4 <i>R</i>		cuticular	[Aranea	<i>Argiope bruennichi</i>	626 (22)	

			lipid (M)	e]	(spider)	
C ₁₉	Me ₂ ,Me ₄ -19:13-OH ester	?	cuticular	[Aranea	<i>Argiope bruennichi</i>	626 [22]
			lipid (M,F)	e]	(spider)	



^a Compounds are arranged in order of length of the main chains.

^b #A, determination by Mosher's method. GC* indicates analyses with the following enantioselective columns; #B, 10% heptakis(2,3,6-tri-*O*-methyl)- β -cyclodextrin in OV-1701-OH; #C, analysis after hydrolysis and derivatization with (*S*)-methylbenzylamine; #D, trifluoroacetylated γ -cyclodextrin phase, ChiralDex GTA.

^c Coleo. = Coleoptera, Hetero. = Heteroptera, Hymeno. = Hymenoptera, Lepido. = Lepidoptera, Dictyo. = Dictyoptera.

^d Also identified from *Nicrophorus interruptus*, *N. tomentosus* and *N. pustulatus* (#1); and *Chlorochroa sayi* and *C. uhleri* (#2).

^e (Year of publication, 19XX or 20XX). [] indicates year when the publication was reported before determination of the absolute configuration.

^f 1-Ethylpropyl 2-methyl-3-hydroxypentanoate.

^g 2,4-Dimethyl-5-hexanolide.

^h Tetrahydro-3,5-dimethyl-6-isopropyl-2*H*-pyran-2-one.

ⁱ Tetrahydro-3,5-dimethyl-6-(1-methylbutyl)-2*H*-pyran-2-one.

^j 3-Methyl-4-(1,3,5,7-tetramethyloctyl)oxetan-2-one.

^k 1-Ethyl-2-methylpropyl 3,13-dimethylpentadecanoate.

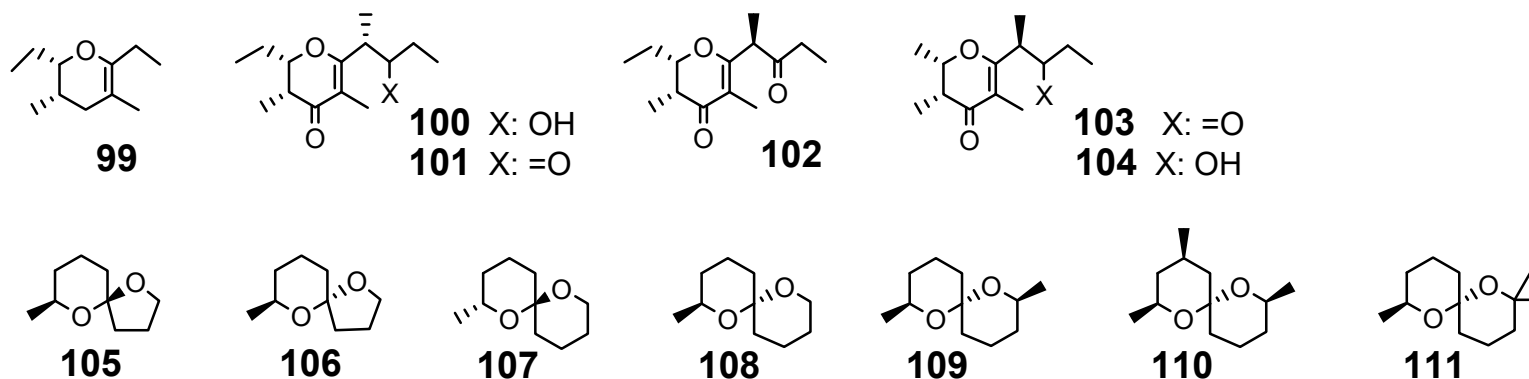
^l 5-(2',4'-Dimethylheptanyl)-3-methyl-2*H*-pyran-2-one.

Table 6. Dihydropyrans and spiroacetals: Pheromones and allomones identified from insects.

Pheromone	Configuration and analytical method ^a		Function (Producer)	Insecta		Reference ^d	
				Order ^b	Species ^c	Identification	Stereoselective synthesis
dihydropyran (DP)							
Et2,Me3,Me5,Et6-DP [anhydroserricornin] (99) ^e	2 <i>S</i> ,3 <i>S</i>		sex (F)	Coleo.	<i>Lasioderma serricorne</i> (deathwatch beetle)	294 [81], 295 (86)	296 (84), 297 (85)
Et2,Me3,Me5,(C ₅ H ₁₀ OH)6-DP-4-one [serricorole] (100) ^f	2 <i>S</i> ,3 <i>R</i> ,1' <i>S</i> ,2' <i>S</i>		sex (F)	Coleo.	<i>L. serricorne</i>	298 [83], 299 [85], 300 (87)	300 (87)
Et2,Me3,Me5,(C ₅ H ₉ O)6-DP-4-one [α-serricorone] (101) ^g	2 <i>S</i> ,3 <i>R</i> ,1' <i>S</i>	CD	sex (F) + marking	Coleo.	<i>L. serricorne</i>	298 [83], 301 (90)	300 (87)
+Et2,Me3,Me5,(C ₅ H ₉ O)6-DP-4-one [β-serricorone] (102)	2 <i>S</i> ,3 <i>R</i> ,1' <i>R</i>						
Me2,Me3,Me5,(C ₅ H ₉ O)6-DP-4-one [stegobinone] (103) ^h	2 <i>S</i> ,3 <i>R</i> ,1' <i>R</i>		sex (F)	Coleo.	<i>Stegobium paniceum</i> (deathwatch beetle) <i>Anobium punctatum</i> (deathwatch beetle)	302 [78], 303 (81) 377 (87)	304 (79), 305 (81), 306 (12)
Me2,Me3,Me5,(C ₅ H ₁₀ OH)6-DP-4-one [stegobiol] (104) ⁱ	2 <i>S</i> ,3 <i>R</i> ,1' <i>S</i>		sex (F)	Coleo.	<i>Stegobium paniceum</i> (deathwatch beetle)	307 (87)	308 (86), 306 (12)
Spiroacetal (SA)							
1,6-dioxaspiro[4.5]decane ([4.5]SA)							
Me7-[4.5]SA [conophthorin] (105)	5 <i>R</i> ,7 <i>S</i>		sex (M)	Diptera	<i>Bactrocera xanthodes</i> (fruit fly)	309 (92)	309 (92)
(106)	5 <i>S</i> ,7 <i>S</i>		sex (M)	Coleo.	<i>Conophthorus coniperda</i> (bark beetle) #1	310 (98)	311 (81)
	5 <i>S</i> ,7 <i>S</i>		allomone ?	Hymeno.	<i>Vespula vulgaris</i> (= <i>Paravespula vulgaris</i>) (wasp)	719 [78], 438 [79], 720 [97]	
Me2,Et7-[4.5]SA	?		gland	Hymeno.	<i>Paravespula vulgaris</i> , <i>P.</i>	438 [79]	

				secretion		<i>germanica, Dolichovespula saxonica</i> <i>Parischnogaster jacobsoni</i> (wasp) <i>Andrena haemorrhoa</i> (mining bee) <i>Coelioxys quadridentata,</i> <i>C. mandibularis</i> (leafcutter bee)	595 [98] 593 [81] 594 [82]	
Me2,Bu7-[4.5]SA				gland secretion	Hymeno.	<i>Andrena haemorrhoa</i> (mining bee)	593 [81]	
1,7-dioxaspiro[5.5]undecane ([5.5]SA)								
Me2-[5.5]SA (107)	2R,6S	GC* #A	(mandibular gland)		Hymeno.	<i>Goniozus nephantidis</i> (wasp) #2	312 (08)	312 (08)
Me2-[5.5]SA (108)	2S,6R	GC* #B	allomone		Phasmatodea	<i>Asceles glaber</i> (walking stick) #3	313 (12)	313 (12)
Me2,Me8-[5.5]SA (109)	2S,6R,8S	GC* #C	sex (F)		Hymeno.	<i>Andrena wilkella</i> (wild bee)	314 [80], 315 (90)	316 (81), 317 (87)
			alarm		Hymeno.	<i>Polybia occidentalis</i> (social wasp) #4	378 (00)	
			sex (F)		Diptera	<i>Bactrocera dorsalis,</i> <i>B. cucurbitae</i>	454 [85],	318 (89)
			sex (M)			<i>B. cucumis, B. halfordiae,</i>	439 (86), 318 (89)	
			sex (M)			<i>B. nigrotibialis.</i>	440 (90)	
			sex (M)			<i>B. kirki, B. kraussi</i> (fruit fly)	309 (92)	
			allomone		Coleo.	<i>Ontholestes murinus,</i> <i>O. tessellatus</i> (rove beetle)	323 (99)	323 (99)
Me2,Et8-[5.5]SA	2S,6R,8S		sex (F)		Diptera	<i>Bactrocera dorsalis</i> <i>B. halfordiae</i>	454 [85], 318 [89]	
			sex (M)					

				sex (M)		<i>B. kirki</i> , <i>B. kraussi</i>	309 [92],	
				sex (F)		<i>B. latifrons</i>	553 (97),	
				sex (M)		<i>B. frauenfeldi</i> (fruit fly)	455 [20]	
Me2,Me4,Me8-[5.5]SA	(110)	2 <i>S</i> ,4 <i>R</i> ,6 <i>R</i> ,8 <i>S</i>		aggregation	Hetero.	<i>Cantao parentum</i> (shield bug)	319 (94)	320 (95), 321 (01), 322 (14)
Me2,Me2,Me8-[5.5]SA	(111)	6 <i>R</i> ,8 <i>S</i>	GC* #D	allomone	Coleo.	<i>Ontholestes murinus</i> (rove beetle)	323 (99)	323 (99)



^a GC* indicates analyses with the following enantioselective columns: #A, 1:1 mixture of OV1701 and hexakis(6-*tert*-butyl-2,3-dimethyl)- β -cyclodextrin; #B, Beta DEX 120 column; #C, per-*n*-hexyl- α -cyclodextrin; #D, Cyclodex-B.

^b Coleo. = Coleoptera, Hetero. = Heteroptera, Hymeno. = Hymenoptera.

^c Also identified from *Conophthorus ponderosae*, *Pityophthorus carmeli*, and *Pityophthorus nitidulus* (#1); *Goniozus legneri* (#2); *Goniozus legneri* and *G. nephantidis* as a minor component (#3); several species in Hymenoptera (#4)

^d (Year of publication, 19XX or 20XX). [] indicates year when the publication was reported before determination of the absolute configuration.

^e 2,6-Diethyl-3,5-dimethyl-3,4-dihydro-2*H*-pyran

^f 2,3-Dihydro-3,5-dimethyl-2-ethyl-6-(1-methyl-2-hydroxybutyl)-4*H*-pyran-4-one

^g 2,3-Dihydro-3,5-dimethyl-2-ethyl-6-(1-methyl-2-oxobutyl)-4*H*-pyran-4-one

^h 2,3-Dihydro-2,3,5-trimethyl-6-(1-methyl-2-oxobutyl)-4*H*-pyran-4-one

ⁱ 2,3-Dihydro-2,3,5-trimethyl-6-(1-methyl-2-hydroxybutyl)-4*H*-pyran-4-one

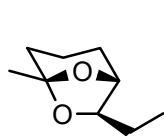
^j 7-Methyl-1,6-dioxaspiro[4.5]decane

Table 7. Dioxabicyclo and dioxatricyclo compounds (cyclic acetals): Pheromones and allomones identified from insects.

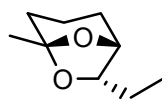
Pheromone			Insecta		Reference ^d	
	Configuration and analytical method ^a	Function	Order ^b Family	Species ^c	Identification	Stereoselective synthesis
<i>exo</i> -7-ethyl-5-methyl-6,8-dioxabicyclo[3.2.1]octane [(+)- <i>exo</i> -brevicomins] (112)	1 <i>R</i> ,5 <i>S</i> ,7 <i>R</i> NMR (#A)	aggregation	Coleo. Scolytidae	<i>Dendroctonus brevicomis</i> <i>D. ponderosae</i> <i>Dryocoetes confuses</i> <i>Dryo. affaber</i> <i>Hylesinus pruinosus</i> (bark beetle)	381 [68], 382 (76), 383 (77) 389 (83) 619 (93) 619 (93), 620 (94) 621 (10)	384 (74), 385 (83), 386 (96), 387 (96), 388 (09), 650 (13)
	?			<i>D. adjunctus</i> #1		
<i>endo</i> -7-ethyl-5-methyl-6,8-dioxabicyclo[3.2.1]octane [(+)- <i>endo</i> -brevicomins] (113)	1 <i>R</i> ,5 <i>S</i> ,7 <i>S</i> GC (#F)	aggregation	Coleo. Scolytidae	<i>Dendroctonus ponderosae</i> <i>Dryocoetes confuses</i> <i>Dryo. affaber</i> <i>Hylesinus pruinosus</i> <i>D. Mesoamericanus</i> (bark beetle)	389 (83), 390 (96) 619 (93) 619 (93), 620 (94) 621 (10) 622 (15)	391 (95), 390 (96), 388 (09), 651 (14), 652 (19)
	?			<i>D. brevicomis</i> #2		
<i>exo</i> - and <i>endo</i> -7-ethyl-5-methyl-6,8-dioxabicyclo[3.2.1]octan-2-ol [breviomins-2-ol] (114)	1 <i>R</i> ,2 <i>R</i> ,5 <i>S</i> ,7 <i>R</i> + 1 <i>R</i> ,2 <i>R</i> ,5 <i>S</i> ,7 <i>S</i>	aggregation	Coleo. Scolytidae	<i>Dendroctonus ponderosae</i> (bark beetle)	390 (96)	390 (96)
<i>exo</i> -7-(1'-hydroxyethyl)-5-methyl-6,8-dioxabicyclo[3.2.1]octane [1-hydroxy- <i>exo</i> -brevicomins]	1 <i>R</i> ,1' <i>R</i> ,5 <i>R</i> ,7 <i>R</i>	aggregation	Coleo. Scolytidae	<i>Dendroctonus ponderosae</i> (bark beetle)	390 (96)	390 (96), 650 (13)
<i>exo</i> -5-ethyl-7-methyl-6,8-dioxabicyclo[3.2.1]octane [isobrevicomins] (115)	1 <i>S</i> ,5 <i>R</i> ,7 <i>S</i>	aggregation	Coleo. Scolytidae	<i>Dendroctonus ponderosae</i> (bark beetle)	390 (96)	390 (96)
1,5-dimethyl-	1 <i>S</i> ,5 <i>R</i> [α] _D (-)	aggregation	Coleo.	<i>Dendroctonus frontalis</i>	392 [69], 383 (77)	(-)-isomer: 394 (75),

6,8-dioxabicyclo[3.2.1]octane [frontalin] (116)	NMR (#A) + 1 <i>R</i> ,5 <i>S</i> (2:1) GC (#G)		Scolytidae	(bark beetle) #3 <i>D. jeffreyi</i>	393 (99)	395 (76), 396 (83), 397 (86), 398 (87), 399 (99), 400 (02), 401 (03), 653 (13)
	?			<i>D. adjunctus</i> #4		(+)-isomer: 394 (75), 402 (78), 397 (86) 403 (98), 404 (00)
5-ethyl-2,4-dimethyl- 6,8-dioxabicyclo[3.2.1]octane [α -multistriatin] (117)	1 <i>S</i> ,2 <i>R</i> ,4 <i>S</i> ,5 <i>R</i> [α] _D (-)	aggregation	Coleo. Scolytidae	<i>Scolytus multistriatus</i> , <i>S.</i> <i>pygmaeus</i> (bark beetle) #5	131 [75], 505 [75], 324 (76), 132 (77), 694 (79)	324 (76), 326 (76), 325 (77), 327 (79), 694 (79), 328 (82), 329 (87)
	?		Dryophthoridae	<i>Diocalandra frumenti</i> (weevil)	506 [17]	
2-ethyl-1,5-dimethyl- 6,8-dioxabicyclo[3.2.1]octane [bicolorin] (118)	1 <i>S</i> ,2 <i>R</i> ,5 <i>R</i> GC (#B)	aggregation	Coleo. Scolytidae	<i>Taphrorychus bicolor</i> (bark beetle)	405 [95], 406 (96)	406 (96), 407 (97), 654 [13]
1-ethyl-3,5,7-trimethyl- 2,8-dioxabicyclo[3.2.1]octane [sordidin] (119)	1 <i>S</i> ,3 <i>R</i> ,5 <i>R</i> ,7 <i>S</i> [α] _D (+),GC (#G) + 1 <i>S</i> ,3 <i>R</i> ,5 <i>R</i> ,7 <i>R</i> 1 <i>R</i> ,3 <i>S</i> ,5 <i>S</i> ,7 <i>S</i> GC (#C)	aggregation	Coleo. Curculionidae	<i>Cosmopolites sordidus</i> (weevil)	408 [95], 409 (96) 410 (97)	409 (96), 412 (05), 413 (08)
		?	Trico. Limnephilidae	<i>Potamophylax latipennis</i> (caddis fly) #6	411 (04)	
1,3-diethyl-4,6-dimethyl- 2,7-dioxabicyclo[2.2.1]heptane (120)	1 <i>S</i> ,3 <i>S</i> ,4 <i>R</i> ,6 <i>S</i> or 1 <i>R</i> ,3 <i>R</i> ,4 <i>S</i> ,6 <i>S</i>	aggregation	Trico. Limnephilidae	<i>Glyphotaelius pellucidus</i> (caddis fly)	411 (04)	
1,3,3-trimethyl- 2,7-dioxabicyclo[2.2.1]heptane (121)	?	gland secretion (defense substance ?)	Hymeno. Formicidae	<i>Iridomyrmex purpureus</i> <i>Eciton burchelli</i> , <i>Aenictus rotundatus</i> (ant)	414 [84] 456 [93] 415 [94]	
3-isopentenyl-1,3-dimethyl- 2,7-dioxabicyclo[2.2.1]heptane (122)	?	gland secretion	Hymeno. Apidae	<i>Nannotrigona testaceicornis</i> (bee)	416 [01]	

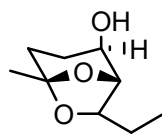
3-ethyl-1,8-dimethyl- 2,9-dioxabicyclo[3.3.1]non-7-ene (123)	1 <i>R</i> ,3 <i>S</i> ,5 <i>S</i> GC (#D)	?	Lepido. Hepialidae	<i>Hepialus hecta</i> (swift moth)	417 [85], 418 (90)	419(86)
+ 6-keto derivative (124)	1 <i>R</i> ,3 <i>S</i> ,5 <i>R</i>	?			418 (90)	
1,3,8-trimethyl derivative (125)	1 <i>R</i> ,3 <i>S</i> ,5 <i>S</i>	?		<i>Endoclita excrescens</i>	420(02)	420 (02)
3,3,7-trimethyl- 2,9-dioxatricyclo[3.3.1.0 ^{4,7}]nonane [lineatin] (126)	1 <i>R</i> ,4 <i>S</i> ,5 <i>R</i> ,7 <i>R</i> [α] _D (+) X-ray (#E)	aggregation	Coleo. Scolytidae	<i>Trypodendron lineatum</i> (bark beetle)	421 [77], 422 (80)	422(80), 423 (80), 424 (82), 425 (85), 426 (08)



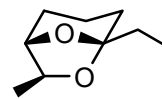
112



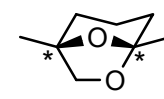
113



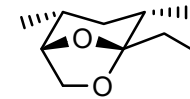
114



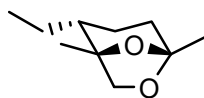
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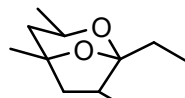
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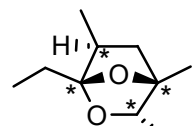
117



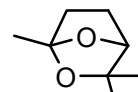
118



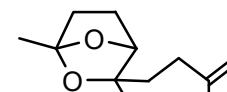
119



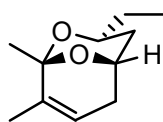
120



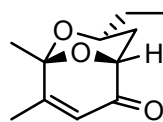
121



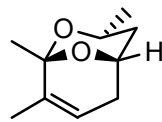
122



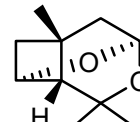
123



124



125



126

^a #A: Analysis using a chiral sift reagent [Eu(hfbc)₃], #B: analysis with an enantioselective column coated with a 1:1 mixture of heptakis(2,6-di-*O*-methyl-3-*O*-pentyl)-β-cyclodextrin and OV1701, #C: analysis with an enantioselective column coated with a 1:1 mixture of heptakis-(2,3-di-*O*-methyl-6-*O*-tert-butyldimethylsilyl)- β-cyclodextrin and OV1701, #D: analysis with an enantioselective column coated with Ni(II)-bis(heptafluorobutanoyl-(1*R*,5*S*)-pinan-4-onate) in OV-1, #E: crystallographic analysis of a synthetic intermediate, #F: analysis with an enantioselective column coated with manganese(II)-bis(1*R*-3-heptafluorobutyrylcamphorate) in OV-101, #G: Cyclodex B column.

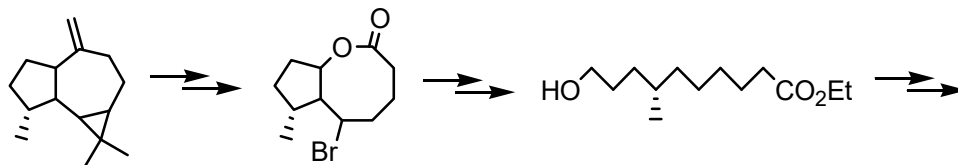
^b Coleo. = Coleoptera, Hetero. = Heteroptera, Hymeno. = Hymenoptera, Lepido. = Lepidoptera, Strepsi. = Strepsiptera.

^c Also identified from *D. armandi*, *D. frontalis*, *D. jeffreyi*, *D. terebrans*, *Leperisinus varius*, and *Dryo. autographus* (#1); *D. frontalis*, *Dryo. autographus* (2), *D. brevicomis* and *D. simplex* (#3); *D. armandi*, *D. ponderosa*, *D. pseudotsugae*, *D. rufipennis*, and *D. terebrans* (#4); *S. scolytus*. (#5); *P. cinquatus* (#6)

Table 8. Chiral synthons (S1 – S14) for enantioselective syntheses of methyl-branched pheromones.

Synthon	Chemical structure and the synthetic route	Targeted pheromone
1a. Citronellol (S1a) or citronellal (S1b)		Me10-12:OAc (30) ⁹⁹ Me6,Me12-15:2-one (76) ²³³ and 2 ²⁰ , 5 ²⁷ , 10 ²⁸ , 28 ⁸⁴ , 29 ^{90,95,96} , 38 ¹¹⁹ , 62 ¹⁸⁹ , 63 ¹⁹⁰ , 74 ²²³ , 77–79 ^{237,238} , 80 ²⁴² , 86 ²⁶¹ , 94 ²⁸⁴ , 97 ^{287,288} , 112 ³²⁶
1b. Citronellic acid (S1c) derived from isopulegol or pulegone		Δ 8,Me14-16:Ald (40) ^{125,126} Me8-10:2-OPr (47) ¹⁴⁵ Me3,Me11-29: 2-one (80) ²⁴¹ and 21 , ⁷⁶ 69 , ²⁰⁸ 110 ³²⁰
2. Isopulegol (S2) or neoisopulegol		Me5,Me9-15:H (2) ¹⁹
3. Dihydromyrcene (S3)		Me4-9:OH (28) ⁸⁵

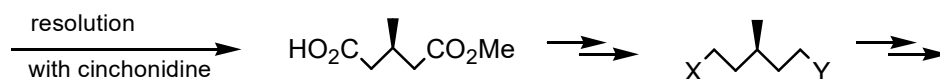
4. Aromadendrene (**S4**)



Me9-19:H (**11**)⁵⁵

Me10-13:2-one (**74**)⁵⁵

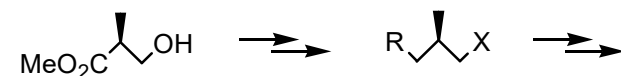
5. 3-Methylglutaric acid monomethyl ester (**S5**)



Me8-10:2-OPr (**47**)¹⁴⁷

Me10-13:2-one (**74**)²²⁴

6. 3-Hydroxy-2-methylpropionate (Roche ester, **S6**)



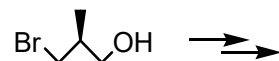
Me11-23:H (**17**)⁶⁷

vittatalactone (**91**)^{272,273}

and **5**²⁷⁻²⁹, **6**³⁵, **9**⁴⁷, **10**⁵², **29**⁹⁵,

74²²⁸, **78**²³⁷, **79**²³⁷, **94**²⁸⁴

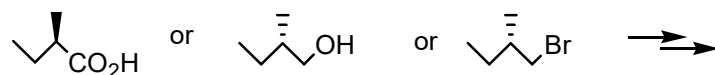
7. 3-Bromo-2-methylpropanol (**S7**)



Me3,Me5,Me9-12:Ald (**34**)¹⁰⁷

supellapyrone (**98**)²⁹²

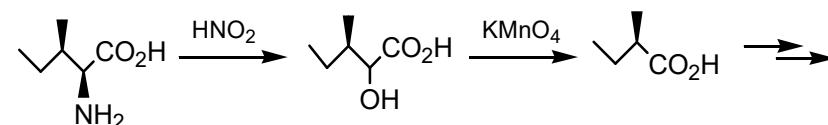
8a. 2-Methylbutanoic acid (**S8a**), 2-methylbutan-1-ol (**S8b**), or 1-bromo-2-methylbutane (**S8c**)



Me3,Me13-15: ester (**97**)^{287,288}

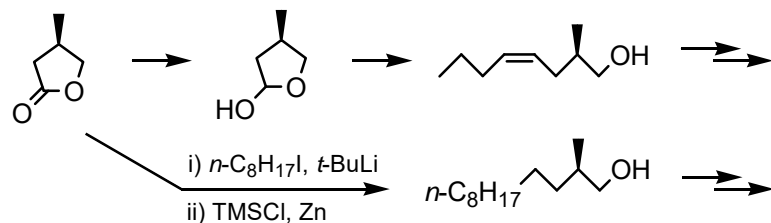
and **29**⁹⁶, **39**¹²², **40**¹²⁴, **68**²⁰⁶

8b. (*R*)-2-Methylbutanoic acid [(*R*)-**S8a**] from L-isoleucine



Me8-10: 2-OPr (**47**)¹⁴⁶

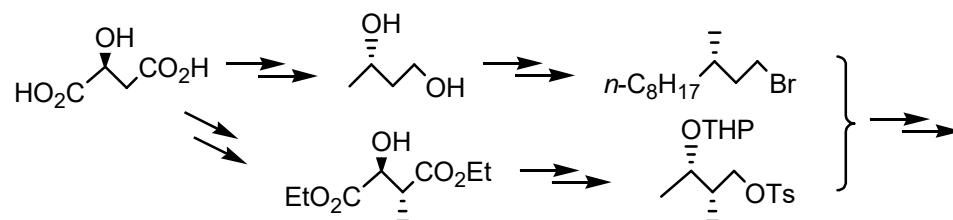
9. 3-Methyl-4-butanolide (**S9**)



Me₅,Me₉-15:H (**2**)²⁰
 invictolide (**90**)²⁶⁷

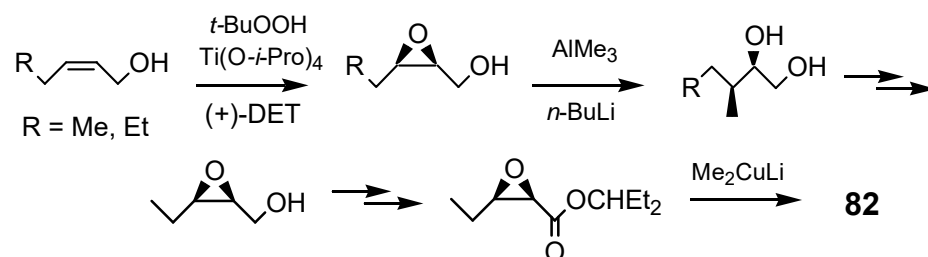
Me₉-19:H (**11**)⁵⁶

10. Malic acid (**S10**)



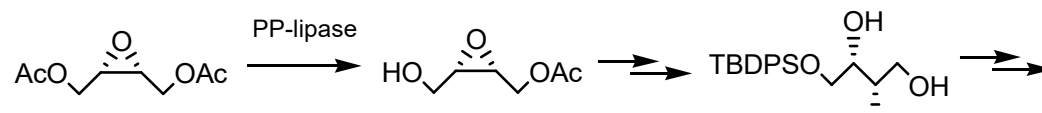
Me₃,Me₇-15:2-OAc (**56**)^{176,178}

11. Chiral epoxide: 2,3-Epoxyalkan-1-ol (**S11**) produce by Sharpless asymmetric epoxidation



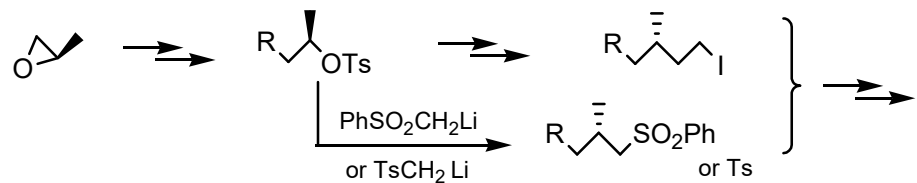
Me₃-8:4-OH (**44**)¹³⁵
 Me₅-8:4-OH (**45**)¹³⁵
 sitophilate (**82**)²⁴⁶
 invictolide (**90**)²⁶⁶

12. Chiral epoxide: (3-Hydroxymethyloxiranyl)methyl acetate (**S12**)



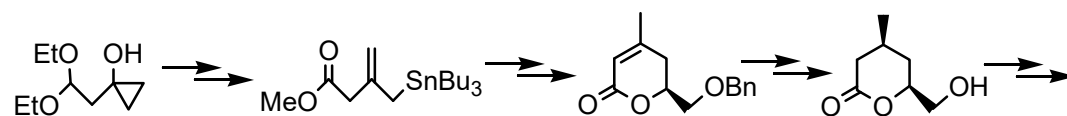
Me₃-8:4-OH (**44**)¹³⁶
 Me₄-9:5-OH (**46**)¹⁴²

13. Chiral epoxide: Propylene oxide (**S13**)



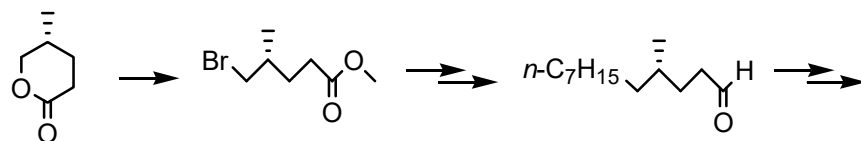
Me5,Me9-17:H (**5**)³²
 Δ 1,Me10,Me14-18:H (**10**)⁵³
 Me5-17:7-OH (**61**)¹⁸⁵
 and **75**²³⁰, **97**²⁸⁹

14. Chiral lactone (**S14**)



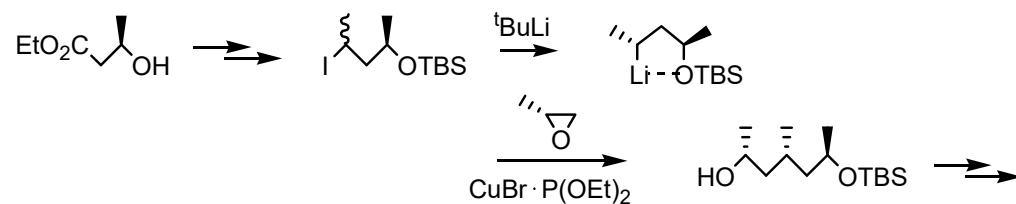
Δ 1,Me10,Me14-18:H (**10**)⁵⁴
 Me10-12:OAc (**30**)¹⁰³
 faranal (**36**)¹¹³
 and **40**¹⁰³, **110**³²²

15. 4-Methyl- δ -valerolactone (**S15**)



Me3,Me7-15:2-OAc (**56**)³⁶⁷

16. Ethyl (*R*)-3-hydroxybutyrate (**S16**)



lardolure (**49**)³⁷⁹

Table 9. Syntheses of methyl-branched pheromones applying an enantioselective organic or biochemical reaction (R-1 – R-5).

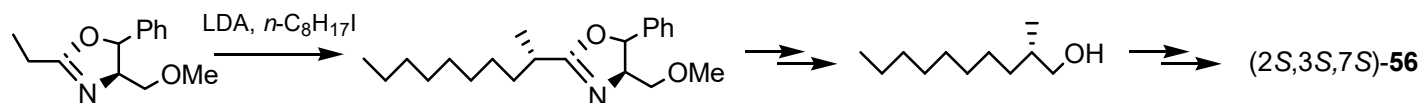
Reaction type

Synthetic route for a targeted chiral pheromone

1. C-C coupling with a chiral intermediate

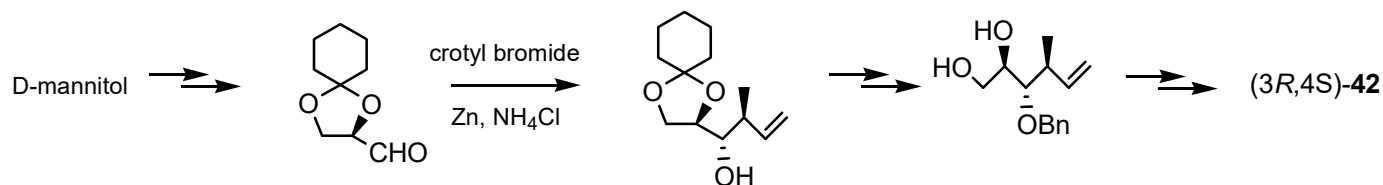
R-1-1. 2-Oxazoline derivative

Me3,Me7-15:2-OAc (**56**)¹⁷⁴

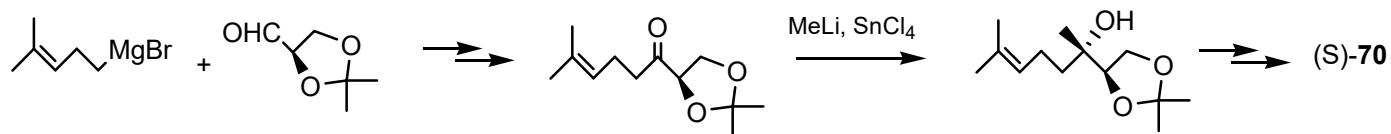


R-1-2. [1,3]Dioxolane-4-carbaldehyde and a keto derivative

a. Me4-6:3-OH (**42**)¹²⁹

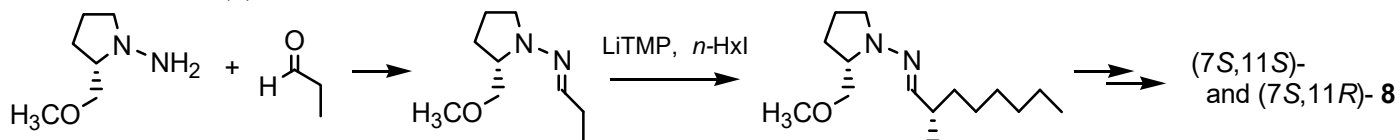


b. Me3,Δ6,Me7-8:1-OH,3-OH,2-one (**70**)²¹³



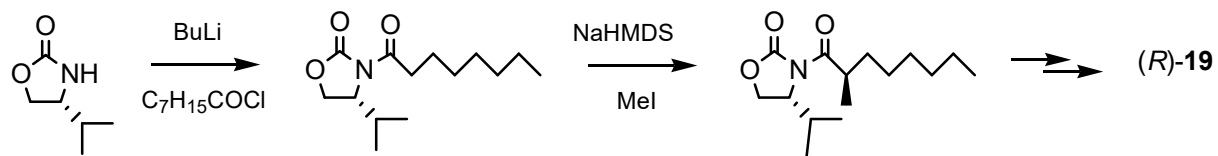
R-1-3. Enders SAMP/RAMP hydrazone-alkylation reaction

Me7,Me11-17:H (**8**)⁴²

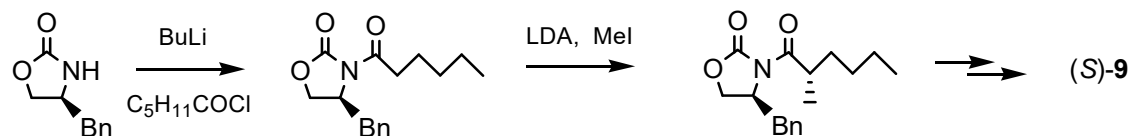


R-1-4. Evans' chiral auxiliaries

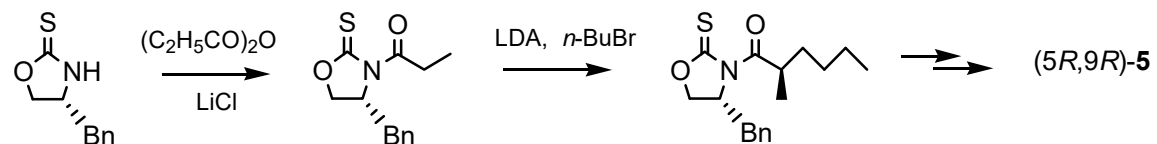
a. Me7-27:H (**20**)⁷²



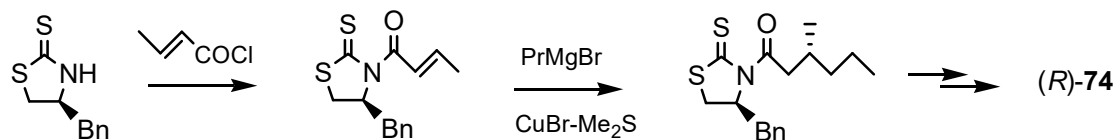
b. Δ1, Me14-18:H (**9**)⁴⁹



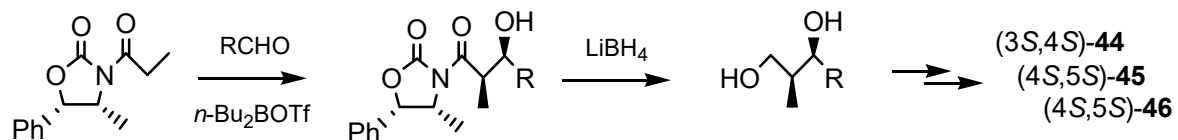
c. Me5,Me9-17:H (**5**)³¹



d. Me10-13:2-one (**74**)²²⁷



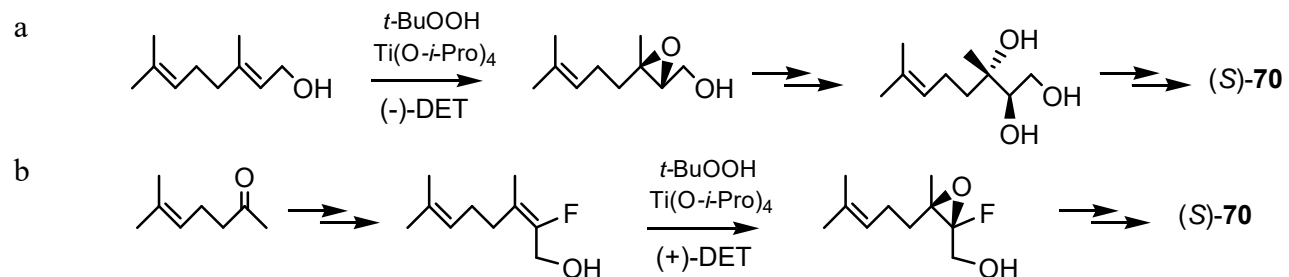
e. Me3-8:4-OH (**44**)¹³⁷ etc.



2. Reaction *via* an epoxy compound

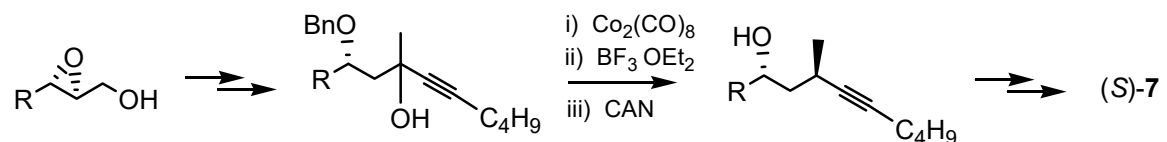
R-2-1. Sharpless asymmetric epoxydation

Me3, Δ 6,Me7-8:1-OH,3-OH,2-one (**70**)^{214, 215}



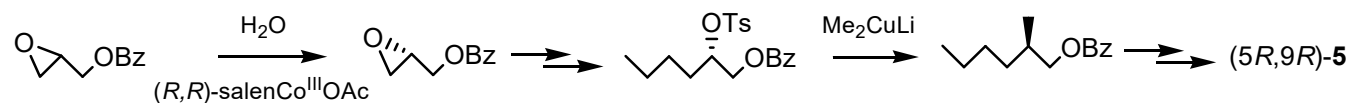
R-2-2. Intermolecular hydride transfer

Me7-17:H (**7**)³⁷

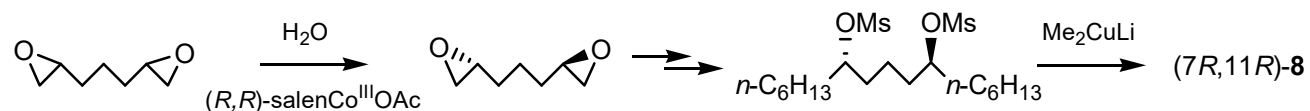


R-2-3. Hydrolytic kinetic resolution (HKR)

a. Me5,Me9-17:H (**5**)³¹

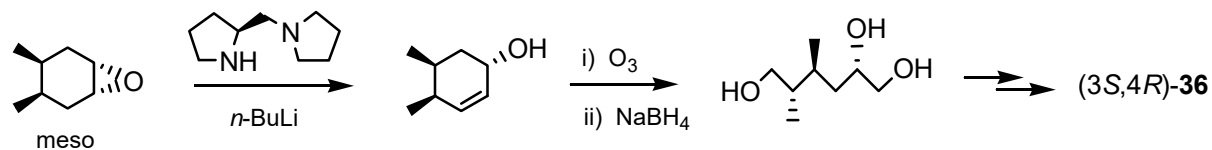


b. Me7,Me11-17:H (**8**)⁴³



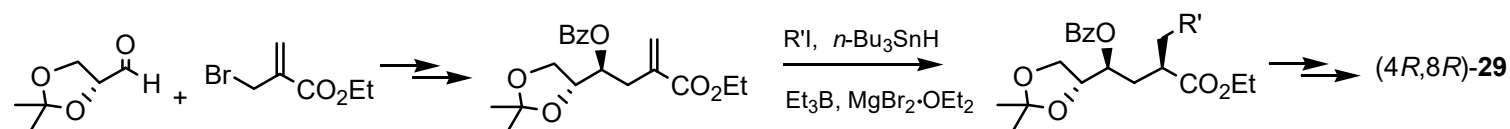
R-2-4. Asymmetric cleavage of an epoxy ring

faranal (**36**)¹¹²



3. Chelation-controlled radical reaction

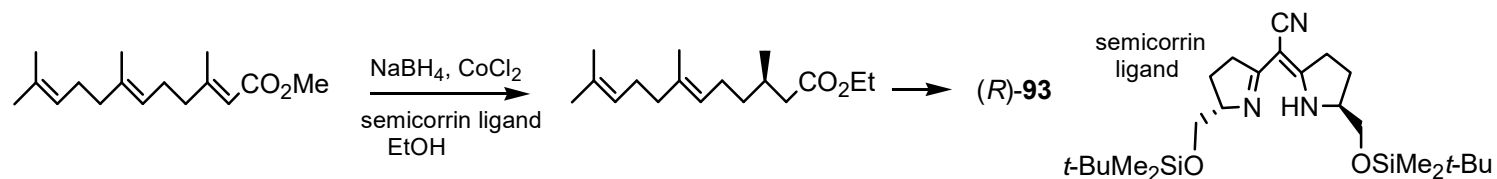
R-3 Me₄,Me₈-10:Ald (**29**)⁹⁴



4. Reaction with a chiral catalyst

R-4-1. NaBH_4 reduction with a chiral cobalt semicorrin complex

dihydrofarnesoate (**93**)²⁸¹

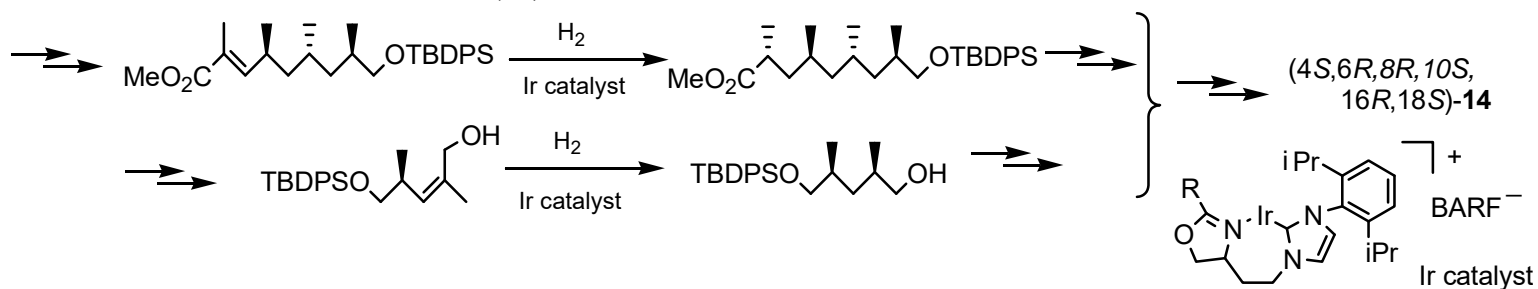


R-4-2. Hydrogenation over a chiral catalyst

a. $\Delta^1, \text{Me}_4\text{-7:3-one}$ (**66**)²⁰⁰

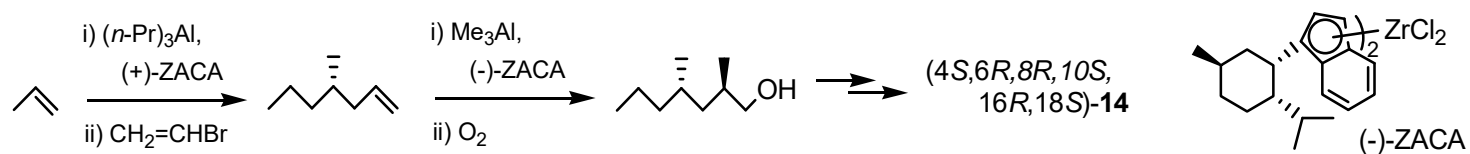


b. Me₄,Me₆,Me₈,Me₁₀,Me₁₆,Me₁₈₋₂₂:H (**14**)⁶³



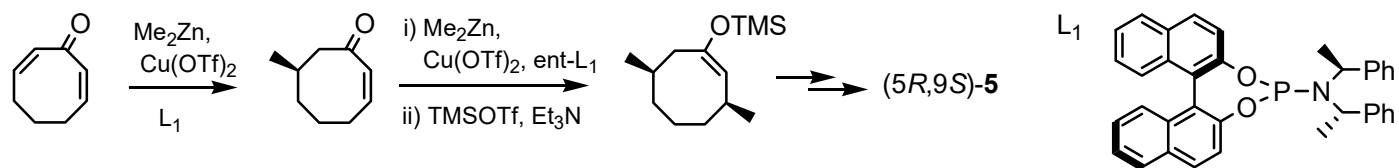
R-4-3. Zr-catalyzed asymmetric carboalumination of alkenes (ZACA reaction)

Me₄,Me₆,Me₈,Me₁₀,Me₁₆,Me₁₈₋₂₂:H (**14**)⁶⁴

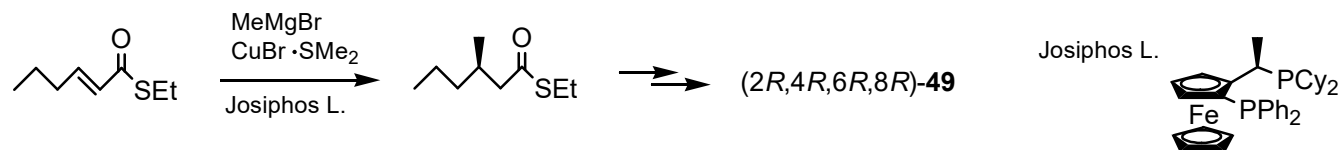


R-4-4. Cu-catalyzed asymmetric Michael addition of organometallic reagents

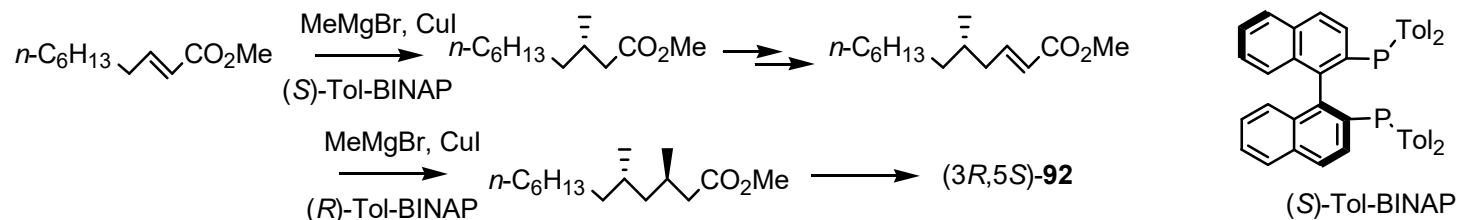
a. Me₅,Me₉₋₁₇:H (**5**)³⁰



b. lardolure (**49**)¹⁵⁷

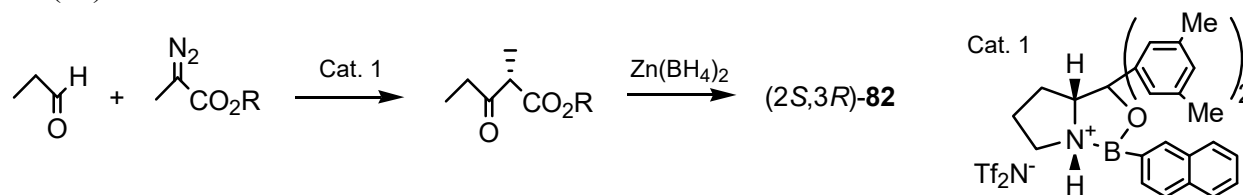


c. Me₃,Me₅-12:acid (**92**)²⁷⁸



R-4-5. Asymmetric Roskamp reaction catalyzed by an oxazaborolidium ion

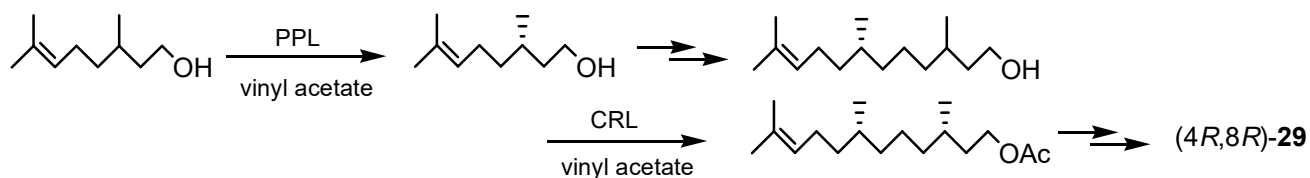
sitophilate (**82**)²⁵¹



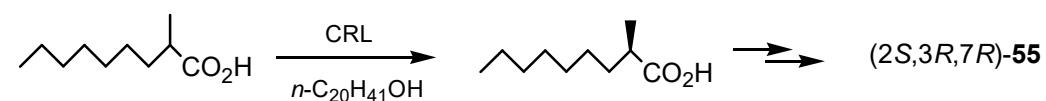
5. Chemoenzymatic reaction

R-5-1. Lipase-catalyzed kinetic resolution

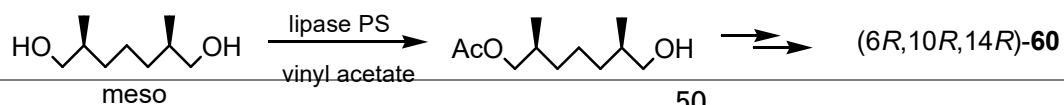
a. Me₄,Me₈-10:Ald (**29**)⁹³



b. Me₃,Me₇-14:2-OPr (**55**)¹⁷¹

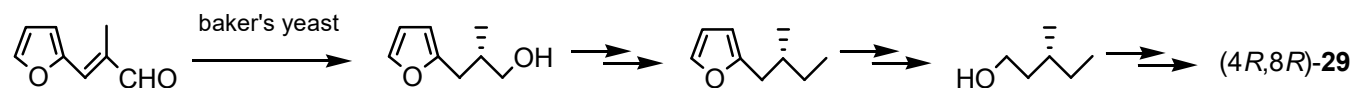


c. Me₆,Me₁₀,Me₁₄-15:2-OH (**60**)¹⁸²

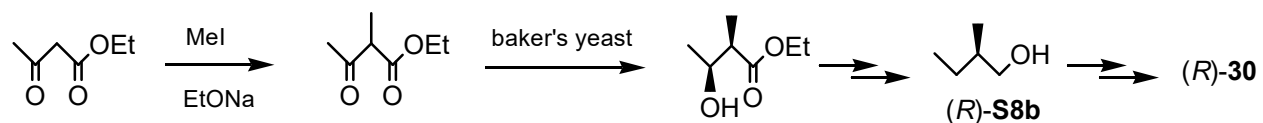


R-5-2. Reduction by baker's yeast

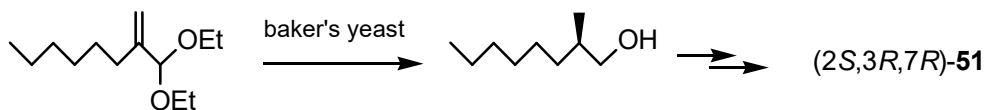
a. Me₄,Me₈-10:Ald (**29**)⁹²



b. Me₁₀-12:OAc (**30**)¹⁰¹

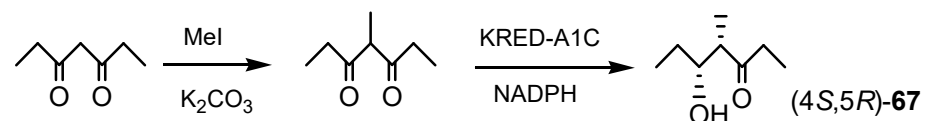


c. Me₃,Me₇-13:2-OAc (**51**)¹⁶⁴



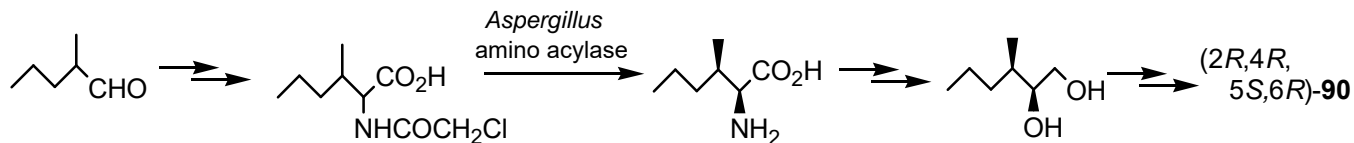
R-5-3. Reduction by isolated ketoreductase

sitophinone (**67**)^{205, 380}



R-5-4. *Aspergillus* amino acylase

invictolide (**90**)²⁶⁸



R-5-5. Ene-reductase-mediated hydrogenation

Me4-7:3-OH (**43**)³⁶¹

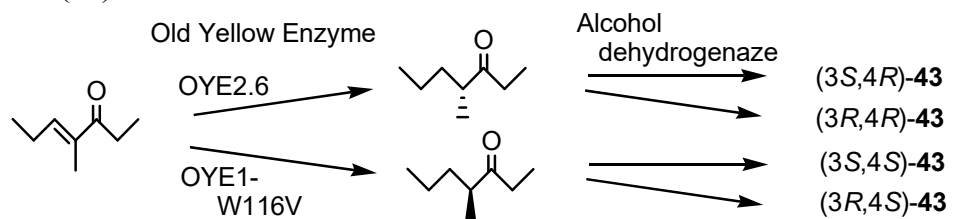
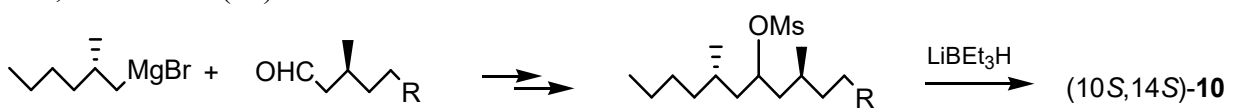
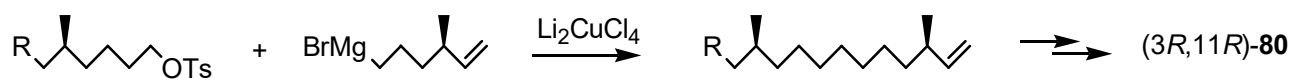
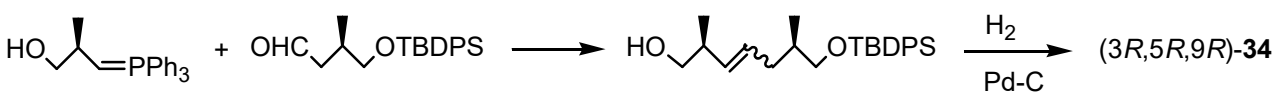
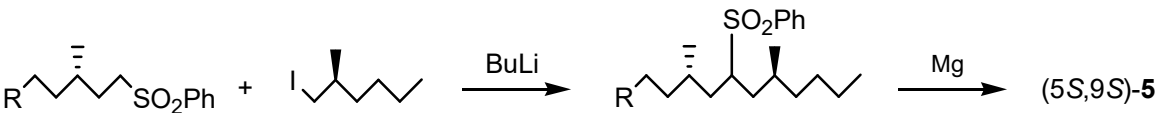
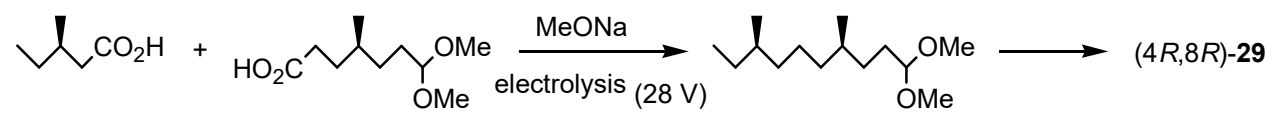
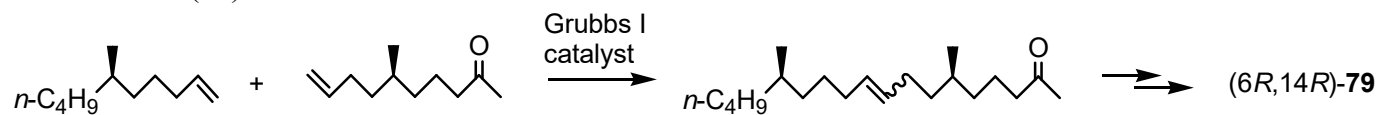


Table 10. Coupling reactions of two chiral blocks (R-6 – R-11) for the syntheses of dimethyl pheromones.

Reaction type
Synthetic route for a targeted chiral pheromone
<p>R-6. Reaction of a Grignard reagent</p> <p>a. $\Delta 1, \text{Me}_{10}, \text{Me}_{14-18}:\text{H}$ (10)²⁸</p>  <p>b. $\text{Me}_3, \text{Me}_{11-29}:\text{2-one}$ (80)²⁴¹</p> 
<p>R-7. Wittig reaction</p> <p>$\text{Me}_3, \text{Me}_5, \text{Me}_9-12:\text{Ald}$ (34)¹⁰⁷</p> 
<p>R-8. Coupling of RSO_2Ph with $\text{R}'\text{I}$</p> <p>$\text{Me}_5, \text{Me}_9-17:\text{H}$ (5)²⁷</p> 
<p>R-9. Kolbe electrolysis</p> <p>$\text{Me}_4, \text{Me}_8-10:\text{Ald}$ (29)⁹¹</p> 

R-10. Olefin cross metathesis

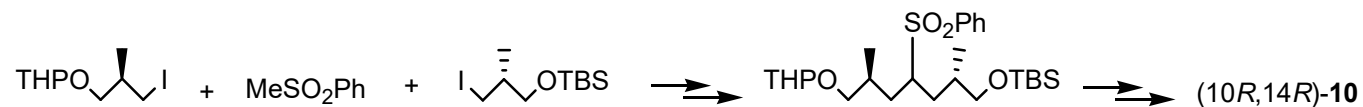
Me6,Me14-18:2-one (**79**)²³⁷



R-11. Coupling with a linchpin

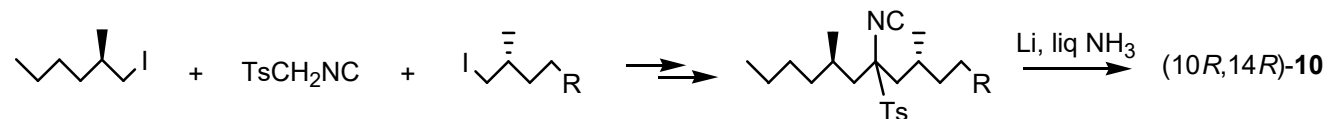
11-1. Methyl phenyl sulfone (MeSO₂Ph)

Δ1,Me10,Me14-18:H (**10**)⁵²



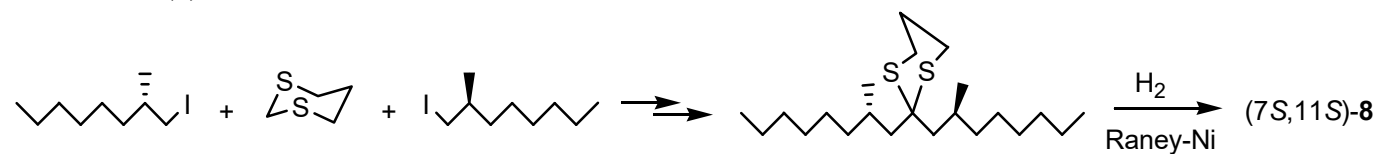
11-2. *p*-Toluenesulfonylmethyl isocyanide [CH₂(NC)SO₂Ts, TosMIC]

Δ1,Me10,Me14-18:H (**10**)³¹

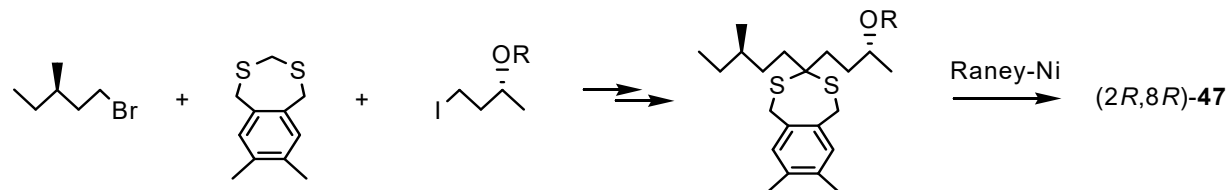


11-3. 1,3-Dithiane

a. Me7,Me11-17:H (**8**)⁴²

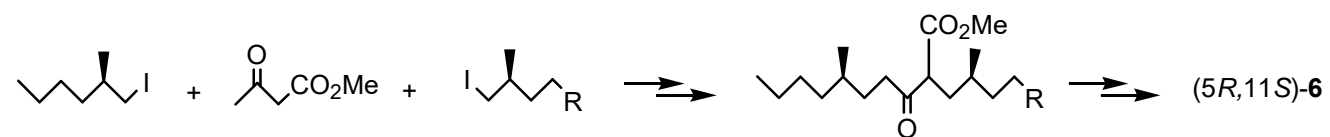


b. Me8-10:2-OPr (**47**)¹⁴⁵



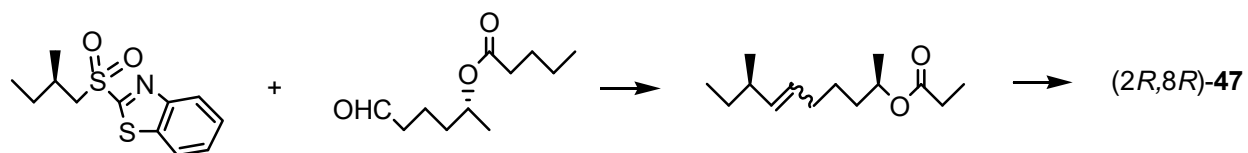
11-4. Methyl acetoacetate

Me5,Me11-17:H (**6**)³⁵



R-12. Julia-Kocienski olefination

Me8 -10:2-OPro (**47**)³⁶⁴



Other target

Me10,Me14-15:

OisoBu (**38**)³⁶⁰

References

- 1 A. M. El-Sayed, 2014, Internet database: <http://www.pherobase.com/>
- 2 K. Mori, *Eur. J. Org. Chem.*, 1998, 1479–1489.
- 3 K. Mori, *Pure Appl. Chem.*, 2001, **73**, 601–606.
- 4 K. Mori, *Topics Current Chem.*, 2004, **239**, 1–50.
- 5 K. Mori, *Bioorg. Med. Chem.*, 2007, **15**, 7505–7523.
- 6 W. Francke and K. Dettner, *Topics Current Chem.*, 2004, **240**, 85–166.
- 7 T. Ando, S. Inomata, M. Yamamoto, *Topics Current Chem.*, 2004, **239**, 51–96.
- 8 C. I. Keeling, E. Plettner, K. N. Slessor, *Topics Current Chem.*, 2004, **239**, 133–177.
- 9 J. G. Millar, *Topics Current Chem.*, 2004, **240**, 37–84.
- 10 W. Francke and S. Schulz. In *Comprehensive Natural Products II, Chemistry and Biology*; L. Mander, H.-W. Lui, Eds.; Elsevier: Oxford, 2010; Vol. 4, 153–223.
- 11 G. J. Blomquist. In *Insect Hydrocarbons*; G. J. Blomquist, A.-G. Bagnères, Eds.; Cambridge University Press, 2010; Chap. 2, 19–34.
- 12 G. J. Blomquist. In *Insect Hydrocarbons*; G. J. Blomquist, A.-G. Bagnères, Eds.; Cambridge University Press, 2010; Chap. 3, 35–52.
- 13 Y. Zou and J. G. Millar, *Nat. Prod. Rep.*, 2015, **32**, 1067–1113.
- 14 R. J. Bartelt. In *Insect Hydrocarbons*; G. J. Blomquist, A.-G. Bagnères, Eds.; Cambridge University Press, 2010; Chap. 19, 448–476.
- 15 T. A. van Beek, I. M. M. S. Silva, M. A. Posthumus and R. Melo, *J. Chromatogr. A*, 2005, **1067**, 311–321.
- 16 A. Tröger, T. A. van Beek, M. E. Huigens, I. M. M. S. Silva, M. A. Posthumus and W. Francke, *Beilstein J. Org. Chem.*, 2014, **10**, 767–773.
- 17 W. Francke, M. Tóth, G. Szöcs, W. Krieg, H. Ernst and E. Buschmann, *Z. Naturforsch. C.*, 1988, **43**, 787–789.
- 18 E. A. Malo, J. C. Rojas, G. Lopez-Guillen and J. F. Barrera, *Fla. Entomol.*, 2009, **92**:548–553.
- 19 J. A. Moreira and A. G. Correa, *Tetrahedron Asymmetry*, 2003, **14**, 3787–3795.
- 20 K. Mori, *Tetrahedron Asymmetry*, 2008, **19**, 857–861.
- 21 G. Gries, R. Gries, J. H. Borden, J.-X. Li, K. N. Slessor, G. G. S. King, W. W. Bowers, R. J. West and E. W. Underhill, *Naturwissenschaften*, 1991, **78**, 315–317.
- 22 J.-X. Li, G. Gries, R. Gries, J. Bikic and K. N. Slessor, *J. Chem. Ecol.*, 1993, **19**, 2547–2561.
- 23 G. Gries, G. G. S. King, R. Gries, P. D. C. Wimalaratne, T. G. Gray, R. F. Shepherd, J.-X. Li, K. N. Slessor and G. J. Khaskin, *J. Chem. Ecol.*, 1993, **19**, 1501–1510.
- 24 G. G. S. King, R. Gries, G. Gries and K. N. Slessor, *J. Chem. Ecol.*, 1995, **21**, 2027–2045.
- 25 W. Francke, S. Franke, M. Tóth, G. Szöcs, P. Guerin and H. Arn, *Naturwissenschaften*, 1987, **74**, 143–144.
- 26 M. Tóth, G. Helmchen, U. Leikauf, GY. Sziráki and G. Szöcs, *J. Chem. Ecol.*, 1989, **15**, 1535–1543.
- 27 K. Mori and J. Wu, *Liebigs Ann. Chem.*, 1991, 439–443.
- 28 T. Tamagawa, H. Takikawa and K. Mori, *Eur. J. Org. Chem.*, 1999, 973–978.
- 29 S. Kuwahara, T. Liang, W. S. Leal, J. Ishikawa and O. Kodama, *Biosci. Biotechnol. Biochem.*, 2000, **64**, 2723–2726.

- 30 R. P. Summeren, S. J. W. Reijmer, B. L. Feringa and A. J. Minnaard, *Chem. Comm.*, 2005, 1387–1389.
- 31 J. S. Yadav, K. U. Gayathri, N. Thrimurtulu and A. R. Prasad, *Tetrahedron*, 2009, **65**, 3536–3544.
- 32 T. Taguri, R. Yamakawa, T. Fujii, Y. Muraki and T. Ando, *Tetrahedron Asymmetry*, 2012, **23**, 852–858.
- 33 G. Gries, R. Gries, S. H. Krannitz, J.-X. Li, G. G. S. King, K. N. Slessor, J. H. Borden, W. W. Bowers, R. J. West and E. W. Underhill, *J. Chem. Ecol.*, 1993, **19**, 1009–1019.
- 34 J. Li, R. Gries, G. Gries, K. N. Slessor, G. G. S. King, W. W. Bowers and R. J. West, *J. Chem. Ecol.*, 1993, **19**, 1057–1062.
- 35 K. Mori and H. Horikiri, *Liebigs Ann. Chem.*, 1996, 501–505.
- 36 D. R. Hall, P. S. Beevor, D. G. Campon, D. J. Chamberlain, A. Cork, R. White, A. Almestre, T. J. Henneberry, V. Nandagopal, J. A. Wightman and G. V. R. Rao, *Bulletin OILB SRQP.*, 1993, **16**, 1–9.
- 37 D. D. Díaz and V. S. Martín, *J. Org. Chem.*, 2000, **65**, 7896–7901.
- 38 Y. Shirai, M. Seki and K. Mori, *Eur. J. Org. Chem.*, 1999, 3139–3145.
- 39 R. Gries, G. Gries, J.-X. Li, C. T. Maier, C. R. Lemmon and K. N. Slessor, *J. Chem. Ecol.*, 1994, **20**, 2501–2511.
- 40 C. M. Duff, G., Gries, K. Mori, Y. Shirai, M. Seki, H. Takikawa, T. Sheng, K. N. Slessor, R. Gries, C. T. Maier and D. C. Ferguson, *J. Chem. Ecol.*, 2001, **27**, 431–442.
- 41 C. T. Maier, R. Gries and G. Gries, *J. Chem. Ecol.*, 1998, **24**, 491–500.
- 42 D. Enders and T. Schüßeler, *Tetrahedron Lett.*, 2002, **43**, 3467–3470.
- 43 S. Chow, W. A. Koenig and W. Kitching, *Eur. J. Org. Chem.*, 2004, 1198–1201.
- 44 H. Nagano, R. Kuwahara and F. Yokoyama, *Tetrahedron*, 2007, **63**, 8810–8814.
- 45 H. Sugie, Y. Tamaki, R. Sato and M. Kumakura, *Appl. Entomol. Zool.*, 1984, **19**, 323–330.
- 46 R. Sato, N. Abe, P. Sonnet, H. Sugie and Y. Tamaki, *Appl. Entomol. Zool.*, 1985, **20**, 411–415.
- 47 M. Kato and K. Mori, *Agric. Biol. Chem.*, 1985, **49**, 2479–2480.
- 48 S. Sankaranarayanan, A. Sharma, B. A. Kulkarni and S. Chattopadhyay, *J. Org. Chem.*, 1995, **60**, 4251–4254.
- 49 T. Zhang, W.-L. Ma, T.-R. Li, J. Wu, J.-R. Wang and Z.-T. Du, *Molecules*, 2013, **18**, 5201–5208.
- 50 R. Gries, G. Gries, G. G. S. King and C. T. Maier, *J. Chem. Ecol.*, 1997, **23**, 1119–1130.
- 51 J. H. Park, K. S. Han, K. Mori and K. S. Boo, *J. Chem. Ecol.*, 2002, **28**, 2515–2525.
- 52 Y. Nakamura and K. Mori, *Eur. J. Org. Chem.*, 2000, 2745–2753.
- 53 T. Taguri, K. Yaginuma, M. Yamamoto, T. Fujii and T. Ando, *Biosci. Biotechnol. Biochem.*, 2014, **78**, 761–765.
- 54 V. N. Kovalenko and I. V. Mineeva, *Russ. J. Org. Chem.*, 2014, **50**, 934–942.
- 55 Y. M. A. W. Lamers, G. Rusu, J. B. P. A. Wijnberg and A. Groot, *Tetrahedron*, 2003, **59**, 9361–9369.
- 56 J. Cao and P. Perimutter, *Org. Lett.*, 2013, **15**, 4327–4329.
- 57 W. Francke, E. Plass, N. Zimmermann, H. Tietgen, T. Tolasch, S. Franke, M. Subchev, T. Toshova, J. A. Pickett, L. J. Wadhams and C. M. Woodcock, *J. Chem. Ecol.*, 2000, **26**, 1135–1149.

- 58 T. Toshova, M. Subchev, E. Plass and W. Francke, *J. Appl. Entomol.*, 2003, **127**, 195–199.
- 59 R. A. Soldi, M. A. C. M. Rodrigues, J. R. Aldrich and P. H. G. Zarbin, *J. Chem. Ecol.*, 2012, **38**, 814–824.
- 60 M. T. Fletcher, S. Chow, L. K. Lambert, O. P. Gallagher, B. W. Cribb, P. G. Allsopp, C. J. Moore and W. Kitching, *Org. Lett.*, 2003, **5**, 5083–5086.
- 61 S. Chow, M. T. Fletcher, L. K. Lambert, O. P. Gallagher, C. J. Moore, B. W. Cribb, P. G. Allsopp and W. Kitching, *J. Org. Chem.*, 2005, **70**, 1808–1827.
- 62 C. Herber and B. Breit, *Eur. J. Org. Chem.*, 2007, 3512–3519.
- 63 J. Zhou, Y. Zhu and K. Burgess, *Org. Lett.*, 2007, **9**, 1391–1393.
- 64 G. Zhu, B. Liang and E. Negishi, *Org. Lett.*, 2008, **10**, 1099–1101.
- 65 N. B. Basar, H. Liu, D. Negi, H. M. Sirat, G. A. Morris and E. J. Thomas, *Org. Biomol. Chem.*, 2012, **10**, 1743–1745.
- 66 O. A. Olaniran, A. V. S. Sudhakar, F. P. Drijfhout, I. A. N. Dublon, D. R. Hall, J. G. C. Hamilton and W. D. J. Kirk, *J. Chem. Ecol.*, 2013, **39**, 559–568.
- 67 K. K. Schlamp, R. Gries, G. Khaskin, K. Brown, E. Khaskin, G. J. R. Judd and G. Gries, *J. Chem. Ecol.*, 2005, **31**, 2897–2911.
- 68 A. Endler, J. Liebig, T. Schmitt, J. E. Parker, G. R. Jones, P. Schreier and B. Hölldobler, *Proc. Natl. Acad. Sci. U.S.A.*, 2004, **101**, 2945–2950.
- 69 A. V. Oystaeyen, R. C. Oliveira, L. Holman, J. S. Zweden, C. Romero, C. A. Oi, P. d’Ettorre, M. Khalesi, J. Billen, F. Wäkers, J. G. Millar and T. Wenseleers, *Science*, 2014, **343**, 287–290.
- 70 G. P. Svensson, E. A. Gündüz, N. Sjöberg, E. Hedenström, J.-M. Lassance, H.-L. Wang, C. Löfstedt and O. Anderbrant, *J. Chem. Ecol.*, 2014, **40**, 387–395.
- 71 E. S. Lacey, M. D. Ginzal, J. G. Millar and L. M. Hanks, *Physiol. Entomol.*, 2008, **33**, 209–216.
- 72 J. E. Bello and J. G. Millar, *Tetrahedro Asymmetry*, 2013, **24**, 822–826.
- 73 E. C. Uebel, P. E. Sonnet, B. A. Bierl and R. W. Miller, *J. Chem. Ecol.*, 1975, **1**, 377–385.
- 74 P. E. Sonnet, E. C. Uebel, R. L. Harris and R. W. Miller, *J. Chem. Ecol.*, 1977, **3**, 245–249.
- 75 P. E. Sonnet, *J. Chem. Ecol.*, 1984, **10**, 771–781.
- 76 Y. Naoshima and H. Mukaidani, *J. Chem. Ecol.*, 1987, **13**, 325–333.
- 77 L. M. Hanks, J. G. Millar, J. A. Moreira, J. D. Barbour, E. S. Lacey, J. S. McElfresh, F. R. Reuter and A. M. Ray, *J. Chem. Ecol.*, 2007, **33**, 889–907.
- 78 A. C. R. Vitta, B. Bohman, C. R. Unelius and M. G. Lorenzo, *J. Chem. Ecol.*, 2009, **35**, 1212–1221.
- 79 T. Sakata, K. Okabe and Y. Kuwahara, *Biosci. Biotechn. Biochem.*, 2001, **65**, 919–927.
- 80 S. J. Keegans, E. D. Morgan, D. Agosti and R. Wehner, *Biochem. System. Ecol.*, 1992, **20**, 559–572.
- 81 D. Agosti, C. Austin, O. A. Gökçen, W. A. König, E. D. Morgan, E. D. Scott and R. Wehner, 1996, *Chemoecology*, **7**, 57–60.
- 82 N. Shimizu, K. Miwa, K. Noge, R. Yakumar, N. Mori and Y. Kuwahara, *Biosci. Biotechn. Biochem.*, 2009, **73**, 2332–2334.
- 83 Y. Tanaka, H. Honda, K. Ohsawa and I. Yamamoto, *J. Pestic. Sci.*, 1986, **11**, 49–55.
- 84 Y. Tanaka, H. Honda, K. Ohsawa and I. Yamamoto, *J. Pestic. Sci.*, 1989, **14**, 197–202.
- 85 G. Y. Ismuratov, M. P. Yakovleva, A. V. Galyautdinova and G. A. Tolstikov, *Chem. Nat. Comp.*, 2003, **39**, 31–33.
- 86 D. L. Li, C. F. Lu, G. C. Yang and Z. X. Chen, *Chem. Natur. Comp.*, 2010, **46**, 440–443.

- 87 T. Suzuki, *Agric. Biol. Chem.*, 1981, **45**, 1357–1363.
- 88 T. Suzuki and K. Mori, *Entomol. Exp. Appl.*, 1983, **18**, 134–136.
- 89 Y. Lu, R. W. Beeman, J. F. Campbell, Y. Park, M. J. Aikins, K. Mori, K. Akasaka, S. Tamogami and T. W. Phillips, *Naturwissenschaften*, 2011, **98**, 755–761.
- 90 K. Mori, S. Kuwahara and H. Ueda, *Tetrahedron*, 1983, **39**, 2439–2444.
- 91 K. Mori, M. Kato and S. Kuwahara, *Liebigs Ann. Chem.*, 1985, 861–865.
- 92 C. Fuganti, P. Grasselli, S. Servi and H.-E. Högberg, *J. Chem. Soc. Perkin Trans. I*, 1988, 3061–3065.
- 93 S. Sankaranarayanan, A. Sharma and S. Chattopadhyay, *Tetrahedron Asymmetry*, 2002, **13**, 1373–1378.
- 94 Y. Kameda and H. Nagano, *Tetrahedron*, 2006, **62**, 9751–9757.
- 95 E. M. Santangelo, A. G. Correa and P. H. G. Zarbin, *Tetrahedron Lett.*, 2006, **47**, 5135–5137.
- 96 K. Akasaka, S. Tamogami, R. W. Beeman and K. Mori, *Tetrahedron*, 2011, **67**, 201–209.
- 97 Y. Tamaki, H. Noguchi, H. Sugie, R. Sato and A. Kariya, *Appl. Entomol. Zool.*, 1979, **14**, 101–113.
- 98 Y. Tamaki, H. Sugie, M. Osakabe and P. Sonnet, *Appl. Entomol. Zool.*, 1983, **18**, 292–294.
- 99 T. Suguro and K. Mori, *Agric. Biol. Chem.*, 1979, **43**, 869–870.
- 100 M. Hjalmarsson and H.-E. Högberg, *Acta Chem. Scand.*, 1985, **B39**, 793–796.
- 101 S. Geresh, T. J. Valiyaveetil, Y. Lavie and A. Shani, *Tetrahedron Asymmetry*, 1998, **9**, 89–96.
- 102 S. Chow and W. Kitching, *Chem. Comm.*, 2001, 1040–1041.
- 103 I. V. Mineeva, *Russ. J. Org. Chem.*, 2014, **50**, 168–174.
- 104 K. Shimomura, H. Koshino, A. Yajima, N. Matsumoto, Y. Kagohara, K. Kamada, S. Yajima and K. Ohsawa, *J. Chem. Ecol.*, 2010, **36**, 824–833.
- 105 K. Shimomura, H. Koshino, A. Yajima, N. Matsumoto, S. Yajima and K. Ohsawa, *Tetrahedron Lett.*, 2010, **51**, 6860–6862.
- 106 A. Luxova, K. Urbanova, I. Valterova, M. Terzo and A. K. Borg-Karlson, *Chirality*, 2004, **16**, 228–233.
- 107 T. Tolasch, S. Kehl and S. Dötterl, *J. Chem. Ecol.*, 2012, **38**, 1493–1503.
- 108 J. Cvacka, P. Jiroš, B. Kalinová, J. Straka, K. Cerná, P. Šebesta, A. Tomcala, S. Sona Vašicková, U. Jahn and J. Šobotník, *J. Chem. Ecol.*, 2012, **38**, 1483–1491.
- 109 R. Lagoutte, P. Šebesta, P. Jiroš, B. Kalinová, A. Jirošová, J. Straka, K. Černá, J. Šobotník, J. Cvačka and U. Jahn, *Chem. Eur. J.*, 2013, **19**, 8515–8524.
- 110 D. Geerdink, J. Buter, T. A. van Beek and A. J. Minnaard, *Beilstein J. Org. Chem.*, 2014, **10**, 761–766.
- 111 F. J. Ritter, I. E. M. Bruggemann Rotgans, P. E. J. Verwiel, C. J. Persoons and E. Talman, *Tetrahedron Lett.*, 1977, **18**, 2617–2618.
- 112 K. Mori and N. Murata, *Liebigs Ann. Chem.*, 1995, 2089–2092.
- 113 I. V. Mineyeva and O. G. Kulinkovich, *Tetrahedron Lett.*, 2010, **51**, 1836–1839.
- 114 J. R. Aldrich, J. E. Oliver, W. R. Lusby and J. P. Kochansky, *Arch. Insect Biochem. Physiol.*, 1986, **3**, 1–12.
- 115 J. Kochansky, J. R. Aldrich and W. R. Lusby, *J. Chem. Ecol.*, 1989, **15**, 1717–1728.
- 116 S. Wakamura, T. Yasuda, A. Ichikawa, T. Fukumoto and F. Mochizuki, *Appl. Entomol. Zool.*, 1994, **29**, 403–411.

- 117 S. Wakamura, A. Ichikawa, T. Yasuda, N. Arakaki and T. Fukumoto, *Appl. Entomol. Zool.*, 1996, **31**, 623–625.
- 118 S. Wakamura, T. Yasuda, Y. Hirai, H. Tanaka, T. Doki, Y. Nasu, M. Shibao, A. Yunotani and K. Kadono, *Appl. Entomol. Zool.*, 2007, **42**, 375–382.
- 119 A. Ichikawa, T. Yasuda and S. Wakamura, *J. Chem. Ecol.*, 1995, **21**, 627–634.
- 120 J. O. Rodin, W. E. Burkholder and J. E. Gorma, *Science*, 1969, **165**, 904–906.
- 121 R. M. Silverstein, R. F. Cassidy, W. E. Burkholder, T. J. Shapas, H. Z. Levinson, A. R. Levinson and K. Mori, *J. Chem. Ecol.*, 1980, **6**, 911–917.
- 122 K. Mori, *Tetrahedron*, 1974, **30**, 3817–3820.
- 123 J. H. Cross, R. C. Byler, R. F. Cassidy, Jr., R. M. Silverstein, R. E. Greenblatt, W. E. Burkholder, A. R. Levinson and H. Z. Levinson, *J. Chem. Ecol.*, 1976, **2**, 457–468.
- 124 R. Rossi and A. Carpita, *Tetrahedron*, 1977, **33**, 2447–2450.
- 125 K. Mori, T. Suguro and M. Uchida, *Tetrahedron*, 1978, **34**, 3119–3123.
- 126 K. Mori, S. Kuwahara, H. Z. Levinson and A. R. Levinson, *Tetrahedron*, 1982, **38**, 2291–2297.
- 127 I. May-Concha, J. C. Rojas, L. Cruz-López, J. G. Millar and J. M. Ramsey, *Med. Vet. Entomol.*, 2013, **27**, 165–174.
- 128 J. M. Pasteels, J. C. Verhaeghe, R. Ottinger, J. C. Braekman and D. Dalozé, 1981, *Insect Biochem.*, **11**, 675–678.
- 129 B. Dhotare, S. A. Hassarajani and A. Chattopadhyay, *Molecules*, 2000, **5**, 1051–1054.
- 130 A. B. Attygalle, O. Vostrowsky, H. J. Bestmann, S. Steghaus-Kovac and U. Maschwitz, *Naturwissenschaften.*, 1988, **75**, 315–317.
- 131 G. T. Pearce, W. E. Gore, R. M. Silverstein, J. W. Peacock, R. A. Cuthbert, G. N. Lanier and J. B. Simeone, *J. Chem. Ecol.*, 1975, **1**, 115–124.
- 132 G. N. Lanier, W. E. Gore, G. T. Pearce, J. W. Peacock and R. M. Silverstein, *J. Chem. Ecol.*, 1977, **3**, 1–8.
- 133 A. Zada, S. Ben-Yehuda, E. Dunkelblum, M. Harel, F. Assael and Z. Mendel, *J. Chem. Ecol.*, 2004, **30**, 631–641.
- 134 G. Gries, R. Gries, A. L. Perez, A. C. Oehlschlager, L. M. Gonzales, H. D. Pierce, Jr., M. Kouda-Bonafos, M. Zebeyou and N. Nanou, *Naturwissenschaften*, 1993, **80**, 90–91.
- 135 A. L. Perez, G. Gries, R. Gries, R. M. Giblin-Davis and A. C. Oehlschlager, *J. Chem. Ecol.*, 1994, **20**, 2653–2671.
- 136 K. Mori, H. Kiyota and D. Rochat, *Liebigs Ann. Chem.*, 1993, 865–870.
- 137 J. M. Odriozola, J. M. García, A. González and P. Gil, *Tetrahedron Asymmetry*, 1999, **10**, 4627–4632.
- 138 J. S. Yadav, C. V. Rao, A. R. Prasad and A. A. K. A. Ghamdi, *Synthesis*, 2011, 3894–3898.
- 139 T. J. Weissling, R. M. Giblin-Davis, G. Gries, R. Gries, A. L. Perez, H. D. Pierce, Jr. and A. C. Oehlschlager, *J. Chem. Ecol.*, 1994, **20**, 505–515.
- 140 R. H. Hallett, G. Gries, R. Gries, J. H. Borden, E. Czyzewska, A. C. Oehlschlager, H. D. Pierce, Jr., N. P. D. Angerilli and A. Rauf, *Naturwissenschaften.*, 1993, **80**, 328–331.
- 141 A. C. Oehlschlager, R. N. B. Prior, A. L. Perez, R. Gries, G. Gries, H. D. Pierce, Jr. and S. Laup, *J. Chem. Ecol.*, 1995, **21**, 1619–1629.
- 142 K. Mori, H. Kiyota, C. Malosse and D. Rochat, *Liebigs Ann. Chem.*, 1993, 1201–1204.
- 143 P. L. Guss, J. H. Tumlinson, P. E. Sonnet and A. T. Proveaux, *J. Chem. Ecol.*, 1982, **8**, 545–556.
- 144 P. L. Guss, P. E. Sonnet, R. L. Carney, T. F. Branson and J. H. Tumlinson, *J. Chem. Ecol.*, 1984, **10**, 1123–1131.
- 145 K. Mori and H. Watanabe, *Tetrahedron*, 1984, **40**, 299–303.
- 146 P. E. Sonnet, R. L. Carney and C. Henrick, *J. Chem. Ecol.*, 1985, **11**, 1371–1387.

- 147 A. Carpita, M. Chini and R. Rossi, *Gaz. Chim. Ital.*, 1986, **116**, 29–33.
- 148 J. L. Le Quere, R. Brossut, C. A. Nalepa and O. Bonnard, *J. Chem. Ecol.*, 1991, **17**, 811–821.
- 149 K. Mori, M. Itou and R. Brossut, *Liebigs Ann. Chem.*, 1990, 1249–1255.
- 150 Y. Kuwahara, L. T. M. Yen, Y. Tominaga, K. Matsumoto and Y. Wada, *Agric. Biol. Chem.*, 1982, **46**, 2283–2291.
- 151 K. Mori and S. Kuwahara, *Tetrahedron*, 1986, **42**, 5545–5550.
- 152 Y. Kuwahara, N. Asami, M. Morr, S. Matsuyama and T. Suzuki, *Appl. Entomol. Zool.*, 1994, **29**, 253–257.
- 153 K. Mori and S. Kuwahara, *Tetrahedron*, 1986, **42**, 5539–5544.
- 154 M. Kaino, Y. Naruse, K. Ishihara and H. Yamamoto, *J. Org. Chem.*, 1990, **55**, 5814–5815.
- 155 M. Morr, C. Proppe and V. Wray, *Liebigs Ann. Chem.*, 1995, 2001–2004.
- 156 N. Hanaki, K. Ishihara, M. Kaino, Y. Naruse and H. Yamamoto, *Tetrahedron*, 1996, **52**, 7297–7320.
- 157 R. D. Mazery, M. Pullez, F. López, S. R. Harutyunyan, A. J. Minnaard and B. L. Feringa, *J. Am. Chem. Soc.*, 2005, **127**, 9966–9967.
- 158 J. S. Yadav, S. Sengupta, N. N. Yadav, D. N. Chary and A. A. A. Ghamdi, *Tetrahedron Lett.*, 2012, **53**, 5952–5954.
- 159 A. Tai, Y. Higashiura, M. Kakizaki, T. Naito, K. Tanaka, M. Fujita, T. Sugimura, H. Hara and N. Hayashi, *Biosci. Biotechn. Biochem.*, 1998, **62**, 607–608.
- 160 A. Tai, E. Syouno, K. Tanaka, M. Fujita, T. Sugimura, Y. Higashiura, M. Kakizaki, H. Hara and T. Naito, *Bull. Chem. Soc. Jap.*, 2002, **75**, 111–122.
- 161 G. Bergström, A. B. Wassgren, O. Anderbrant, J. Fagerhag, H. Edlund, E. Hedenström, H. E. Högberg, C. Geri, M. A. Auger, M. Varama, B. S. Hansson and J. Löfqvist, *Experientia*, 1995, **51**, 370–380.
- 162 J. Bång, E. Hedenström and K. Sjödin, *J. Chem. Ecol.*, 2011, **37**, 125–133.
- 163 A. V. Bekish, K. N. Prokhorevich and O. G. Kulinkovich, *Tetrahedron Lett.*, 2004, **45**, 5253–5255.
- 164 K. N. Prokhorevich and O. G. Kulinkovich, *Tetrahedron Asymmetry*, 2006, **17**, 2976–2980.
- 165 A. B. Wassgren, G. Bergström, A. Sierpinski, O. Anderbrant, H. E. Högberg and E. Hedenström, *Naturwissenschaften*, 2000, **87**, 24–29.
- 166 S.-Y. Wang, P. Song, Y.-J. Chin and T.-P. Loh, *Chem. Asian J.*, 2011, **6**, 385–388.
- 167 G. Bergström, A.-B. Wassgren, O. Anderbrant, S. A. Ochieng, F. Östrand, B. S. Hansson, E. Hedenström and H.-E. Högberg, *Naturwissenschaften*, 1998, **85**, 244–248.
- 168 F. Östrand, O. Anderbrant, A.-B. Wassgren, G. Bergström, E. Hedenström, H.-E. Högberg, B.-V. Nguyen and M. Larsson, *Chemoecology*, 2003, **13**, 155–162.
- 169 Y. Nakamura and K. Mori, *Eur. J. Org. Chem.*, 1999, 2175–2182.
- 170 S. Dandapani, M. Jeske and D. P. Curran, *Proc. Natl. Acad. Sci. U.S.A.*, 2004, **101**, 12008–12012.
- 171 E. Hedenström, H. Edlund, A. B. Wassgren, G. Bergström, O. Anderbrant, F. Östrand, A. Sierpinski, M. A. Auger-Rozenberg, A. Herz, W. Heitland and M. Varama, *J. Chem. Ecol.*, 2006, **32**, 2525–2541.
- 172 D. M. Jewett, F. Matsumura and H. C. Coppel, *Science*, 1976, **192**, 51–53.
- 173 O. Anderbrant, J. Löfqvist, H. E. Högberg, E. Hedenström, N. Baldassari, P. Baronio, G. Kolmakova, B. Lyons, T. Naito, V. Odinkov, J. Simand, A. Supatashvii, A. Tai and R. Tourianov, *Entomol. Exp. Appl.*, 2000, **95**, 229–239.

- 174 S. Byström, H.-E Högberg and T. Norin, *Tetrahedron*, 1981, **37**, 2249–2254.
- 175 S. Ebert and N. Krause, *Eur. J. Org. Chem.*, 2001, 3831–3835.
- 176 P.-Q. Huang, H.-Q. Lan, X. Zheng and Y.-P. Ruan, *J. Org. Chem.*, 2004, **69**, 3964–3967.
- 177 V. Kovalenko and E. Matushenkov, *Tetrahedron Asymmetry*, 2012, **23**, 1393–1399.
- 178 J.-F. Zheng, H.-Q. Lan, R.-F. Yang, Q.-L. Peng, Z.-H. Xiao, S.-C. Tuo, K.-Z. Hu, Y.-G. Xiang, Z. Wei, Z. Zhang and P.-Q. Huang, *Helv. Chim. Acta*, 2012, **95**, 1799–1808.
- 179 E. Hedenström, H. Edlund, A. B. Wassgren, G. Bergström, O. Anderbrant, F. Östrand, A. Sierpinski, M. A. Auger-Rozenberg, A. Herz, W. Heitland and M. Varama, *Z. Naturforsch. C.*, 2009, **64**, 733–742.
- 180 D. R. Hall, A. Cork, R. Lester, B. F. Nesbitt and P. Zagatti, *J. Chem. Ecol.*, 1987, **13**, 1575–1589.
- 181 K. Mori, H. Harada, P. Zagatti, A. Cork and D. R. Hall, *Liebigs Ann. Chem.*, 1991, 259–267.
- 182 Y. Nakamura and K. Mori, *Biosci. Biotechn. Biochem.*, 2000, **64**, 1713–1721.
- 183 R. V. Shafikov, A. Y. Spivak and V. N. Odinkov, *Russ. J. Org. Chem.*, 2011, **47**, 290–294.
- 184 R. Yamakawa, R. Kiyota, T. Taguri and T. Ando, *Tetrahedron Lett.*, 2011, **52**, 5808–5811.
- 185 Y. Muraki, T. Taguri, R. Yamakawa and T. Ando, *J. Chem. Ecol.*, 2014, **40**, 250–258.
- 186 J. G. Pomonis, L. Hammack and H. Hakk, *J. Chem. Ecol.*, 1993, **19**, 985–1008.
- 187 D. A. Carlson, D. R. Berkebile, S. R. Skoda, K. Mori and S. Mihok, *Med. Vet. Entomol.*, 2007, **21**, 93–96.
- 188 K. Akasaka, D. A. Carlson, T. Ohtaka, H. Ohruai, K. Mori and D. R. Berkebile, *Vet. Entomol.*, 2009, **23** (Suppl. 1), 126–130.
- 189 K. Mori, T. Ohtaki, H. Ohruai, D. R. Berkebile and D. A. Carlson, *Eur. J. Org. Chem.*, 2004, 1089–1096.
- 190 K. Mori, T. Ohtaki, H. Ohruai, D. R. Berkebile and D. A. Carlson, *Biosci. Biotechnol. Biochem.*, 2004, **68**, 1768–1778.
- 191 H. M. Fales, M. S. Blum, R. M. Crewe and J. M. Brand, *J. Insect Physiol.*, 1972, **18**, 1077–1088.
- 192 K. Mori, 1992, In Total Synthesis of Natural Products, **9**, 1–521. doi: 10.1002/9780470129722.ch1.
- 193 R. G. Riley, R. M. Silverstein and J. C. Moser, *J. Insect Physiol.*, 1974, **20**, 1629–1637.
- 194 B. Hölldobler, N. J. Oldham, E. D. Morgan and W. A. König, *J. Insect Physiol.*, 1995, **41**, 739–744.
- 195 J. Bergmann, C. Löfstedt, V. D. Ivanov and W. Francke, *Eur. J. Org. Chem.*, 2001, 3175–3179.
- 196 H. M. Fales, T. M. Jaouni, J. O. Schmidt and M. S. Blum, *J. Chem. Ecol.*, 1980, **6**, 895–903.
- 197 J. Meinwald, A. F. Kluge, J. E. Carrel and T. Eisner, *Proc. Natl. Acad. Sci. U.S.A.*, 1971, **68**, 1467–1468.
- 198 R. G. Riley and R. M. Silverstein, *Tetrahedron*, 1974, **30**, 1171–1174.
- 199 G. Schmeda-Hirschmann, *Z. Naturforsch. C.*, 2006, **61**, 592–594.
- 200 M. Espinoza-Moraga, R. Cornejo-Morales and L. S. Santos, *Tetrahedron Asymmetry*, 2009, **20**, 1062–1064.
- 201 N. R. Schmuff, J. K. Phillips, W. E. Burkholder, H. M. Fales, C. W. Chen, P. P. Roller and M. Ma, *Tetrahedron Lett.*, 1984, **25**, 1533–1534.
- 202 C. A. Walgenbach, J. K. Phillips, W. E. Burkholder, G. G. S. King, K. N. Slessor and K. Mori, *J. Chem. Ecol.*, 1987, **13**, 2159–2169.

- 203 K. Mori and T. Ebata, *Tetrahedron*, 1986, **42**, 4421–4426.
- 204 K. Mori, T. Yoshimura and T. Sugai, *Liebigs Ann. Chem.*, 1988, 899–902.
- 205 D. Kalaitzakis, J. D. Rozzell, S. Kambourakis and I. Smonou, *Eur. J. Org. Chem.*, 2006, 2309–2313.
- 206 H. J. Bestmann, A. B. Attygalle, J. Glasbrenner, R. Riemer, O. Vostrowsky, M. G. Constantino, G. Melikian and E. D. Morgan, *Liebigs Ann. Chem.*, 1988, 55–60.
- 207 R. M. Crewe, M. S. Blum and C. A. Collingwood, *Comp. Biochem. Physiol.*, 1972, **43B**, 703–716.
- 208 Y. Naoshima, D. Hayashi and M. Ochi, *Agric. Biol. Chem.*, 1988, **52**, 1605–1606.
- 209 F. Y. Zhou, C. F. Lu, Z. X. Chen and G. C. Yang, *Chem. Nat. Comp.*, 2010, **46**, 83–85.
- 210 S. Song, S.-F. Zhu, Y.-B. Yu and Q.-L. Zhou, *Angew. Chem. Int. Ed.*, 2013, **52**, 1556–1559.
- 211 J. E. Oliver, J. C. Dickens and T. E. Glass, *Tetrahedron Lett.*, 2002, **43**, 2641–2643.
- 212 T. Tashiro and K. Mori, *Tetrahedron Asymmetry*, 2005, **16**, 1801–1806.
- 213 B. N. Babu and K. R. Chauhan, *Tetrahedron Lett.*, 2009, **50**, 66–67.
- 214 J. A. Faraldos, R. M. Coates and J.-L. Giner, *J. Org. Chem.*, 2013, **78**, 10548–10554.
- 215 S.-N. Li, L.-L. Fang, J.-C. Zhong, J.-J. Shen, H. Xu, Y.-Q. Yang, S.-C. Hou and Q.-H. Bian, *Tetrahedron Asymmetry*, 2014, **25**, 591–595.
- 216 T. Chuman, M. Kohno, K. Kato and M. Noguchi, *Tetrahedron Lett.*, 1979, **25**, 2361–2364.
- 217 K. Mochizuki, T. Chuman, M. Mori, M. Kohno and K. Kato, *Agric. Biol. Chem.*, 1984, **48**, 2833–2834.
- 218 J. Fleischhauer, S. Gabriel, A. Job, D. Enders and A. Wollmer, *Z. Naturforsch. B*, 2001, **56**, 1344–1348.
- 219 T. Chuman, K. Mochizuki, M. Mori, M. Kohno, K. Kato and M. Noguchi, *J. Chem. Ecol.*, 1985, **11**, 417–434.
- 220 G. Sabitha, C. Srinivas, C. Maruthi and J. S. Yadav, *Tetrahedron Asymmetry*, 2011, **22**, 2071–2079.
- 221 S. Schulz, J. Fuhlendorff, J. L. M. Steidle, J. Collatz and J. T. Franz, *Chembiochem.*, 2004, **5**, 1500–1507.
- 222 P. L. Guss, J. H. Tumlinson, P. E. Sonnet and J. R. McLaughlin, *J. Chem. Ecol.*, 1983, **9**, 1363–1375.
- 223 P. E. Sonnet, *J. Org. Chem.*, 1982, **47**, 3793–3796.
- 224 S. Senda and K. Mori, *Agric. Biol. Chem.*, 1983, **47**, 795–798.
- 225 S. Chow and W. Kitching, *Tetrahedron Asymmetry*, 2002, **13**, 779–793.
- 226 P. Y. Hayes, M. T. Fletcher, S. Chow, M. J. McGrath, Y. Q. Tu, H. Zhang, N. L. Hungerford, C. S. P. McErlean, J. E. Stok, C. J. Moore, J. J. Devoss and W. Kitching, *Chirality*, 2003, **15**, S116–S127.
- 227 C.-F. Lu, S.-B. Zhang, Y. Li, G.-C. Yang and Z.-X. Chen, *Tetrahedron Asymmetry*, 2009, **20**, 2267–2269.
- 228 Y. Shikichi and K. Mori, *Biosci. Biotechnol. Biochem.*, 2012, **76**, 407–409.
- 229 C. F. Fávaro, R. A. Soldi, T. Ando, J. R. Aldrich and P. H. G. Zarbin, *Org. Lett.*, 2013, **15**, 1822–1825.
- 230 Y. Muraki, T. Taguri, M. Yamamoto, P. H. G. Zarbin and T. Ando, *Eur. J. Org. Chem.*, 2013, 2209–2215.
- 231 T. Chuman, P. L. Guss, R. E. Doolittle, J. R. McLaughlin, J. L. Krysan, J. M. Schalk and J. H. Tumlinson, *J. Chem. Ecol.*, 1987, **13**, 1601–1616.

- 232 J. R. McLaughlin, J. H. Tumlinson and K. Mori, *J. Econ. Entomol.*, 1991, **84**, 99–102.
- 233 K. Mori and Y. Igarashi, *Liebigs Ann. Chem.*, 1988, 717–720.
- 234 D. Enders, B. Jandeleit and O. F. Prokopenko, *Tetrahedron*, 1995, **51**, 6273–6284.
- 235 M. Yamamoto, T. Kamata, N. D. Do, Y. Adachi, M. Kinjo and T. Ando, *Biosci. Biotechn. Biochem.*, 2007, **71**, 2860–2863.
- 236 Y. Adachi, N. D. Do, M. Kinjo, S. Makisako, R. Yamakawa, K. Mori and T. Ando, *J. Chem. Ecol.*, 2010, **36**, 814–823.
- 237 K. Mori, *Tetrahedron*, 2009, **65**, 2798–2805.
- 238 Y. Shikichi and K. Mori, *Biosci. Biotechnol. Biochem.*, 2012, **76**, 1943–1951.
- 239 R. Nishida, H. Fukami and S. Ishii, *Experientia*, 1974, **30**, 978–979.
- 240 R. Nishida, Y. Kuwahara, H. Fukami and S. Ishii, *J. Chem. Ecol.*, 1979, **5**, 289–297.
- 241 K. Mori, S. Masuda and T. Suguro, *Tetrahedron*, 1981, **37**, 1329–1340.
- 242 K. Mori, *Tetrahedron*, 2008, **64**, 4060–4071.
- 243 D. Eliyahu, K. Mori, H. Takikawa, W. S. Leal and C. Schal, *J. Chem. Ecol.*, 2004, **30**, 1839–1848.
- 244 J. K. Phillips, S. P. F. Miller, J. F. Andersen, H. M. Fales and W. E. Burkholder, *Tetrahedron Lett.*, 1987, **28**, 6145–6146.
- 245 J. K. Phillips, J. M. Chong, J. F. Andersen and W. E. Burkholder, *Entomol. Exp. Appl.*, 1989, **51**, 149–153.
- 246 J. M. Chong, *Tetrahedron*, 1989, **45**, 623–628.
- 247 K. Mori and M. Ishikura, *Liebigs Ann. Chem.*, 1989, 1263–1265.
- 248 J. Razkin, A. Gonzalez and P. Gil, *Tetrahedron Asymmetry*, 1996, **7**, 3479–3484.
- 249 C. R. Mateus, M. P. Feltrin, A. M. Costa, F. Coelho and W. P. Almeida, *Tetrahedron*, 2001, **57**, 6901–6908.
- 250 D. Kalaitzakis, S. Kambourakis, D. J. Rozzellb and I. Smonou, *Tetrahedron Asymmetry*, 2007, **18**, 2418–2426.
- 251 L. Gao, B. C. Kang, G.-S. Hwang and D. H. Ryu, *Angew. Chem. Int. Ed.*, 2012, **51**, 8322–8325.
- 252 S. P. Ravia, M. Risso, S. Kröger, S. Vero, G. A. Seoane and D. Gamnara, *Tetrahedron Asymmetry*, 2013, **24**, 1207–1211.
- 253 R. A. Laumann, M. Borges, J. R. Aldrich, A. Khimian and M. C. Blassioli-Moraes, 2012. *Psyche*, doi:10.1155/2012/280340.
- 254 H. J. Bestmann, U. Haak, E. Kern and B. Hölldobler, *Naturwissenschaften*, 1995, **82**, 142–144.
- 255 H. J. Bestmann, B. Liepold, A. Kress and A. Hofmann, *Chem. Eur. J.*, 1999, **5**, 2984–2989.
- 256 P. D. Swedenborg, R. L. Jones, H.-W. Liu and T. P. Krick, *J. Chem. Ecol.*, 1993, **19**, 485–503.
- 257 P. D. Swedenborg, R. L. Jones, H.-Q. Zhou, I. Shin and H.-W. Liu, *J. Chem. Ecol.*, 1994, **20**, 3373–3380.
- 258 I. Shin, H.-Q. Zhou, N. L. S. Que, H.-W. Liu, P. D. Swedenborg and R. L. Jones, *J. Org. Chem.*, 1993, **58**, 2923–2926.
- 259 G.-Q. Lin and W.-C. Xu, *Tetrahedron*, 1996, **52**, 5907–5912.
- 260 D. Shklyaruck and E. Matiushenkov, *Tetrahedron Asymmetry*, 2011, **22**, 1448–1454.
- 261 B. V. Burger and W. G. B. Petersen, *J. Chem. Ecol.*, 2002, **28**, 501–513.

- 262 B. V. Burger, Z. Munro, M. Roth, H. S. C. Spies, V. Truter, G. D. Tribe and R. M. Crewe, *Z. Naturforsch. C.*, 1983, **38**, 848–855.
- 263 R. H. Hallett, A. L. Perez, G. Gries, R. Gries, H. D. Pierce, Jr., J. Yue, A. C. Oehlschlager, L. M. Gonzalez and J. H. Borden, *J. Chem. Ecol.*, 1995, **21**, 1549–1570.
- 264 G. Gries, R. Gries, A. L. Perez, A. C. Oehlschlager, L. M. Gonzales, H. D. Pierce, Jr., M. Zebeyou and B. Kouame, *Z. Naturforsch. C.*, 1994, **49**, 363–366.
- 265 J. R. Rocca, J. H. Tumlinson, B. M. Glancey, and C. S. Lofgren, *Tetrahedron Lett.*, 1983, **24**, 1893–1896.
- 266 K. Mori and Y. Nakazono, *Tetrahedron*, 1986, **42**, 6459–6464.
- 267 F. E. Ziegler, E. P. Stirchak and R. T. Wester, *Tetrahedron Lett.*, 1986, **27**, 1229–1232.
- 268 S. Senda and K. Mori, *Agric. Biol. Chem.*, 1987, **51**, 1379–1384.
- 269 T. Honda, S. Yamane, F. Ishikawa and M. Katoh, *Tetrahedron*, 1996, **52**, 12177–12184.
- 270 J. S. Yadav, K. A. Lakshmi, N. M. Reddy, A. R. Prasad and A. A. K. A. Ghamdi, *Synthesis*, 2012, 2595–2600.
- 271 B. D. Morris, S. P. Foster, R. R. Smyth, M. P. Hoffmann, W. L. Roelofs, S. Franke and W. Francke, *J. Nat. Prod.*, 2005, **68**, 26–30.
- 272 Y. Schmidt and B. Breit, *Org. Lett.*, 2009, **11**, 4767–4769.
- 273 Y. Schmidt, K. Lehr, U. Breuninger, G. Brand, T. Reiss and B. Breit, *J. Org. Chem.*, 2010, **75**, 4424–4433.
- 274 J. S. Yadav, N. N. Yadav, T. S. Rao, B. V. S. Reddy and A. A. K. A. Ghamdi, *Eur. J. Org. Chem.*, 2011, 4603–4608.
- 275 C. F. Weise, M. Pischl, A. Pfaltz and C. Schneider, *Chem. Commun.*, 2011, **47**, 3248–3250.
- 276 C. F. Weise, M. C. Pischl, A. Pfaltz and C. Schneider, *J. Org. Chem.*, 2012, **77**, 1477–1488.
- 277 J. Rodstein, J. S. McElfresh, J. D. Barbour, A. M. Ray, L. M. Hanks and J. G. Millar, *J. Chem. Ecol.*, 2009, **35**, 590–600.
- 278 J. Rodstein, J. G. Millar, J. D. Barbour, J. S. McElfresh, I. M. Wright, K. S. Barbour, A. M. Ray and L. M. Hanks, *J. Chem. Ecol.*, 2011, **37**, 114–124.
- 279 E. C. Maki, J. Rodstein, J. G. Millar, K. S. Barbour, L. M. Hanks and J. D. Barbour, *J. Chem. Ecol.*, 2011, **37**, 714–716.
- 280 H.-Y. Ho and J. G. Millar, *J. Chem. Ecol.*, 2001, **27**, 1177–1201.
- 281 H.-Y. Ho and J. G. Millar, *J. Chem. Ecol.*, 2001, **27**, 2067–2095.
- 282 J. R. Aldrich, J. E. Oliver, W. R. Lusby, J. P. Kochansky and M. Borges, *J. Chem. Ecol.*, 1994, **20**, 1103–1111.
- 283 P. H. G. Zarbin, A. Reckziegel, E. Plass, M. Borges and W. Francke, *J. Chem. Ecol.*, 2000, **26**, 2737–2746.
- 284 K. Mori and N. Murata, *Liebigs Ann. Chem.*, 1994, 1153–1160.
- 285 P. H. G. Zarbin, F. Carla, C. F. Fávoro, D. M. Vidal and M. A. C. M. Rodrigues, *J. Chem. Ecol.*, 2012, **38**, 825–835.
- 286 R. Gries, G. Khaskin, Z.-X. Tan, B.-G. Zhao, G. G. S. King, A. Miroshnychenko, G.-Q. Lin, M. Rhains and G. Gries, *J. Chem. Ecol.*, 2006, **32**, 1673–1685.
- 287 K. Mori, T. Tashiro, B. Zhao, D. M. Suckling and A. M. El-Sayed, *Tetrahedron*, 2010, **66**, 2642–2653.
- 288 K. Mori and T. Tashiro, *Tetrahedron Lett.*, 2009, **50**, 3266–3269.
- 289 T. Taguri, M. Yamamoto, T. Fujii, Y. Muraki and T. Ando, *Eur. J. Org. Chem.*, 2013, 6924–6933.
- 290 R. E. Charlton, F. X. Webster, A. J. Zhang, C. Schal, D. S. Liang, I. Sreng and W. L. Roelofs, *Proc. Natl. Acad. Sci. U.S.A.*, 1993, **90**, 10202–10205.
- 291 W. S. Leal, X. Shi, D. Liang, C. Schal and J. Meinwald, *Proc. Natl. Acad. Sci. U.S.A.*, 1995, **92**, 1033–1037.

- 292 X. Shi, W. S. Leal, Z. Liu, E. Schrader and J. Meinwald, *Tetrahedron Lett.*, 1995, **36**, 71–74.
- 293 K. Fujita and K. Mori, *Eur. J. Org. Chem.*, 2001, 493–502.
- 294 H. Z. Levinson, A. R. Levinson, W. Francke, W. Mackenroth and V. Heemann, *Naturwissenschaften*, 1981, **68**, 148–149.
- 295 K. Mochizuki, M. Mori, T. Chuman, M. Kohno, A. Ohnishi, H. Watanabe and K. Mori, *J. Chem. Ecol.*, 1986, **12**, 179–186.
- 296 R. W. Hoffmann, W. Ladner and W. Helbig, *Liebigs Ann. Chem.*, 1984, 1170–1179.
- 297 T. Chuman, K. Mochizuki, M. Mori, M. Kohno, K. Kato and M. Noguchi, *J. Chem. Ecol.*, 1985, **11**, 417–434.
- 298 T. Chuman, K. Mochizuki, K. Kato, M. Ono and A. Okubo, *Agric. Biol. Chem.*, 1983, **47**, 1413–1415.
- 299 T. Chuman, K. Mochizuki, M. Mori, M. Kohno, K. Kato and M. Noguchi, *J. Chem. Ecol.*, 1985, **11**, 417–434.
- 300 T. Ebata and K. Mori, *Agric. Bio. Chem.*, 1987, **51**, 2925–2928.
- 301 T. Imai, H. Kodama, T. Chuman and M. Kohno, *J. Chem. Ecol.*, 1990, **16**, 1237–1247.
- 302 Y. Kuwahara, H. Fukami, R. Howard, S. Ishii, F. Matsumura and W. E. Burkholder, *Tetrahedron*, 1978, **34**, 1769–1774.
- 303 R. W. Hoffmann, W. Ladner, K. Steinbach, W. Massa, R. Schmidt and G. Snatzke, *Chem. Ber.*, 1981, **114**, 2786–2801.
- 304 R. W. Hoffmann and W. Ladner, *Tetrahedron Lett.*, 1979, **20**, 4653–4656.
- 305 K. Mori, T. Ebata and M. Sakakibara, *Tetrahedron*, 1981, **37**, 709–713.
- 306 D. Kalaitzakis and I. Smonou, *Eur. J. Org. Chem.*, 2012, 43–46.
- 307 H. Kodama, M. Ono, M. Kohno and A. Ohnishi, *J. Chem. Ecol.*, 1987, **13**, 1871–1879.
- 308 K. Mori and T. Ebata, *Tetrahedron*, 1986, **42**, 4685–4689.
- 309 M. T. Fletcher, J. A. Wells, M. F. Jacobs, S. Krohn, W. Kitching, R. A. I. Drew, C. J. Moore and W. Francke, *J. Chem. Soc. Perkin Trans. I*, 1992, 2827–2831.
- 310 P. De Groot, G. L. Debarr and G. Birgersson, *Environ. Entomol.*, 1998, **27**, 382–387.
- 311 K. Hintzer, R. Weber and V. Schurig, *Tetrahedron Lett.*, 1981, **22**, 55–58.
- 312 M. Goubault, T. P. Batchelor, R. Romani, R. S. T. Linforth, M. Fritzsche, W. Francke and I. C. W. Hardy, *Biol. J. Linnean Soc.*, 2008, **94**, 837–852.
- 313 A. T. Dossey, J. M. Whitaker, M. C. A. Dancel, R. K. V. Meer, U. R. Bernier, M. Gottardo and W. R. Roush, *J. Chem. Ecol.*, 2012, **38**, 1105–1115.
- 314 W. Francke, W. Reith, G. Bergström and J. Tengö, *Naturwissenschaften*, 1980, **67**, 149–150.
- 315 J. Tengö, L. Agren, B. Baur, R. Isaksson, T. Liljefors, K. Mori, W. König and W. Francke, *J. Chem. Ecol.*, 1990, **16**, 429–441.
- 316 K. Mori and K. Tanida, *Heterocycles*, 1981, **15**, 1171–1174.
- 317 B. Giese, D. Bartmann and T. Hasskerl, *Liebigs Ann. Chem.*, 1987, 427–430.
- 318 W. Kitching, J. A. Lewis, M. V. Perkins, R. Drew, C. J. Moore, V. Schurig, W. A. Koenig and W. Francke, *J. Org. Chem.*, 1989, **54**, 3893–3902.
- 319 C. J. Moore, A. Hubener, Y. Q. Tu, W. Kitching, J. R. Aldrich, G. K. Waite, S. Schulz and W. Francke, *J. Org. Chem.*, 1994, **59**, 6136–6138.
- 320 Y. Q. Tu, C. J. Moore and W. Kitching, *Tetrahedron Asymmetry*, 1995, **6**, 397–400.
- 321 P. Hayes, M. T. Fletcher, C. J. Moore and W. Kitching, *J. Org. Chem.*, 2001, **66**, 2530–2533.

- 322 I. V. Mineeva, *Russ. J. Org. Chem.*, 2014, 408–417.
- 323 H. Zhang, M. T. Fletcher, K. Dettner, W. Francke and W. Kitching, *Tetrahedron Lett.*, 1999, **40**, 7851–7854.
- 324 G. T. Pearce, W. E. Gore and R. M. Silverstein, *J. Org. Chem.*, 1976, **41**, 2797–2803.
- 325 G. J. Cernigliaro and P. J. Kocienski, *J. Org. Chem.*, 1977, **42**, 3622–3624.
- 326 K. Mori, *Tetrahedron*, 1976, **32**, 1979–1981.
- 327 P. A. Bartlett and J. Myerson, *J. Org. Chem.*, 1979, **44**, 1625–1627.
- 328 D. E. Plaumann, B. J. Fitzsimmons, B. M. Ritchie and B. Fraser-Reid, *J. Org. Chem.*, 1982, **47**, 941–946.
- 329 M. Larcheveque and S. Henrot, *Tetrahedron*, 1987, **43**, 2303–2310.
- 330 W. Francke and W. Kitching, *Current Org. Chem.*, 1977, **64**, 590–591.
- 331 W. Francke, V. Heemann, B. Gerken, J. A. Renwick and J. P. Vite, *Naturwissenschaften*, 1977, **64**, 590–591.
- 332 B. D. Schwartz, C. J. Moore, F. Rahm, P. Y. Hayes, W. Kitching and J. J. De Voss, *J. Am. Chem. Soc.*, 2008, **130**, 14853–14860.
- 333 Y. K. Booth, W. Kitching and J. J. De Voss, *Nat. Prod. Rep.*, 2009, **26**, 490–525.
- 334 T. Ando and R. Yamakawa, *Trends Anal. Chem.*, 2011, **3**, 990–1002.
- 335 E. J. Lenardão, G. V. Botteselle, F. Azambuja, G. Perin and R. G. Jacob, *Tetrahedron*, 2007, **63**, 6671–6712.
- 336 D. A. Evans, M. D. Ennis and D. J. Matthe, *J. Am. Chem. Soc.*, 1982, **104**, 1737–1739.
- 337 C. P. Stevenson, L. P. C. Nielsen and E. N. Jacobsen, *Org. Synth.*, 2006, **83**, 162–169.
- 338 R. E. Charlton and W. L. Roelofs, *Arch. Insect Biochem. Physiol.*, 1991, **18**, 81–97.
- 339 R. A. Jurenka, M. Subchev, J.-L. Abad, M.-Y. Choi and G. Fabriàs, *Proc. Natl. Acad. Sci. USA*, 2003, **100**, 809–814.
- 340 F. Pankewitz and M. Hilker, *Biol. Rev.*, 2008, **83**, 209–226.
- 341 J. W. Dillwith, J. H. Nelson, J. G. Pomonis, D. R. Nelson and G. J. Blomquist, *J. Biol. Chem.*, 1982, **257**, 11305–11314.
- 342 H. J. Bestmann, E. Übler and B. Hölldobler, *Angew. Chem. Int. Ed.*, 1997, **36**, 395–397.
- 343 N. Islam, R. Bacala, A. Moore and D. Vanderwel, *Insect Biochem. Molec. Biol.*, 1999, **29**, 201–208.
- 344 J. Chase, R. A. Jurenka, C. Schal, P. P. Halarnkar and G. J. Blomquist, *Insect Biochem.*, 1990, **20**, 149–156.
- 345 J. Chase, K. Touhara, G. D. Prestwich, C. Schal and G. J. Blomquist, *Proc. Natl. Acad. Sci. USA*, 1992, **89**, 6050–6054.
- 346 A. P. Jarvis, J. Liebig, B. Hölldobler and N. J. Oldham, *Chem. Commun.*, 2004, 1196–1197.
- 347 K. Ablard, R. Gries, G. Khaskin, P. W. Schaefer and G. Gries, *J. Chem. Ecol.*, 2012, **38**, 1306–1317.
- 348 G. P. Hughes, J. E. Bello, J. G. Millar and M. D. Ginzl, *J. Chem. Ecol.*, 2015, **41**, 1050–1057.
- 349 K. Mori and C. Y. Yang, *Tetrahedron*, 2016, **72**, 4593–4603.
- 350 B. V. Burger, C. A. Klerk, M. Morr and W. J. G. Burger, *J. Chem. Ecol.*, 2017, **43**, 94–105.
- 351 W. D. Silva, J. G. Millar, L. M. Hanks and J. M. S. Bento, *PloS One*, 2016, **11**, e0160727.

- 352 C. Bordereau, M. J. Lacey, E. Sémon, J.-C. Braekman, J. Ghostin, A. Robert, J. S. Sherman and D. Sillam-Dussès, *Biol. J. Linnean Soc.*, 2010, **100**, 519–530.
- 353 J. Ghostin, C. Bordereau and J. C. Braekman, *Nat. Prod. Res.*, 2011, **25**, 560–568.
- 354 L. Poppe, L. Novák, P. Kolonits, Á. Bata and C. Szántay, *Tetrahedron*, 1988, **44**, 1477–1487.
- 355 J. Skotnitzki, L. Spessert and P. Knochel, *Ang. Chem.*, 2019, **58**, 1509–1514.
- 356 M. Hrabar, H. Zhai, R. Gries, P. W. Schaefer, J. Draper, R. Britton and G. Gries, *J. Chem. Ecol.*, 2015, **41**, 732–739.
- 357 H. Zhai, M. Hrabar, R. Gries, G. Gries and R. Britton, *Chem. Euro. J.*, 2016, **22**, 6190–6193.
- 358 C.-H. Zhao, J. G. Millar, K.-H. Pan and C.-S. Xu, *J. Chem. Ecol.*, 1998, **24**, 1347–1353.
- 359 Z.-F. Sun, L.-N. Zhou, Y. Meng, T. Zhang, Z.-T. Dua and H. Zheng, *Tetrahedron Asymmetry*, 2017, **28**, 1562–1567.
- 360 H.-L. Zhang, Z.-F. Sun, L.-N. Zhou, L. Liu, T. Zhang and Z.-T. Du, *Molecules*, 2018, **23**, 1347.
- 361 E. Brenna, M. Crotti, F. G. Gatti, D. Monti, F. Parmeggiani and A. Pugliese, *Molecules*, 2017, **22**, 1591.
- 362 M. M. Blight, F. A. Mellon, L. J. Wadhams and M. J. Wenham, *Experientia*, 1977, **33**, 845–846.
- 363 J. T. B. Ferreira and F. Simonelli, *Tetrahedron*, 1990, **46**, 6311–6318.
- 364 Z.-F. Sun, T. Zhang, J. Liu, Z.-T. Du and H. Zheng, *Molecules*, 2018, **23**, 667.
- 365 I. V. Mineeva, *Russ. J. Org. Chem.*, 2013, **49**, 979–985.
- 366 I. V. Mineyeva, V. S. Masyuk, V. N. Kovalenko and M. M. Bandarenko, *Russ. J. Org. Chem.*, 2014, **50**, 1621–1627.
- 367 Z. Wang, Q. Xu, W. Tian and X. Pan, *Tetrahedron Lett.*, 2007, **48**, 7549–7551.
- 368 J. Kindl, P. Jiroš, B. Kalinová, P. Žáček and I. Valterová, *J. Chem. Ecol.*, 2012, **38**, 400–407.
- 369 A. C. Reis, P. L. S. Neta, J. P. Jordão, J. I. L. Moura, D. M. Vidal, P. H. G. Zarbin and C. F. Fávaro, *J. Chem. Ecol.*, 2018, **44**, 463–470.
- 370 R. A. Soldi, D. Szczerbowski and P. H. G. Zarbin, *Tetrahedron*, 2018, **74**, 88–95.
- 371 C. M. Nieberding, H. de Vos, M. V. Schneider, J.-M. Lassance, N. Estramil, J. Andersson, J. Bång, E. Hedenström, C. Löfstedt and P. M. Brakefield, *PLoS One*, 2008, **3**, e2751.
- 372 E. Hedenström, E. A. Wallin, J. Andersson, J. Bang, H.-L. Wang, C. Löfstedt, O. Brattström and P. Bâquet, *J. Chem. Ecol.*, 2015, **41**, 44–51.
- 373 A. Sengupta and S. Hosokawa, *Tetrahedron Lett.*, 2019, **60**, 411–414.
- 374 W. Haberer, T. Schmitt, P. Schreier, A.-K. Eggert and J. K. Müller, *J. Chem. Ecol.*, 2017, **43**, 971–977.
- 375 S. P. Chinta, S. Goller, G. Uhl and S. Schulz, *Chem. Biodiversity*, 2016, **13**, 1202–1220.
- 376 Z.-F. Sun, L.-N. Zhou, T. Zhang and Z.-T. Du, *Chin. Chem. Lett.*, 2017, **28**, 558–562.
- 377 White, P. R. and M. C. Birch, *J. Chem. Ecol.*, 1987, **13**, 1695–1706.
- 378 F. R. Dani, R. L. Jeanne, S. R. Clarke, G. R. Jones, E. D. Morgan, W. Francke and S. Turillazzi, *Physio. Entomol.*, 2000, **25**, 363–369.
- 379 V. Morozova, J. Skotnitzki, K. Moriya, K. Karaghiosoff and P. Knochel, *Angew. Chem. Int. Ed.*, 2018, **57**, 5516–5519.
- 380 T. Nagai, S. Sakurai, N. Natori, M. Hataoka, T. Kinoshita, H. Inoue, K. Hanaya, M. Shoji and T. Sugai, *Bioorg. Med. Chem.*, 2018, **26**, 1304–1313.
- 381 R. M. Silverstein, R. G. Brownlee, T. E. Bellas, D. L. Wood and L. E. Browne, *Science*, 1968, **159**, 889–891.

- 382 D. L. Wood, L. E. Browne, B. Ewing, K. Lindahl, W. D. Bedard, P. E. Tilden, K. Mori, G. B. Pitman and P. R. Hughes, *Science*, 1976, **192**, 896–898.
- 383 T. E. Stewart, E. L. Plummer, L. L. McCandless, J. R. West and R. M. Silverstein, *J. Chem. Ecol.*, 1977, **3**, 27–43.
- 384 K. Mori, *Tetrahedron*, 1974, **30**, 4223–4227.
- 385 D. S. Matterson and K. M. Sadhu, *J. Am. Chem. Soc.*, 1983, **105**, 2077–2078.
- 386 H. Takahata, M. Kusunoki, Y. Takeda and T. Momose, *Tetrahedron Asymmetry*, 1996, **7**, 2093–2098.
- 387 S. Hu, S. Jayaraman and A. C. Oehlschlager, *J. Org. Chem.*, 1999, **64**, 2524–2526.
- 388 S. Singh and P. J. Guiry, *J. Org. Chem.*, 2009, **74**, 5758–5761.
- 389 V. Schurig, R. Weber, G. J. Nichoisen, A. C. Oehlschlager, H. D. Pierce Jr., J. H. Borden and L. C. Ryker, *Naturwissenschaften*, 1983, **70**, 92–93.
- 390 W. Francke, F. Schröder, P. Philipp, H. Meyer, V. Sinnwell and G. Gries, *Bioorg. Med. Chem.*, 1996, **4**, 363–374.
- 391 M.-J. Kim, G.-B. Choi, J.-Y. Kim and H.-J. Kim, *Tetrahedron Lett.*, 1995, **36**, 6253–6256.
- 392 G. W. Kinzer, A. F. Fentiman, T. F. Page, R. L. Folt, J. P. Vite and G. B. Pitman, *Nature*, 1969, **221**, 477–478.
- 393 T. D. Paine, J. G. Millar, C. C. Hanlon and J. S. Hwang, *J. Chem. Ecol.*, 1999, **25**, 433–453.
- 394 K. Mori, *Tetrahedron*, 1975, **31**, 1381–1384.
- 395 H. Ohruï and S. Emoto, *Agric. Biol. Chem.*, 1976, **40**, 2267–2270.
- 396 C. Fuganti, P. Grasselli and S. Servi, *J. Chem. Soc. Perkin Trans. I*, 1983, 241–244.
- 397 J. K. Whiteside and C. M. Buchanan, *J. Org. Chem.*, 1986, **51**, 5443–5445.
- 398 M.-C. Trinh, J.-C. Florent and C. Monneret, *J. Chem. Soc. Chem. Comm.*, 1987, **8**, 615–616.
- 399 M. Scholl and R. H. Grubbs, *Tetrahedron Lett.*, 1999, **40**, 1425–1428.
- 400 R. Chenevert and D. Caron, *Tetrahedron Asymmetry*, 2002, **13**, 339–342.
- 401 M. Yus, D. J. Ramon and O. Prieto, *Eur. J. Org. Chem.*, 2003, **15**, 2745–2748.
- 402 P. O. Magnus and G. Roy, *J. Chem. Soc. Chem. Comm.*, 1978, **7**, 297–298.
- 403 M. Majewski and P. Nowak, *Tetrahedron Asymmetry*, 1998, **9**, 2611–2617.
- 404 R. M. Kanada, T. Taniguchi and K. Ogasawara, *Tetrahedron Lett.*, 2000, **41**, 3631–3635.
- 405 W. Francke, J. Bartels, H. Meyer, F. Sch roder, U. Kohnle, E. Baader and J. P. Vite, *J. Chem. Ecol.*, 1995., **21**, 1043–1063.
- 406 W. Francke, F. Schroder, U. Kohnle and M. Simon, *Liebigs Ann.*, 1996, 1523–1527.
- 407 H. Takikawa, S. Sano and K. Mori, *Liebigs Ann.*, 1997, 2495–2498.
- 408 J. Beauhaire, P. H. Ducrot, C. Malosse, D. Rochat, I. O. Ndiege and D. O. Otieno, *Tetrahedron Lett.*, 1995, **36**, 1043–1046.
- 409 K. Mori, T. Nakayama and H. Takikawa, *Tetrahedron Lett.*, 1996, **37**, 3741–3744.
- 410 M. T. Fletcher, C. J. Moore and W. Kitching, *Tetrahedron Lett.*, 1997, **38**, 3475–3476.
- 411 J. Bergmann, C. Löfstedt, V. D. Ivanov and W. Francke, *Tetrahedron Lett.*, 2004, **45**, 3669–3672.

- 412 D. Enders, I. Breuer and A. Nührling, *Eur. J. Org. Chem.*, 2005, 2677–2683.
- 413 J. S. Yadav, K. B. Reddy, A. R. Prasad and H. U. Rehman, *Tetrahedron*, 2008, **64**, 2063–2070.
- 414 G. W. K. Cavill, P. L. Robertson, J. J. Brophy, R. K. Duke, J. McDonald and W. D. Plant, *Insect Biochem.*, 1984, **14**, 505–513.
- 415 N. J. Oldham, E. D. Morgan, B. Gobin, E. Schoeters and J. Billen, *J. Chem. Ecol.*, 1994, **20**, 3297–3305.
- 416 L. Cruz-López, E. F. L. R. A. Patricio and E. D. Morgan, *J. Chem. Ecol.*, 2001, **27**, 69–80.
- 417 V. Sinnwell, S. Schulz, W. Francke, R. Kittmann and D. Schneider, *Tetrahedron Lett.*, 1985, **26**, 1707–1710.
- 418 S. Schulz, W. Francke, W. A. König, V. Schurig, K. Mori, R. Kittmann and D. Schneider, *J. Chem. Ecol.*, 1990, **16**, 3511–3521.
- 419 K. Mori and H. Kisida, *Tetrahedron*, 1986, **42**, 5281–5290.
- 420 K. Marukawa and K. Mori, *Eur. J. Org. Chem.*, 2002, 3974–3978.
- 421 J. G. MacConnell, J. H. Borden, R. M. Silverstein and E. Stokkink, *J. Chem. Ecol.*, 1977, **3**, 549–561.
- 422 K. Mori and M. Sasaki, *Tetrahedron*, 1980, **36**, 2197–2208.
- 423 K. N. Slessor, A. C. Oehlschlager, B. D. Johnston, H. D. Pierce, S. K. Grewel and L. K. G. Wickremesinghe, *J. Org. Chem.*, 1980, **45**: 2290–2297.
- 424 K. Mori, T. Uematsu, M. Minobe and K. Yanagi, *Tetrahedron Lett.*, 1982, **23**, 1921–1924.
- 425 A. A. Kandil and K. N. Slessor, *J. Org. Chem.*, 1985, **50**, 5649–5655.
- 426 M. Racamonde, R. Alibes, M. Figueredo, J. Font and P. de March, *J. Org. Chem.*, 2008, **73**, 5944–5952.
- 427 T. Cai, D. Wang, X. Wu, K. Xie, Y. Jiang, D. Fang, X. Chen and Z. Wu, *Int. J. Mass Spectro.*, 2019, **435**, 168–172.
- 428 H. Z. Levinson and K. Mori, *Naturwissenschaften*, 1983, **70**, 190–192.
- 429 M. Kobayashi, T. Koyama, K. Ogura, S. Seto, F. J. Ritter and L. E. M. Brüggemann-Rotgans, *J. Am. Chem. Soc.*, 1980, **102**, 6604–6605.
- 430 J. C. Dickens, J. E. Oliver, B. Hollister, J. C. Davis and J. A. Klun, *J. Exp. Biol.*, 2002, **205**, 1925–1933.
- 431 C. Y. Yang, K. Mori, J. Kim and K. B. Kwon, *Sci. Rep.*, 2020, **10**, 10281.
- 432 B. Kullenberg, G. Bergström and S. Ställberg-Stenhagen, *Acta Chem. Scand.*, 1970, **24**, 1481–1483
- 433 A. L. Perez, Y. Campoa, C. M. Chinchilla, A. C. Oehlschlager, G. Gries, R. Gries, R. M. Giblin-Davis G. Castrillo, J. E. Pena, R. E. Duncan, L. M. Gonzalez, H. D. Pierce, Jr., R. McDonald and R. Andrade, *J. Chem. Ecol.*, 1997, **28**, 869–888.
- 434 A. Renyard, S. K. Alamsetti, R. Gries, A. Munoz and G. Gries, *J. Chem. Ecol.*, 2019, **45**, 901–913.
- 435 E. Kohl, B. Hölldobler and H. J. Bestmann, *Chemoecology*. 2001, **11**: 67–73.
- 436 J. A. Torres, R. R. Snelling, M. S. Blum, R. C. Flournoy, T. H. Jones and R. M. Duffield, *Biochem. Syst. Ecol.*, 2001, **29**: 673–680.
- 437 W. Haberer, T. Schmitt, K. Peschke, P. Schreier and J. K. Müller, *J. Chem. Ecol.*, 2008, **34**, 94–98.
- 438 W. Francke, G. Hindorf and W. Reith, *Naturwissenschaften*, 1979, **66**, 618–619.
- 439 W. Kitching, J. A. Lewis, M. T. Fletcher, R. A. I. Drew, C. J. Moore and W. Francke, *J. Chem. Soc. Chem. Comm.*, 1986, 853–854.
- 440 M. V. Perkins, W. Kitching, R. A. I. Drew, C. J. Moore and W. A. König, *J. Chem. Soc. Perkin Trans. I*, 1990, 1111–1117.

- 441 K. Matsuura, C. Himuroa, T. Yokoia, Y. Yamamotoa, E. L. Vargob and L. Kellerc, *Proc. Natl. Acad. Sci. USA*, 2010, **107**, 12963–12968.
- 442 A. A. Cossé, B. W. Zilkowski, Y. Zou, J. G. Millar, L. Bauer and T. Poland, *J. Chem. Ecol.*, 2020, **46**, 508–519.
- 443 E. Janssen, E. Übler, L. Bauriegel, F. Kern, H. J. Bestmann, A. B. Attygalle, S. Steghaus-Kovac, and U. Maschwitz, *Naturwissenschaften*, 1997, **84**, 122–125.
- 444 R. Maile, H. Jungnickel., E. D. Morgan, F. Ito and J. Billen, *J. Chem. Ecol.*, 2000, **26**, 2497–2506.
- 445 J. C. Rojas, E. Rios-Candelaria, L. Cruz-Lopez, A. Santiesteban, J. G. Bond-Compean, Y. Brindis and E. A. Malo, *J. Med. Entomol.*, 2002, **39**, 256–265.
- 446 A. A. Cossé, R. Bartelt and B. Zilkowski, *J. Nat. Prod.*, 2002, **65**, 1156–1160.
- 447 M. D. Ginzal, G. J. Blomquist, J. G. Millar and M. L. Hanks, *J. Chem. Ecol.*, 2003, **29**, 533–545.
- 448 W. J. Etges and L. L. Jackson, *J. Chem. Ecol.*, 2001, **27**, 2125–2149.
- 449 D. Rochat, P. Ramirez-Lucas, C. Malosse, R. Aldana, T. Kakul and J.-P. Morin, *J. Chromatogr. A*, 2000, **885**, 433–444.
- 450 H. A. Lloyd, M. S. Blum, R. R. Snelling and S. L. Evans, *J. Chem. Ecol.*, 1989, **15**, 2589–2599.
- 451 C. T. Hogan, T. H. Jones, M. Zhukova, J. Sosa-Calvo and R. M. M. Adams, *Biochem. Ayst. Ecol.*, 2017, **72**, 56–62.
- 452 U. Haak, B. Hölldobler, H. J. Bestmann and F. Kern, *Chemoecology*, 1996, **7**, 85–93.
- 453 E. Kohl, B. Hölldobler and H.-J. Bestmann, *Chemoecology*, 2003, **13**, 113–122.
- 454 R. Baker and A. J. Bacon, *Experientia*, 1985, **41**, 1484–1485.
- 455 S. Noushini, J. Perez, S. J. Park, D. Holgate, V. M. Alvarez, I. Jamie, J. Jamie and P. Taylor, *Molecules*, 2020, **25**, 1275.
- 456 S. J. Keegans, J. Billen, E. D. Morgan and O. A. Gökçen, *J. Chem. Ecol.*, 1993, **19**, 2705–2719.
- 457 W. S. Leal, S. Matsuyama, Y. Kuwahara, S. Wakamura and M. Hasegawa, *Naturwissenschaften*, 1992, **79**, 184–185.
- 458 A. Zhang, P. S. Robbins, W. S. Leal, C. E. Linn Jr., M. G. Villani and W. L. Roelofs, *J. Chem. Ecol.*, 1997, **23**, 231–245.
- 459 W. S. Leal, A. C. Oehlschlager, P. H. G. Zarbin, E. Hidalgo, P. S. Shannon, Y. Murata, L. Gonzales, R. Andrade and M. Ono, *J. Chem. Ecol.*, 2003, **29**, 15–25.
- 460 T. Tolasch, M. Fragstein and J. L. M. Steidle, *J. Chem. Ecol.*, 2007, **33**, 2156–2166.
- 461 T. Eisner and Y. C. Meinwald, *Science*, 1965, **150**, 1733–1735.
- 462 K. Honda, *J. Insect Physiol.*, 1980, **26**, 39–45.
- 463 K. Kanehisa and K. Kawazu, *Appl. Entomol. Zool.*, 1982, **17**, 460–466.
- 464 T. Suzuki, K. Haga, S. Kodama and Y. Kuwahara, *Appl. Entomol. Zool.*, 1988, **23**, 291–297.
- 465 R. M. Giblin-Davis, R. Gries, B. Crespi, L. N. Robertson, A. H. Hara, G. Gries, C. W. O'Brien and H. D. Pierce, Jr., *J. Chem. Ecol.*, 2000, **26**, 2763–2780.
- 466 P. H. G. Zarbin, E. de B. Arrigoni, A. Reckziegel, J. A. Moreira, P. T. Baraldi and P. C. Viera, *J. Chem. Ecol.*, 2003, **29**, 377–386.
- 467 A. C. Oehlschlager, H. D. Pierce, Jr., B. Morgan, P. D. C. Wimalaratne, K. N. Slessor, G. G. S. King, G. Gries, R. Gries, J. Jorden, C. M. Chinchilla and R. G. Mexzan, *Naturwissenschaften*, 1992, **79**, 134–135.
- 468 M. D. Papke, S. E. Richert and S. Schulz, *Anim. Behav.*, 2001, **61**, 877–886.
- 469 R. Nishida, S. Schulz, C. H. Kim, H. Fukami, Y. Kuwahara, K. Honda and N. Hayashi, *J. Chem. Ecol.*, 1996, **22**, 949–972.

- 470 K. Stritzke, S. Schulz and R. Nishida R, *Eur. J. Org. Chem.*, 2002, 3884–3892.
- 471 P. S. Robbins, S. Nojima, S. Polavarapu, A. M. Koppenhöfer, C. Rodriguez-Saona, R. J. Holdcraft, N. H. Consolie, D. C. Peck and W. L. Roelofs, *J. Chem. Ecol.*, 2009, **35**, 336–341.
- 472 W. S. Leal, J. M. S. Bento, E. F. Vilela and T. M. C. D. Lucia, *Experientia*, 1994, **50**, 853–856.
- 473 S. Nojima, P. S. Robbins, G. A. Salsbury, B. D. Morris, W. L. Roelofs and M. G. Villani, *J. Chem. Ecol.*, 2003, **29**, 2439–2446.
- 474 L. Arnaud, G. Lognay, M. Verscheure, L. Leenaers, C. Gaspar and E. Haubruge, *J. Chem. Ecol.*, 2002, **28**, 523–532.
- 475 J. I. Olaifa, F. Matsumura and H. C. Coppel, *J. Chem. Ecol.*, 1987, **13**, 1395–1408.
- 476 J. I. Olaifa, F. Matsumura, T. Kikukawa and H. C. Coppel, *J. Chem. Ecol.*, 1988, **14**, 1131–114.
- 477 R. M. Sultanov, E. V. Samoiloova and U. M. Dzhemilev, *Chem. Nat. Comp.*, 2015, **51**, 1006.
- 478 G. N. Lanier, Y. -T. Qi, J. R. West, S. C. Park, F. X. Webster and R. M. Silverstein, *J. Chem. Ecol.*, 1989, **15**, 1645–1659.
- 479 B. E. Hibbard, G. N. Lanier, S. C. Parks, Y. T. Qi, F. X. Webster and R. M. Silverstein, *J. Chem. Ecol.*, 1991, **17**, 89–102.
- 480 S. C. Park, A. J. Wi and H. S. Kim, *J. Chem. Ecol.*, 1994, **20**, 2185–2196.
- 481 X.-W. Shi, F. X. Webster and J. Meinwald, *Tetrahedron Lett.*, 1995, **36**, 7201–7204.
- 482 C. L. Cywin, F. X. Webster and J. Kallmerten, *J. Org. Chem.*, 1991, **56**, 2953–2955.
- 483 K. Mori and S. Harashima, *Liebigs Ann. Chem.*, 1993, 993–1001.
- 484 G.-Q. Lin and W.-C. Xu, *Tetrahedron Lett.*, 1993, **34**, 5931–5934.
- 485 K. Mori, T. Furuuchi and K. Matsuyama, *Liebigs Ann. Chem.*, 1995, 2093–2099.
- 486 X. Shi, F. X. Webster, J. Kallmerten and J. Meinwald, *Tetrahedron Lett.*, 1995, **36**, 7197–7200.
- 487 X. Shi, F. X. Webster and J. Meinwald, *Tetrahedron*, 1995, **51**, 10433–10442.
- 488 G.-Q Lin and W.-C. Xu, *Bioorg. Med. Chem.*, 1996, **4**, 375–380.
- 489 H. Watanabe, T. Watanabe, T. Kitahara and K. Mori, *Biosci. Biotechnol. Biochem.*, 1997, **61**, 127–130.
- 490 S. Kurosawa, M. Takenaka, E. Dunkelblum, Z. Mendel and K. Mori, *ChemBioChem*, 2000, **1**, 56–66.
- 491 E. Dunkelblum, Z. Mendel, F. Asael, M. Harel, L. Kerhoas and J. Einhorn, *Tetrahedron Lett.*, 1993, **34**, 2805–2808.
- 492 E. Dunkelblum, R. Gries, G. Gries, K. Mori and Z. Mendel, *J. Chem. Ecol.*, 1995, **21**, 849–858.
- 493 L. Zegelman, A. Hassner, Z. Mendel and E. Dunkelblum, *Tetrahedron Lett.*, 1993, **34**, 5641–5644.
- 494 K. Mori and M. Amaike, *J. Chem. Soc. Perkin Trans. I*, 1994, 2727–2733.
- 495 C. L. Cywin and J. Kallmerten, *J. Nat. Prod.*, 1991, **54**, 1664–1667.
- 496 K. Mori and S. Harashima, *Liebigs Ann. Chem.*, 1993, 391–401.
- 497 J. Einhorn, P. Menassieu, C. Malosse and P.-H. Ducrot, *Tetrahedron Lett.*, 1990, **31**, 6633–6636.
- 498 H. Jactel, P. Menassieu, M. Lettere, K. Mori and J. Einhorn, *J. Chem. Ecol.*, 1994, **20**, 2159–2170.
- 499 V. C. Norman, T. Butterfield, F. Drijfhout, K. Tasman and W. O. H. Hughes, *J. Chem. Ecol.*, 2017, **43**, 225–235.

- 500 O. U. Igwe and P. N. Eze, *Am. Chem. Sci. J.*, 2015, **6**, 16–24.
- 501 Y. Carriere, J. G. Millar, J. N. McNeil, D. Miller and E. W. Underhill, *J. Chem. Ecol.*, 1988, **14**, 947–956.
- 502 M. J. Lacey, E. Semon, J. Krasulova, D. Sillam-Dusses, A. Robert, R. Cornette, M. Hoskovec, P. Zacek, I. Valterova and C. Bordereau, *J. Insect Physiol.*, 2011, **57**, 1585–1591.
- 503 T. Kikukawa, M. Imaida and A. Tai, *Chem. Lett.*, 1982, **11**, 1799–1802.
- 504 D. Szczerbowski, S. Schulz and P. Zarbin, *Org. Biomol. Chem.*, 2020, **18**, 5034–5044.
- 505 W. E. Gore, G. T. Pearce and R. M. Silverstein, *J. Org. Chem.*, 1975, **40**, 1705–1708.
- 506 S. Vacas, I. Navarro, E. Seris, C. Ramos, E. Hernández, V. Navarro-Llopis and J. Primo, *J. Agric. Food Chem.*, 2017, **65**, 270–275.
- 507 J. K. Phillips, C. A. Walgenbach, J. A. Klein, W. E. Burkholder, N. R. Schmuff and H. M. Fales, *J. Chem. Ecol.*, 1985, **11**, 1263–1274.
- 508 M. M. Blight, J. A. Pickett, M. C. Smith and L. J. Wadhams, *Naturwissenschaften*, 1984, **71**, 480.
- 509 C. R. Unelius, K.-C. Park, M. McNeill, S. L. Wee, B. Bohman and D. M. Suckling, *Naturwissenschaften*, 2013, **100**, 135–143.
- 510 R. Baker, A. H. Parton, V. B. Rao and V. J. Rao, *Tetrahedron Lett.*, 1982, **23**, 3103–3104.
- 511 R. G. Yarger, R. M. Silverstein and W. E. Burkholder, *J. Chem. Ecol.*, 1975, **1**, 323–334.
- 512 R. E. Greenblatt, W. E. Burkholder, J. H. Cross, R. F. Cassidy, Jr., R. M. Silverstein, A. R. Levinson and H. Z. Levinson, *J. Chem. Ecol.*, 1977, **3**, 337–347.
- 513 I. V. Mineeva, *Rus. J. Org. Chem.*, 2020, **56**, 994–1000.
- 514 R. J. Bartelt, P. F. Dowd, R. D. Plattner and D. Weisleder, *J. Chem. Ecol.*, 1990, **16**, 1015–1039.
- 515 R. J. Bartelt, P. F. Dowd, H. H. Shorey and D. Weisleder, *Chemoecology*, 1990, **1**, 105–113.
- 516 R. J. Bartelt, D. Weisleder, P. F. Dowd and R. D. Plattner, *J. Chem. Ecol.*, 1992, **18**, 379–402.
- 517 R. J. Bartelt, D. G. Carlson, R. S. Vetter and T. C. Baker, *J. Chem. Ecol.*, 1993, **19**, 107–118.
- 518 R. J. Bartelt, K. L. Seaton and P. F. Dowd, *J. Chem. Ecol.*, 1993, **19**, 2203–2216.
- 519 R. J. Bartelt and D. G. James, *J. Chem. Ecol.*, 1994, **20**, 3207–3219.
- 520 R. J. Bartelt, D. K. Weaver and R. T. Arbogast, *J. Chem. Ecol.*, 1995, **21**, 1763–1779.
- 521 A. A. Cossé and R. J. Bartelt, *J. Chem. Ecol.*, 2000, **26**, 1735–1748.
- 522 W. Barros-Parada, J. Bergmann, T. Curkovic, C. Espinosa, E. Fuentes-Contreras, J. Guajardo, H. Herrera, S. Morales, A. F. O. Queiroz and A. Vidal, *J. Chem. Ecol.*, 2020, **46**, 820–829.
- 523 W. D. Silva, J. G. Millar, L. M. Hanks, C. M. Costa, M. O. G. Leite, M. Tonelli and J. M. S. Bento, *J. Chem. Ecol.*, 2018, **44**, 268–275.
- 524 W. L. Roelofs and R. T. Cardé, *Science*, 1971, **171**, 684–686.
- 525 S. B. Krasnoff and W. L. Roelofs, *Nature*, 1988, **333**, 263–265.
- 526 A. A. Romero-López, R. Reyes-Chilpa, F. J. Pérez-Flores, G. A. Lugo-García and J. I. Maldonado-Rodríguez, *Southwest. Entomol.*, 2019, **44**, 457–464.
- 527 S. P. Chinta, S. Goller, J. Lux, S. Funke, G. Uhl and S. Schulz, *Angew. Chem. Int. Ed.*, 2010, **49**, 2033–2036.
- 528 Z. A. Kosi, Y. Zou, M. Hoskovec, A. Vrezec, N. Stritih and J. G. Millar, *Plos One*, 2017, **12**, 0183279.

- 529 J. A. Edgar, C. C. J. Culvenor and T. E. Pliske, *J. Chem. Ecol.*, 1976, **2**, 263–270.
- 530 S. Schulz, G. Beccaloni, K. S. Jr. Brown, M. Boppre, A. V. L. Freitas, P. Ockenfels and J. R. Trigo, *Biochem. Syst. Ecol.*, 2004, **32**, 699–713.
- 531 R. F. Mitchell, P. F. Reagel, J. C. H. Wong, L. R. Meier, W. D. Silva, J. Mongold-Diers, J. G. Millar and L. M. Hanks, *J. Chem. Ecol.*, 2015, **41**, 431–440.
- 532 M. A. Molander and M. C. Larsson, *J. Chem. Ecol.*, 2018, **44**, 987–998.
- 533 M. A. Molander, I. B. Winde, J. Burman, F. N. Nyabuga, T. U. T. Lindblom, L. M. Hanks, J. G. Millar and M. C. Larsson, *J. Chem. Ecol.*, 2019, **45**, 537–548.
- 534 D. Rochat, K. Mohammadpoor, C. Malosse, A. Avand-Faghih, M. Lettere, J. Beauhaire, J.-P. Morin, A. Pezier, M. Renou and G. A. Abdollahi, *J. Chem. Ecol.*, 2004, **30**, 387–407.
- 535 I. Saïd, N. Hasni, Z. Abdallah, P. Couzi, M. Ouhichi, M. Renou and D. Rochat, *J. Chem. Ecol.*, 2015, **41**, 446–457.
- 536 C. F. Fávoro, J. G. Millar and P. H. G. Zarbin, *J. Chem. Ecol.*, 2015, **41**, 859–868.
- 537 J. R. Linley and D. A. Carlson, *J. Insect Physiol.*, 1978, **24**, 423–427.
- 538 M. A. Peterson, S. Dobler, E. L. Larson, D. Juarez, T. Schlarbaum, K. J. Monsen and W. Francke, *Chemoecology*, 2007, **17**, 87–96.
- 539 K. Hoover, M. Keena, M. Nehme, S. Wang, P. Meng and A. Zhang, *J. Chem. Ecol.*, 2014, **40**, 169–180.
- 540 S. A. Adams, M. Gerbaulet, S. Schulz, R. G. Gillespie and G. Uhl, *J. Chem. Ecol.*, 2021, **47**, 63–72.
- 541 H. Ômura, K. Yakumaru, K. Honda and T. Itoh, *Naturwissenschaften*, 2013, **100**, 373–377.
- 542 S. L. Lapointe, R. T. Alessandro, P. S. Robbins, A. Khrimian, A. Svatos, J. C. Dickens, F. Otálora-Luna, F. Kaplan, H. T. Alborn and P. E. Teal, *J. Chem. Ecol.*, 2012, **38**, 408–417.
- 543 J. Ruther, M. Döring and S. Steiner, *Entomol. Exp. Appl.*, 2011, **140**, 59–68.
- 544 M. R. Hara, A. J. Cavalheiro, P. Gnaspini and D. Y. A. C. Santos, *Biochem. Syst. Ecol.*, 2005, **33**, 1210–1225.
- 545 F. C. Wouters, D. F. Rocha, C. C. Gonçalves, G. Machado and A. J. Marsaioli, *J. Nat. Prod.*, 2013, **76**, 1559–1564.
- 546 A. E. Spikes, M. A. Paschen, J. G. Millar, J. A. Moreira, P. B. Hamel, N. M. Schiff and M. D. Ginzler, *J. Chem. Ecol.*, 2010, **36**, 943–954.
- 547 P. J. Silk, J. Sweeney, J. Wu, S. Sopow, P. D. Mayo and D. Magee, *Environ. Entomol.*, 2011, **40**, 714–726.
- 548 M. Fukaya, T. Yasuda, S. Wakamura and H. Honda, *J. Chem. Ecol.*, 1996, **22**, 259–270.
- 549 M. Fukaya, S. Wakamura, T. Yasuda, S. Senda, T. Omata and E. Fukusaki, *Appl. Entomol. Zool.*, 1997, **32**, 654–656.
- 550 E. Fukusaki, S. Satoda, H. Yuasa, S. Senda, T. Omata, M. Fukaya and S. Wakamura, *J. Ferment. Bioeng.*, 1998, **85**, 120–121.
- 551 K. Doman, H. Takikawa and K. Mori, *Eur. J. Org. Chem.*, 1999, 979–980.
- 552 G.-G. He, B.-Q. Rao, T. Zhang, H.-L. Zhang, H. Bai and Z.-T. Du, *Russ. J. Org. Chem.*, 2021, **57**, 455–461.
- 553 H. Zhang, M. T. Fletcher, J. W. Avery and W. Kitching, *Tetrahedron Lett.*, 1997, **38**, 3477–3478.
- 554 Z. M. Zhang, W. W. Wu and G. K. Li, *J. Chromatogr. Sci.*, 2009, **47**, 291–296.
- 555 J. P. Lelito, K. Böröczky, T. H. Jones, I. Fraser, V. C. Mastro, J. H. Tumlinson and T. C. Baker, *J. Chem. Ecol.*, 2009, **35**, 104–110.
- 556 C. Guédot, J. G. Millar, D. R. Horton and P. J. Landolt, *J. Chem. Ecol.*, 2009, **35**, 1437–1447.
- 557 K. Marukawa, H. Takikawa and K. Mori, *Biosci. Biotechnol. Biochem.*, 2001, **65**, 305–314.
- 558 K. Mori, *Tetrahedron: Asymmetry*, 2011, **22**, 1006–1010.

- 559 G. Yuan, Y. Yang, J. Liu, Q. Bian, M. Wang and J. Zhong, 2021, *Chirality*, **33**, 274–280.
- 560 C. E. Rutledge, J. G. Millar, C. M. Romero and L. M. Hanks, *Environ. Entomol.*, 2009, **38**, 1267–1275.
- 561 C. Ruiz-Montiel, G. Garcia-Coapio, J. C. Rojas, E. A. Malo, L. Cruz-López, I. Del Real and H. Gonzalez-Hernandez, *Entomol. Exp. Appl.*, 2008, **127**, 207–217.
- 562 C. Ruiz-Montiel, H. González-Hernández, J. Leyva, C. Llanderal-Cazares, L. Cruz-López and J. C. Rojas, *J. Econ. Entomol.*, 2003, **96**, 1126–1131.
- 563 T. Tolasch, *Chemoecology*, 2008, **18**, 177–180.
- 564 A. Hefetz and H. A. Lloyd, *J. Chem. Ecol.*, 1983, **9**, 607–613.
- 565 F. Tafoya, M. E. Whalon, C. Vandervoot, A. B. Coombs and J. Cibrian-Tovar, *Environ. Entomol.*, 2007, **36**, 53–57.
- 566 M. Tsoukatou, L. Cheng, C. Vagias and V. Roussis, *Z. Naturforsch.*, 2001, **56c**, 597–602.
- 567 D. A. Carlson, P. A. Langley and P. Huyton, *Science*, 1978, **201**, 750–754.
- 568 C. Hoshino and K. Mori, *Agric. Biol. Chem.*, 1980, **44**, 3007–3009.
- 569 K. Kuwahara and K. Mori, *Agric. Biol. Chem.*, 1983, **47**, 2599–2606.
- 570 D. A. Carlson, D. R. Nelson, P. A. Langley, T. W. Coates, T. L. Davis and M. E. L.-V. D. Linden. *J. Chem. Ecol.*, 1984, **10**, 429–450.
- 571 P. G. McDowell, A. Hassanali and R. Dransfield, *Physiol. Entomol.*, 1985, **10**, 183–190.
- 572 D. R. Nelson and D. A. Carlson, *Insect Biochem.*, 1986, **16**, 403–416.
- 573 D. R. Nelson, D. A. Carlson and C. L. Fatland, *J. Chem. Ecol.*, 1988, **14**, 963–987.
- 574 K. Matsuyama and K. Mori, *Biosci. Biotechnol. Biochem.*, 1994, **58**, 539–543.
- 575 D. A. Carlson, I. I. Offor, S. E. Messoussi, K. Matsuyama, K. Mori and J.-M. Jallon, 1998, *J. Chem. Ecol.*, **24**, 1563–1575.
- 576 D. A. Carlson, B. D. Sutton and U. R. Bernier, *Insect Sci. Appl.*, 2000, **20**, 281–294.
- 577 T. Kimura, D. A. Carlson and K. Mori, *Eur. J. Org. Chem.*, 2001, 3385–3390.
- 578 D. A. Carlson, F. Mramba, B. D. Sutton, U. R. Bernier, C. J. Geden and K. Mori, *Med. Vet. Entomol.*, 2005, **19**, 470–479.
- 579 W. Sugeno, M. Hori and M. Matsuda, *Appl. Entomol. Zool.*, 2006, **41**, 269–276.
- 580 K. Mori and K. Ishigami, *Liebigs Ann. Chem.*, 1992, **11**, 1195–1198.
- 581 A. Cork, D. R. Hall, R. J. Hodges and J. A. Pickett, *J. Chem. Ecol.*, 1991, **17**, 789–803.
- 582 J. Dendy, P. Dobie, J. A. Saidi, J. Smith and B. Urono, *J. Stored Prod. Res.*, 1991, **27**, 69–74.
- 583 R. J. Hodges, S. Addo, D. I. Farman and D. R. Hall, *J. Stored Prod. Res.*, 2004, **40**, 439–449.
- 584 A. Khorramshahi and W. E. Burkholder, *J. Chem. Ecol.*, 1981, **7**, 33–38.
- 585 H. J. Williams, R. M. Silverstein, W. E. Burkholder and A. Khorramshahi, *J. Chem. Ecol.*, 1981, **7**, 759–784.
- 586 R. J. Hodges, D. R. Hall, P. Golob and J. Meik, *Entomol. Exp. Appl.*, 1983, **34**, 266–272.
- 587 E. Ade, G. Helmchen and G. Heiligemann, *Tetrahedron Lett.*, 1980, **21**, 1137–1140.
- 588 W. F. Wood, *Biochem. Syst. Ecol.*, 2005, **33**, 651–658.

- 589 H.-Y. Ho, R. Kou and H.-K. Tseng, *J. Chem. Ecol.*, 2003, **29**, 2101–2114.
- 590 H.-Y. Ho, H.-Y. Hsu, Y.-C. Chuang and Y.-S. Chow, *J. Chem. Ecol.*, 2005, **31**, 29–37.
- 591 J. W. Wheeler, S. L. Evans, M. S. Blum, H. H. V. Velthuis, J. M. F. D. Camargo and R. Preto, *Tetrahedron Lett.*, 1976, **17**, 4029–4032.
- 592 W. H. Pirkle and P. E. Adams, *J. Org. Chem.*, 1978, **43**, 378–379.
- 593 W. Francke, W. Reith, G. Bergström and J. Tengö, *Z. Naturforsch.*, 1981, **36c**, 928–932.
- 594 J. Tengö, G. Bergström, A.-K. Borg-Karlson, I. Groth and W. Francke, *Z. Naturforsch.*, 1982, **37c**, 376–380.
- 595 F. R. Dani, E. D. Morgan, G. R. Jones, S. Turillazzi, R. Cervo and F. Wittko, *J. Chem. Ecol.*, 1998, **24**, 1091–1104.
- 596 S. Rao, A. A. Cossé, B. W. Zilkowski and R. J. Bartelt, *J. Chem. Ecol.*, 2003, **29**, 2165–2175.
- 597 R. J. Bartelt, L. L. Jackson and A. M. Schaner, *J. Chem. Ecol.*, 1985, **11**, 1197–1208.
- 598 R. J. Bartelt, A. M. Schaner and L. L. Jackson, *J. Chem. Ecol.*, 1988, **14**, 1319–1327.
- 599 Y. Adachi, K. Kanehisa and H. Tsumuki, *Appl. Entomol. Zool.*, 1985, **20**, 492–493.
- 600 A. B. Attygalle, X. Wu, J. Ruzicka, S. Rao, S. Garcia, K. Herath, J. Meinwald, D. R. Maddison and K. W. Will, *J. Chem. Ecol.*, 2004, **30**, 577–588.
- 601 A. B. Attygalle, X. Wu and K. W. Will, *J. Chem. Ecol.*, 2007, **33**, 963–970.
- 602 G.-G. He, S.-F. Liu, B.-Q. Rao, H.-J. Bai and Z.-T. Du, *Nat. Prod. Comm.*, 2021, **16**, 1934578X211020149.
- 603 W. F. Wood, T. M. Palmer and M. L. Stanton, *Biochem. Syst. Ecol.*, 2002, **30**, 217–222.
- 604 L. B. Bjostad, D. K. Jewett and D. L. Brigham, *J. Chem. Ecol.*, 1996, **22**, 103–121.
- 605 J. R. Aldrich and T. R. Yonke, *Ann. Entomol. Soc. Am.*, 1975, **68**, 955–960.
- 606 J. R. Aldrich, A. Zhang and J. E. Oliver, *Can. Entomol.*, 2000, **132**, 915–923.
- 607 M. S. Blum, H. M. Fales, R. A. Morse and B. A. Underwood, *J. Chem. Ecol.*, 2000, **26**, 801–807.
- 608 S. Schulz, J. Gross and M. Hilker, *Tetrahedron*, 1997, **53**, 9203–9212.
- 609 A. Termonia and J. M. Pasteels, *Chemoecology*, 1999, **9**, 13–23.
- 610 K. Honda, *Insect Biochem.*, 1980, **10**, 583–588.
- 611 P. J. Apps, H. W. Viljoen and V. Pretorius, *J. Vet. Res.*, 1988, **55**, 135–137.
- 612 J. Billen, F. Ito, R. Maile and E. D. Morgan, *Naturwissenschaften*, 1998, **85**, 596–597.
- 613 J. V. Hernández, A. Cabrera and K. Jaffe, *J. Chem. Ecol.*, 1999, **25**, 2433–2444.
- 614 F. Matsumura, A. Tai, H. C. Coppel and M. Imaida, *J. Chem. Ecol.*, 1979, **5**, 237–249.
- 615 G. Yuan, J. Liu, S. Yu, X. Wang, Q. Bian, M. Wang and J. Zhong, *Synlett*, 2022, **33**, 80–83.
- 616 K. Honda and N. Hayashi, *J. Chem. Ecol.*, 1995, **21**, 859–867.
- 617 H. Ômura, K. Honda and P. Feeny, *J. Chem. Ecol.*, 2006, **32**, 1999–2012.
- 618 H. R. Hermann, M. S. Blum, J. W. Wheeler, W. L. Overal, J. O. Schmidt and J.-T. Chao, *Ann. Entomol. Soc. Am.*, 1984, **77**, 272–279.

- 619 A. D. Camacho, H. D. Pierce Jr. and J. H. Borden, *J. Chem. Ecol.*, 1993, **19**, 2169–2182.
- 620 A. D. Camacho, H. D. Pierce Jr. and J. H. Borden, *J. Chem. Ecol.*, 1994, **20**, 111–124.
- 621 W. P. Shepherd, B. T. Sullivan, B. M. Hoosier, J. P. Barrett and T. A. Bauman, *Environ. Entomol.*, 2010, **39**, 633–641.
- 622 A. Niño-Domínguez, B. T. Sullivan, J. H. López-Urbina and J. E. Macías-Sámano, *J. Chem. Ecol.*, 2015, **41**, 746–756.
- 623 R. J. Petroski, R. J. Bartelt and R. S. Vetter, *J. Chem. Ecol.*, 1994, **20**, 1483–1493.
- 624 R. N. Williams, M. S. Ellis and R. J. Bartelt, *Entomol. Exp. Appl.*, 1995, **77**, 141–147.
- 625 D. R. Hall, S. J. Harte, D. I. Farman, M. Ero and A. Pokana, *J. Chem. Ecol.*, 2022, **48**, 289–301.
- 626 M. Gerbaulet, A. Möllerke, K. Weiss, S. Chinta, J. M. Schneider and S. Schulz, *J. Chem. Ecol.*, 2022, **48**, 244–262.
- 627 G. H. Kim, J. Takabayashi, S. Takahashi and K. Tabata, *Appl. Entomol. Zool.*, 1993, **28**, 525–535.
- 628 G.-G. He, C.-T. He, B.-Q. Rao, B.-B. Chen, H.-J. Bai, T. Zhang and Z.-T. Du, *Chem. Nat. Comp.*, 2022, **58**, 320–325.
- 629 D. A. Carlson and Y. Schlein, *J. Chem. Ecol.*, 1991, **17**, 267–284.
- 630 C. M. B. Gomes, J. P. A. Souza, J. G. Millar and P. H. G. Zarbin, *J. Chem. Ecol.*, 2022, **48**, 502–517.
- 631 K. Singleton, R. Gries, W. G. V. Herk, S. K. Alamsetti, E. Lemke, K. Furtado and G. Gries, *J. Chem. Ecol.*, 2022, **48**, 491–501.
- 632 J. Tabata and H. Yasui, *J. Chem. Ecol.*, 2022, **48**: 609–617.
- 633 M. Frenzel, K. Dettner, W. Boland and P. Erbes, *Experientia*, 1990, **46**: 542–547.
- 634 M. Sakuma and H. Fukami, *Appl. Entomol. Zool.*, 1990, **25**, 355–368.
- 635 J. R. Rangaswamy and V. B. Sasikala, *Indian J. Exp. Biol.*, 1991, **29**, 52–55.
- 636 J. Swatschek, L. Grothues, J. O. Bauer, C. Strohmann and M. Christmann, *J. Org. Chem.*, 2014, **79**, 976–983.
- 637 B. S. Davidson, T. Eisner, B. Witz and J. Meinwald, *J. Chem. Ecol.*, 1989, **15**, 1689–1697.
- 638 K. Mori and M. Kato, *Liebigs Ann. Chem.*, 1985, 2083–2087.
- 639 K. Mori, H. Nomi, T. Chuman, M. Kohno, K. Kato and M. Noguchi, *Tetrahedron*, 1982, **38**, 3705–3711.
- 640 K. Mori and H. Watanabe, *Tetrahedron*, 1985, **41**, 3423–3428.
- 641 Santangelo, E. M., P. H. G. Zarbin, Q. B. Cass, J. T. B. Ferreira and A. G. Corrêa, *Synth. Commun.*, 2001, **31**, 3685.
- 642 Bernardo, V. B., M. R. F. Lima and A. E. G. Santana, *Results Chem.*, 2022, **4**, 100368.
- 643 X. Wang, J. Wang, F. Ma, Q. Bian, M. Wang and J. Zhong, *Molecules*, 2022, **27**, 6897.
- 644 Petukhova, N. I., V. V. Zorin, A. R. Sakaeva, A. V. Mityagina, E. R. Nurieva, V. A. Vydrina, M. P. Yakovleva and G. Y. Ishmuratov, *Russ. J. Appl. Chem.*, 2022, **95**, 442–450.
- 645 G.-G. He, X. Yang, Y. Cheng, H.-J. Bai, T. Zhang and Z.-T. Du, *Russ. J. Org. Chem.*, 2022, **58**, 1311–1318.
- 646 H. D. Pierce, Jr., A. M. Pierce, B. D. Johnston, A. C. Oehlschlager and J. H. Borden, *J. Chem. Ecol.*, 1988, **14**, 2169–2184.
- 647 T. Suzuki, H. Nakakita and Y. Kuwahara, *Appl. Entomol. Zool.*, 1987, **22**, 340–347.
- 648 R. A. Moats, R. J. Bartelt, L. L. Jackson and A. M. Schaner, *J. Chem. Ecol.*, 1987, **13**, 451–462.

- 649 J. L. Krysan, P. H. Wilkin, J. H. Tumlinson, P. E. Sonnet, R. L. Carney and P. L. Guss, *Ann. Entomol. Soc. Am.*, 1986, **79**, 742–746.
- 650 G. Sabitha, A. M. Reddy, S. S. S. Reddy and J. S. Yadav, *Helv. Chim. Acta*, 2013, **96**, 1610–1615.
- 651 J. Hartung and R. H. Grubbs, *Angew. Chem. Int. Ed.*, 2014, **53**, 3885–3888.
- 652 G. B. Gwon, H. G. Jung and Y. B. Seu, *Bull. Korean Chem. Soc.*, 2019, **40**, 1150–1151.
- 653 A. Kolb, W. Zuo, J. Siewert, K. Harms and P. von Zezschwitz, *Chem. Eur. J.*, 2013, **19**, 16366–16373.
- 654 D. A. Astashko, E. A. Ulashchik and V. I. Tyvorskii, *Russ. J. Org. Chem.*, 2013, **49**, 1803–1806.
- 655 N.-S. Li and J. A. Piccirilli, *Tetrahedron*, 2013, **69**, 9633–9641.
- 656 K. Mori and K. Akasaka, *Tetrahedron*, 2015, **71**, 4102–4115.
- 657 T.-D. Nguyen, C.-H. Nguyen, C. Im and C.-H. Dang, *Chem. Papers*, 2015, **69**, 380–384.
- 658 N. Basar, K. Damodaran, H. Liu, G. A. Morris, H. M. Sirat, E. J. Tomas and D. P. Curran, *J. Org. Chem.*, 2014, **79**, 7477–7490.
- 659 I. V. Mineeva, *Russ. J. Org. Chem.*, 2015, **51**, 341–351.
- 660 K. Mori and K. Akasaka, *Tetrahedron: Asymmetry*, 2016, **27**, 182–187.
- 661 D. Vanderwel, C. H. Bacala, R. Bacala, and R. W. Currie, *J. Stored Prod. Res.*, 2017, **70**, 60–64.
- 662 R. M. Sultanov, F. S. Khafizov, I. F. Khafizov and I. V. Ozden, *Chem. Nat. Comp.*, 2018, **54**, 218–219.
- 663 G. Y. Ishmuratov, V. A. Vydrina, I. S. Nazarov, Y. A. Galkina, M. P. Yakovleva, I. F. Lobko, R. R. Muslukhov and A. G. Tolstikov, *Chem. Nat. Compd.*, 2013, **48**, 981–984.
- 664 L. Wei, G.-G. He, L. Liu, M. Tang, T. Zhang, H. Bai and Z.-T. Du, *Russ. J. Org. Chem.*, 2020, **56**, 1089–1095.
- 665 C.-H. Dang, V.-D. Le, C.-H. Nguyen and T.-D. Nguyen, *Arkivoc*, 2017, **2017**, 187–195.
- 666 V.-D. Le, C.-H. Dang, C.-H. Nguyen, H.-U. Nguyen and T.-D. Nguyen, *J. Agric. Food Chem.*, 2021, **69**, 5882–5886.
- 667 W. D. Silva, L. M. Hanks, J. C. S. Alvarez, F. Z. Madalon, J. M. S. Bento, J. E. Bello and J. G. Millar, *Insects*, 2020, **11**, 222.
- 668 F. Mann, D. Szczerbowski, L. D. Silva, M. McClure, M. Elias and S. Schulz, *Beilstein J. Org. Chem.*, 2020, **16**, 2776–2787.
- 669 O. Anderbrant, D. S. Matteson, C. R. Unelius, P. S. Pharazyn, E. M. Santangelo, F. Schlyter and G. Birgersson, *Chemoecology*, 2010, **20**, 179–187.
- 670 C. Wang, C. He, Y. Shi, H. Xiang and W. Tian, *Chin. J. Chem.*, 2015, **33**, 627–631.
- 671 J. Shi, L. Wei, L. Liu, M. Tang, T. Zhang, H. Bai and Z. Du, *J. Chin. Chem. Soc.*, 2019, **66**, 756–760.
- 672 J. Shi, L. Liu, M. Tang, T. Zhang, H. Bai and Z. Du, *Chem. Nat. Comp.*, 2020, **56**, 197–201.
- 673 T. Subramanian, M. Webb, G. Bhagavathy, A. Rozek, B. R. Paraselli and K. R. Chauhan, *J. Agric. Chem. Environ.*, 2016, **5**, 223–230.
- 674 W. Shen, X. Hao, Y. Shi and W.-S. Tian, *Nat. Prod. Commun.*, 2015, **10**, 2155–2160.
- 675 R. M. Sultanov, I. F. Khafizov, N. V. Shutov, I. V. Ozden and F. S. Khafizov, *Chem. Nat. Comp.*, 2018, **54**, 161–162.
- 676 V. Liautard, M. Birepinte, C. Bettoli and M. Pucheault, 2018, *Catalysts*, **8**, 529.
- 677 S.-C. Lee, J. H. Kwon, D. J. Cha, D.-S. Kim, D. H. Lee, S.-M. Seo, H.-R. Lee, M.-J. Huh, M. Jung and I.-K. Park, *J. Econ. Entomol.*, 2019, **112**, 1752–1759.
- 678 Linne, Y., A. Schönwald, S. Weißbach and M. Kalesse, *Chem. Eur. J.*, 2020, **26**, 7998–8002.

- 679 R. M. Sultanov, R. R. Ismagilov and U. M. Dzhemilev, *Chem. Nat. Comp.*, 2013, **48**, 1122–1123.
- 680 S. Zhang, Y. Shi and W. Tian, *Chin. J. Chem.*, 2015, **33**, 674–678.
- 681 Pandey, R. and R. Prakash, *Arkivoc*, 2018, **2018**, 442–448.
- 682 M. Drozdowska, J. Tromans, B. Zhang, R. Jarling, H. Wilkes and B. T. Golding, *ChemistrySelect*, 2021, **6**, 3976–3981.
- 683 S. Yu, G. Yuan, J. Liu, Q. Bian, M. Wang and J. Zhong, *Chirality*, 2023, **35**, 118–128.
- 684 R. Bartelt, J., A. M. Schaner and L. L. Jackson, *Physiol. Entomol.*, 1986, **11**, 367–376.
- 685 T. H. Jones, W. E. Conner, A. F. Kluge, T. Eisner and J. Meinwald, *Experientia*, 1976, **32**, 1234–1235.
- 686 T. H. Jones, J. Meinwald, K. Hicks and T. Eisner, *Proc. Natl. Acad. Sci. U.S.A.*, 1977, **74**, 419–422.
- 687 M. S. Blum and A. L. Edgar, *Insect Biochem.*, 1971, **1**, 181–188.
- 688 O. Ekpa, J. W. Wheeler, J. C. Cokendolpher and R. M. Duffield, *Comp. Biochem. Physiol.*, 1985, **81B**, 555–557.
- 689 L. E. Lopes, E. T. Frank, Z. Karpati, T. Schmitt and D. J. C. Kronauer, *J. Chem. Ecol.*, 2023, **49**, 1–10.
- 690 M. Fukaya, T. Akino, T. Yasuda, S. Wakamura, S. Satoda and S. Senda, *Entomol. Sci.*, 2000, **3**, 211–218.
- 691 H. Yasui, N. Uechi and N. Fujiwara-Tsujii, *Insects*, 2023, **14**, 171.
- 692 T. Bashir, L. A. Birkinshaw, D. Farman, D. R. Hall and R. J. Hodges, *J. Stored Prod. Res.*, 2003, **39**, 159–169.
- 693 L. Cai, S. Macfadyen, B. Hua, H. Zhang, W. Xu and Y. Ren, *Molecules*, 2022, **27**, 1963.
- 694 W. J. Elliott, G. Hromnak, J. Fried and G. N. Lanier, *J. Chem. Ecol.*, 1979, **5**, 279–287.
- 695 X. Wang, Y. Yang, B. An, J. Wu, Y. Li, Q. Bian, M. Wang and J. Zhong, *Tetrahedron Lett.*, 2023, **118**, 154401.
- 696 M. Rossiter and B. W. Staddon, *Experientia*, 1983, **39**, 380–381.
- 697 M. M. Blight, N. C. Henderson and L. J. Wadhams, *Insect Biochem.*, 1983, **13**, 27–38.
- 698 A. Huth and K. Dettner, *J. Chem. Ecol.*, 1990, **16**, 2691–2711.
- 699 M. Aluja, F. Diaz-Fleisher, A. F. Edmundus and L. Hagmann, *U.S. Patent*, 2003, 6,555,120 B1,
- 700 A. J. F. Edmunds, M. Aluja, F. Diaz-Fleischer, B. Patrian and L. Hagmann, *Chimia*, 2010, **64**, 37–42.
- 701 C. Longhurst, R. Baker and K. Mori, *Experientia*. 1980, **36**, 946–947.
- 702 T. Kikukawa, F. Matsumura, M. Kraemer, H. C. Coppel and A. Tai, *J. Chem. Ecol.*, 1982, **8**, 301–314.
- 703 C. Gnanasunderam, H. Young and R. F. N. Hutchins, *Insect Biochem.*, 1982, **12**, 221–224.
- 704 W. V. Brown, J. T. Doyen, B. P. Moore and J. F. Lawrence, *J. Aust. Entomol. Soc.*, 1992, **31**, 79–89.
- 705 J. R. Aldrich, J. P. Kochansky, W. R. Lusby and S. R. Dutky, *J. Chem. Ecol.*, 1982, **8**, 1369–1376.
- 706 N. Vesović, S. Čurčić, M. Todosijević, M. Nenadić, W. Zhang and L. Vujisić, *Chemoecology*, 2020, **30**, 59–68.
- 707 P. M. Huyton, P. A. Langley, D. A. Carlson and M. Schwarz, *Physiol. Entomol.*, 1980, **5**, 253–264.
- 708 P. J. Silk, K. Ryall, D. B. Lyons, J. Sweeney and J. Wu, *Naturwissenschaften*, 2009, **96**, 601–608.

- 709 S. Yu, J. Wu, Q. Bian, M. Wang and J. Zhong, *ChemistrySelect*, 2023, **8**, e202302084.
- 710 J. D. Warthen, Jr., E. C. Uebel, W. R. Lusby and V. E. Adler, *Insect Biochem.*, 1981, **11**, 467–472.
- 711 T. Suzuki, J. Kozaki, R. Sugawara and K. Mori, *Appl. Entomol. Zool.*, 1984, **19**, 15–20.
- 712 L. J. Fish and G. Pattenden, *J. Insect Physiol.*, 1975, **21**, 741–744.
- 713 P. E. Sonnet, E. C. Uebel, W. R. Lusby, M. Schwarz and R. W. Miller, *J. Chem. Ecol.*, 1979, **5**, 353–361.
- 714 R. Rossi and A. Niccoli, *Naturwissenschaften*, 1978, **65**, 259–260.
- 715 R. Rossi, P. A. Salvadori, A. Carpita and A. Nicoli, *Naturwissenschaften*. 1979, **66**, 211.
- 716 M. L. S. Vieira, M. R. Hara, A. C. Mendes, R. H. Willemart, A. B. Cruz, D. Y. A. C. dos Santos and M. Sannomiya, *Chemoecology*, 2023, **33**, 1–15.
- 717 M. C. Cammaerts, M. R. Inwood, E. D. Morgan, K. Parry and R. C. Tylor, *J. Insect Physiol.*, 1978, **24**, 207–214.
- 718 E. D. Morgan, M. R. Inwood and M. C. Cammaerts, *Physiol. Entomol.*, 1978, **3**, 107–114.
- 719 W. Francke, G. Hindorf and W. Reith, *Angew. Chem.*, 1978, **90**, 915.
- 720 R. J. Weston, A. D. Woolhouse, E. B. Spurr, R. J. Harris and D. M. Suckling, *J. Chem. Ecol.*, 1997, **23**, 553–568.
- 721 T. J. Pawar, L. Barcelona-Cazanave, I. Bonilla-Landa, M. Escobar, J. O. C. Jimenez-Halla, A. Altuzar-Molina, P. Romero-Arellano, A. J. F. Edmunds, M. Aluja and J. L. Olivares-Romero, *Org. Chem. Front.*, 2023, **10**, 4827–4835.
- 722 S. Schulz, *Liebigs Ann. Chem.*, 1992, 829–834.
- 723 R. Nishida, T. Sato, Y. Kuwahara, H. Fukami and S. Ishii, *J. Chem. Ecol.*, 1976, **2**, 449–455.
- 724 A. W. Burgstahler, L. O. Weigel, M. E. Sanders, C. G. Shafer, W. J. Bell and S. B. Vuturo, *J. Org. Chem.*, 1977, **42**, 566–568.
- 725 D. Eliyahu, S. Nojima, K. Mori and C. Schal, *J. Chem. Ecol.*, 2008, **34**, 229–237.
- 726 H. Z Levinson and K. Mori, *Naturwissenschaften*, 1980, **67**, 148–149.
- 727 J. Tengö and G. Bergström, *Comp. Biochem. Physiol.*, 1976, **55B**, 179–188.
- 728 K. Shimomura, S. Matsui, K. Ohsawa and S. Yajima, *Chemoecology*, 2017, **27**, 65–73.
- 729 J. Wu, C. Lin, D. Liu, Q. Bian, M. Wang and J. Zhong, *Chirality*, 2024, **36**, e23658.
- 730 J. J. Brophy, G. W. K. Cavill and J. S. Shannon, *J. Insect Physiol.*, 1973, **19**, 791–798.
- 731 F. E. Regnier, M. Nieh and B. Hölldobler, *J. Insect Physiol.*, 1973, **19**, 981–992.
- 732 X. Wang, J. Wu, J. Wang, D. Liu, Q. Bian and J. Zhong, *Int. J. Mol. Sci.*, 2024, **25**, 4893.
- 733 I. J. May-Concha, L. C. Cruz-López, J. C. Rojas and J. M. Ramsey, *Parasites Vectors*, 2018, **11**, 95.
- 734 W. D. Silva, Y. Zou, L. M. Hanks, J. M. S. Bento and J. G. Millar, *Chemoecology*, 2024, **34**, 61–69.
- 735 B. M. Mitić, V. B. Jovanović, M. M. Todosijević, M. Eckhard, L. C. Vasiljević, V. V. Tešević and L. V. Vujisić, *J. Insect Physiol.*, 2024, **155**, 104649.
- 736 M. M. Martin and J. G. MacConnell, *Tetrahedron*, 1970, **26**, 307–319.
- 737 K. Arriola, W. D. Silva, L. M. Hanks, L. R. Meier and J. G. Millar, *J. Chem. Ecol.*, 2024, **50**, 338–350.

- 738 Y. Zhou, J. Wang, Y. Zhang, X. Fu, H. Xie, J. Han, J. Zhang, J. Zhong and C. Shan, *Molecules*, 2024, **29**, 2918.
- 739 Z.-F. Sun, H. Liu, Y.-F. Li, Y.-P. Duan, L.-X. Jin, X.-H. Ji, H.-P. Dai and J.-F. Lu, *Molecules*, 2024, **29**, 3866.
- 740 C. Lin, W. Zhu, S. Wu, Q. Bian and J. Zhong, *Int. J. Mol. Sci.*, 2024, **25**, 11699.
- 741 Y. Sugawara, H. Inoue, S. Toda and J. Tabata, *J. Chem. Ecol.*, 2024, **50**, 858–865.
- 742 H. Kpongbe, F. M. Khamis, X. Cheseto, H. K. Kirwa, M. Tamo and B. Torto, *Chem. Biol. Technol. Agric.*, 2024, **11**, 189.
- 743 Y.-N. Cheng, P. Wen, S.-H. Dong, K. Tan and J. C. Nieh, *J. Exp. Biol.*, 2017, **220**, 645–651.
- 744 Berville, L., C. Lucas, M. Haouzi, A. Khalil, J. Gevar, A.-G. Bagnères and E. Darrouzet, *Comptes Rendus Chimie*, 2023, **26**, S2 1–16.