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The synthesis of the insect pheromone (2*S*,3*R*,7*R*)-3,7-dimethyltridec-2-yl acetate from racemic 3,4-dimethyl-γ-butyrolactone by diastereoselective chiral resolution

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Abstract—The insect pheromone (2*S*,3*R*,7*R*)-3,7-dimethyltridec-2-yl acetate **1-Ac** was prepared from diastereomerically enriched (2*S**,3*R**,7*R*)-**1**, which in turn was obtained by the coupling of racemic 3,4-dimethyl-γ-butyrolactone with (7*S*)-2-methyloctyllithium, followed by a Wolff–Kishner reduction of the resulting ketone. Conversion of (2*S**,3*R**,7*R*)-**1** to the corresponding alkyl hydrogen phthalate and diastereomer salt formation with (*S*)-PhCHMeNH$_2$ provided after several crystallizations individual diastereomer, which was later transformed into target **1-Ac** after hydrolysis and acylation.
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1. Introduction

Pine sawfly (*Diprion pini* L.) is a widespread pest of pine forests in Europe, Asia and North America, the sex pheromone of which is the acetate of (2*S*,3*R*,7*R*)-3,7-dimethyltridecan-2-ol **1-Ac**.[1] Individual (2*S*,3*R*,7*R*)-3,7-dimeth- yltridecan-2-ol **1** was first synthesized starting from (*R*)-(−)-2-methyloctanoic acid[1] and (3*R*,4*R*)-3,4-dimethyl-γ-butyrolactone **2**. The latter was obtained with a high enantiomeric excess in 10 steps from (2*R*,3*R*)-tartaric acid, whereas (*R*)-(−)-2-methyloctanoic acid was synthesized over two consecutive lipase catalyzed esterifications of racemic 2-methyloctanoic acid. The desired configuration of alcohol **1** at the C2 carbon atom was obtained after Mitsunobu inversion at the last step of the synthesis.[1] Hedenström et al.[2] have performed the synthesis of (2*S*,3*R*,7*R*/*S*)-**1**, based on the resolution of racemic (2*S**,3*R**,7*R*/*S*)-3,7-dimethyltridecan-2-ol **1** by enantioselective enzymatic acylation. Recently, we have reported the successful separation of (2*S*,3*R*,7*R*/*S*)-**1** from a mixture of diastereomers (2*S*,3*R*/*S*,7*R*/*S*)-**1** by their conversion to alkyl hydrogen phthalates followed by recrystallization of the salts obtained and hydrolysis.[3] Herein we report the successful utilization of this classical method for the resolution of enantiomers of secondary alcohols[4] for the separation of (2*S*,3*R*,7*R*)-**1** from (2*S**,3*R**,7*R*)-**1**. The latter was prepared by the Hedenström approach[1] started from a racemic *trans*-3,4-dimethyl-γ-butyrolactone **2**.

2. Results and discussion

3,4-Dimethyl-γ-butyrolactone **2** with a diastereomeric ratio of *trans*/*cis* = 1.5:1 was obtained by a free radical addition of ethanol to ethyl crotonate with subsequent lactonization.[5] Heating compound **2** with perchloric acid without a solvent at 100 °C for 3 days led to the formation of the equilibrating mixture,[6] consisting of nearly 85% *trans*-diastereomer. Coupling of lactone **2** with a chiral alkyllithium **3** led to the formation of ketoalcohol **4** with a ratio of *S***R**/*S***S** = 5.5:1. Wolff–Kishner reduction[7] of the latter gave alcohol (2*S**,3*R**,7*R*)-**1** with the same diastereomeric composition (Scheme 1). Preparation of the alkyl hydrogen phthalate **5** and its salt with (*S*)-(−)-PhCHMeNH$_2$ **6**[8,9] provided, after 10 recrystallizations from acetone, the individual (2*S*,3*R*,7*R*)-diastereomer **6**[3] (de = 98%) in 32% yield from the alcohol (2*S**,3*R**,7*R*)-**1** (after five recrystallizations the yield was 36%, de = 92%). Decomposition of salt (2*S*,3*R*,7*R*)-**6** and basic hydrolysis of alkyl hydrogen phthalate **7** in methanol led to the chiral alcohol (2*S*,3*R*,7*R*)-**1**, the acylation of which furnished the target pheromone (2*S*,3*R*,7*R*)-**1-Ac** in a total yield of 18% starting from lactone **2**. The (*S*)-configuration at the C-2 atom (>99.5%)

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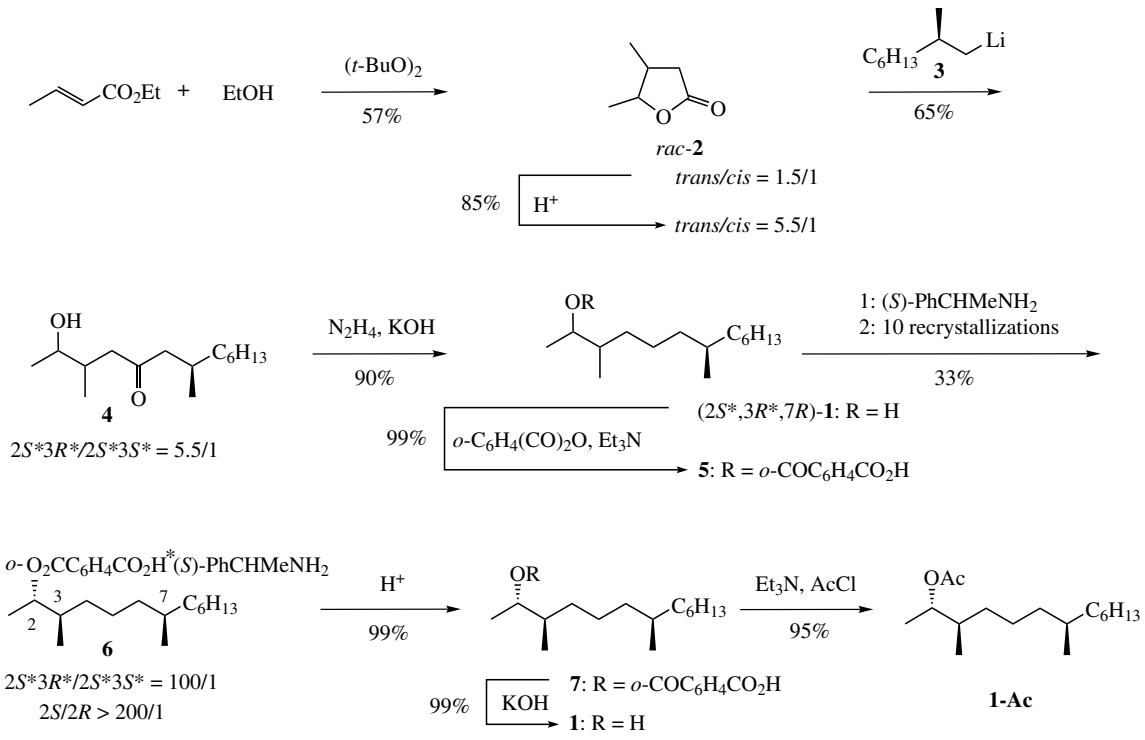


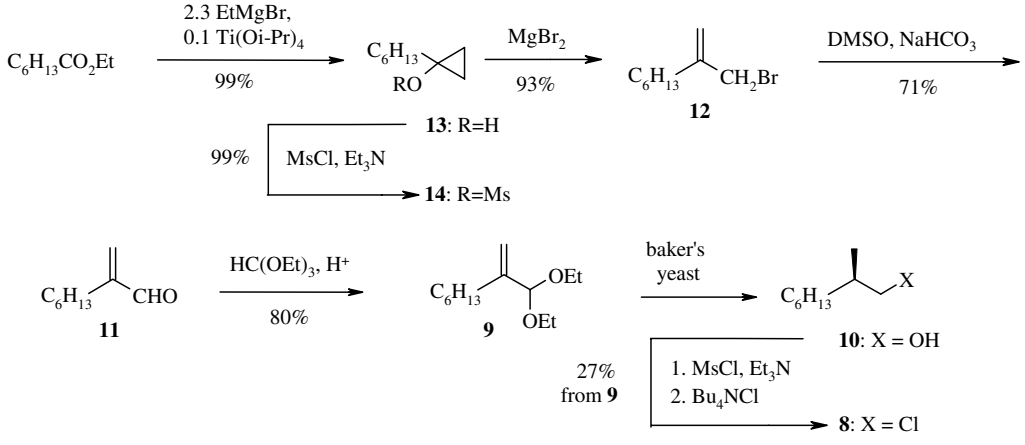
Scheme 1.

was determined after derivatization of compound **1** to the corresponding ester with (*R*)-(+)-Mosher's acid and comparison of the obtained ^{1}H NMR spectrum with the spectra of authetic samples of (2*S*,3*R*,7*R*/*S*)-3,7-dimethyltridecan-2-ol and its Mosher esters.[3,10]

Chiral lithium reagent **3** was generated from chloride **8** according to Scheme 2. The key step of this reaction sequence was the enantioselective reduction of acetal **9** to a chiral alcohol **10** (ee 95%) by baker's yeast *Saccharomyces cerevisiae*.[11,12] The stereochemical outcome was confirmed by the comparison of the resonances of the CH_2O moiety in the ^{1}H NMR spectrum of the (*R*)-(+)-Mosher's ester with that published previously.[11] The required unsaturated aldehyde **11** was obtained by Kornblum oxidation of bromide **12** under mild conditions,[13] which in turn was synthesized from ethyl heptanoate via cyclopropanol **13** and its mesylate **14** by previously elaborated procedure.[14] Conversion of chiral alcohol **10** into chloride **8** was carried out by the reaction of the corresponding mesylate with tetrabutylammonium chloride.[15]

3. Conclusion

Acetate **1-Ac**, the sex pheromone of the pine sawfly *D. pini*, has been prepared in its stereoisomerically pure form from a racemic lactone **2** in a total yield of 18%. For the enantioselective formation of methyl branches at C2, C3 and C7 in compound (2*S*,3*R*,7*R*)-**1**, the diastereomer salt



Scheme 2.

6 formation and the enantioselective reduction of the carbon–carbon double bond in an unsaturated acetal of α-methylenealdehyde **9** were used.

4. Experimental

4.1. General

Commercially available chemicals were used without further purification unless otherwise stated. Et_2O (Na, benzophenone), hexane (Na), benzene (Na), DMSO (CaH_2) and EtOH (CaH_2) were distilled from the indicated drying agents prior to use. Column chromatography was performed on silica gel (Merk 60, 70–230 mesh) employing a gradient technique using an increasing concentration of diethyl ether in petroleum ether or of ethyl acetate in petroleum ether (0→20%), as eluent. Progress of the reaction was monitored by thin layer chromatography, which was performed on silica gel plates (Merk 60 F_{254}) eluted with ethyl acetate (20–40%) in cyclohexane. GC analyses were carried out with a HP 5890 Series II gas chromatograph with helium as a carrier gas and an HP-INNOWAX, 19095N-123 capillary column. Optical rotations were measured at 20 ± 3 °C with polarimeter CM-3 (scale factor = 0.05°). IR spectra were recorded with a Specord 75 IR or Vertex 70 spectrometer. ^{1}H and ^{13}C NMR spectra were obtained with a Bruker AC 400 instrument at 400 and 100 MHz, respectively, in $CDCl_3$ ($CHCl_3$ at $\delta = 7.26$ for ^{1}H and $\delta = 77.0$ for ^{13}C as an internal standard).

4.2. Synthesis of (2*R*)-1-chloro-2-methyloctane 8

4.2.1. 1-Hexylcyclopropanol 13. A solution of ethylmagnesium bromide (600 mmol) prepared from magnesium turnings (14.6 g, 600 mmol) and ethyl bromide (65.4 g, 600 mmol) in diethyl ether (300 mL) was slowly added dropwise with stirring to a solution of ethyl heptanoate (33.2 g, 210 mmol) and titanium tetraisopropoxide (4.26 g, 15 mmol) in dry diethyl ether (200 mL).[16] The reaction mixture was then added with stirring and cooling to sulfuric acid (20% aqueous solution, 310 mL) at such a speed that the temperature did not exceed 10 °C. Extractive workup with diethyl ether (3×100 mL), $NaHCO_3$ (aqueous saturated solution, 50 mL) and brine (100 mL), drying over $MgSO_4$ and concentration gave the crude cyclopropanol **13** (29.60 g, 99%) which could be used without purification for the next step. Pure cyclopropanol **13** was obtained after distillation (28.41 g, 95%, bp 67–71 °C, 2 mmHg). IR (CCl_4), cm^{-1}: 3593, 3327, 3080; ^{1}H NMR, δ, ppm: 0.43 (dd, $J = 6.5$, 5.0 Hz, 2H, H-2, H-3), 0.72 (dd, $J = 6.5$, 5.0 Hz, 2H, H-2, H-3), 0.88 (t, $J = 6.7$ Hz, 3H, CH_3), 1.23–1.38 (m, 6H, $(CH_2)_3$), 1.43–1.59 (m, 4H, $(CH_2)_2$), 1.91 (br s, 1H, O*H*); ^{13}C NMR, δ, ppm: 13.3, 14.0, 22.6, 25.8, 29.3, 31.8, 38.2, 55.6. $C_9H_{18}O$ (142.2): calcd C, 76.00; H, 12.75. Found: C, 76.05; H, 12.80.

4.2.2. 1-Hexylcyclopropyl methanesulfonate 14. A solution of methanesulfonyl chloride (25.2 g, 220 mmol) in diethyl ether (100 mL) was added dropwise with stirring and cooling at 0 °C to the solution of cyclopropanol **13** (28.16 g, 198 mmol) and triethylamine (25.3 g, 250 mmol) in dry diethyl ether (500 mL). The reaction mixture was kept at room temperature overnight and then treated with water (150 mL). The water phase was extracted with diethyl ether (3×100 mL) and the combined organic phases were washed with brine (100 mL), dried over $MgSO_4$ and concentrated to give the crude mesylate **14** (43.20 g, 99%), which was used without purification in the next step. IR (CCl_4), cm^{-1}: 3093, 1340, 1167, 1153; ^{1}H NMR, δ, ppm: 0.66 (t, $J = 7.0$ Hz, 2H, H-2, H-3), 0.85 (t, $J = 6.7$ Hz, 3H, CH_3), 1.20 (t, $J = 7.0$ Hz, 2H, H-2, H-3), 1.23–1.36 (m, 6H, $(CH_2)_3$), 1.44–1.54 (m, 2H, CH_2), 1.77–1.84 (m, 2H, CH_2), 2.95 (s, 3H, OSO_2CH_3); ^{13}C NMR, δ, ppm: 11.6, 13.9, 22.4, 25.4, 28.8, 31.6, 35.8, 39.7, 66.9. $C_{10}H_{20}O_3S$ (220.3): calcd C, 54.51; H, 9.15. Found: C, 54.58; H, 9.19.

4.2.3. 2-(Bromomethyl)oct-1-ene 12. A solution of $MgBr_2$ prepared from magnesium turnings (9.72 g, 400 mmol) and 1,2-dibromoethane (75.2 g, 400 mmol) in dry diethyl ether (250 mL) was added to a stirred and refluxed solution of mesylate **14** (36.35 g, 165 mmol) in dry diethyl ether (250 mL). The reaction mixture was stirred at reflux for 4 h and then quenched with water (300 mL). Extractive workup with diethyl ether (3×150 mL) and brine (50 mL), drying over $MgSO_4$ and concentration followed by distillation (bp 97 °C, 16 mmHg) gave bromide **12** (31.42 g, 93%). IR (CCl_4), cm^{-1}: 3080, 1640; ^{1}H NMR, δ, ppm: 0.89 (t, $J = 6.7$ Hz, 3H, H-8), 1.23–1.35 (m, 6H, $(CH_2)_3$), 1.46 (m, 2H, H-4), 2.21 (t, $J = 7.6$ Hz, 2H, H-3), 3.97 (s, 2H, CH_2Br), 4.95 (m, 1H, H-1), 5.15 (m, 1H, H-1); ^{13}C NMR, δ, ppm: 14.0, 22.6, 27.3, 28.9, 31.7, 33.3, 36.8, 114.7, 145.7. $C_9H_{17}Br$ (205.1): calcd C, 52.70; H, 8.35. Found: C, 52.71; H, 8.36.

4.2.4. 2-Hexylacrylaldehyde 11. A solution of allylbromide **12** (29.66 g, 144.6 mmol) and $NaHCO_3$ (20.70 g, 246 mmol) in dry DMSO (360 mL) was magnetically stirred at room temperature for 48 h with periodical removal (every 1 h) of the resulting CO_2 and Me_2S in 15 mmHg vacuum. The mixture was then diluted with water (1.0 L) and extracted with petroleum ether (4×250 mL). Evaporation of the solvent, and column chromatography gave aldehyde **11** (14.45 g, 71%). IR (CCl_4), cm^{-1}: 3080, 1690, 1633; ^{1}H NMR, δ, ppm: 0.83 (t, $J = 6.8$ Hz, 3H, CH_3), 1.19–1.31 (m, 6H, $(CH_2)_3$), 1.40 (m, 2H, CH_2); 2.19 (t, $J = 7.7$ Hz, 2H, (CH_2)), 5.94 (s, 1H, H-3), 6.20 (s, 1H, H-3), 9.49 (s, 1H, H-1); ^{13}C NMR, δ, ppm: 13.9, 22.5, 27.6, 27.7, 28.8, 31.5, 133.7, 150.4, 194.6. $C_9H_{16}O$ (140.2): calcd C, 77.09; H, 11.50. Found: C, 77.15; H, 11.54.

4.2.5. 2-(Diethoxymethyl)oct-1-ene 9. A solution of aldehyde **11** (14.02 g, 100 mmol), triethyl orthoformate (14.8 g, 100 mmol) and NH_4NO_3 (0.1 g) in dry ethanol (30 mL) was stirred at 50 °C for 8 h. The mixture was concentrated and subjected to column chromatography to give acetal **9** (17.21 g, 80%). IR (CCl_4), cm^{-1}: 1647; ^{1}H NMR, δ, ppm: 0.88 (t, $J = 7.1$ Hz, 3H, H-8), 1.21 (t, $J = 7.0$ Hz, 6H, CH_3CH_2O), 1.19–1.37 (m, 6H, $(CH_2)_3$), 1.46 (m, 2H, H-4), 2.06 (t, $J = 7.8$ Hz, 2H, H-3), 3.45 (dd, $J = 9.4$, 7.0 Hz, 2H, OCH_2Me), 3.59 (dd, $J = 9.4$, 7.0 Hz, 2H, OCH_2Me), 4.73 (s, 1H, CH(OEt)$_2$), 4.98 (m, 1H, H-1), 5.17 (m, 1H, H-1); ^{13}C NMR, δ, ppm: 14.0, 15.1, 22.6,

27.6, 29.1, 30.7, 31.7, 61.4, 103.3, 112.2, 146.5. $C_{13}H_{26}O_2$ (214.3): calcd C, 72.85; H, 12.23. Found: C, 72.88; H, 12.2.

4.2.6. (2*R*)-2-Methyloctan-1-ol 10. A slightly modified method of baker's yeast mediated reduction[12] was adapted for the preparative scale synthesis. A solution of acetal **9** (17.14 g, 80.0 mmol) in ethanol (30 mL) was added portionwise (in 12 portions over a period of 2 days) with stirring at 34–38 °C to the suspension of pressed baker's yeast (5000 g) in a buffer solution (pH ~ 5.25) of citric acid monohydrate (75.6 g, 360 mmol) and NH_4HCO_3 (49.8 g, 630 mmol) in water (7.0 L). The reaction mixture was stirred for 3 days and sugar (3–5 g in 12–20 times a day) was added. A yeast suspension was then subjected to steam distillation and the distillate (3 × 3 L) was carefully extracted with petroleum ether (3 × 1 L), dried over Na_2SO_4 and concentrated to give crude alcohol **10**[1] as a pale yellow liquid (9.86 g, ~86%, purity ~60%), which was used without purification for the next step. The enantiomeric purity of **10** was 95% and was determined by comparison of ^{1}H NMR-spectra of the (+)- and (−)-MTPA-esters.[10,11]

4.2.7. (2*R*)-1-Chloro-2-methyloctane 8. A crude mesylate of (2*R*)-2-methyloctan-1-ol (12.14 g) was prepared from alcohol **10** (9.86 g) as above for 1-hexylcyclopropyl methanesulfonate **14**. Tetrabutylammonium chloride (18.04 g, 65.0 mmol) was added to a solution of mesylate of (2*R*)-2-methyloctan-1-ol (12.14 g) in benzene (30 mL). The reaction mixture was stirred at 70 °C for 8 h, cooled to room temperature and then quenched with water (60 mL). The water phase was extracted with petroleum ether (2 × 50 mL) and the combined organic phases were washed with water (20 mL) and concentrated. The crude product was diluted with *n*-hexane (60 mL), washed with concentrated sulfuric acid (3 × 15 mL), brine (10 mL), dried ($MgSO_4$) and concentrated. Title compound **8** was obtained after distillation as a colourless liquid (3.48 g, 27% from acetal **9**, bp 82 °C, 16 mmHg). $[\alpha]_D^{20} = +3.3$ (*c* 34.8, hexane). IR (CCl_4), cm^{-1}: 2960, 2933, 2860, 687; ^{1}H NMR, δ, ppm: 0.88 (t, $J = 6.8$ Hz, 3H, H-8), 0.99 (d, $J = 6.6$ Hz, 3H, CH_3CH), 1.14–1.38 (m, 9H, $(CH_2)_4$, H-3), 1.38–1.51 (m, 1H, H-3), 1.80 (m, 1H, H-2), 3.40 (dd, $J = 10.6$, 6.2 Hz, 1H, H-1), 3.47 (dd, $J = 10.6$, 5.2 Hz, 1H, H-1); ^{13}C NMR, δ, ppm: 14.0, 17.7, 22.6, 26.8, 29.4, 31.8, 34.0, 35.5, 51.2. $C_9H_{19}Cl$ (162.7): calcd C, 66.44; H, 11.77. Found: C, 66.48; H, 11.80.

4.3. Synthesis of (2*S**,3*R**,7*R*)-3,7-dimethyltridecan-2-ol (2*S**,3*R**,7*R*)-1

4.3.1. *trans*-4,5-Dimethyldihydrofuran-2(3*H*)-one 2. A solution of ethyl crotonate (3.21 g, 28.1 mmol) and (*t*-BuO)$_2$ (2.06 g, 14.1 mmol) in absolute ethanol (25 g) was heated to 170 °C in a soldered high-pressure glass or steel tube for 4 h.[5] After cooling, the reaction mixture was concentrated and distilled (bp 99 °C, 20 mmHg) to give lactone **2** (1.84 g, 16.1 mmol, 57%) with a *trans*/*cis* ratio of 60:40 by ^{1}H NMR. Lactone **2** (1.80 g, 15.8 mmol) was heated with $HClO_4$ (72% aqueous solution, 0.5 mL) at 100 °C for 3 days. After cooling, water (5 mL) was added. Extraction with diethyl ether (3 × 20 mL), neutralization of the organic phase with $NaHCO_3$ (aqueous saturated solution, 10 mL), drying over $MgSO_4$ and concentration furnished a dark liquid, which after distillation (bp 100 °C, 20 mmHg) gave lactone **2** (1.53 g, 85%) with a *trans*/*cis* ratio of 85:15 by ^{1}H NMR. The ^{1}H NMR spectral data corresponded to that reported in the literature.[5] ^{13}C NMR, δ, ppm: 16.4, 18.8, 37.0, 37.9, 83.2, 176.3.

4.3.2. (2*S,3*R**,7*R*)-2-Hydroxy-3,7-dimethyltridecan-5-one 4.** This compound was prepared from lactone **2** (1.43 g, 12.5 mmol) and (7*S*)-2-methyloctyllithium **3** according to the previously described procedures.[1] Column chromatography gave ketoalcohol **4** (1.96 g, 65%) with a *S***R**/*S***S** ratio of 5:1 determined by ^{1}H NMR. IR (CCl_4), cm^{-1}: 3613, 3447, 1713; ^{1}H NMR, δ, ppm: 0.74–0.80 (m, 9H, CH_3CH, CH_3CH, H-13), 1.03 (d, $J = 6.4$ Hz, 0.5H, H-1), 1.09 (d, $J = 6.3$ Hz, 2.5H, H-1), 0.99–1.35 (m, 10H, $(CH_2)_5$), 1.81–2.37 (m, 5H, CH_2, H-3, H-7, O*H*), 2.44–2.66 (m, 2H, CH_2), 3.45 (app. quint, $J = 6.3$ Hz, 0.85H, H-2), 3.68 (dq, $J = 3.8$, 6.4 Hz, 0.15H, H-2); ^{13}C NMR, δ, ppm: 13.9, 16.5, 19.64, 19.67, 20.7, 22.4, 26.7, 29.0, 29.05, 29.3, 31.7, 31.8, 36.3, 36.7, 36.8, 46.7, 46.8, 50.75, 50.80, 71.5, 211.7.

4.3.3. (2*S,3*R**,7*R*)-3,7-Dimethyltridecan-2-ol (2*S**,3*R**,7*R*)-1.** Wolff–Kishner reduction of ketoalcohol **4** (1.96 g, 8.1 mmol) in distilled triethanolamine[7] (18 mL) containing KOH (0.51 g, 9.1 mmol) and hydrazine monohydrate (2.00 g, 40.0 mmol)[1] furnished a yellow oil, which after column chromatography gave the alcohol (2*S**,3*R**,7*R*)-**1** (1.66 g, 90%) with a *S***R**/*S***S** ratio of 5:1 by ^{1}H NMR. IR (CCl_4), cm^{-1}: 3633; ^{1}H NMR, δ, ppm: 0.75–0.87 (m, 9H, CH_3CH, CH_3CH, H-13), 1.07 (d, $J = 6.4$ Hz, 2.5H, H-1), 1.10 (d, $J = 6.4$ Hz, 0.5H, H-1), 0.97–1.53 (m, 18H, $(CH_2)_8$, H-3, H-7), 1.79–2.09 (br s, 1H, O*H*), 3.55–3.67 (m, 1H, H-2); ^{13}C NMR, δ, ppm: 14.0, 14.35, 14.37, 19.05, 19.1, 19.5, 19.6, 22.6, 24.6, 24.65, 26.95, 27.0, 29.6, 31.9, 32.64, 32.67, 32.8, 32.9, 36.9, 37.1, 37.25, 37.35, 39.90, 39.95, 71.50, 71.55.

4.4. Synthesis of (2*S*,3*R*,7*R*)-3,7-dimethyltridec-2-yl acetate 1-Ac

4.4.1. Salt of 2-({[(1*S*,2*R*,6*R*)-1,2,6-trimethyldodecyl]oxy}carbonyl)benzoic acid with (*S*)-(−)-1-phenylethylamine 6. Alcohol (2*S**,3*R**,7*R*)-**1** (1.66 g, 7.3 mmol) was added to a solution of *o*-phthalic anhydride (1.18 g, 8.0 mmol) and triethylamine (1.82 g, 18.0 mmol) in dry benzene (4 mL). The reaction mixture was stirred at 70 °C for 3 h and after cooling to room temperature, HCl (10% aqueous solution, 20 mL) was added. The water phase was extracted with benzene (4 × 30 mL), and the combined organic phases were dried over $MgSO_4$ and concentrated. The crude phthalate **5** (2.74 g, 7.3 mmol) was added to a hot solution of (*S*)-(−)-1-phenylethylamine (1.33 g, 11.0 mmol) in acetone (50 mL). The solution was cooled to −10 °C and the crystalline salt was filtered off. After nine recrystallizations the title product was isolated (1.20 g, 33%, mp 121 °C). IR (CCl_4), cm^{-1}: 1713; ^{1}H NMR, δ, ppm: 0.81 (d, $J = 6.3$ Hz, 3H, CH_3CH), 0.87 (t, $J = 6.6$ Hz, 3H, H-12), 0.90 (d, $J = 6.9$ Hz, 3H, CH_3CH), 1.13 (d, $J = 6.2$ Hz, 3H, CH_3CH), 0.98–1.43 (m, 17H, $(CH_2)_8$, H-6),

1.51 (d, $J = 6.9$ Hz, 3H, $CH(NH_3^+)CH_3$), 1.69–1.79 (m, 1H, H-2), 4.26 (q, $J = 6.7$ Hz, 1H, $CH(NH_3^+)$), 4.90 (app. quint, $J = 6.2$ Hz, 1H, H-1), 4.96–5.37 (br s, 3H, $-NH_3^+$), 7.18–7.29 (m, 3H, C_6H_5), 7.31–7.39 (m, 4H, C_6H_5, C_6H_4), 7.39–7.46 (m, 1H, C_6H_4), 7.60–7.66 (m, 1H, C_6H_4); ^{13}C NMR, δ, ppm: 14.1, 14.6, 15.5, 19.6, 21.3, 22.6, 24.7, 27.0, 29.6, 31.9, 32.7, 32.9, 37.0, 37.33, 37.35, 51.0, 74.7, 126.60, 127.67, 127.69, 127.9, 128.1, 128.5, 130.5, 130.7, 140.0, 140.3, 167.6, 174.5. $C_{31}H_{47}NO_4$ (497.7): calcd C, 74.81; H, 9.52. Found: C, 74.85; H, 9.53.

4.4.2. (2*S*,3*R*,7*R*)-3,7-Dimethyltridecan-2-ol (2*S*,3*R*,7*R*)-1. Salt **6** (1.05 g, 2.1 mmol) was added to a mixture of HCl (10% aqueous solution, 10 mL) and benzene (50 mL). The organic phase was removed and the water phase was extracted with benzene (3×50 mL). The combined organic phases were dried over $MgSO_4$ and concentrated to give phthalate **7** (0.78 g, 2.1 mmol, 99%), which was added to a solution of KOH (1.12 g, 20.0 mmol) in methanol (25 mL). The reaction mixture was refluxed for 3 h, diluted with water (70 mL) and extracted with diethyl ether (3×50 mL), dried over $MgSO_4$ and concentrated. Title product **1** (0.48 g, 99%) was obtained as a colourless liquid with a purity of >98% and a S^*R^*/S^*S^* ratio of 99.0:1.0 determined by GC. A purity of 99.5% with an (*S*) configuration at C-2 atom was determined after derivatization to the corresponding ester with (*R*)-(+) Mosher's acid by ^{1}H NMR. $[\alpha]_D^{20} = +16.5$ (*c* 4.8, hexane). IR (CCl_4), cm^{-1}: 3628; ^{1}H NMR, δ, ppm: 0.82 (d, $J = 6.5$ Hz, 3H, CH_3CH), 0.84 (d, $J = 6.6$ Hz, 3H, CH_3CH), 0.86 (t, $J = 6.8$ Hz, 3H, H-13), 1.09 (d, $J = 6.2$ Hz, 3H, H-1), 0.97–1.52 (m, 18H, $(CH_2)_8$, H-7, O*H*), 1.69–1.82 (m, 1H, H-3), 3.63 (app. quint, $J = 6.2$ Hz, 1H, H-2); ^{13}C NMR, δ, ppm: 14.0, 14.4, 19.2, 19.7, 22.6, 24.7, 27.0, 29.6, 31.9, 32.7, 32.9, 37.0, 37.3, 40.0, 71.6. The ^{1}H NMR and ^{13}C NMR spectral data corresponded to that reported in the literature.[1]

4.4.3. (2*S*,3*R*,7*R*)-3,7-Dimethyltridec-2-yl acetate 1-Ac. This compound was prepared from (2*S*,3*R*,7*R*)-3,7-dimethyltridecan-2-ol **1** (0.24 g, 1.1 mmol) by esterification with acetyl chloride by a standard procedure.[1] The crude product was concentrated and subjected to column chromatography to give ester **1-Ac** (0.27 g, 95%). $[\alpha]_D^{23} = +8.3$ (*c* 2.7, hexane). IR (CCl_4), cm^{-1}: 1733; ^{1}H NMR, δ, ppm: 0.82 (d, $J = 6.7$ Hz, 3H, CH_3CH), 0.85 (d, $J = 6.9$ Hz, 3H, CH_3CH), 0.86 (t, $J = 6.8$ Hz, 3H, H-13), 1.12 (d, $J = 6.4$ Hz, 3H, H-1), 0.99–1.42 (m, 17H, $(CH_2)_8$, H-7), 1.59–1.69 (m, 1H, H-3), 2.01 (s, 3H, CH_3CO_2), 4.79 (app. quint, $J = 6.4$ Hz, 1H, H-2); ^{13}C NMR, δ, ppm: 14.0, 14.5, 15.7, 19.7, 21.3, 22.6, 24.5, 27.0, 29.6, 31.9, 32.7, 32.9, 36.9, 37.2, 37.3, 74.2, 170.6. The ^{1}H NMR and ^{13}C NMR spectral data corresponded to that reported in the literature.[1]

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References

1. Bergström, G.; Wassgren, A.-B.; Anderbrant, O.; Fägerhag, J.; Edlund, H.; Hedenström, E.; Högberg, H.-E.; Geri, C.; Auger, M. A.; Varama, M.; Hansson, B. S.; Löfqvist, J. *Experimentia* **1995**, *51*, 370–380, and references cited therein.
2. Hedenström, E.; Edlund, H.; Lund, S.; Abersten, M.; Persson, D. *J. Chem. Soc., Perkin Trans. 1* **2002**, 1810–1817.
3. Bekish, A. V.; Prokhorevich, K. N.; Kulinkovich, O. G. *Tetrahedron Lett.* **2004**, *45*, 5253–5255.
4. Pickard, R. H.; Kenyon, J. *J. Chem. Soc.* **1911**, *99*, 45–72.
5. Troyanskii, E. I.; Svitan'ko, I. V.; Nikishin, G. I. *Izv. Akad. Nauk SSSR, Ser. Khim.* **1985**, 133–139.
6. Bartlett, P. A.; Myerson, J. *J. Am. Chem. Soc.* **1978**, *100*, 3950–3952.
7. Gardner, P. D.; Rand, L.; Haynes, G. R. *J. Am. Chem. Soc.* **1956**, *78*, 3425–3427.
8. Ault, A. *Org. Synth.* **1969**, *49*, 93–98.
9. Baker, R.; Boyes, R. H. O.; Broom, D. M. P.; Devlin, J. A.; Swain, C. J. *J. Chem. Soc., Chem. Commun.* **1983**, 829–831.
10. Dale, J. A.; Dull, D. L.; Mosher, H. S. *J. Org. Chem.* **1969**, *34*, 2543–2549.
11. Ferraboschi, P.; Reza-Elahi, S.; Versa, E.; Rivolta, F. M.; Santaniello, E. *Synlett* **1996**, 1176–1178.
12. Ferraboschi, P.; Reza-Elahi, S.; Versa, E.; Rivolta, F. M.; Santaniello, E. *Tetrahedron: Asymmetry* **1999**, *10*, 2639–2642.
13. Babler, J. H.; Coghlan, M. J.; Feng, M.; Fries, P. *J. Org. Chem.* **1979**, *44*, 1716–1717.
14. Kozyrkov, Yu. Yu.; Kulinkovich, O. G. *Synlett* **2002**, 443–446.
15. Binkley, R. W.; Ambrose, M. G.; Hehemann, D. G. *J. Org. Chem.* **1980**, *45*, 4387–4391.
16. Kulinkovich, O. G.; Sviridov, S. V.; Vasilevskii, D. A. *Synthesis* **1991**, 234.