Oxidative Radical Cyclisations for the Synthesis of $\gamma$-Lactones

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Introduction

$^1$H and $^{13}$C NMR spectra were recorded on Bruker instruments (DPX-200, DPX-400, DQX-400 or DRX-500), using deuterochloroform as an internal deuterium lock. Chemical shifts are quoted in units of $\delta$ relative to tetramethylsilane ($\delta=0$). Multiplets are indicated as s, singlet; d, doublet; t, triplet; q, quartet; qq, quintet; dd, double doublet; m, multiplet; br, broad, etc. Coupling constants $J$ are quoted in Hz. Where useful, the FID was zero-filled (128 K) and sine-bell shifted (ssb = 30) prior to Fourier Transformation in order to provide baseline-resolved multiplets and easily identifiable coupling constants. Double Quantum Filtered and magnitude COSY and HMQC spectra were typically acquired with 256 slices in $F_1$ and 2048 points in $F_2$ (acquisition time approximately 20 min). $^{13}$C spectra were recorded with proton decoupling; $J$ resolved spin-echo APT or DEPT-135, and in some cases HMQC, were recorded to assist assignment.

Infrared spectra were recorded on a Perkin-Elmer 1600 series FTIR spectrometer calibrated relative to polystyrene absorption at 1630 cm$^{-1}$. The samples were prepared as a thin film or a solution in the solvent indicated.

Mass spectra were recorded by the Mass Spectrometry Service at the University of Cambridge Chemical Laboratory, or the Mass Spectrometry Service at the University of Oxford Chemistry Research Laboratory. Microanalyses were carried out by the Microanalytical Service at the University of Cambridge Chemical Laboratory.

Optical specific rotations were measured on a Perkin-Elmer 241 polarimeter and are quoted in units of $^\circ$10$^{-1}$cm$^2$g$^{-1}$. The concentration ($c$) is expressed in g/0.1 dm$^3$.

Flash chromatography was carried out on silica gel [Merck 9385 Kieselgel 60 (230-400 ASTM)]. Analytical TLC was carried out on 0.25 mm thick plates precoated with Merck Kieselgel F$_{254}$ silica gel and visualised by UV and aqueous potassium permanganate solution or ethanolic phosphomolybdic acid solution. Preparative layer chromatography was carried out on 1 mm thick plates of Merck Kieselgel PF$_{254}$.

Melting points were determined using a Kofler hot-stage apparatus and are uncorrected. Kugelrohr bulb-to-bulb distillations were carried out using a Büchi GKR-51 machine. Boiling points are oven temperatures.

The experimental procedures for the preparation of the lactone 2, the methylenecyclopentane 3 and the methylcyclopentane 4 are representative.

(3aR$^*$,6aS$^*$)-Methyl 3-oxohexahydro-1H-cyclopenta[c]furan-3a-carboxylate 2

Manganese(III) acetate (536 mg, 2.0 mmol) and copper(II) triflate (362 mg, 1.0 mmol) were added to a solution of dimethyl 4-pentenyl malonate (200 mg, 1.0 mmol) in dry degassed acetonitrile (5 mL) (nitrogen bubbled through the solvent for 2 h prior to use). The resulting suspension was then heated to 80 °C for 24 h. Water (20 mL) and diethyl ether (20 mL) were added, the mixture was filtered and then extracted with diethyl ether (3 × 100 mL). The combined organics were then dried (MgSO$_4$), filtered and concentrated in vacuo. The resultant oil was then purified by flash column chromatography (gradient elution 5-20% diethyl ether/petroleum ether) to yield the title compound 2 (167.4 mg, 0.91 mmol, 91%) as a colourless oil; $^1$H NMR (400 MHz, CDCl$_3$): $\delta$=4.55 (dd, $J$(H, H)=9.3, 7.6 Hz, 1H; 1-H), 4.07 (dd, $J$(H, H)=9.3, 2.4 Hz, 1H; 1-H$'$), 3.77 (s, 3H; OCH$_3$), 3.14-3.06 (m, 1H; 6a-H), 2.42-2.32 (m, 1H; 4-H), 2.29-2.22 (m, 1H; 4-H$'$), 2.12-2.00 (m, 1H; 6-H), 1.88-1.77 (m, 1H; 5-H), 1.71-1.56 (m, 2H; 6-H$'$, 5-H$'$); $^{13}$C NMR (50 MHz, CDCl$_3$): $\delta$=176.9 (C=O), 170.9 (C=O), 73.4 (1-C), 62.0 (3a-C), 53.5 (CH$_3$O), 46.0 (6a-C), 35.1 (4-C), 34.5 (6-C), 26.3 (5-C). Data consistent with literature.$^{[1-3]}$
(3aR*, 6R*, 6aS*)-Methyl 6-(tert-butyldiphenylsilyloxyethyl)-3-oxohexahydro-1H-cyclopenta[c]furan-3a-carboxylate 6

Rf 0.68 (EtOAc:hexane, 1:1); (Found: C, 68.83; H, 7.09%; C26H33O5Si requires C, 68.99; H 7.13); ^1H NMR (400 MHz, CDCl3): δ=7.65-7.59 (m, 4H; ArH), 7.47-7.36 (m, 6H; ArH), 4.48 (dd, 2J (H, H)=9.4, 3J (H, H)=6.8 Hz, 1H; 1-H), 4.23 (dd, 2J (H, H)=9.4, 3J (H, H)=6.8 Hz, 1H; 1-H'), 3.76 (s, 3H; OMe), 3.69 (dd, 2J (H, H)=10.0, 3J (H, H)=5.6 Hz, 1H; CHHOSi), 3.54 (dd, 2J (H, H)=10.0, 3J (H, H)=7.2 Hz, 1H; CHHOSi), 2.85 (td, 3J (H, H)=6.8, 1.6 Hz, 1H; 6a-H), 2.53 (ddd, 2J (H, H)=14.0, 3J (H, H)=8.3, 5.5 Hz, 1H, 4-H), 2.19-2.09 (m, 2H), 1.77 (ddd, 2J (H, H)=13.0, 3J (H, H)=7.2, 7.2, 5.5 Hz, 1H), 1.58 (dq, 2J (H, H)=13.0, 3J (H, H)=8.3 Hz, 1H), 1.04 (s, 9H; (CH3)3C); 13C NMR (100 MHz, CDCl3): δ=176.5 (3-C), 170.3 (C), 135.5 (CH), 135.5 (CH), 133.2 (C), 133.1 (C), 129.9 (CH), 129.9 (CH), 127.8 (CH), 127.8 (CH), 72.0 (CH2), 65.7 (CH2), 61.4 (C), 53.1 (CH3), 50.1 (CH), 49.5 (CH), 29.1 (CH2), 26.8 (CH3), 19.2 (C); IR (film): 1775, 1741; MS (+ESI): m/z (%): Found: (M+Na)+, 475.1908 (100), C26H32O5SiNa req. 475.1917.

The diastereomers were partly separable by flash chromatography.

Minor diastereomer: ^1H NMR (400 MHz, CDCl3): δ=7.64 (m, 4H; ArH), 7.47-7.36 (m, 6H; ArH), 4.56 (dd, 2J (H, H)=9.2, 3J (H, H)=6.6 Hz, 1H; 1-H), 4.07 (dd, 2J (H, H)=9.2, 3J (H, H)=1.7 Hz, 1H; 1-H'), 3.77 (s, 3H; OMe), 3.66-3.54 (m, 2H; CH2OSi), 3.17-3.09 (m, 1H; 6a-H), 2.44-2.31 (m, 1H; 4-H), 2.27-2.15 (m, 2H; 5-H, 6-H), 1.99-1.89 (m, 1H; 4-H'), 1.32-1.24 (m, 1H; 6-H'), 1.05 (s, 9H; (CH3)3C); 13C NMR (100 MHz, CDCl3): δ=176.5 (3-C), 170.3 (C), 135.5 (CH), 135.5 (CH), 129.9 (CH), 129.9 (CH), 127.8 (CH), 127.8 (CH), 71.4 (1-C), 65.4 (CH2OSi), 60.8 (3a-C), 53.2 (OMe), 47.2 (6a-C), 44.0 (5-C), 35.2 (6-C), 36.2 (6-C), 35.9 (4-C), 26.9 (CH3), 19.3 (C); IR (film): 1776, 1744; MS (+ESI): m/z (%): Found: (M+Na)+, 475.1908 (100), C26H32O5SiNa req. 475.1911.

Major diastereomer: ^1H NMR (400 MHz, CDCl3): δ=7.66-7.61 (m, 4H; ArH), 7.47-7.36 (m, 6H; ArH), 4.50 (dd, 2J (H, H)=9.3, 3J (H, H)=7.7 Hz, 1H; 1-H), 4.15 (dd, 2J (H, H)=9.3, 3J (H, H)=2.5 Hz, 1H; 1-H'), 3.79 (s, 3H; OMe), 3.63 (dd, 2J (H, H)=10.2, 3J (H, H)=5.5 Hz, 1H; CHHOSi), 3.57 (dd, 2J (H, H)=10.2, 3J (H, H)=6.0 Hz, 1H; CHHOSi), 3.13-3.05 (m, 1H; 6a-H), 2.69 (ddd, 2J (H, H)=13.9, 3J (H, H)=8.0, 1.5 Hz, 1H; 4-H), 2.45-2.32 (m, 1H; 5-H), 2.27-2.17 (m, 1H; 6-H), 1.97 (ddd, 2J (H, H)=13.9, 3J (H, H)=10.3 Hz, 1H; 4-H'), 1.48-1.38 (m, 1H; 6-H'), 1.05 (s, 9H; (CH3)3C); 13C NMR (100 MHz, CDCl3): 176.3 (3-C), 170.2 (C), 135.5 (CH), 133.5 (C), 129.7 (CH), 127.7 (CH), 71.4 (1-C), 65.4 (CH2OSi), 60.8 (3a-C), 53.2 (OMe), 47.2 (6a-C), 44.0 (5-C), 36.2 (6-C), 35.9 (4-C), 26.9 (CH3), 19.3 (C); IR (film): 1776, 1744; MS (+ESI): m/z (%): Found: (M+Na)+, 475.1919 (100), C26H32O5SiNa req. 475.1911.

(3aR*, 5R*, 6aS*)-Methyl 5-(tert-butyldiphenylsilyloxyethyl)-3-oxohexahydro-1H-cyclopenta[c]furan-3a-carboxylate 8maj and (3aS*, 5R*, 6aR*)-methyl 5-(tert-butyldiphenylsilyloxy)methyl)-3-oxohexahydro-1H-cyclopenta[c]furan-3a-carboxylate 8min
The diastereomers were partly separable by flash chromatography. Major diastereomer \(10^{\text{maj}}\): mp 97.3-98.0 °C; \(^1\)H NMR (400 MHz, CDCl\(_3\)): \(\delta=7.69-7.62 (m, 4H; \text{ArH}), 7.48-7.38 (m, 6H; \text{ArH}), 4.47 (dd, 2J(H, H)=9.2, 3J(H, H)=6.1 Hz, 1H; \text{1-H}), 3.79 (dd, 2J(H, H)=10.4, 3J(H, H)=6.0 Hz, 1H; CH(OSi)), 3.71 (dd, 2J(H, H)=10.4, 3J(H, H)=4.0 Hz, 1H; \text{1'-H}), 3.63 (s, 3H; OMe), 3.43-3.36 (m, 1H; \text{6a-H}), 2.89-2.82 (m, 1H; \text{4-H}), 2.32 (dtt, 2J(H, H)=13.3, 9.6, 8.0 Hz, 1H; 6-H), 1.93-1.79 (m, 2H; 5-H, 6-H'), 1.64-1.54 (m, 1H; 6-H'), 1.05 (s, 9H; (CH\(_3\))\(_3\)C); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)): \(\delta=175.5 (3-C), 167.9 (C), 135.7 (CH), 135.6 (CH), 133.1 (C) 133.1 (C), 129.8 (CH), 129.8 (CH), 127.7 (CH), 73.2 (1-C), 63.9 (3a-C), 63.8 (CH\(_2\)OSi), 52.9 (OMe), 49.3 (4-C), 44.2 (6a-C), 31.6 (6-C), 29.7 (5-C), 26.8 (CH\(_3\)), 19.1 (C); IR (KBr): 1776, 1732; MS (+ESI): \(m/z(\%)\): 475.2 ((M+Na)+, 90); Found: (M+Na)+, 475.1921, C\(_{26}\)H\(_{32}\)O\(_5\)SiNa req. 475.1911.

Minor diastereomer \(10^{\text{min}}\): \(^1\)H NMR (400 MHz, CDCl\(_3\)): \(\delta=7.71-7.67 (\text{app dt, } 2J(H, H)=7.9, 1.5 Hz; \text{ArH}), 7.45-7.35 (m, 6H; \text{ArH}), 4.56 (\text{app t, } 2J(H, H)=8.9, 3J(H, H)=8.9, 1H; \text{1-H}), 4.03-3.97 (m, 2H; \text{1-H}', \text{CH(OSi)}), 3.88 (dd, 2J(H, H)=10.5, 5J(H, H)=6.3 Hz, 1H; CH(OSi)), 3.74 (s, 3H; OMe), 3.34-3.27 (m, 1H; \text{6a-H}), 2.99-2.91 (m, 1H; 4-H), 2.07-1.91 (m, 2H; 5-H, 6-H), 1.79-1.65 (m, 2H; 5-H', 6-H'), 1.05 (s, 9H; (CH\(_3\))\(_3\)C); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)): \(\delta=174.0 (3-C), 171.0 (C), 135.7 (CH), 135.6 (CH), 133.4 (C), 129.6 (CH), 129.6 (CH), 127.6 (CH), 72.3 (1-C), 62.6 (CH\(_2\)OSi), 61.5 (3a-C), 53.2 (OMe), 49.4 (4-C), 46.9 (6a-C), 31.3 (6-C), 28.7 (5-C), 26.7 (CH\(_3\)), 19.3 (C); IR (film): 1774, 1737; MS (+ESI): \(m/z(\%)\): 453.3 ((M+H)+, 100); Found: (M+Na)+, 475.1915, C\(_{26}\)H\(_{32}\)O\(_5\)SiNa req. 475.1911.

**Dimethyl 2-methylcyclopentane-1,1-dicarboxylate 4**

Manganese(III) acetate (536 mg, 2.0 mmol) was added to a solution of the malonate \(\text{1} (200 \text{ mg, 1.0 mmol})\) in dry degassed ethanol (50 mL) (nitrogen bubbled through the solvent for 2 h prior to use). The resulting suspension was then heated to 80 °C for 24 h. Water (50 mL) and diethyl ether (100 mL) were added and the mixture was filtered and then extracted with diethyl ether (3 × 100 mL). The combined organics were dried (MgSO\(_4\)), filtered and concentrated \textit{in vacuo}. The resultant oil was purified by flash column chromatography (gradient elution 5-20% diethyl ether/petroleum ether) to yield the title compound \(\text{4} (132 \text{ mg, 0.66 mmol, 66%})\) as a colourless oil; \(^1\)H NMR (400 MHz, CDCl\(_3\)): \(\delta=3.72 (s, 3H; \text{CH})\), 3.71 (s, 3H; \text{CH})\), 2.68 (ddq, 3J(H, H)=8.9, 7.0, 7.0 Hz, 1H; \text{2-H}), 2.44 (ddd, 3J(H, H)=13.9, 8.8, 7.6 Hz, 1H; 5-H), 2.03 (ddd, 3J(H, H)=13.9, 9.3, 4.7 Hz, 1H; 5-H'), 1.98-1.77 (m, 2H; 4-H, 3-H), 1.64-1.50 (m, 1H; 4-H'), 1.46-1.35 (m, 1H; 3-H'), 0.98 (d, 3J(H, H)=7.0 Hz, 3H; 2-CH\(_3\)). Data consistent with literature.\([3]\)

**\((2S^*, 3R^*)\)-Dimethyl 3-(tert-butyldiphenylsilyloxyethyl)-2-methylcyclopentane-1,1-dicarboxylate 11**
(2S*, 4R*)-Dimethyl 4-(tert-butyldiphenylsilyloxy)methyl)-2-methylcyclopentane-1,1-dicarboxylate 12maj and (2R*, 4R*)-dimethyl 4-(tert-butyldiphenylsilyloxy)methyl)-2-methylcyclopentane-1,1-dicarboxylate 12min

The diastereomers were partly separable by flash chromatography.

Major diastereomer 12maj:1H NMR (400 MHz, CDCl3): δ=7.71-7.64 (m, 4H; ArH), 7.47-7.36 (m, 6H; ArH), 3.75 (s, 3H; OMe), 3.70 (s, 3H; OMe), 3.66 (d, 3J (H, H)=5.9 Hz, 2H; CH2OSi), 2.78 (ddq, 3J (H, H)=10.7, 3J (H, H)=5.7 Hz, 1H; CH/OSi), 2.50 (dq, 3J (H, H)=9.8, 7.0 Hz, 1H; 2-H), 2.35 (ddd, 3J (H, H)=13.3, 3J (H, H)=7.7, 7.7 Hz, 1H; 5-H), 2.05 (m, 2H), 1.87 (ddddd, 3J (H, H)=9.8, 3J (H, H)=8.6, 8.6, 5.7, 5.0 Hz, 1H), 1.57-1.42 (m, 1H), 1.04 (s, 9H; (CH3)3C), 0.95 (d, 3J (H, H)=7.0 Hz, 3H; 2-C3H3); 13C NMR (125 MHz, CDCl3): δ=172.9 (C), 171.9 (C), 135.6 (CH), 133.9 (C), 129.6 (CH), 129.5 (CH), 127.6 (CH), 67.1 (CH2OSi), 63.5 (1-C), 52.3 (OMe), 51.9 (CH3), 48.2 (CH), 33.3 (CH2), 27.2 (CH2), 26.8 (CH3), 19.3 (C), 15.5 (CH3); IR (film): 1731; MS (+ESI): m/z (%): 491.3 ((M+H)+, 100); Found: (M+Na)+, 491.2234, C27H36O5SiNa req. 491.2230.

Minor diastereomer 12min:1H NMR (400 MHz, CDCl3): δ=7.69-7.60 (m, 4H; ArH), 7.45-7.33 (m, 6H; ArH), 3.73 (s, 3H; OMe), 3.71 (s, 3H; OMe), 3.53 (dd, 3J (H, H)=6.2, 1.8 Hz, 2H; CH2OSi), 2.72 (ddq, 3J (H, H)=10.4, 8.8, 7.2 Hz, 1H; 2-H), 2.64-2.48 (m, 2H; 5-H, 4-H), 1.85-1.77 (m, 2H; 5-H’, 3-H), 1.64-1.54 (m, 1H; 3-H’), 1.07 (s, 9H; (CH3)3C), 1.01 (d, 3J (H, H)=7.0 Hz, 3H; 2-C3H3); 13C NMR (100 MHz, CDCl3): δ=172.7 (C), 171.7 (C), 135.7 (CH), 133.8 (C), 129.6 (CH), 127.6 (CH), 67.4 (CH2OSi), 63.8 (1-C), 52.3 (OMe), 52.0 (OMe), 40.3 (4-C), 40.1 (2-C), 36.9 (3-C), 36.8 (5-C), 26.8 (CH3), 19.3 (C), 16.9 (2-C3H3); IR (film): 1733; MS (+ESI): m/z (%): 469.3 ((M+H)+, 40); Found: (M+Na)+, 491.2226, C27H36O5SiNa req. 491.2224.

(2S*, 5S*)-Dimethyl 2-(tert-butyldiphenylsilyloxy)methyl)-5-methylcyclopentane-1,1-dicarboxylate 13maj and (2S*, 5R*)-dimethyl 2-(tert-butyldiphenylsilyloxy)methyl)-5-methylcyclopentane-1,1-dicarboxylate 13min

The diastereomers were partly separable by flash chromatography.

Major diastereomer 13maj:1H NMR (400 MHz, CDCl3): δ=7.68-7.61 (m, 4H; ArH), 7.45-7.35 (m, 6H; ArH), 3.72-3.63 (m, 4H; CH/OSi, OMe), 3.56-3.51 (m, 1H; CH/OSi), 3.50 (s, 3H; OMe), 2.95-2.87 (m, 1H; 2-H), 2.87-2.76 (m, 1H; 5-H), 2.13-1.99 (m, 2H; 4-H, 3-H), 1.74-1.61 (m, 1H; 4-H’), 1.35-1.25 (m, 1H; 3-H’), 1.05 (s, 9H; (CH3)3C), 0.94 (d, 3J (H, H)=7.0 Hz, 3H; 2-C3H3); 13C NMR (100 MHz, CDCl3): δ=(100 MHz, CDCl3) 171.6 (C), 171.2 (C), 135.7 (CH), 135.7 (CH), 133.7 (C), 133.5 (C), 129.6 (CH), 129.5 (CH), 127.6 (CH), 65.4 (1-C), 64.9 (CH2OSi), 53.4 (OMe), 52.3 (OMe), 47.5 (2-C), 42.2 (5-C), 32.2 (3-C), 27.7 (4-C), 27.0 (CH3), 19.8 (C), 17.8 (2-C3H3); IR (film): 1731; MS (+ESI): m/z (%): 491.2 ((M+Na)+, 100); Found: (M+Na)+, 491.2227, C27H36O5SiNa req. 491.2224.
minor diastereomer 13min: $^1$H NMR (400 MHz, CDCl₃): $\delta$=7.69-7.60 (m, 4H; ArH), 7.45-7.33 (m, 6H; ArH), 4.03 (dd, $^2$J (H, H)=9.7, $^2$J (H, H)=4.6 Hz, 1H; CH/HOSi), 3.65-3.51 (m, 7H; CH/HOSi, 2 × OMe), 2.69 (m, 1H; 2-H), 2.56-2.44 (m, 1H; 5-H), 2.17-2.08 (m, 1H; 3-H), 1.98-1.80 (m, 2H; 4-H, 3-H'), 1.66-1.51 (m, 1H; 4'-H'), 1.10-1.05 (m, 12H; (CH₃)₃C, 5-CCH₃); $^{13}$C NMR (100 MHz, CDCl₃): $\delta$=172.3 (C), 169.8 (C), 135.6 (CH), 133.9, 133.8 (C), 129.6, 129.5 (CH), 127.7 (CH), 127.6 (CH), 65.3 (CH₂OSi), 64.6 (1-C), 52.5 (OMe), 51.8 (OMe), 50.5 (2-C), 43.8 (3-C), 31.4 (5-C), 27.0 (CH₂), 19.3 (C), 16.0 (5-C); IR (film): 1731; MS (+ESI): m/z (%): 491.2 ((M+Na) +, 100); Found: (M+Na)⁺, 491.2225, C₂₇H₃₆O₅SiNa req. 491.2224.

**Dimethyl 2-methylene cyclopentane-1,1-dicarboxylate 3**

![3](image)

Manganese(III) acetate (536 mg, 2.0 mmol) and copper(II) acetate (218 mg, 1.0 mmol) were added to a solution of the malonate 1 (200 mg, 1.0 mmol) in dry degassed DMSO (5 mL) (nitrogen bubbled through the solvent for 2 h prior to use). The resulting suspension was then heated to 80 °C for 24 h. Water (50 mL) and diethyl ether (100 mL) were added and the mixture was filtered and then extracted with diethyl ether (3 × 100 mL). The combined organics were washed with water (100 mL), dried (MgSO₄), filtered and then concentrated in vacuo. The resultant oil was purified by flash column chromatography (gradient elution 5-20% diethyl ether/petroleum ether) to yield in order of elution the title compound 3 (152 mg, 0.77 mmol, 77%) as a colourless oil; $^1$H NMR (400 MHz, CDCl₃): $\delta$=5.31 (d, $^2$J (H, H)=2.2 Hz, 1H; C=C=H), 5.28 (d, $^2$J (H, H)=2.2 Hz, 1H; C=CH), 3.75 (s, 6H; OCH₃), 2.47 (tt, $^2$J (H, H)=7.3, 2.2 Hz, 2H; 3-H, 3-H'), 2.36 (t, $^2$J (H, H)=6.9 Hz, 2H; 5-H, 5-H'), 1.75 (qn, $^3$J (H, H)=7.1 Hz, 2H; 4-H, 4-H'); and lactone 6 (13 mg, 0.07 mmol, 7%). Data consistent with literature.[4]

**Dimethyl 3-(tert-butyldiphenylsilyloxymethyl)-2-methylene cyclopentane-1,1-dicarboxylate 14**

![14](image)

$^1$H NMR (400 MHz, CDCl₃): $\delta$=7.67-7.62 (m, 4H; ArH), 7.41-7.34 (m, 6H; ArH), 5.36 (d, $^2$J (H, H)=2.5 Hz, 1H; C=CH/H), 5.28 (d, $^2$J (H, H)=2.1 Hz, 1H; C=CH/H), 3.72 (m, 4H; OMe, CH/HOSi), 3.71 (s, 3H, OMe), 3.55 (dd, $^2$J (H, H)=10.1, $^3$J (H, H)=7.9 Hz, 1H; CH/HOSi), 2.83 (m, 1H; 3-H), 2.41-2.34 (dt, $^2$J (H, H)=6.6, 12.2 Hz, 1H; 5-H), 2.27-2.14 (m, 1H; 5-H'), 1.97-1.89 (m, 1H; 4-H), 1.75-1.66 (m, 1H; 4-H'), 1.04 (s, 9H; (CH₃)₃C); $^{13}$C NMR (50 MHz, CDCl₃): $\delta$=171.8 (C), 171.4 (C), 149.1 (C), 136.0 (CH), 135.6 (C), 130.0 (CH), 128.1 (CH), 113.9 (C=CH₂), 66.9 (CH₂OSi), 65.0 (6-C), 53.3 (OMe), 53.2 (OMe), 47.4 (3-C), 34.5 (5-C), 19.7 (C); IR (film): 1735; MS (+ESI): m/z (%): Found (M+Na)⁺, 489.2066 (100), C₂₇H₃₆O₅SiNa req. 489.2068.

**Dimethyl 4-(tert-butyldiphenylsilyloxymethyl)-2-methylene cyclopentane-1,1-dicarboxylate 15**

![15](image)

$^1$H NMR (400 MHz, CDCl₃): $\delta$=7.72-7.67 (m, 4H; ArH), 7.49-7.38 (m, 6H; ArH), 5.35 (s, 1H; C=CH/H), 5.30 (s, 1H; C=CH/H), 3.78 (s, 3H; OMe), 3.76 (s, 3H; OMe), 3.70-3.50 (m, 2H; CH₂OSi), 2.65-2.57 (m, 2H; 3-H, 5-H), 2.50-2.30 (m, 2H; 3-H', 4-H), 2.17 (dd, $^2$J (H, H)=12.8, $^3$J (H, H)=10.5, Hz, 1H; 5-H'), 1.10 (s, 9H; (CH₃)₃C); $^{13}$C NMR (100 MHz, CDCl₃): $\delta$=171.2 (C), 147.6 (2-C), 135.6 (CH), 133.7 (C),
129.7 (CH), 127.7 (CH), 112.5 (C=CH), 66.1 (CH2OSi), 63.5 (1-C), 52.9 (OMe), 52.8 (OMe), 40.1 (4-C), 38.5 (5-C), 36.9 (3-C), 26.9 (CH3), 19.3 (C); IR (film): 1735; MS (+ESI): m/z (%): 489.2 ((M+Na)+, 100); Found: (M+Na)+, 489.2068, C27H34O5SiNa req. 489.2068.

**Dimethyl 2-(tert-butylidiphenylsilyloxymethyl)-5-methylenecyclopentane-1,1-dicarboxylate 16**

Dimethyl 2-(tert-butyldiphenylsilyloxymethyl)-5-methylenecyclopentane-1,1-dicarboxylate

1H NMR (400 MHz, CDCl3): δ=7.68-7.64 (m, 4H; ArH), 7.46-7.36 (m, 6H; ArH), 5.29 (t, J (H, H)=2.4 Hz, 1H; C=CH), 5.22 (t, J (H, H)=2.2 Hz, 1H; C=CH), 3.71 (s, 3H; OMe), 3.58-3.51 (m, 4H; CH2OSi), 3.07-2.98 (m, 1H; 2-H), 2.65-2.55 (m, 1H; 4-H), 2.51-2.38 (m, 1H; 4-H′), 2.08 (ddd, J (H, H)=12.2, J (H, H)=6.3, 3.9 Hz, 1H; 3-H), 1.74 (ddd, J (H, H)=12.2, J (H, H)=9.3, 9.2 Hz, 1H; 3-H′), 1.06 (s, 9H; (CH3)3C); 13C NMR (100 MHz, CDCl3): δ=170.3 (C), 170.0 (C), 148.8 (5-C), 135.6 (C H), 133.7 (C), 129.6 (CH), 127.6 (CH), 111.9 (C=CH2), 65.1 (1-C), 63.8 (CH2OSi), 52.7 (OMe), 52.2 (OMe), 49.8 (2-C), 31.8 (4-C), 27.1 (3-C), 26.8 (CH3), 19.3 (C); IR (film): 1734; MS (+ESI): m/z (%): 489.2 ((M+Na)+, 100); Found: (M+Na)+, 489.2072, C27H34O5SiNa req. 489.2068.

**3aR*, 6aS*)-Methyl 3-oxo-1-butyl-hexahydro-1H-cyclopenta[c]furan-3a-carboxylate 18**

Isolated as an inseparable 1.7:1 mixture of diastereomers. Characterisation is on the mixture of compounds.

1H NMR (500 MHz, CDCl3): δ=4.65 (dt, J (H, H)=7.2, 5.4 Hz, 1H; 1-H [d1]), 4.06 (ddd, J (H, H)=7.9, 5.6, 4.0 Hz, 1H; 1-H [d2]), 3.77 (s, 6H; OCH3 [d1, d2]), 2.97 (dt, J (H, H)=13.2, 6.3 Hz, 1H; 6a-H [d1]), 2.79 (ddd, J (H, H)=8.3, 3.7, 2.7 Hz, 1H; 6a-H [d2]), 2.43-2.31 (m, 2H; [d1, d2]), 2.00-1.93 (m, 1H; 6-H [d1]), 1.90-1.43 (m, 13H , [d1, d2]), 1.42-1.22 (m, 10H, [d1, d2]), 1.40-1.25 (m, 10H, [d1, d2]), 0.88 (3H, t, J (H, H)=7.2 Hz, 6H; CH2CH3 [d1, d2]); 13C NMR (125 MHz, CDCl3): δ=176.1 (C=O), 175.9 (C=O), 171.0 (C0, 170.5 (C), 83.2 (CH), 78.3 (CH), 63.4 (C), 62.2 (C), 59.8 (CH2), 59.0 (CH2), 53.2 (CH3), 53.1 (CH3), 50.7 (CH), 50.3 (CH), 38.8 (CH2), 35.5 (CH2), 34.1 (CH2), 31.6 (CH2), 31.4 (CH2), 30.7 (CH2), 27.1 (CH2), 26.4 (CH2), 25.8 (CH2), 25.7 (CH2), 25.0 (CH2), 22.5 (CH2), 22.4 (CH2), 13.9 (CH3); IR (CDCl3): 2952, 2871, 1773 (C=O), 1742 (C=O); MS (+ESI): m/z (%): 277.1410 ((M+Na)+, 100); Found: (M+Na)+, 277.1410, C14H22O4Na req. 277.1416.

**3aR*, 6aS*)-Methyl 1-(2-hydroxyethyl)-3-oxohexahydro-1H-cyclopenta[c]furan-3a-carboxylate 20**

Isolated as an inseparable 1.7:1 mixture of diastereomers. Characterisation is on the mixture of compounds.

Rf = 0.09 (hexane:EtoAc, 1:1); 1H NMR (500 MHz, CDCl3): δ=4.89 (ddd, J (H, H)=9.8, 6.0, 4.0 Hz, 1H; 1-H [d1]), 4.32 (qn, J (H, H)=4.2 Hz, 1H; 1-H [d2]), 3.88-3.80 (m, 4H; CH2OH, [d1, d2]), 2.86 (dt, J (H, H)=4.2, 2.8 Hz, 1H; 6a-H [d2]), 2.45-2.32 (m, 2H), 2.98-2.20 (m, 2H), 2.05-1.90 (m, 2H), 1.89-1.80 (m, 2H), 1.75-1.65 (m, 3H), 1.62-1.52 (m, 1H); 13C NMR (125 MHz, CDCl3): δ=175.9 (C), 175.8 (C), 171.0 (C0, 170.5 (C), 83.2 (CH), 78.3 (CH), 63.4 (C), 62.2 (C), 59.8 (CH2), 59.0 (CH2), 53.2 (CH3), 53.1 (CH3), 50.7 (CH), 50.3 (CH), 38.8 (CH2), 35.5 (CH2), 34.1 (CH2), 33.9 (CH2), 33.7 (CH2), 27.5 (CH2), 26.4 (CH2), 25.7 (CH2);
1R (CHCl₃): 3423, 1769, 1739; MS (+ESI): m/z (%): Found: (M+Na)⁺, 251.0882 (100), C₁₁H₁₆O₅Na req. 251.0895.

(2aS*, 4aS*, 6S*, 6aR*, 6bR*)-Methyl 6-(2-tert-butyldiphenylsilyloxyethyl)-2-oxo-hexahydropentaleno[1,6-bc]furan-2a-carboxylate 22

\[ R_f = 0.84 \text{(PE:EtOAc, 1:1)}; ^1H \text{ NMR (400 MHz, CDCl}_3\text{): } \delta=7.67-7.62 \text{ (m, 4H, ArH)}, 7.44-7.35 \text{ (m, 6H, ArH)}, 4.78 \text{ (dd, } J(H, H)=5.4, 4.4 \text{ Hz, 1H; 6a-H)}, 3.76 \text{ (s, 3H; OMe)}, 3.79-3.67 \text{ (m, 2H; CH}_2\text{OSi)}, 3.31 \text{ (dd, } J(H, H)=9.8, 6.0 \text{ Hz, 1H)}, 2.74-2.64 \text{ (m, 1H)}, 2.55 \text{ (ddd, } J(H, H)=14.0, 8.4, 6.6 \text{ Hz, 1H)}, 2.31 \text{ (dt, } J(H, H)=14.0, 7.0 \text{ Hz, 1H)}, 2.26-2.15 \text{ (m, 1H)}, 2.08-1.82 \text{ (m, 3H), 1.72-1.63 \text{ (m, 1H)}, 1.58-1.49 \text{ (m, 1H)}, 1.04 \text{ (s, 9H; (CH}_3\text{)₃C}); ^13C \text{ NMR (125 MHz, CDCl}_3\text{): } \delta=176.4 \text{ (C)}, 170.6 \text{ (C), 135.5 \text{ (CH)}}, 133.8 \text{ (C), 129.6 \text{ (CH)}, 127.7 \text{ (CH)}, 85.4 \text{ (CH)}, 62.3 \text{ (C)}, 62.2 \text{ (CH}_2\text{)}, 57.2 \text{ (CH)}, 53.0 \text{ (CH}_3\text{), 44.7 \text{ (CH)}, 44.1 \text{ (CH)}, 35.9 \text{ (CH}_2\text{)}, 35.5 \text{ (CH}_2\text{)}, 32.7 \text{ (CH}_2\text{)}, 32.1 \text{ (CH}_2\text{)}, 26.9 \text{ (CH}_3\text{), 19.2 \text{ (C); IR (film): 1772, 1742; MS (+ESI): m/z (%): Found: (M+Na)⁺ 515.2208 (100), C₂₉H₃₆O₅SiNa req. 515.2230.}

(3aR*, 5R*, 6aS*)-Ethyl 5-((tert-butyldiphenylsilyloxy)methyl)-1,1-dimethyl-3-oxohexahydro-1H-cyclopenta[c]furan-3a-carboxylate 24maj

Isolated as an inseparable 5:1 mixture of diastereomers; data for major diastereomer
\[ R_f = 0.63 \text{(PE:EtOAc, 2:1)}; ^1H \text{ NMR (400 MHz, CDCl}_3\text{): } \delta=7.64-7.60 \text{ (m, 4H; ArH)}, 7.44-7.34 \text{ (m, 6H; ArH)}, 4.29-4.20 \text{ (m, 2H; OC}_2\text{H}_5\text{CH}_3), 3.62 \text{ (dd, } J(H, H)=10.4, 3J(H, H)= 5.8 \text{ Hz, 1H; CHHOSi), 3.59 \text{ (dd, } J(H, H)=10.4, 3J(H, H)=6.0 \text{ Hz, 1H; CHHOSi), 2.94 \text{ (dd, } J(H, H)=11.4, 7.4 \text{ Hz, 1H)}, 2.48-2.30 \text{ (m, 2H)}, 2.00-1.90 \text{ (m, 2H)}, 1.48-1.46 \text{ (m, 1H)}, 1.42 \text{ (s, 3H; 1-CCH}_3\text{), 1.37 \text{ (s, 3H; 1-CCH}_3\text{), 1.29 \text{ (t, } J(H, H)= 7.0 \text{ Hz, 3H; OCH}_2\text{CH}_3), 1.03 \text{ (s, 9H; (CH}_3\text{)₃C); ^13C \text{ NMR (125 MHz, CDCl}_3\text{): } \delta=175.4 \text{ (C), 171.9 \text{ (C), 135.5 \text{ (CH)}, 133.5 \text{ (C), 129.7 \text{ (CH)}, 127.7 \text{ (CH)}, 83.8 \text{ (C), 65.4 \text{ (CH}_2\text{)}, 62.7 \text{ (C), 62.2 \text{ (CH}_2\text{)}, 55.8 \text{ (CH)}, 44.1 \text{ (CH)}, 38.8 \text{ (CH)}, 32.8 \text{ (CH}_2\text{)}, 29.4 \text{ (CH}_2\text{)}, 26.8 \text{ (CH}_3\text{)}, 24.4 \text{ (CH}_3\text{)}, 19.2 \text{ (C), 14.0 \text{ (CH}_3\text{); IR (film): 1769, 1732; MS (+ESI): m/z (%): Found: (M + Na)⁺ 517.2398 (100), C₂₉H₃₈O₅SiNa req. 517.2386.}

(3aR*, 6aS*)-Methyl 1-((E)-hept-1-enyl)-3-oxohexahydro-1H-cyclopenta[c]furan-3a-carboxylate 26

Isolated as an inseparable 1:1 mixture of diastereomers.
\[ ^1H \text{ NMR (500 MHz, CDCl}_3\text{): } \delta=5.84 \text{ (ddt, } J(H, H)=15.4, 6.8, 0.9 \text{ Hz; 1H; CH=CHCH₂CH₂ [d1]), 5.74 \text{ (5.84 (dd, } J(H, H)=15.3, 6.3 \text{ Hz; 1H; CH=CHCH₂CH₂ [d2]), 5.51 \text{ (ddt, } J(H, H)=15.3, 7.8, 1.5 \text{ Hz; 1H; CH=CHCH₂CH₂ [d2]), 5.43 \text{ (ddt, } J(H, H)=15.4, 7.0, 1.4 \text{ Hz; 1H; CH=CHCH₂CH₂ [d1]), 5.10 \text{ (t, } J(H, H)= 7.0 \text{ Hz, 1H; 1-H [d1]), 4.44 \text{ (dd, } J(H, H)=8.0, 3.8 \text{ Hz, 1H; 1-H [d2]), 3.75 \text{ (s, 3H; OCH}_3\text{), 3.74 \text{ (s, 3H; OCH}_3\text{), 2.98 \text{ (dt, } J(H, H)=8.0, 7.0 \text{ Hz, 1H; 6a-H [d1]), 2.87 \text{ (dt, } J(H, H)=8.0, 3.1 \text{ Hz, 1H; 6a-H [d2])}, 2.40-2.22 \text{ (m, 2H), 2.22-2.18 \text{ (m, 2H), 2.08-2.00 \text{ (m, 4H; CH=CHCH₂ [d1, d2]), 1.98-1.88 \text{ (m, 1H, 6-H [d2]), 1.86-1.80 \text{ (m, 1H), 1.75-1.53 \text{ (m, 6H), 1.40-1.32 \text{ (m, 4H; CH=CHCH₂CH₂ [d1, d2]), 1.30-1.20.}}}

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S8
(m, 8H; (CH₂)CH₃ [d1, d2]), 0.86 (t, (J (H, H)=6.7 Hz, 6H; CH₂CH₃ [d1, d2]); ^{13}C NMR (125 MHz, CDCl₃): \delta=175.9 (C=O), 175.8 (C=O), 171.0 (C=O), 170.5 (C=O), 136.9 (CH), 135.8 (CH), 127.6 (CH), 123.6 (CH), 86.4 (CH), 81.6 (CH), 63.4 (C), 62.2 (C), 53.1 (CH), 51.7 (CH), 50.9 (CH), 35.5 (CH), 34.3 (CH₂), 33.4 (CH₂), 32.2 (CH₂), 32.0 (CH₂), 31.3 (CH₂), 31.2 (CH₂), 28.4 (CH₂), 28.4 (CH₂), 28.2 (CH₂), 26.2 (CH₂), 25.6 (CH₂), 22.4 (CH₂), 22.4 (CH₂), 14.0 (CH₃), 13.9 (CH₃); IR (CDCl₃): 2955, 2828, 2858, 1772 (C=O), 1740 (C=O); MS (+ESI): m/z (%) 303.1568 ((M+Na)^+, 100); Found: (M+Na)^+, 303.1568, C_{13}H_{22}O_{5}Na req. 303.1572.

(3aR*,6R*,6aS*)-Methyl 6-(hydroxymethyl)-3-oxohexahydro-1H-cyclopenta[c]furan-3a-carboxylate 27

Tetrabutyl ammonium fluoride (1.0 M, in THF, 300 µL, 0.30 mmol) was added dropwise to a solution of the[3.3.0]-bicyclic γ-lactone 6 (45 mg, 0.10 mmol) in THF (7 mL) buffered with acetic acid (17 µL, 0.30 mmol) at 0 °C. The reaction mixture is allowed to reach RT and stirred for 16 h. Water (40 mL) and diethyl ether (40 mL) were both added and the aqueous layer was extracted with diethyl ether (3 × 40 mL). The combined organic layers were dried (MgSO₄), filtered, and the solvent removed in vacuo. The resulting compound was purified by column chromatography (20% diethyl ether/petroleum ether) to give the title compound 27 as a colourless oil (19.2 mg, 90 µmol, 90%); (Found: C, 55.72; H, 6.65%; C_{10}H_{14}O_{5} requires C, 56.07; H, 6.59); 1H NMR (400 MHz, CDCl₃): \delta=4.57 (dd, (J (H, H)=9.4, 7.0 Hz, 1H; 1-H), 4.23 (dd, (J (H, H)=9.3, 1.8 Hz, 1H; 1-H'), 3.78 (s, 3H; OMe), 3.72 (dd, (J (H, H)=10.5, 5.8 Hz, 1H; CHHOSi), 2.93 (td, (J (H, H)=6.9, 1.8 Hz, 1H; 6a-H), 2.57 (ddd, (J (H, H)=14.2, 8.1, 6.4 Hz, 1H; 4-H), 2.25-2.09 (m, 2H; 6-H, 4-H'), 1.90-1.80 (m, 1H; 5-H), 1.72 (br s, 1H; OH), 1.64 (dq, (J (H, H)=13.1, 7.6 Hz, 1H; 5-H'); 13C NMR (100 MHz, CDCl₃): \delta=176.5 (C), 170.4 (C), 72.1 (1-C), 64.6 (CH₂OH), 61.4 (3a-C), 53.2 (CH₂), 49.7 (6a-C), 49.3 (6-C), 32.8 (4-C), 29.0 (5-C); IR (film): 3431, 1768, 1738; MS (+ESI): m/z(%): 237.0737 ((M+Na)^+, 100); Found: (M+Na)^+, 237.0737, C_{10}H_{14}O_{5}Na req. 237.0739.

(3aR*,6R*,6aS*)-6-(tert-Butyldiphenylsilyloxymethyl)-3-oxohexahydro-1H-cyclopenta[c]furan-3a-carboxylic acid 28

Aqueous 10% KOH solution (4 mL) was added to the γ-lactone 6 (452 mg, 1.0 mmol) in THF (20 mL) and the resulting mixture was stirred at RT for 16 h. Sulfate buffer (pH 2, 40 mL) was then added to acidify the mixture. The mixture was extracted with ether (5 × 50 mL), the organic layers combined, dried (MgSO₄), filtered, and the solvent removed in vacuo. The resulting compound was recrystallised (diethyl ether/hexane) to give the title compound 28 as a white crystalline solid (395 mg, 0.90 mmol, 90%); mp 118.0-118.5°C; 1H NMR (400 MHz, CDCl₃): \delta=7.65-7.61 (m, 4H; ArH), 7.48-7.38 (m, 6H; ArH), 4.55 (dd, (J (H, H)=9.3, 7.1 Hz, 1H; 1-H), 4.27 (dd, (J (H, H)=9.3, 1.9 Hz, 1H; 1-H'), 3.71 (dd, (J (H, H)=10.5, 5.7 Hz, 1H; CHHOSi), 3.58 (dd, (J (H, H)=10.3, 7.5 Hz, 1H; CHHOSi), 3.00 (dd, (J (H, H)=7.8, 1.6 Hz, 1H; 6a-H), 2.51 (dd, (J (H, H)=13.8, 8.1, 5.5 Hz, 1H; 4-H), 2.24-2.12 (m, 2H; 6a-H, 4-H'), 1.86-1.77 (m, 1H; 5-H), 1.58 (dq, (J (H, H)=13.0, 8.3 Hz, 1H; 4-H'), 1.06 (s, 9H; (CH₃)₃C); 13C NMR (50 MHz, CDCl₃): \delta=176.5 (C), 175.4 (C), 136.0 (CH), 133.5 (C), 130.4 (CH), 128.3 (CH), 72.7 (1-C), 66.1 (CH₂OSi), 61.9 (3a-C), 50.5 (6a-C), 50.1 (6-C), 33.2 (4-C), 27.3 (5-C), 27.3 (CH₃), 19.6 (C); IR (KBr): 3073, 1760, 1737; MS (+ESI): m/z(%): 502.2 ((M+Na+MeCN)^+, 60)); Found: (M+Na)^+, 461.1757, C_{25}H_{30}O_{5}SiNa req. 461.1755.
Benzyl (3aS*,6R*,6aS*)-6-((tert-butyldiphenylsilyloxy)methyl)-3-oxohexahydro-1H-cyclopenta[c]furan-3a-ylcarbamate 31

Diphenyl phosphoryl azide (15.8 µL, 0.074 mmol) was added to a solution of the [3.3.0]-bicyclic γ-lactone 28 (30.7 mg, 0.07 mmol) and triethylamine (10.7 µL, 0.077 mmol) in toluene (1 mL). The mixture was then heated to 110°C for 2 h, at which point benzyl alcohol (1 mL) was added, and the reaction was stirred at this temperature for a further 16 h. Saturated aqueous NaHCO₃ (10 mL) and diethyl ether (20 mL) were then added and the aqueous layer was extracted with ether (2 × 20 mL). The combined organics were concentrated *in vacuo* and water was added (20 mL) and then concentrated *in vacuo* for azeotropic removal of the benzyl alcohol. Diethyl ether (20 mL) was then added and the solution was dried (MgSO₄), filtered and concentrated *in vacuo* to give the title compound 31 as a white solid (35.1 mg, 64 µmol, 92%); mp 113.5-114.0°C; NMR shows compound exists as rotomers; ¹H NMR (400 MHz, CDCl₃): δ=7.63 (m, 4H; ArH), 7.48-7.30 (m, 11H; ArH), 5.22 (br s, 1H; NH), 5.10 (br s, 2H; CH₂Ar), 4.79 (t, J(H, H)=8.5 Hz, 1H; 1-H), 4.05 (d, J(H, H)=8.5 Hz, 1H; 1-H'), 3.66-3.55 (m, 2H; CH₂OSi), 2.81 (br s, 1H; 6a-H), 2.26-2.09 (m, 2H; 4-H, 6-H), 1.85-1.59 (m, 3H; 4-H', 5-H, 5-H'), 1.06 (9H, s, (CH₃)₃C); ¹³C NMR (125 MHz, CDCl₃): δ=178.6 (C), 155.9 (C), 136.0 (CH), 133.7 (C), 130.3 (CH), 129.1 (CH), 128.8(CH), 128.7 (CH), 128.2 (CH), 73.9 (1-C), 67.7 (CH₂Ar), 65.9 (CH₂OSi), 51.8 (6-C), 48.6 (6a-C), 37.9 (4-C), 28.1 (5-C), 27.3 (CH₃), 19.6 (C); IR (KBr) 1753, 1713; MS (+ESI): m/z (%): 566.2 ((M+Na)+, 100), Found: (M+Na)+, 566.2333, C₃₂H₃₇NO₅SiNa req. 566.2333.

(3aS*,4R*,6aR*)-4-((tert-Butyldiphenylsilyloxy)methyl)hexahydro-1H-cyclopenta[c]furan-1-one 30

The [3.3.0]-bicyclic γ-lactone 5 (226 mg, 0.50 mmol) and LiCl (42 mg, 1.00 mmol) were dissolved in DMSO (0.9 mL) and water (9 µL, 0.50 mmol), the resulting mixture was heated to 160°C and stirred for 2 h. After cooling, water (30 mL) and diethyl ether (50 mL) were added and the aqueous layer extracted with ether (5 × 50 mL). The combined organic layers were washed with water (2 × 50 mL), brine (50 mL), dried (MgSO₄), filtered, and the solvent removed *in vacuo*. The resulting compound was purified via flash chromatography (gradient elution 5-20% diethyl ether/hexane) to give the title compound 30 as a white crystalline solid (178.2 mg, 90%); mp 51.7-52.3°C; ¹H NMR (400 MHz, CDCl₃): δ=7.66-7.62 (m, 4H), 7.48-7.37 (m, 6H), 4.40 (dd, J(H, H)=9.4, 7.3 Hz, 1H; 3-H), 4.19 (dd, 3J(H, H)=9.4, 2.4 Hz, 1H; 3-H'), 3.68 (dd, J(H, H)=10.2, 5.8 Hz, 1H; CHHOSi), 3.54 (dd, 3J(H, H)=10.2, 7.2 Hz, 1H; CHHOSi), 3.10 (td, 3J(H, H)=9.5, 4.3 Hz, 1H' 6a-H), 2.69 (ddd, 3J(H, H)=9.3, 7.2, 7.0, 2.3 Hz, 1H; 3a-H), 2.19-1.93 (m, 3H; 4-H, 6-H, 6-H'), 1.82-1.72 (m, 1H; 5-H), 1.56-1.46 (m, 1H; 5-H'), 1.06 (s, 9H; (CH₃)₃C); ¹³C NMR (125 MHz, CDCl₃): δ=181.0 (C), 135.5 (C), 133.9 (C), 129.8 (CH), 127.8 (CH), 72.4 (3-C), 65.9 (CH₂OSi), 48.9 (4-C), 44.5 (6a-C), 43.5 (3a-C), 29.1 (6-C), 28.4 (5-C), 26.8 (CH₃), 19.2 (C); IR (KBr) 1763; MS (+ESI): m/z (%): 458.3 ((M+Na)+MeCN), 100; Found (M+Na)+, 417.1855, C₃₂H₃₇NO₅SiNa req. 417.2333.
A solution of the [3.3.0]-bicyclic γ-lactone 30 (39.5 mg, 0.10 mmol) in dry THF (2 mL) was cooled to -78 °C and LiHMDS (300 µL of a 1.0 M solution in toluene, 0.3 mmol) was added dropwise and the solution was allowed to warm to -30°C and then cooled back down to -78°C. Benzyl bromide (35.6 µL, 0.3 mmol) was then added dropwise to the reaction mixture which was allowed to reach RT. over 16 h. Saturated aqueous NH₄Cl (20 mL) and diethyl ether (20 mL) were added and the aqueous layer was extracted with diethyl ether (3 × 20 mL). The combined organic layers were dried (MgSO₄), filtered, and the solvent removed in vacuo. The resulting compound was purified by flash chromatography (gradient elution 5-20% diethyl ether/hexane) to give the title compound as a colourless oil (43.3 mg, 89 µmol, 89%); 1H NMR (400 MHz, CDCl₃): δ=7.66-7.61 (m, 4H; ArH), 7.49-7.37 (m, 6H; ArH), 7.32-7.24 (m, 3H; ArH), 7.19-7.15 (m, 2H; ArH), 3.82 (dd, J(H, H)=9.2, 1.4 Hz, H; 3-H), 3.62 (dd, J(H, H)=10.2, 5.8 Hz, 1H; CHHOSi), 3.54 (dd, J(H, H)=10.2, 6.8 Hz, 1H; CHHOSi), 3.31-3.24 (m, 2H; 3-H', CHHAr), 2.66 (d, J(H, H)=13.5 Hz, 1H; CHHAr), 2.49 (t, 1H; J(H, H)=6.9 Hz, 1H; 3a-H), 2.17 (app dt, J(H, H)=13.5, 7.4 Hz, 1H; 6-H), 2.05 (app sext, J(H, H)=6.8 Hz, 1H; 4-H), 1.89 (ddd, J(H, H)=13.6, 7.6, 6.2 Hz, 1H; 6-H'), 1.73 (ddd, J(H, H)=13.0, 6.8, 6.2 Hz, 1H; 5-H'), 1.64-1.49 (m, 1H; 5-H'), 1.07 (s, 9H; (CH₃)₃C); 13C NMR (125 MHz, CDCl₃): δ=183.5 (C), 137.3 (C), 136.0 (CH), 133.8 (C), 130.3 (CH), 129.9 (CH), 129.1 (CH), 128.2 (CH), 127.6 (CH), 72.1 (3-C), 66.0 (CH₂OSi), 57.7 (6a-C), 50.7 (4-C), 46.9 (3a-C), 43.4 (CH₂Ar), 37.2 (6-C), 28.8 (5-C), 27.3 (CH₃), 19.7 (C); IR (film): 1765; MS (+ESI): m/z(%): 548.3 ((M+Na+MeCN)+, 100); Found (M+Na)+, 507.2326, C₃₁H₃₆O₃SiNa req. 507.2326.

Prepared as for (3aS,4R,6aS*)-6a-benzyl-4-((t-butyldiphenylsilyloxy)methyl)hexahydro-1H-cyclopenta[c]furan-1-one using allylbromide in place of benzyl bromide. 1H NMR (400 MHz, CDCl₃): δ=7.67-7.63 (m, 4H; ArH), 7.49-7.38 (m, 6H; ArH), 5.79-5.66 (m, 1H; CH=CH₂), 5.18-5.12 (m, 2H; CH=CH₂), 4.25 (dd, J(H, H)=9.4, 7.3 Hz, 1H; 3-H), 4.10 (dd, J(H, H)=9.4, 2.0 Hz, 1H; 3-H'), 3.67 (dd, J(H, H)=10.3, 5.7, 1H; CHHOSi), 3.55 (dd, J(H, H)=10.2, 7.2 Hz, 1H; CHHOSi), 2.51 (dd, J(H, H)=13.6, 6.8 Hz, 1H; CHCH=CH₂), 2.42 (app td, J(H, H)=7.0, 1.7, 1H; 3a-H), 2.25 (dd, J(H, H)=13.6, 8.0 Hz, 1H; CHCH=CH₂), 2.16-2.00 (m, 2H; 4-H, 6-H), 1.82-1.65 (m, 2H; 5-H, 6-H'), 1.57-1.46 (m, 1H; 5-H'), 1.07 (s, 9H; (CH₃)₃C); 13C NMR (125 MHz, CDCl₃): δ=183.0 (C), 136.0 (CH), 133.8 (C), 133.3 (CH), 130.3 (CH), 128.2 (CH), 119.8 (CH), 72.1 (3-C), 66.0 (CH₂OSi), 55.7 (6a-C), 50.7 (4-C), 47.6 (3a-C), 41.3 (CH₂CH=CH₂), 35.9 (6-C), 28.9 (5-C), 27.3 (CH₃), 19.7 (C); IR (film): 1765; MS (+ESI): m/z(%): 498.3 ((M+Na+MeCN)+, 80); Found (M+Na)+, 457.2170, C₂₇H₃₄O₃SiNa req. 457.2169.
(1S, 4S, 5R, 6S, 7S)-6-(tert-Butyldiphenylsilyloxyethyl)-4-((E)-hept-1-enyl)-3,8-dioxatricyclo[5.2.1.01,5]decane-2,9-dione 33

$$\alpha_D^{20} = +11.3 \, (c \, 1.1, \, CH_2Cl_2)$$; $^1$H NMR (400 MHz, CDCl$_3$): $\delta = 7.63-7.62$ (m, 4H; ArH), 7.48-7.38 (m, 6H; ArH), 5.83 (dt, $^3$J (H, H)=15.3, 6.8 Hz, 1H; CH=CHCH$_2$), 5.40 (dd, $^3$J (H, H)=15.3, 7.5 Hz, 1H; CH=CHCH$_2$), 5.12 (s, 1H; 7-H), 4.72 (dd, $^3$J (H, H)=15.3, 6.8 Hz, 1H; CH=CHCH$_2$), 3.70 (1H, dd, $^3$J (H, H)=15.3, 7.5 Hz, 1H; CH=CHCH$_2$), 2.62-2.58 (m, 2H; 6-H, 10-H), 2.43 (d, $^3$J (H, H)=15.3, 7.5 Hz, 1H; CH=CHCH$_2$), 2.26 (dd, $^3$J (H, H)=9.6, 4.7 Hz, 1H; 5-H), 1.98 (td, $^3$J (H, H)=8.2, 6.8 Hz, 2H; CH=CHCH$_2$), 1.34-1.18 (m, 6H; 6-H, 10-H), 1.06 (s, 9H; (CH$_3$)$_3$C), 0.86 (t, $^3$J (H, H)=7.1 Hz, 3H; CH$_2$C$_3$); 13C NMR (100 MHz, CDCl$_3$): $\delta = 169.1$ (C), 167.3 (C), 138.7 (CH=CHCH$_2$), 135.5 (CH), 135.4 (CH), 130.0 (C), 129.9 (C), 127.9 (CH), 127.8 (CH), 124.7 (CH=CHCH$_2$), 84.2 (4-C), 82.2 (7-C), 62.2 (CH$_2$OSi), 56.8 (1-C), 50.1 (5-C), 49.4 (6-C), 40.6 (10-C), 31.2 (C$_3$H$_2$), 28.2 (CH$_2$), 26.8 (C(CH$_3$)$_3$), 24.4 (CH$_2$), 22.4 (CH$_2$), 19.2 (C(CH$_3$)$_3$), 14.0 (CH$_2$CH$_3$); IR (CDCl$_3$): 1813 (CO), 1783 (CO), 1728 (CO); MS (+ESI): m/z (%): Found: (M+Na) + 555.2335 (100), C$_{25}$H$_{34}$NaO$_3$Si req. 555.2335.

(1S, 3aS, 5S, 6S, 6aR)-Methyl 6-(tert-butyldiphenylsilyloxyethyl)-1-((E)-hept-1-enyl)-5-hydroxy-3-oxohexahydro-1H-cyclopenta[c]furan-3a-carboxylate 34

$$\alpha_D^{20} = +22 \, (c \, 0.53, \, CH_2Cl_2)$$; $^1$H NMR (400 MHz, CDCl$_3$): $\delta = 7.66-7.63$ (m, 4H; ArH), 7.48-7.38 (m, 6H; ArH), 5.66 (dt, $^3$J (H, H)=15.4, 6.7 Hz, 1H; CH=CHCH$_2$), 5.55 (dd, $^3$J (H, H)=15.4, 7.2 Hz, 1H; CH=CHCH$_2$), 4.66 (d, $^3$J (H, H)=7.2 Hz, 1H; CH=CHCH$_2$), 4.42 (d, $^3$J (H, H)=6.8, 4.2 Hz, 1H; CH=CHCH$_2$), 4.39 (dd, $^3$J (H, H)=10.7, 3.3 Hz, 1H; CH=CHCH$_2$), 3.96 (dd, $^3$J (H, H)=10.7, 3.3 Hz, 1H; CH=CHCH$_2$), 3.80 (s, 3H; OMe), 3.08 (s, 3H; OMe); 13C NMR (100 MHz, CDCl$_3$): $\delta = 175.3$ (C), 171.5 (C), 135.7 (CH), 135.6 (CH), 135.0 (C), 129.9 (C), 127.9 (CH), 127.8 (CH), 124.7 (CH=CHCH$_2$), 84.2 (4-C), 82.2 (7-C), 62.2 (CH$_2$OSi), 60.4 (1-C), 54.5 (6-C), 53.5 (OMe), 52.8 (5-C), 43.3 (6-C), 32.0 (CH=CHCH$_2$), 31.3 (CH$_2$), 28.4 (CH$_2$), 26.8 (C(CH$_3$)$_3$), 22.5 (CH$_2$), 19.1 (C(CH$_3$)$_3$), 14.0 (CH$_2$CH$_3$); IR (CDCl$_3$): 3508 (OH), 1773 (CO), 1738 (CO); MS (+ESI): m/z (%): Found: (M+Na) + 555.2335 (100), C$_{26}$H$_{34}$NaO$_3$Si req. 555.2335.

References
1H NMR (400 MHz, CDCl3)

13 C NMR (100 MHz, CDCl3)
1H NMR (400 MHz, CDCl3)

13C NMR (100 MHz, CDCl3) with minor diastereomer present
7.5 NMR (500 MHz, CDCl3)

13C NMR (125 MHz, CDCl3)
1H NMR (400 MHz, CDCl3) mixture of diastereomers

\[
\text{MeO}_2\text{C} \quad \text{CO}_2\text{Me} \\
\text{TBDPSO} \quad 12
\]

13C NMR (100 MHz, CDCl3) mixture of diastereomers

\[
\text{MeO}_2\text{C} \quad \text{CO}_2\text{Me} \\
\text{OTBDPS} \quad 12
\]
$^1$H NMR (400 MHz, CDCl$_3$)

13C NMR (100 MHz, CDCl$_3$) mixture of diastereomers
$^1$H NMR (400 MHz, CDCl$_3$) with the cyclohexene as a slight impurity

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$^{13}$C NMR (50 MHz, CDCl$_3$)

S19
**1H NMR (400 MHz, CDCl3)**

![1H NMR spectrum](image)

**13C NMR (100 MHz, CDCl3)**

![13C NMR spectrum](image)
1H NMR (400 MHz, CDCl3) with the cyclohexene as a slight impurity

13C NMR (100 MHz, CDCl3)
1H NMR (500 MHz, CDCl3)

DEPT QGPSP (125 MHz, CDCl3) mixture of diastereomers
$^1$H NMR (500 MHz, CDCl$_3$) mixture of diastereomers

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$^{13}$C NMR (125 MHz, CDCl$_3$) mixture of diastereomers
1H NMR (400 MHz, CDCl3)

13 C NMR (125 MHz, CDCl3)
1H NMR (500 MHz, CDCl3) mixture of diastereomers

13 C NMR (125 MHz, CDCl3) mixture of diastereomers
1H NMR (500 MHz, CDCl3) mixture of diastereomers

13C NMR (125 MHz, CDCl3) mixture of diastereomers
1H NMR (400 MHz, CDCl3)

13 C NMR (100 MHz, CDCl3)
Supplementary Material (ESI) for Chemical Communications
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1H NMR (400 MHz, CDCl3)

13 C NMR (50 MHz, CDCl3)
**1H NMR (400 MHz, CDCl3)**

![1H NMR spectrum](image)

**13C NMR (100 MHz, CDCl3)**

![13C NMR spectrum](image)
1H NMR (400 MHz, CDCl3)

13C NMR (50 MHz, CDCl3)
1H NMR (400 MHz, CDCl3)

13C NMR (50 MHz, CDCl3)
**1H NMR (500 MHz, CDCl3)**

![1H NMR spectrum](image1)

**13C NMR (125 MHz, CDCl3)**

![13C NMR spectrum](image2)
$^1$H NMR (500 MHz, CDCl₃)

$^{13}$C NMR (125 MHz, CDCl₃)