Total Synthesis of 1α,25-Dihydroxyvitamin D₃ (Calcitriol) Through a Si-Assisted Allylic Substitution

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**General methods:** Reagents were purchased from Aldrich Chemical or Acros Organics and used without further purification. All reactions involving oxygen or moisture sensitive compounds were carried out under dry argon atmosphere. Reaction temperatures refer to external bath temperatures. All solvents were distilled under argon immediately prior to use. THF, Et₂O and toluene were distilled from Na/benzophenone. CH₂Cl₂ was distilled from P₂O₅. Pyridine was distilled from CaH₂. MeOH was distilled from Mg/I₂. Acetone was distilled from K₂CO₃. DMSO was distilled from CaH₂ and stored over activated 4 Å molecular sieves. DMF (ACS-reagent) was dried over activated 4 Å molecular sieves. tert-Butylmethyl ether (MTBE) was used for extractions. CuBr was purified by solution in sat. aq. NaBr at 100 ºC for 30 min. The mixture was cooled to 0 ºC and filtered. The solids were successively washed H₂O, EtOH, EtOAc, Et₂O, and hexanes. CuCN was purified by washing with H₂O and EtOH. Solutions of organolithium compounds were titrated with o-fenantroline and sec-butanol before use. Acetone−dry ice baths were used for reactions at low temperature. Alternatively, acetone baths were cooled with a CRYOCOOL immersion cooler, provided with a temperature regulator. Organic extracts were dried over anhydrous Na₂SO₄, filtered and concentrated using rotary evaporator at aspirator pressure (20−30 mmHg). Reactions were monitored by thin-layer chromatography (TLC) using aluminum-backed MERCK 60 silica gel plates (0.2 mm thickness). After visualization under ultraviolet light at 254 nm, the plates were developed by immersion in a solution containing either a mixture of p-anisaldehyde (2.5%), acetic acid (1%), and sulfuric acid (3.4%) in 95% ethanol or a solution of ceric ammonium nitrate (0.5 g) and ammonium molybdate (4.8 g) in H₂O (100 mL) and H₂SO₄ (5.6 mL) followed by heating with a hot gun. Flash column chromatography was performed with Merk silica gel (230–400 mesh). NMR spectra were recorded in CDCl₃ solutions on a Bruker AMX 500 MHz, Varian Inova 400 MHz or Bruker DPX 250 MHz. Chemical shifts are reported on the δ scale (ppm) downfield from tetramethylsilane (δ = 0.0 ppm) using the residual solvent signal at δ = 7.26 ppm (¹H, CDCl₃) or δ = 77.0 ppm (¹³C, t, CDCl₃) as internal standard; coupling constants (J) are reported in Hz. Distortionless enhancement by polarization transfer (DEPT) was used to assign carbon types. NMR signals have been assigned using IUPAC numbering for compounds except for vitamin D derivatives that are assigned following the steroidal numbering. Infrared (IR) spectra were recorded on a Bruker spectrometer, model IFS-66 V FTIR. Low (MS) and high resolution mass spectra (HRMS) were performed in a Micromas Instruments Autospec spectrometer for (CI) and (FAB) while (ESI-TOF) was performed in a Bruker-Microtost spectrometer. Elementary analysis (EA) were recorded on element analyzer FISONS, model EA 1108. Optical rotations were measured at 25 ºC on a Jasco, model DIP-370. UV spectra were recorded on a HP spectrophotometer, model 8452A. HPLC purifications were performed on a Shimadzu preparative liquid chromatograph, model LC- 8A, equipped with a TSP 1100 UV absorbance detector using a HPLC Phenomenex-Luna silica column (Ø 25 x 250 mm 5Å~10 µm).

TBSCl = tert-butyldimethylsilyl chloride, NMO = N-methylmorpholine N-oxide, TBAF = tetra-n-butylammonium fluoride, tolBINAP = 2,2′-bis(di-p-tolyolphosphino)-1,1′-binaphthalene, DMP = Dess–Martin periodinane, B₂pin₂ = bis(pinacolato)diboron, PCy₃ = tricyclohexylphosphine, dppf = 1,1′-ferrocenediyl-bis(diphenylphosphine), Tf = trifluoromethanesulfonyl, pTs = p-toluenesulfonyl, DMF = dimethylformamide, DIBAL-H = diisobutylaluminum hydride, HMPA = hexamethylphosphoramide.
1. Synthesis of 1α,25-dihydroxycholecalciferol (1).

Oct-1-en-7-yn-3-ol (rac-9)

DMSO (3.62 mL, 50.9 mmol, 5 equiv) was added to a solution of (COCl)₂ (1.89 mL, 22.4 mmol, 2.2 equiv) in dry CH₂Cl₂ (20 mL). After stirring at -78 °C for 15 min, a solution of 8 (1.12 mL, 10.18 mmol, 1 equiv) in dry CH₂Cl₂ (20 mL) and dry Et₃N (14.11 mL, 101.8 mmol, 10 equiv) was successively added. The reaction mixture was allowed to warm to 23 °C. Sat. aq. NH₄Cl (20 mL) was added. The mixture was extracted with CH₂Cl₂ (3x10 mL). The combined organic extracts were washed with NaCl/H₂O (1/1, 2x10 mL), dried, filtered and concentrated. A solution of vinylmagnesiumbromide (81 mL, 81 mmol, 10 equiv) was added to a -78 °C cooled solution of the residue in Et₂O (110 mL). The reaction mixture was allowed to warm to 23 °C overnight. The reaction was quenched with sat. aq. NH₄Cl (80 mL). The mixture was extracted with Et₂O (3x50 mL) and the combined organic extracts were dried, filtered and concentrated. The residue was purified by flash chromatography (SiO₂, Ø 5x11 cm, 12% EtOAc/hexanes) to afford rac-9 [0.809 g, 64%, Rₜ = 0.29 (30% EtOAc/hexanes), colorless oil].

(3R)-Oct-1-en-7-yn-3-ol (9)

Dicyclohexyltartrate¹ (13.95 g, 44.43 mmol, 1.2 equiv) was added to a solution of rac-9 (4.59 g, 37.02 mmol, 1 equiv) in dry CH₂Cl₂ (120 mL). After 30 min, the mixture was cooled to -20 °C and Ti(OiPr)₄ (10.72 mL, 37.02 mmol, 1 equiv) was added. After 30 min, a solution of tert-butylhydroperoxide in decane (4.89 mL, 24.43 mmol, 5 M, 0.7 equiv) was added. The mixture was kept in the fridge at -20 °C for 21 days. The reaction was quenched by the addition of FeSO₄·7H₂O (24 g) and a solution of tartaric acid (8 g) in H₂O (80 mL). The mixture was extracted with Et₂O (3x 50 mL) and the combined organic extracts were dried, filtered and concentrated. The residue was purifed by flash chromatography (SiO₂, Ø 8x40 cm, 30% EtOAc/hexanes) to afford 9 [2.02 g, 44%, Rₜ = 0.29 (30% EtOAc/hexanes), [α]₁₀⁰³ = -6.2 (c = 1.8, CHCl₃), colorless oil]. ¹H-NMR (250 MHz, CDCl₃): δ = 5.86 (ddd, J₁ = 16.9, J₂ = 10.4, J₃ = 6.2, 1H, H-2), 5.17 (d, J = 17.0, 1H, H-1), 5.05 (d, J = 10.3, 1H, H-1), 4.06 (m, 1H, H-3), 2.17 (m), 1.93 (t, J = 2.4, 1H, H-8), 1.6 (4H, m). ¹³C-NMR (63 MHz, CDCl₃): δ = 140.9 (CH, C-2), 114.5 (CH₂, C-1), 84.1 (C, C-7), 72.2 (CH, C-3), 68.6 (CH, C-8), 35.6 (CH₂), 24.1 (CH₂), 18.1 (CH₂). IR (film, cm⁻¹): 3299 (νO=O).

(3R)-3-(tert-Butyldimethylsilyl)oxy-1-octen-7yne (10)

Imidazole (1.19 g, 17.52 mmol, 2.8 equiv) and TBSCI (1.26 g, 8.38 mmol, 1.4 equiv) were successively added to a solution of 9 (0.772 g, 6.22 mmol, 1 equiv) in dry DMF (30 mL). After stirring at 23 °C for 3 h, the reaction was quenched by the addition of sat. aq. NaCl (40 mL). The aqueous layer was extracted with hexanes (3x10 mL). The combined organic extracts were dried, filtered and concentrated. The residue was purified by flash chromatography (SiO₂, Ø 8x40 cm, 30% EtOAc/hexanes) to afford 10 [1.86 g, 91% (9→10)].

chromatography (SiO₂, Ø 2.5x13 cm, 10% Et₂O/hexanes) to afford 10 [1.364 g, 92%, R₁ = 0.83 (16% EtOAc/hexanes), [α]D²⁵ = -11.8 (c = 0.8, CHCl₃), colorless oil]. ³¹H-NMR (250 MHz, CDCl₃): δ = 5.80 (ddd, J₁ = 16.7, J₂ = 10.4, J₃ = 6.2, 1H, H-2), 5.15 (d, J = 17.1, 1H, H-1), 5.02 (d, J = 10.4, 1H, H-1), 4.10 (m, 1H, H-3), 2.18 (m, 1H), 1.93 (t, J = 2.6, 1H, H-8), 1.57 (m, 4H), 0.89 (s, 9H, Me₂C-Si), 0.05 (s, 3H, Me-Si), 0.02 (s, 3H, Me-Si). ¹³C-NMR (63 MHz, CDCl₃): δ = 142.2 (CH, C-2), 115.3 (CH₂, C-1), 85.1 (C, C-7), 73.7 (CH, C-3), 68.7 (CH, C-8), 37.3 (CH₂), 25.5 (CH₃), 3x3CH₃, Me₂C-Si), 24.9 (CH₂), 18.8 (CH₂), -4.0 (CH₃, Me-Si), -4.5 (CH₃, Me-Si). IR (film, cm⁻¹): 2174 (νC=O).

(3R)-8-Benzylidimethylsilyl-3-(tert-butylidimethylsilyl)oxy-1-octen-7-yno (11)

A solution of nBuLi in hexanes (0.41 mL, 1.02 mmol, 2.5 M, 1.2 equiv) was added to a -78 °C cooled solution of 10 (0.203 g, 0.85 mmol, 1 equiv) in dry THF (6 mL). The mixture was stirred for 1 h. SiBnMe₂Cl (0.20 mL, 1.11 mmol, 1.3 equiv) was added dropwise. The mixture was warmed to 23 °C and stirred for 14 h. The reaction was quenched with sat. aq. NaCl (20 mL). The mixture was extracted with hexanes (3x15 mL). The combined organic extracts were dried, filtered and concentrated. The residue was purified by flash chromatography (SiO₂, Ø 2.5x8 cm, hexanes) to afford 11 [0.327 g, 99%, R₁ = 0.17 (2% EtOAc/hexanes), [α]D²⁵ = -9.1 (c = 1.3, CHCl₃), colorless oil]. ³¹H-NMR (250 MHz, CDCl₃): δ = 7.23 (t, J = 7.5, 2H, H₉), 7.10 (m, 1H, H₆), 7.08 (m, 2H, H₅), 5.81 (ddd, J₁ = 17.3, J₂ = 10.3, J₃ = 6.2, 1H, H-7), 5.18 (d, J = 17.1, 1H, H-8), 5.06 (d, J = 10.6, 1H, H-8), 4.14 (m, 1H, H-6), 2.31 (m, 2H), 2.19 (s, 2H, CH₂-SiBn), 1.59 (m, 4H), 0.93 (s, 9H, Me₂C-Si), 0.12 (s, 6H, 2xMe-SiBu), 0.09 (s, 3H, Me-SiBn), 0.07 (s, 3H, Me-SiBn). ¹³C-NMR (63 MHz, CDCl₃): δ = 141.6 (CH, C-7), 139.3 (C), 128.5 (CH), 128.2 (CH), 124.4 (CH), 113.9 (CH₂, C-8), 108.9 (C, C-1), 83.1 (C, C-2), 73.4 (CH, C-6), 37.1 (CH₂), 26.7 (CH₂), 26.1 (3xCH₃, Me₂C-Si), 24.2 (CH₂), 20.0 (CH₂), 18.4 (C, CSI), -1.8 (2xCH₃, Me-SiBn) -4.3 (CH₃, Me-SiBu), -4.7 (CH₃, Me-SiBu). IR (film, cm⁻¹): 2120 (νC=O). HRMS (ESI-TOF): m/z: calcd for [C₃₀H₃₂O₃Si]⁺: 387.2533 [M+H]⁺; found 387.2525. EA calcd for C₃₀H₃₂O₃Si: C 71.43%, H 9.90%; found C 71.54%, H 9.58%.

(7R,7aR)-3-Benzylidimethylsilyl-7-(tert-butylidimethylsilyl)oxy-5,6,7,7a-tetrahydro-1H-inden-2(4H)-one (12)

Co₂(CO)₈ (1.490 g, 4.36 mmol, 1.7 equiv) was added to a solution of 11 (0.991 g, 2.56 mmol, 1 equiv) in dry CH₂Cl₂ (12 mL). After 2 h, dry CH₂Cl₂ (23 mL) and dry THF (35 mL) were successively added. The mixture was cooled to 0 °C and NMO (3.603 g, 30.76 mmol, 12 equiv) was added. The mixture was warmed to 23 °C and stirred for 14 h. A solution of EtOAc/hexanes (10%, 100 mL) was added. The mixture was filtered through a silica pad. The combined organic extracts were dried, filtered and concentrated. The residue was purified by flash chromatography (SiO₂, 3x8 cm, hexanes) to afford 12 [0.848 g, 80%, R₁ = 0.27 (2% EtOAc/hexanes), [α]D²⁵ = -26.2 (c = 1.0, CHCl₃), colorless oil]. ³¹H-NMR (250 MHz, CDCl₃): δ = 7.16 (t, J = 7.3, 2H, H₉), 7.05 (t, J = 7.3, 1H, H₆), 6.94 (d, J = 6.6, 2H, H₅), 3.10 (td, J₁ = 10.6, J₂ = 4, 1H, H-7), 2.57 (m, 3H), 2.31 (m, 3H), 1.84 (m, 3H), 1.63 (s, 2H, CH₂Ph), 0.88 (s, 9H, Me₂C-Si), 0.22 (s, 6H, 2xMe-SiBu), 0.06 (s, 3H, Me-SiBn), 0.04 (s, 3H, Me-SiBn). ¹³C-NMR (63 MHz, CDCl₃): δ = 213.2 (C, C-2), 189.4 (C, 3ca), 140.1 (C, C-3), 136.5 (C), 128.2 (CH), 128.1 (CH), 124.1 (CH), 76.7 (CH, C-7), 52.9 (CH, C-7a), 41.0 (CH₂), 35.2 (CH₂), 30.5 (CH₂), 25.9 (3xCH₃, Me₂C-Si), 25.5 (CH₂), 23.8 (CH₂), 18.1 (C, CSI), -2.0 (CH₃, Me-SiBn), -2.2 (CH₃, Me-SiBu), -3.8 (2xCH₃, Me-SiBn). IR (film, cm⁻¹): 1689 (νC=O). HRMS (ESI-TOF): m/z: calcd for [C₃₃H₃₇O₃Si]⁺: 415.2483 [M+H]⁺; found 415.2464.


⁴ Compound 12: Coupling constant (J = 10.6 Hz) of the signal at δ 3.10 ppm indicates a trans relationship between H-7 and H-7a.
(2S,3aR,4R)-1-Benzylidemethylsilyl-4-((tert-butylidemethylsilyl)oxy)-2,3,3a,4,5,6,7-heptahydro-2H-inden-2-ol (7a)

A solution of DIBAL·H in CH₂Cl₂ (2.11 mL, 2.11 mmol, 1 M, 2.5 equiv) was added dropwise to a -78 °C cooled solution of 12 (0.350 g, 0.84 mmol, 1 equiv) in dry Et₂O (17 mL) at -78 °C. The reaction mixture was allowed to warm to 23 ºC and stirred for 1 h. The reaction was quenched with HCl (5%, 25 mL). The mixture was extracted with MTBE (3x10 mL) and the combined organic extracts were dried, filtered and concentrated. The residue was purified by flash chromatography (SiO₂, Ø 2.5×7 cm, 3% EtOAc/hexanes) to afford 7a [0.349 g, 99%, Rf = 0.44 (10% EtOAc/hexanes), [α]D = -23.8 (c = 1.2, CHC₃, colorless oil). 

1H-NMR (250 MHz, CDCl₃): δ = 7.20 (t, J = 7.2, 2H, Hₓ), 7.09 (t, J = 7.5, 1H, Hₙ), 7.01 (d, J = 6.8, 2H, Hₓ₁), 4.73 (bs, 1H, H₋₂), 3.25 (td, J₁ = 9.9, J₂ = 4.0, 1H, H₋⁴), 2.4 (m, 2H), 2.24 (d, J = 6.0, 2H, CH₂Ph), 1.85 (m, 3H), 1.3 (m, 4H), 0.91 (s, 9H, Me₂C-Si), 0.19 (s, 3H, Me-Si), 0.17 (s, 3H, Me-Si), 0.10 (s, 3H, Me-Si), 0.09 (s, 3H, Me-Si). 

13C-NMR (63 MHz, CDCl₃) δ = 158.8 (C, C-7a), 140.3 (C, C-1), 135.1 (C, CH), 128.4 (CH), 128.2 (CH), 124.2 (CH), 81.6 (CH, C₁), 76.7 (CH, C-2), 56.5 (CH, C-3a), 40.0 (CH₂), 35.4 (CH₂), 28.9 (CH₂), 26.8 (CH₂), 26.0 (3xCH₃, Me₂C-Si), 24.2 (CH₂), 18.2 (C, CSi), -1.6 (CH₃, Me-Si), -2.3 (CH₃, Me-Si), -3.8 (CH₃, Me-Si), -4.3 (CH₃, Me-Si). IR (film, cm⁻¹): 3456 (νO-H), 2857 (νC-H). HRMS (ESI-TOF⁺): m/z: calcd for [C₂₆H₄₂O₂NaSi₂]⁺: 439.2459 [M+Na]⁺; found 439.2442. EA calcd for C₂₆H₂₉O₃Si₂: C 69.17%, H 9.67%; found C 68.92%, H 9.24%.

(2S,7R,7aR)-3-(Benzylidemethylsilyl)-7-((tert-butylidemethylsilyl)oxy)-2,4,5,6,7,7a-hexahydro-1H-inden-2-yl 2-(diphenylphosphanyloxy)benzoate (7b)

2-(Diphenylphosphoryl)-benzoic acid (0.269 g, 0.88 mmol, 1.2 equiv) and DMAP (0.107 g, 0.88 mmol, 1.2 equiv) were successively added to a 0 °C cooled solution of 7a (0.305 g, 0.73 mmol, 1 equiv) in CH₂Cl₂ (12 mL). DCC (0.181 g, 0.88 mmol, 1.2 equiv) was added. The resulting mixture was stirred at 23 ºC for 24h and then filtered through a pad of Celite washing the solids with CH₂Cl₂. The filtrate was concentrated. The residue was purified by flash chromatography (SiO₂, Ø 2.5×7 cm, 2% ETOAc/hexanes) to afford 7b [0.432 g, 85%, Rf = 0.50 (10% EtOAc/hexanes, white foam). 

1H-NMR (250 MHz, CDCl₃): δ = 7.33 (m, 4H), 7.10 (t, J = 7.5, 6H, Hₓ), 6.04 (s, 1H, NH), 5.68 (bs, 1H, H₋₁), 3.31 (td, J₁ = 10.0, J₂ = 4.0, 1H, H₋₇), 2.62 (m, 3H), 2.21 (d, J = 6.0, 2H, CH₂Ph), 1.91 (m, 3H), 1.50 (m, 3H), 0.89 (s, 9H, Me₂C-Si), 0.18 (s, 3H, Me-Si), 0.09 (s, 3H, Me-Si), 0.07 (s, 3H, Me-Si), 0.06 (s, 3H, Me-Si). 

13C-NMR (63 MHz, CDCl₃) δ = 165.9 (C, C=O), 161.5 (C, C=O), 141.3 (C), 140.9 (C), 139.8 (C), 138.4 (C), 138.3 (C), 134.3 (C), 134.2 (C), 134.0 (C), 133.9 (CH), 133.8 (CH), 133.4 (CH), 131.8 (CH), 130.4 (CH), 128.4 (CH), 128.3 (CH), 128.1 (CH), 128.0 (CH), 123.9 (CH), 85.0 (CH), 77.8 (CH, C₋₂), 56.7 (CH, C₋₇a), 36.3 (CH₂), 35.2 (CH₂), 28.9 (CH₂), 26.3 (CH₂), 25.8 (3xCH₃, Me₂C-Si), 24.0 (CH₂), 17.9 (C, CSi), -2.3 (CH₃, Me-Si), -2.5 (CH₃, Me-Si), -4.0 (CH₃, Me-Si), -4.5 (CH₃, Me-Si). IR (film, cm⁻¹): 2940 (νC-H), 1718 (νC=O). HRMS (ESI-TOF⁺): m/z: calcd for [C₄₃H₅₄NO₃PSi₂]⁺: 705.3349 [M+H]⁺; found 705.3357.
A solution of nBuLi in hexanes (0.204 mL, 0.29 mmol, 1.4 M, 1.2 equiv) was added dropwise to a -78 °C cooled solution of 7a (0.099 g, 0.24 mmol, 1 equiv) in dry THF (10 mL). The mixture was stirred at 23 °C for 30 min and then cooled to -78 °C. After 10 min, benzylic chloride (0.033 mL, 0.29 mmol, 1.2 equiv) was added. After stirring for 30 min, sat. aq. NaCl (20 mL) was added. The mixture was extracted with MTBE (3x5 mL) and the combined organic extracts were dried, filtered and concentrated. The residue was purified by flash chromatography (SiO$_2$, 2.5 × 7 cm, 2% EtOAc/hexanes) to afford 7c [0.093 g, 75%, $R_l = 0.85$ (10% EtOAc/hexanes), white foam].

$^1$H-NMR (250 MHz, CDCl$_3$): δ = 7.83 (m, 2H, H$_a$), 7.35 (m, 1H, H$_b$), 7.24 (m, 2H, H$_a$), 6.99 (m, 2H, H$_a$), 6.87 (m, 1H, H$_b$), 6.81 6.0 (m, 2H, H$_a$) 5.80 (dd, 2H, $J_1 = 10.2, J_2 = 3.1$), 3.12 (td, $J_1 = 10.2, J_2 = 4.0$, 1H, H-7), 2.52 (dt, $J_1 = 22.8, J_2 = 8.0$, 1H), 2.25 (m, 2H), 2.03 (s, 2H, CH$_2$Ph), 1.68 (m, 3H), 1.42 (m, 1H), 1.07 (m, 2H) 0.65 (s, 9H, Me$_3$Si), 0.10 (s, 6H, 2xMe-Si), -0.19 (s, 3H, Me-Si), -0.24 (s, 3H, Me-Si). 13C-NMR (63 MHz, CDCl$_3$): δ = 166.2 (C, C=O), 161.7 (C, C=O), 139.7 (C), 132.7 (CH), 130.7 (CH), 130.4 (CH), 129.5 (CH), 128.6 (C), 128.3 (CH), 128.2 (CH), 124.0 (CH), 84.0 (C), 79.7 (CH, C-2), 56.8 (CH, C-7a), 36.4 (CH$_2$), 28.9 (CH$_3$), 26.4 (CH$_3$), 25.8 (3xCH$_3$, Me$_3$C-Si), 24.1 (CH$_2$), 17.9 (C, C-Si), -2.3 (CH$_3$, Me-Si), -2.5 (CH$_3$, Me-Si), -4.1 (CH$_3$, Me-Si), -4.6 (CH$_3$, Me-Si). IR (film, cm$^{-1}$): 2930 (v$_{CH}$), 1722 (v$_{C=O}$). HRMS (ESI-TOF$^+$): m/z: calcd for [C$_3$H$_8$O$_2$Si$_2$]$: 521.2907 [M+H]$^{+}$; found 521.2999.

A solution of nBuLi in hexanes (0.955 mL, 1.34 mmol, 1.4 M, 1.1 equiv) was added dropwise to a -30 °C cooled solution of 7a (0.506 g, 1.21 mmol, 1 equiv) in dry Et$_2$O (10 mL). After 10 min, PhNCO (0.145 mL, 0.145 mL, 1.34 mmol, 1.1 equiv) was added. After stirring at 23 °C overnight, sat. aq. NaHCl (20 mL) was added. The mixture was extracted with MTBE (3x15 mL) and the combined organic extracts were dried, filtered and concentrated. The residue was purified by flash chromatography (SiO$_2$, 2.5 × 7 cm, 4% EtOAc/hexanes) to afford 7d [0.564 g, 87%, $R_l = 0.55$ (10% EtOAc/hexanes), [a]$_D^{25} = -3.0$ (c = 2.5, CHCl$_3$), white foam]. $^1$H-NMR (250 MHz, CDCl$_3$): δ = 7.33 (m, 4H), 7.10 (t, $J = 7.5$, 6H, H$_a$), 6.04 (s, 1H, NH), 5.68 (bs, 1H, H-2), 3.31 (td, $J_1 = 10.0, J_2 = 4.0$, 1H, H-7), 2.62 (m, 3H), 2.21 (d, $J = 6.0$, 2H, CH$_2$Ph), 1.91 (m, 3H), 1.50 (m, 3H), 0.89 (s, 9H, Me$_3$C-Si), 0.18 (s, 3H, Me-Si), 0.09 (s, 3H, Me-Si), 0.07 (s, 3H, Me-Si), 0.06 (s, 3H, Me-Si). 13C-NMR (63 MHz, CDCl$_3$): δ = 161.6 (C, C=O), 153.3 (C), 140.3 (C), 138.2 (C), 130.4 (C), 129.1 (CH), 128.9 (CH), 128.4 (CH), 128.1 (CH), 118.6 (CH), 84.8 (CH), 78.1 (CH, C-2), 57.0 (CH, C-7a), 36.3 (CH$_2$), 35.4 (CH$_2$), 29.0 (CH$_2$), 27.0 (CH$_2$), 26.0 (3xCH$_3$, Me$_3$C-Si), 24.2 (CH$_2$), 18.2 (C, C-Si), -1.6 (CH$_3$, Me-Si), -3.9 (CH$_3$, Me-Si), -4.3 (CH$_3$, Me-Si). IR (film, cm$^{-1}$): 3475 (v$_{NH}$), 2940 (v$_{CH}$), 1713 (v$_{C=O}$). HRMS (ESI-TOF$^+$): m/z: calcd for [C$_{3}$H$_{10}$NO$_{3}$Si$_{2}$]$^{+}$: 536,2938 [M+H]$^{+}$; found 536,2943.

A solution of nBuLi in hexanes (0.62 mL, 0.869 mmol, 1.4 M, 1.1 equiv) was added dropwise to a -30 °C cooled
solution of 7a (0.345 g, 0.828 mmol, 1 equiv) in dry Et₂O (10 mL). After 10 min, PhNCO (0.099 mL, 0.911 mmol, 1.1 equiv) was added. After stirring at 23 °C for 2 h, CuCN (0.092 g, 0.828 mmol, 1.0 equiv) was added. The mixture was stirred for 1 h and then cooled to 0 °C. A solution of MeLi in Et₂O (0.569 mL, 0.911 mmol, 1.6 M, 1.1 equiv) was slowly added dropwise. After stirring at 23 °C overnight, sat. aq. NH₄Cl (20 mL) was added. The mixture was extracted with MTBE (3x15 mL) and the combined organic extracts were dried, filtered, and concentrated. The residue was purified by flash chromatography (SiO₂, ¯ 2.5x7 cm, hexanes) to afford 13a [0.274 g, 80%, Rₜ = 0.80 (2% EtOAc/hexanes), [α]D²⁵ = -7.0 (c = 1.6, CHC₃), colorless oil]. ¹H-NMR (250 MHz, CDCl₃): δ = 7.20 (t, J = 7.7, 2H, Hмыш), 7.07 (t, J = 7.5, 1H, Hₗ), 7.01 (d, J = 6.8, 2H, H₄), 6.02 (bs, 1H, H-2), 3.78 (td, J₁ = 10.5, J₂ = 4.5, 1H, H-7), 2.33 (m, 1H, H-7a), 2.18 (s, 2H, CH₂Si), 2.08 (m, 1H), 1.94 (m, 1H), 1.78 (m, 1H), 1.61 (4H, m), 1.36 (td, J₁ = 10.5, J₂ = 4.5, 1H), 0.91 (s, 9H, Me₂C-Si), 0.80 (s, 3H, H-8), 0.08 (s, 6H, 2xMe-Si), 0.06 (s, 3H, Me-Si), 0.03 (s, 3H, Me-Si). ¹³C-NMR (63 MHz, CDCl₃): δ = 155.0 (C, C-3), 141.8 (CH, C-2), 140.2 (C), 128.5 (CH), 128.2 (CH), 124.1 (CH), 70.5 (CH, C-7), 58.6 (CH, C-7a), 51.9 (C, C-3a), 37.0 (CH₃), 36.1 (CH₃), 34.2 (CH₂), 26.6 (CH₂), 26.0 (3xCH₃, Me₂C-Si), 22.1 (CH₃), 18.4 (C, CSI), 17.3 (CH₃, C-8), -2.1 (CH₃, Me-Si), -2.5 (CH₃, Me-Si), -4.1 (CH₃, Me-Si), -4.5 (CH₃, Me-Si). IR (film, cm⁻¹): 2856 (νC-H). HRMS (ESI-TOF⁺): m/z: calcd for [C₂₅H₄₃O₂Si₃]+: 415.3058 [M+H]+; found 415.3049.

Allenic substitution on 7b using Breit’s method

CuBr·SMé₂ (0.060 g, 0.292 mmol, 0.5 equiv) was added to a solution of 7b (0.411 g, 0.584 mmol, 1 equiv) in dry Et₂O (20 mL). A solution of MeMgBr in Et₂O (214 μL, 0.642 mmol, 3 M, 1.1 equiv) was added dropwise. After stirring for 15 min, sat. aq. NH₄Cl (10 mL) and aq. NH₂OH (25%, 2 mL) were successively added. The mixture was extracted with MTBE (3x10 mL) and the combined organic extracts were dried, filtered, and concentrated. The residue was purified by flash chromatography (SiO₂, ¯ 2.5x7 cm, 100% hexanes) to afford 13b (145 mg, 60%), and 13c (73 mg, 30%).

(3aR,7R,7aR)-3-Benzylidemethylsilyl-7-((tert-butyldimethylsilyl)oxy)-3a-methyl-4,5,6,7,7a-hexahydro-1H-indene (13b) ¹H-NMR (400 MHz, CDCl₃): δ = 7.18 (t, J = 7.5, 2H, Hмыш), 7.04 (t, J = 7.3, 1H, Hₗ), 6.98 (d, J = 7.5, 2H, H₄), 5.90 (br s, 1H), 3.55 (m, 1H), 2.40 (ddd, J₁ = 16.6, J₂ = 7.0, J₃ = 1.9, 1H), 2.17 (s, 2H, CH₂Ph), 2.14 (dd, J₁ = 6.0, J₂ = 2.0, 1H), 1.72 (dd, J₁ = 12.2, J₂ = 6.2, 1H), 1.63 (m, 2H), 1.53 (m, 2H), 1.37 (m, 2H), 1.15 (s, 3H), 0.87 (s, 9H, Me₂C-Si), 0.01 (s, 12H, 4xMe-Si). ¹³C-NMR (100 MHz, CDCl₃) δ = 153.5 (C, C-3), 141.1 (CH, C-2), 140.2 (C), 128.4 (CH), 128.0 (CH), 123.9 (CH), 71.7 (CH, C-7), 54.5 (CH, C-7a), 51.7 (C, C3a), 37.0 (CH₃), 35.7 (CH₂), 32.2 (CH₃), 27.9 (CH₃, Me-3a), 26.6 (CH₂), 25.9 (3xCH₃, Me₂C-Si), 18.5 (CH₃), 18.0 (C, CSI), -2.1 (CH₃, Me-Si), -2.1 (CH₃, Me-Si), -4.3 (CH₃, Me-Si), -4.8 (CH₃, Me-Si). IR (film, cm⁻¹): 2922 (νC-H). HRMS (ESI-TOF⁺): m/z: calcd for [C₂₅H₄₃O₂Si₃]+: 415.2852 [M+H]+; found 415.2858.

(2R,7R,7aR)-3-Benzylidemethylsilyl-7-((tert-butyldimethylsilyl)oxy)-2-methyl-4,5,6,7,7a-hexahydro-1H-indene (13c) ¹H-NMR (400 MHz, CDCl₃): δ = 7.15 (t, J = 7.5, 2H, Hмыш), 7.02 (t, J = 7.3, 1H, Hₗ), 6.95 (d, J = 7.4, 2H, H₄), 3.30 (td, J₁ = 10.5, J₂ = 4.1, 1H), 2.66 (q, J = 8, 1H), 2.53 (c, J = 8.4, 1H), 2.35 (dd, J₁ = 15.5, J₂ = 5.1, 1H), 2.14 (s, 2H, CH₂Ph), 1.74-1.66 (m, 2H), 1.65-1.54 (m, 2H), 1.42-1.28 (m, 1H), 1.18-1.03 (m, 2H), 0.87 (s, 9H, Me₂C-Si), 0.80 (d, J = 6.9, 3H), 0.08 (s, 3H, 2xMe-Si), 0.06 (s, 3H, 2xMe-Si), 0.03 (s, 6H, 2xMe-Si). ¹³C-NMR (63 MHz, CDCl₃): δ = 154.0 (C, C-3), 140.2 (C), 137.3 (C), 128.2 (CH), 127.9 (CH), 123.8 (CH), 79.1 (CH, C-7), 55.7 (CH, C-7a), 43.1 (CH), 39.0 (CH₂), 35.3 (CH₂), 28.7 (CH₂), 26.8 (CH₂), 25.8 (3xCH₃, Me₂C-Si), 23.9 (CH₃), 21.9 (CH₃, Me-C-2), 18.1 (C, CSI), -1.9 (CH₃, Me-Si), -2.1 (CH₃, Me-Si), -4.0 (CH₃, Me-Si), -4.5 (CH₃, Me-Si). IR (film, cm⁻¹): 2920 (νC-H). HRMS (ESI-TOF⁺): m/z: calcd for [C₂₅H₄₃O₂Si₃]+: 415.2852 [M+H]+; found 415.2845.
Allylic substitution on benzoate 7c

CuBr.SMe$_2$ (49 mg, 0.237 mmol, 0.5 equiv) was added to a solution of 7c (240 mg, 0.474 mmol, 1 equiv) in dry Et$_2$O (15 mL). The mixture was warmed to 23 ºC and a solution of MeMgBr in Et$_2$O (0.174 mL, 0.521 mmol, 3 M, 1.1 equiv) was added dropwise. After stirring for 1 h, sat. aq. NH$_4$Cl (25 mL) and aq. NH$_4$OH (25%, 10 mL) were successively added. The mixture was extracted with MTBE (3x10 mL) and the combined organic extracts were dried, filtered and concentrated. The residue was purified by flash chromatography (SiO$_2$, Ø 2.5×7 cm, 100% hexanes) to afford 13b (94 mg, 48%) and 13c (37 mg, 19%).

Allylic substitution on benzoate 7c

A solution of MeLi in Et$_2$O (0.89 mL, 1.434 mmol, 6 equiv) was added to a 0 ºC cooled suspension of CuI (0.137 g, 0.719 mmol, 3 equiv) in dry Et$_2$O (5 mL). A solution of 7c (0.125 g, 0.239 mmol, 1 equiv) in Et$_2$O (2 mL) was added dropwise. The reaction mixture was stirred in the dark for 48 h. Sat. aq. NH$_4$Cl (15 mL) was added. The mixture was stirred for 30 min and then extracted with MTBE (3x10 mL). The combined organic extracts were dried, filtered and concentrated. The residue was purified by flash chromatography (SiO$_2$, Ø 2.5×7 cm, 100% hexanes) to afford 13b (17 mg, 17%) and 13c (35 mg, 35%).

(3aR,4R,7aS)-4-(tert-Butyldimethylsilyl)oxy)-7a-methyl-octahydro-1H-inden-1-one (6)

A solution of TBAF in THF (1.61 mL, 1.61 mmol, 1 M, 2 equiv) was added to a solution of 13a (0.318 g, 0.767 mmol, 1 equiv) in THF (0.5 mL). After 1 h, MeOH (2 mL), KHCO$_3$ (0.153 g, 1.53 mmol, 2 equiv) and H$_2$O$_2$ (30 %, 1.60 mL) were successively added. After stirring at 23 ºC for 40 h, the reaction was quenched with sat. aq. Na$_2$S$_2$O$_3$ (2.5 g). The mixture was filtered through a layer of silica gel washing with CH$_2$Cl$_2$ (3x20 mL). The filtrate was concentrated and the residue was purified by flash chromatography (SiO$_2$, Ø 2.5×6 cm, 1% EtOAc/hexanes) to give 6 [0.155 g, 71%, $R_f$ = 0.31 (8% EtOAc/hexanes), $[a]_D^{25} = 65.7$ (c = 1.5, CHCl$_3$), colorless oil]. $^1$H-NMR (250 MHz, CDCl$_3$): $\delta = 3.70$ (td, $J_1 = 10.5$, $J_2 = 4.5$, 1H, H-4), 2.42 (m, 1H, H-3a), 2.10 (m, 3H), 1.69-1.50 (m, 5H), 1.20 (m, 2H), 0.88 (s, 9H, Me$_3$C-Si), 0.86 (s, 3H, H-8), 0.08 (s, 6H, 2xMe-Si), $^{13}$C-NMR (63 MHz, CDCl$_3$): $\delta = 220.5$ (C, C-1), 70.8 (CH, C-4), 52.5 (CH, C-3a), 49.5 (C, C-7a), 36.8 (CH$_2$), 35.6 (CH$_2$), 31.1 (CH$_2$), 25.9 (3xCH$_3$, Me$_3$C-Si), 22.1 (CH$_2$) 21.0 (CH$_3$), 18.3 (C, CSI), 13.8 (CH$_3$, C-8), -4.1 (CH$_3$, Me-Si), -4.6 (CH$_3$, Me-Si). IR (film, cm$^{-1}$): 2857 (v(C=H)), 1744 (v(C=O)). HRMS (EI$^+$): m/z: calcd for [C$_{16}$H$_{30}$O$_2$Si]$^+$: 282.2015 [M]$^+$; found 282.2011. EA calcd for C$_{16}$H$_{30}$O$_2$Si: C 68.03%, H 10.70%; found C 68.17%, H 10.96%.
A solution of TBAF in THF (0.597 mL, 0.597 mmol, 1 M) was added to a solution of 6 (0.112 g, 0.397 mmol, 1 equiv) in THF (4 mL). The reaction mixture was stirred at 60 °C for 7 h. The reaction was quenched with saturated NH₄Cl (15 mL). The mixture was extracted with EtOAc (3x8 mL) and the combined organic extracts were dried, filtered and concentrated. The residue was purified by flash chromatography (SiO₂, 0.25×6 cm, 1% EtOAc/hexanes) to afford 14 [0.102 g, 80%, colorless crystals, mp = 132.4-133.3 °C (EtOAc); TLC (8% EtOAc/hexanes): Rₜ = 0.35, [α]D²⁵ = 0.8 (c = 1.9, CHCl₃)]. ¹H NMR (250 MHz, CDCl₃): δ = 7.77 (d, J = 8.5, 2H, H₉), 7.32 (d, J = 8.5, 2H, H₈), 4.55 (td, J₁ = 10.6, J₂ = 4.7, 1H, H-4), 2.42 (s, 3H, Me-Ph), 2.35 (m, 1H, H-3a), 2.00 (m, 3H), 1.67 (m, 3H), 1.55-1.07 (m, 4H), 0.81 (s, 3H, H-8), C NMR (63 MHz, CDCl₃): δ = 218.5 (C, C-1), 144.8 (C), 134.4 (C), 129.9 (CH), 127.7 (CH), 81.7 (CH, C-4), 50.1 (CH, C-3a), 49.6 (C, C-7a), 35.0 (CH₂), 33.4 (CH₂), 30.5 (CH₃), 21.7 (CH₃, Me-Ph) 21.3 (CH₃), 20.8 (CH₂), 13.6 (CH₃, C-8). IR (film, cm⁻¹): 2875 (νC-H), 1743 (C=O). HRMS (EI⁺, m/z): [M]⁺ calcd. for C₁₇H₂₂O₂Si, 322.1223; found, 322.1232. 

**(3aR,4R,7aS)-4-(p-Toluenesulfonyl)oxy-7a-methyloctahydro-1H-inden-1-one (14)**
(3R)-Ethyl 3-\((\text{3a}R,\text{4}R,\text{7}a\text{R})\)-4-\((\text{tert-butyldimethylsilyl})\)oxy)-7a-methyloctahydro-1H-inden-1-yl)butanoate (16)

A solution of 4 (0.038g, 0.10 mmol, 1 equiv) in PTS/H2O (2%, 1.5 mL) was sonicated for 15 min. (R)-BINAP (0.007 g, 0.01 mmol, 0.1 equiv), Cu(OAc)2 (2 mg, 0.01 mmol, 0.1 equiv) and PMHS (0.096 g, 1.60 mmol, 16 equiv) were successively added. The mixture was sonicated for 45 min, heated at 60 ºC for 40 h and then cooled to 23 ºC. Ag. NH4F (0.5 mL) was added. The mixture was filtered through a layer of silica gel washing with CH2Cl2 (40 mL). The filtrate was concentrated. The residue was purified by flash chromatography (SiO2, Ø 2.5x8 cm, 2% EtOAc/hexanes) to afford 16 [0.027 g, 72%, \(R_I = 0.61\) (4% EtOAc/hexanes), \(\alpha_{D}^{25} = 2.5\) (c = 1.6, CHCl3), yellow oil].

1H-NMR (500 MHz, CDCl3): \(\delta = 5.34\) (m, 1H, H-2'), 4.09 (m, 1H, OCH2CH3), 3.73 (td, Jf = 10.4, Jr = 4.4, 1H, H-7'), 2.63 (m, 1H), 2.5 (dd, Jf = 14.9, Jr = 7.5, 1H, H-2), 2.35 (dd, Jf = 14.9, Jr = 7.8, 1H, H-2), 2.20 (m, 1H, H-7a'), 1.91 (m, 2H), 1.63 (m, 4H), 1.31 (m, 1H), 1.19 (m, 1H), 1.23 (t, J = 7.2, 3H, OCH2CH3), 1.04 (d, J = 6.7, 3H, H-4), 0.87 (s, 9H, Me3C-Si), 0.76 (s, 3H, H-8'), 0.04 (s, 6H, 2xCH2-Si).

13C-NMR (126 MHz, CDCl3): \(\delta = 172.9\) (C, C-1), 159.0 (C, C-3'), 121.4 (CH, C-2'), 70.2 (CH, C-7'), 60.3 (CH3, OCH2CH3), 58.1 (CH, C-7a'), 49.2 (C, C-3a'), 41.8 (CH2), 37.1 (CH2), 34.5 (CH3), 31.6 (CH2), 29.4 (CH3, OCH2CH3), 26.0 (3xCH3, Me2C-Si), 21.9 (CH3), 21.8 (CH, C-20), 18.3 (C, Csi), 15.9 (CH3, C-8'), 14.4 (CH3, C-4'), -4.1 (CH3, Me-Si), -4.6 (CH3, Me-Si). IR (film, cm\(^{-1}\)): 2930 (vC=H), 1713 (vC-O). HRMS (ESI-TOF\(^{+}\)): m/z: calcd for [C\(_{22}\)H\(_{38}\)O\(_{3}\)Na\(_{x}\)]\(^{+}\): 381.2819 [M+Na]\(^{+}\); found 381.2824.

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LiAlH₄ (0.033 g, 0.857 mmol, 2 equiv) was added to a 0 °C cooled solution of 16 (0.163 g, 0.428 mmol, 1 equiv) in dry THF (2 mL). The reaction mixture was allowed to warm to 23 °C for 45 min and then cooled to 0 °C. H₂O (0.5 mL) was added. Aq. HCl (10%, 15 mL) was added. The mixture was extracted with MTBE (3x8 mL) and the combined organic extracts were dried, filtered, and concentrated. The residue was purified by flash chromatography (SiO₂, Ø 2x8 cm, 4% EtOAc/hexanes) to afford 17 [0.143 g, 99%, Rₜ = 0.20 (20% EtOAc/hexanes), [α]D²⁵ = -1.3 (c = 1.2, CHCl₃), oily solid]. ¹H-NMR (400 MHz, CDCl₃): δ = 5.31 (m, 1H, H-2), 3.74 (td, J₁ = 10.4, J₂ = 4.6, 1H, H-7’), 3.60 (td, J₂ = 6.7, J₂ = 2.8, 2H, H-1), 2.20 (m, 2H), 1.74 (m, 8H), 1.01 (d, J = 6.9, 3H, H-4), 0.87 (s, 9H, Me₃C-Si), 0.76 (s, 3H, H-8’), 0.04 (s, 6H, 2xMe-Si). ¹³C-NMR (63 MHz, CDCl₃): δ = 159.8 (C, C-3’), 121.0 (CH, C-2’), 70.2 (CH, C-7’), 61.5 (CH₂, C-1), 58.3 (CH, C-7a’), 49.0 (C, C-3a’), 39.4 (CH₂), 37.1 (CH₂), 34.3 (CH₂), 31.5 (CH₂), 29.0 (CH, C-20), 26.0 (3xCH₃, Me₂Si), 22.4 (CH₃, C-4), 21.9 (CH₂), 18.3 (C, CSi), 16.0 (CH₃, C-8’), -4.1 (CH₃, Me-Si), -4.6 (CH₃, Me-Si). IR (film, cm⁻¹): 3334 (υO-H), 2853 (υC-H). HRMS (ESI-TOF⁺): m/z: calcd for [C₂₀H₁₈O₂Si]⁺: 339.2713 [M+H⁺]⁺; found 339.2702.

Pd/C (10%, 0.010 g) was added to a solution of 17 (0.104 g, 0.307 mmol, 1.0 equiv) in EtOAc (6 mL). The mixture was degassed under reduced pressure and refilled with H₂ for three times. The reaction mixture was stirred under H₂ atmosphere (balloon pressure) for 72 h. The mixture was filtered through a layer of silica gel. The solids were rinsed with EtOAc (3x20 mL), and the resulting filtrate was concentrated. The residue was purified by flash chromatography (SiO₂, Ø 2x7 cm, 6% EtOAc/hexanes) to afford 18 [0.096 g, 91%, Rₜ = 0.44 (20% EtOAc/hexanes), [α]D²⁵ = 5.1 (c = 4.2, CHCl₃), yellow oil]. ¹H-NMR (400 MHz, CDCl₃): δ = 3.59 (m, 3H, H-4, 2xH-1), 1.65 (m, 8H), 1.20 (m, 7H), 0.92 (d, J = 6.9, 3H, H-4), 0.86 (s,9H, Me₃C-Si), 0.66 (s, 3H, H-8’), 0.00 (s, 6H, 2xMe-Si). ¹³C-NMR (63 MHz, CDCl₃): δ = 71.8 (CH, C-4’), 60.9 (CH₂, C-1), 57.3 (CH), 57.0 (CH), 44.6 (C, C-7a’), 39.4 (CH₂), 39.0 (CH₂), 36.6 (CH₂), 32.7 (CH), 27.9 (CH₂), 26.0 (3xCH₃, Me₂Si), 24.5 (CH₂), 22.0 (CH₂), 18.9 (CH₂, C-4), 18.2 (C, CSi), 12.1 (CH₂, C-8’), -4.0 (CH₂, Me-Si), -4.5 (CH₂, Me-Si). IR (film, cm⁻¹): 3319 (υO-H), 2856 (υC-H). HRMS (ESI-TOF⁺): m/z: calcd for [C₂₀H₁₈O₂Si]⁺: 341.2870 [M+H⁺]⁺; found 341.2860.

A solution HF in H₂O (30%, 15 drops) was added dropwise to a solution of 18 (0.075 g, 0.220 mmol, 1 equiv) in CH₂Cl₂ (3 mL) and CH₃CN (1 mL). After 1 h, sat. aq. NaHCO₃ (8 mL) was added. The mixture was extracted with EtOAc (3x5 mL) and the combined organic extracts were dried, filtered, and concentrated. The residue was purified by flash chromatography (SiO₂, Ø 2x6 cm, 40% EtOAc/hexanes) to afford 19 [0.045 g, 91%, Rₜ = 0.32 (50% EtOAc/hexanes), [α]D²⁵ = 45.6 (c = 2.5, CHCl₃), colorless solid, mp = 92.7-93.5 °C (CH₂Cl₂)]. ¹H-NMR (400 MHz, CDCl₃): δ = 3.62 (m, H-4’, 3H, H-1), 1.65 (m, 8H), 1.94-1.02 (m, 15H), 0.90 (d, J = 6.5, 3H, H-4), 0.65 (s,
3H, H-8’). 13C-NMR (63 MHz, CDCl3): δ = 70.9 (CH, C-4’), 60.7 (CH2, C-1), 57.1 (CH), 56.6 (CH), 44.6 (C, C-7a’), 39.0 (CH2), 38.8 (CH2), 35.7 (CH2), 32.3 (CH), 27.9 (CH2), 23.3 (CH2), 21.6 (CH2), 18.6 (CH3, C-4), 11.8 (CH3, C-8’). IR (film, cm⁻¹): 3223 (νO-H), 2877 (νC-H). HRMS (ESI-TOF): m/z: calcd for [C14H24O2Si]+: 208.1819 [M-H2O]+; found 208.1822.

tert-Butyl(((3aR,4R,7aR)-(4-iodobutan-2-yl)-7a-methyloctahydro-1H-inden-4-yl)oxy) dimethylsilane (20)

PPh3 (0.084 g, 0.321 mmol, 1.2 equiv), imidazole (0.035 g, 0.507 mmol, 1.9 equiv) and I2 (0.081 g, 0.321 mmol, 1.2 equiv) were successively added to a solution of 18 (0.091 g, 0.267 mmol, 1 equiv) in dry THF (5 mL). After 2 h, the reaction was quenched by successive addition of sat. aq. NaHCO3 (10 mL) and Na2SO4 (10 mL). The mixture was extracted with MTBE (3x8 mL) and the combined organic extracts were dried, filtered, and concentrated. The residue was purified by flash chromatography (SiO2, 100% hexanes) to afford 20 [0.120 g, 99%, Rf = 0.91 (20% EtOAc/hexanes), [α]D = 23.4 (c = 2.9, CHCl3), colorless oil]. 1H-NMR (400 MHz, CDCl3): δ = 3.55 (td, J1 = 9.7, J2 = 4.2, 1H, H-4’), 3.30 (td, J3 = 9.5, J4 = 4.8, 1H, H-1), 3.10 (m, 1H, H-1), 2.05 (m, 1H, H-3a’), 1.80 (m, 4H), 1.55 (m, 6H), 1.15 (m, 4H), 0.90 (d, J = 6.9, 3H, H-4’), 0.88 (s, 9H, Me8C-Si), 0.68 (s, 3H, H-8’), 0.04 (s, 6H, 2xCH2Si). 13C-NMR (63 MHz, CDCl3): δ = 71.7 (CH, C-4’), 57.3 (CH), 56.3 (CH), 44.7 (C, C-7a’), 40.4 (CH3), 39.4 (CH3), 37.0 (CH), 36.6 (CH2), 27.7 (CH2), 26.0 (3xCH3, Me8C-Si), 22.0 (CH2), 18.3 (C, C-Si), 17.9 (CH3, C-4), 12.2 (CH3, C-8’), 5.4 (CH2, C-1), -4.0 (CH3,Me-Si), -4.5 (CH3, Me-Si). IR (film, cm⁻¹): 2856 (νC-H). HRMS (ESI-TOF): m/z: calcd for [C24H30O2Si]+: 341.1887 [M+H]+; found 341.1887.

(5R)-tert-Butyl 5-((3aR,4R,7aR)-4-((tert-butyldimethylsilyl)oxy)-7a-methyloctahydro-1H-inden-1-yl) hexanoate (21)

HMPA (0.058 mL, 0.333 mmol, 3 equiv) and tBuOAc (0.045 mL, 0.333 mmol, 3 equiv) were successively added dropwise to a -78 °C cooled solution of LDA in dry THF (0.67 mL, 0.5 M, 0.333 mmol, 3 equiv). After 15 min, a solution of 20 (0.050 g, 0.111 mmol, 1 equiv) in dry THF (3 mL) was added. After 1.5 h, sat. aq. NH4Cl (15 mL) was added. The mixture was warmed to 23 °C and extracted with MTBE (3x5 mL) and the combined organic extracts were dried, filtered, and concentrated. The residue was purified by flash chromatography (SiO2, 100% hexanes) to afford 21 [0.046 g, 94%, Rf = 0.42 (10% EtOAc/hexanes), [α]D = 8.7 (c = 3, CHCl3), oily solid]. 1H-NMR (400 MHz, CDCl3): δ = 3.52 (td, J1 = 9.8, J2 = 4.4, 1H, H-4’), 2.16 (td, J3 = 7.6, J4 = 3.0, 2H, H-2’), 1.70 (m, 9H), 1.43 (s, 9H, t-BuO), 1.20 (m, 8H), 0.90 (d, J = 6.5, 3H, H-6’), 0.88 (s, 9H, Me8C-Si), 0.65 (s, 3H, H-8’), 0.03 (s, 6H, 2xMe-Si). 13C-NMR (63 MHz, CDCl3): δ = 173.4 (C, C-1), 80.0 (C, OCtBu), 71.8 (CH, C-4’), 57.3 (CH), 56.6 (CH), 44.6 (C, C-7a’), 39.4 (CH3), 36.7 (CH2), 36.2 (CH2), 35.4 (CH2), 28.3 (3xCH3, Me8C-Si), 27.8 (CH2), 26.0 (3xCH3, Me8C-Si), 24.6 (CH3), 22.0 (CH2), 21.9 (CH3), 18.7 (CH3, C-6), 18.3 (C, C-Si), 12.1 (C, C-8’), -4.0 (CH3, Me-Si), -4.5 (CH3, Me-Si). IR (film, cm⁻¹): 2856 (νC-H), 1731 (νC-O). HRMS (ESI-TOF): m/z: calcd for [C25H32O2Si]+: 349.3250 [M+H]+; found 349.3258.

(5R)-tert-Butyl 5-((3aR,4R,7aR)-4-hydroxy-7a-methyloctahydro-1H-inden-1-yl)hexanoate (22)

A solution of TBAF in THF (0.53 mL, 1 M, 0.53 mmol, 1.5 equiv) was added dropwise to a solution of 21 (0.155...
g, 0.353 mmol, 1 equiv) in dry THF (5 mL). The mixture was heated at 50 °C for 7 h. Sat. aq. NH₄Cl (10 mL) was added. The mixture was extracted with MTBE (4×5 mL) and the combined organic extracts were dried, filtered, and concentrated. The residue was purified by flash chromatography (SiO₂, 2×8 cm, 12% EtOAc/hexanes) to afford 22 [0.112 g, 98%, R₁ = 0.50 (30% EtOAc/hexanes), δ_C<sup>13</sup> = 7.6 (C = 2.3, CHCl₃), yellow oil].<sup>1</sup>H-NMR (500 MHz, CDCl₃): δ = 3.53 (td, J₁ = 10.3, J₂ = 5.1, 1H, H₄), 2.14 (td, J₁ = 7.5, J₂ = 5.8, 2H, H₁), 1.43 (s, 9H, tBuO), 0.90 (d, J = 6.4, 3H, H₆), 0.65 (s, 3H, H₈).<sup>13</sup>C-NMR (63 MHz, CDCl₃): δ = 73.4 (C, C-1), 80.0 (C, OC(tBu)), 71.1 (CH, C-4), 57.3 (CH), 56.4 (CH), 44.8 (C, C-7a), 39.3 (CH₂), 36.1 (CH₂), 35.4 (CH₂), 28.1 (3xCH₃, Me₃CO), 28.0 (CH₂), 23.5 (CH₂), 21.9 (CH₂), 21.8 (CH₂), 18.6 (CH₃, C-6), 12.1 (CH₃, C-8). IR (film, cm⁻¹): = 3399 (ν<sub>OH</sub>), 2868 (ν<sub>CH</sub>), 1730 (ν<sub>C=O</sub>). HRMS (ESI-TOF<sup>+</sup>): m/z: calcd for [C<sub>28</sub>H<sub>30</sub>O<sub>3</sub>Na]<sup>+</sup>: 347.2556 [M+Na]<sup>+</sup>; found 347.2564.

(5R)-tert-Butyl 5-((3aR,7aR)-7a-methyl-4-oxooctahydro-1H-inden-1-yl)hexanoate (23)

Dess-Martin periodinane (0.323 g, 0.762 mmol, 1.5 equiv) in dry CHCl₃ (5 mL) was added to a solution of 22 (0.165 g, 0.508 mmol, 1 equiv) in dry CHCl₃ (5 mL). After 1 h, sat. aq. NaHCO₃ (15 mL) was added. The mixture was extracted with MTBE (4×5 mL) and the combined organic extracts were dried, filtered, and concentrated. The residue was purified by flash chromatography (SiO₂, 0.2×8 cm, 4% EtOAc/hexanes) to afford 23 [0.152 g, 93%, R₁ = 0.50 (30% EtOAc/hexanes), δ_C<sup>13</sup> = 1.7 (C = 2.3, CHCl₃), yellow oil].<sup>1</sup>H-NMR (400 MHz, CDCl₃): δ = 2.44 (dd, J₁ = 11.7, J₂ = 7.5, 1H, C-3a), 1.44 (s, 9H, tBuO), 0.90 (d, J = 5.8, 3H, H₆), 0.63 (s, 3H, H₈).<sup>13</sup>C-NMR (63 MHz, CDCl₃): δ = 212.1 (C, C-4), 173.2 (C, C-8), 175.3 (C, C-1), 80.0 (C, OC(tBu)), 62.0 (CH), 56.4 (CH), 49.9 (C, C-3a), 41.0 (CH₂), 39.0 (CH₃), 35.9 (CH₂), 35.3 (CH), 35.1 (CH₂), 28.1 (3xCH₃, Me₃CO), 27.5 (CH₂), 24.1 (CH₂), 21.6 (CH₂), 19.1 (CH₃), 18.7 (CH₃, C-6), 12.5 (CH₃, C-8). IR (film, cm⁻¹): = 2874 (ν<sub>CH</sub>), 1712 (ν<sub>C=O</sub>). HRMS (ESI-TOF<sup>+</sup>): m/z: calcd for [C<sub>28</sub>H<sub>30</sub>O<sub>3</sub>Na]<sup>+</sup>: 323.2580 [M+H]<sup>+</sup>; found 323.2583.

(5R)-tert-Butyl 5-((3aR,7aR,E)-4-(bromomethylene)-7a-methyloctahydro-1H-inden-1-yl)hexanoate (24)

A suspension of (Ph<sub>3</sub>PCH₂Br)<sub>2</sub>Br (2.83 g, 6.49 mmol, 6 equiv) in dry toluene (20 mL) was sonicated for 30 min. After cooling at -15 °C, a solution of KOtBu in dry THF (3.76 mL, 1 M, 6.38 mmol, 5.9 equiv) was added. The resulting mixture was stirred for 2 h. A 0 °C cooled solution of ketone 23 (0.349 g, 1.08 mmol, 1 equiv) in dry toluene (5 mL) was added via cannula. The mixture was stirred for 1 h at -17 °C and at 23 °C for 2 h. Sat. aq. NH₄Cl (1 mL) was added. The mixture was filtered through a layer of silica gel. The solids were rinsed with EtOAc (3×5 mL), and the filtrate was concentrated. The residue was purified by flash chromatography (SiO₂, 0.2×8 cm, hexanes) to afford 24 [0.340 g, 79%, R₁ = 0.50 (5% EtOAc/hexanes), δ_C<sup>13</sup> = 82.2 (C = 2.5, CHCl₃), yellow oil].<sup>1</sup>H-NMR (400 MHz, CDCl₃): δ = 5.63 (s, 1H, HBr), 2.85 (m, 1H, H-5´), 2.16 (m, 2H, H-2), 1.44 (s, 9H, tBuO), 0.93 (d, J = 5.8, 3H, H-6), 0.63 (s, 3H, H-8).<sup>13</sup>C-NMR (63 MHz, CDCl₃): δ = 173.4 (C, C-1), 145.2 (C, C-4), 97.5 (CH, CHBr), 80.0 (C, OC(tBu)), 56.0 (CH), 45.6 (C, C-7a), 39.9 (CH₂), 36.1 (CH₃), 35.9 (CH), 35.3 (CH₃), 31.1 (CH₃), 28.2 (3xCH₃, Me₃CO), 27.7 (CH₂), 22.7 (CH₂), 22.1 (CH₃), 21.8 (CH₃), 18.8 (CH₃, C-6), 11.8 (CH₃, C-8). IR (film, cm⁻¹): = 2871 (ν<sub>CH</sub>), 1729 (ν<sub>C=O</sub>). HRMS (ESI-TOF<sup>+</sup>): m/z: calcd for [C<sub>29</sub>H<sub>30</sub>O<sub>2</sub>Br]<sup>+</sup>: 399.1893 [M+H]<sup>+</sup>; found 399.1898.
(5R)-tert-Butyl 5-((3aS,7aR,E)-7a-methyl-4-((4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)methylene) octahydro-1H-inden-1-yl)hexanoate (3)

PCy₃ (2 mg, 0.007 mmol, 0.06 equiv) and PdCl₂(dppe)-CH₂Cl₂ (3 mg, 0.004 mmol, 0.03 equiv) were dissolved in dry DMSO (1 mL), and the mixture was stirred for 15 min. A solution of 24 (0.049 g, 0.123 mmol, 1 equiv) in dry DMSO (1.5 mL), KOAc (0.036 g, 0.369 mmol, 3 equiv), and B₂Pin₂ (0.062 g, 0.246 mmol, 2 equiv) were successively added. The mixture was heated at 80 °C for 2 h and then cooled to 23 °C. The reaction was quench with H₂O (10 mL). The mixture was extracted with MTBE (3x8 mL). The combined organic extracts were dried, filtered, and concentrated. The residue was purified by flash chromatography (SiO₂, 0.2x7 cm, 1-2% EtOAc/hexanes) to afford 3 [0.045 g, 82%, Rₚ = 0.21 (4% EtOAc/hexanes), [α]D² = 62.3 (c = 2.3, CHCl₃), yellow oil].

**H NMR** (400 MHz, CDCl₃): δ = 4.89 (s, 1H, HCB), 3.15 (m, 1H, H-5”), 2.16 (m, 2H, H-2”), 1.43 (s, 9H, tBuO), 1.25 (s, 12H, 4xCH₂-pinacidol), 0.92 (d, J = 6.1, 3H, H-6), 0.53 (s, 3H, H-8”).

**C NMR** (63 MHz, CDCl₃): δ = 173.4 (C, C-1), 166.3 (C, C-4”), 82.6 (C, C-pinacidol), 80.0 (C, OC₆Bu), 58.1 (CH), 56.6 (CH), 46.3 (C, C-7”), 40.5 (CH₂), 36.1 (CH₂), 35.9 (CH), 35.3 (CH₂), 33.4 (CH₂), 28.2 (3xCH₃, Me₂CO), 27.5 (CH₂), 25.0 (2xCH₃, CH₂-pinacidol), 24.9 (2xCH₃, CH₂-pinacidol), 24.4 (CH₂), 22.4 (CH₂), 21.8 (CH₂), 18.8 (CH₃, C-6), 11.8 (CH₃, C-8”).

**IR** (film, cm⁻¹): 2871 (νC=H), 1731 (νC=O). **HRMS** (ESI-TOF): m/z: calcd for [C₂₇H₄₈BO₄⁺]: 447.3640 [M+H⁺]; found 447.3625.

1α-[(Triethylsilyl)oxy]-24-(tert-butoxycarbonyl)-25,26,27-trisnorvitamin D₃ triethylsilyl ether (25).

An aqueous solution of K₂PO₄ (1.5 mL, 2M) and PdCl₂(PPh₃)₂ (5 mg, 0.007 mmol, 0.05 equiv) were successively added to a solution of 3 (0.056 g, 0.14 mmol, 1 equiv) and 2 (0.086 g, 0.17 mmol, 1.2 equiv) in THF (3 mL). The reaction mixture was protected from light and vigorously stirred for 1 h. Water (10 mL) was added, and the resulting mixture was extracted with MTBE (4x10 mL). The combined organic extracts were dried, filtered, and concentrated. The residue was purified by flash chromatography (SiO₂, 0.5x7 cm, 50% EtOAc/hexanes) to afford 25 [0.056 g, 0.081 mmol, 86%, Rₚ = 0.8 (10% EtOAc/hexanes), [α]D² = 12.1 (c = 1.4, CHCl₃), oily solid].

**H NMR** (400 MHz, CDCl₃): δ = 6.24 (d, J = 11.3, 1H, H-6), 6.04 (d, J = 11.2, 1H, H-7), 5.21 (s, 1H, H-19), 4.88 (s, 1H, H-19), 4.39 (m, 1H, H-1), 4.20 (m, 1H, H-3), 2.82 (m, 1H), 2.45 (m, 1H), 2.18 (m, 4H), 1.97 (m, 2H), 1.87 (m, 3H), 1.64 (m, 7H), 1.44 (s, 9H, tBuO), 1.25 (m, 4H), 0.95 (t, J = 7.9, 6H, CH₃-TEs), 0.95 (d, 3H, H-21, overlapped), 0.60 (q, J = 7.9, 2H, CH₂-TEs), 0.59 (q, J = 7.9, 2H, CH₂-TEs), 0.54 (s, 3H, H-18”).

**C NMR** (63 MHz, CDCl₃): δ = 173.5 (C, C-25), 148.5 (C, C-10), 141.3 (C, C-8),135.1 (C, C-5), 123.3 (CH, C-6), 118.0 (CH, C-7), 111.4 (CH₂, C-19), 80.1 (CH, C-1), 67.3 (CH, C-3), 56.5 (CH, C-17), 46.2 (CH₂), 45.9 (CH₂), 45.2 (CH₂), 40.7 (CH₂), 36.1 (CH₂), 39.6 (CH₂), 35.4 (CH₂), 30.1 (3xCH₃, Me₂CO), 27.8 (CH₂), 23.7 (CH₂), 22.2 (CH₂), 21.9 (CH₂), 18.9 (CH₃, C-21), 12.0 (CH₂, C-18), 7.04 (3xCH₂, TES), 4.99 (3xCH₂, TES). **IR** (film, cm⁻¹): 2875 (νC=H), 1732 (νC=O). **HRMS** (ESI-TOF): m/z: calcd for [C₉₁H₁₃O₁₂Si₂⁺]: 687.5198 [M+H⁺]; found 687.5187.
1α,25-Dihydroxycholecalciferol (1)

A solution of MeLi in Et₂O (0.098 mL, 1.6 M, 0.156 mmol, 3 equiv) was added to 0 ºC cooled solution of 25 (0.036 g, 0.052 mmol, 1 equiv) in dry Et₂O (2 mL). After 30 min, the reaction was quenched with sat. aq. NH₄Cl (10 mL). The mixture was extracted with Et₂O (3x5 mL). The combined organic extracts were dried, filtered, and concentrated. The residue was dissolved in THF (2 mL) and a solution of TBAF in THF (0.26 mL, 1M, 0.26 mmol, 3 equiv) was added. After 45 min in the dark, the reaction was quenched with sat. aq. NH₄Cl (10 mL). The mixture was extracted with EtOAc (5x5 mL). The combined organic extracts were dried, filtered, and concentrated. The residue was purified by flash chromatography (SiO₂, Ø 2×8 cm, 35% EtOAc/hexanes) to afford 1 [0.018 g, 81% (two steps), Rf = 0.14 (80% EtOAc/hexanes), [α]D²⁵ = 47.4 (c = 0.42, EtOH), (lit. [α]D⁶ = 47.9 (c = 0.3, EtOH)), white solid, mp = 92-93 ºC (EtOAc/PhH), (lit. mp = 94-96 ºC (EtOAc/PhH))].

1H-NMR (500 MHz, CD₃OD): δ = 6.32 (d, J = 11.0, 1H, H-6), 6.09 (d, J = 11.1, 1H, H-7), 5.29 (s, 1H, H-19), 4.35 (m, 1H, H-1), 4.14 (m, 1H, H-3), 2.90 (m, 1H, H-20), 2.04 (m, 2H, 1.92 (m, 2H), 1.72 (m, 2H), 1.47 (m, 13H, 1.17 (s, 6H, H-26 and H-27), 0.97 (d, J = 6.8, 3H, H-21), 0.57 (3H, s), H-18).

13C-NMR (126 MHz, CDCl₃): δ = 149.7 (C, C-10), 142.5 (C, C-8), 135.6 (C, C-5), 124.9 (CH, C-6), 118.9 (CH; C-7), 112.0 (CH₂, C-19), 79.4 (C, C-25), 71.5 (CH, C-1), 67.4 (CH, C-3), 58.0 (CH), 57.6 (CH), 46.9 (CH₂), 46.1 (CH₂), 45.3 (CH₂), 43.7 (CH₂), 41.9 (CH₂), 37.7 (CH₂), 37.4 (CH), 29.9 (CH₂), 29.3 (CH₂, C-26), 29.2 (CH₃, C-27), 28.7 (CH₂), 24.6 (CH₂), 23.3 (CH₂), 21.9 (CH₂), 19.4 (CH₂, C-21), 12.4 (CH₃, C-18).

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$^1$H and $^{13}$C NMR spectra

$^1$H-NMR (250 MHz, CDCl$_3$): \( \delta = 5.86 \) (ddd, \( J_1 = 16.9 \), \( J_2 = 10.4 \), \( J_3 = 6.2 \), 1H, H-2), 5.17 (d, \( J = 17.3 \), 1H, H-1), 5.05 (d, \( J = 10.3 \), 1H, H-1), 4.06 (m, 1H, H-3), 2.17 (m, 2H), 1.93 (t, \( J = 2.4 \), 1H, H-8), 1.6 (m, 4H).

$^{13}$C-NMR (63 MHz, CDCl$_3$): \( \delta = 140.9 \) (CH, C-2), 114.5 (CH$_2$, C-1), 84.1 (C, C-7), 72.2 (CH, C-3), 68.6 (CH, C-8), 35.6 (CH$_2$), 24.1 (CH$_2$), 18.1 (CH$_2$).
$^1$H-NMR (250 MHz, CDCl$_3$): $\delta$ = 5.80 (ddd, $J_1$ = 16.7, $J_2$ = 10.4, $J_3$ = 6.2, 1H, H-2), 5.15 (d, $J$ = 17.0, 1H, H-1), 5.02 (d, $J$ = 10.4, 1H, H-1), 4.10 (m, 1H, H-3), 2.18 (m, 1H), 1.93 (t, $J$ = 2.6, 1H, H-8), 1.57 (m, 4H), 0.89 (s, 9H, Me$_3$C-Si), 0.05 (s, 3H, Me-Si), 0.02 (s, 3H, Me-Si).

$^{13}$C-NMR (63 MHz, CDCl$_3$): $\delta$ = 142.2 (CH, C-2), 115.3 (CH$_3$, C-1), 85.1 (C, C-7), 73.7 (CH, C-3), 68.7 (CH, C-8), 37.3 (CH$_2$), 25.5 (CH$_3$, 3xCH$_3$, Me$_3$C-Si), 24.9 (CH$_2$), 18.8 (CH$_2$), -4.0 (CH$_3$, Me-Si), -4.5 (CH$_3$, Me-Si)
$^1$H-NMR (250 MHz, CDCl$_3$): $\delta = 7.23$ (t, $J = 7.5$, 2H, H$_{ar}$), 7.10 (m, 1H, H$_{ar}$), 7.08 (m, 2H, H$_{ar}$), 5.81 (ddd, $J_1 = 17.3$, $J_2 = 10.3$, $J_3 = 6.2$, 1H, H-7), 5.18 (d, $J = 17.1$, 1H, H-8), 5.06 (d, $J = 10.6$, 1H, H-8), 4.14 (m, 1H, H-6), 2.31 (m, 2H), 2.19 (s, 2H, CH$_2$-SiBn), 1.59 (m, 4H), 0.93 (s, 9H, Me$_3$C-Si), 0.12 (s, 6H, 2xMe-SiBu), 0.09 (s, 3H, Me-SiBn), 0.07 (s, 3H, Me-SiBn).

$^{13}$C-NMR (63 MHz, CDCl$_3$): $\delta = 141.6$ (CH, C-7), 139.3 (C), 128.5 (CH), 128.2 (CH), 124.4 (CH), 113.9 (CH$_2$, C-8) 108.9 (C, C-1), 83.1 (C, C-2), 73.4 (CH, C-6), 37.1 (CH$_2$), 26.7 (CH$_3$), 26.1 (3xCH$_3$, Me$_3$C-Si), 24.2 (CH$_2$), 20.0 (CH$_2$), 18.4 (C, C$_3$Si), -1.8 (2xCH$_3$, Me-SiBn) -4.3 (CH$_3$, Me-SiBu), -4.7 (CH$_3$, Me-SiBu).
$^1$H-NMR (250 MHz, CDCl$_3$): $\delta = 7.16$ (t, $J = 7.3$, 2H, H$_{ar}$), 7.05 (t, $J = 7.3$, 1H, H$_{ar}$), 6.94 (d, $J = 6.6$, 2H, H$_{ar}$), 3.10 (td, $J_1 = 10.6$, $J_2 = 4$, 1H, H-7),[7] 2.57 (m, 3H), 2.31 (m, 3H), 1.84 (m, 3H), 1.63 (s, 2H, CH$_2$Ph), 0.88 (s, 9H, Me$_3$C-Si), 0.22 (s, 6H, 2xMe-SiBu), 0.06 (s, 3H, Me-SiBn), 0.04 (s, 3H, Me-SiBn).

13C-NMR (63 MHz, CDCl$_3$) $\delta = 213.2$ (C, C-2) 189.4 (C, C-3a), 140.1 (C, C-3), 136.5 (C), 128.2 (CH), 128.1 (CH), 124.1 (CH), 76.7 (CH, C-7), 52.9 (CH, C-7a), 41.0 (CH$_2$), 35.2 (CH$_2$), 30.5 (CH$_2$), 25.9 (3xCH$_3$, Me$_3$C-Si), 25.5 (CH$_2$), 23.8 (CH$_2$), 18.1 (C, CSi), -2.0 (CH$_3$, Me-SiBu), -2.2 (CH$_3$, Me-SiBu), -3.8 (2xCH$_3$, Me-SiBn).

[7] Compound 16: Coupling constant ($J = 10.6$ Hz) of the signal at $\delta$ 3.10 ppm indicates a trans relationship for H-7 and H-7a.
$^1$H-NMR (250 MHz, CDCl$_3$): $\delta$ = 7.20 (t, $J = 7.2$, 2H, H$_{\text{ar}}$), 7.09 (t, $J = 7.5$, 1H, H$_{\text{ar}}$), 7.01 (d, $J = 6.8$, 2H, H$_{\text{ar}}$), 4.73 (bs, 1H, H-2), 3.25 (td, $J_1 = 9.9$, $J_2 = 4.0$, 1H, H-4), 2.4 (m, 2H), 2.24 (d, $J = 6.0$, 2H, CH$_{3}$Ph), 1.85 (m, 3H), 1.3 (m, 4H), 0.91 (s, 9H, Me$_3$C-Si), 0.19 (s, 3H, Me-Si), 0.17 (s, 3H, Me-Si), 0.10 (s, 3H, Me-Si), 0.09 (s, 3H, Me-Si).

$^{13}$C-NMR (63 MHz, CDCl$_3$) $\delta$ = 158.8 (C, C-7a), 140.3 (C, C-1), 135.1 (C, CH), 128.4 (CH), 128.2 (CH), 124.2 (CH), 81.6 (CH, C-4), 76.7 (CH, C-2), 56.5 (CH, C-3a), 40.0 (CH$_2$), 35.4 (CH$_2$), 28.9 (CH$_2$), 26.8 (CH$_2$), 26.0 (3xCH$_3$, Me$_3$C-Si), 24.2 (CH$_2$), 18.2 (C, CSi), -1.6 (CH$_3$, Me-Si), -2.3 (CH$_3$, Me-Si), -3.8 (CH$_3$, Me-Si), -4.3 (CH$_3$, Me-Si).
\textbf{H-NMR (250 MHz, CDCl\textsubscript{3})}: $\delta$ = 7.33 (m, 4H), 7.10 (t, $J$ = 7.5, 6H, H\textsubscript{ar}), 6.04 (s, 1H, NH), 5.68 (bs, 1H, H-2), 3.31 (td, $J\textsubscript{1}$ = 10.0, $J\textsubscript{2}$ = 4.0, 1H, H-7), 2.62 (m, 3H), 2.21 (d, $J$ = 6.0, 2H, CH\textsubscript{2}Ph), 1.91 (m, 3H), 1.50 (m, 3H), 0.89 (s, 9H, Me\textsubscript{3}C-Si), 0.18 (s, 3H, Me-Si), 0.09 (s, 3H, Me-Si), 0.07 (s, 3H, Me-Si), 0.06 (s, 3H, Me-Si).

\textbf{C-NMR (63 MHz, CDCl\textsubscript{3}) $\delta$ = 161.6 (C, C=O), 153.3 (C), 140.3 (C), 138.2 (C), 130.4 (C), 129.1 (CH), 128.9 (CH), 128.2 (CH), 128.1 (CH), 118.6 (CH), 84.8 (CH), 78.1 (CH, C-2), 57.0 (CH, C-7a), 36.3 (CH\textsubscript{2}), 35.4 (CH\textsubscript{2}), 29.0 (CH\textsubscript{2}), 27.0 (CH\textsubscript{2}), 26.0 (3xCH\textsubscript{3}, Me\textsubscript{3}C-Si), 24.2 (CH\textsubscript{2}), 18.2 (C, C\textsubscript{Si}), -1.6 (CH\textsubscript{3}, Me-Si), -3.0 (CH\textsubscript{3}, Me-Si), -3.9 (CH\textsubscript{3}, Me-Si), -4.3 (CH\textsubscript{3}, Me-Si).
$^1$H-NMR (250 MHz, CDCl$_3$): $\delta = 7.83$ (m, 2H, H$_{ar}$), 7.35 (m, 1H, H$_{ar}$), 7.24 (m, 2H, H$_{ar}$), 6.99 (m, 2H, H$_{ar}$), 6.87 (m, 1H, H$_{ar}$), 6.81 6.0(m, 2H, H$_{ar}$) 5.80 (dd, 2H, $J_1 = 10.2$, $J_2 = 3.1$), 3.12 (td, $J_1 = 10.2$, $J_2 = 4.0$, 1H, H-7), 2.52 (dt, $J_1 = 22.8$, $J_2 = 8.0$, 1H), 2.25 (m, 2H), 2.03 (s, 2H, CH$_2$Ph), 1.68 (m, 3H), 1.42 (m, 1H),1.07 (m, 2H) 0.65 (s, 9H, Me$_3$C-Si), 0.10 (s, 6H, 2xMe-Si), -0.19 (s, 3H, Me-Si), -0.24 (s, 3H, Me-Si).

$^{13}$C-NMR (63 MHz, CDCl$_3$) $\delta = 166.2$ (C, C=O), 161.7 (C, C=O), 139.7 (C), 132.7 (CH), 130.7 (CH), 130.4 (CH), 129.5 (CH), 128.6 (C), 128.3 (CH), 128.2 (CH), 128.1 (CH), 124.0 (CH), 85.0 (CH), 77.9 (CH, C-2), 56.8 (CH, C-7a), 36.4 (CH$_2$), 35.4 (CH$_2$), 28.9 (CH$_2$), 26.4 (CH$_3$), 25.8 (3xCH$_3$, Me$_3$C-Si), 24.1 (CH$_2$), 17.9 (C, CSi), -2.3 (CH$_3$, Me-Si), -2.5 (CH$_3$, Me-Si), -4.1 (CH$_3$, Me-Si), -4.6 (CH$_3$, Me-Si).
\textbf{1H-NMR} (250 MHz, CDCl$_3$): $\delta = 7.33$ (m, 4H), 7.10 (t, $J = 7.5$, 6H, H$_a$), 6.04 (s, 1H, NH), 5.68 (bs, 1H, H-2), 3.31 (td, $J_1 = 10.0$, $J_2 = 4.0$, 1H, H-7), 2.62 (m, 3H), 2.21 (d, $J = 6.0$, 2H, CH$_2$Ph), 1.91 (m, 3H), 1.50 (m, 3H), 0.89 (s, 9H, Me$_3$C-Si), 0.18 (s, 3H, Me-Si), 0.09 (s, 3H, Me-Si), 0.07 (s, 3H, Me-Si), 0.06 (s, 3H, Me-Si).

\textbf{13C-NMR} (63 MHz, CDCl$_3$) $\delta =$ 161.6 (C, C=O), 153.3 (C), 140.3 (C), 138.2 (C), 130.4 (C), 129.1 (CH), 128.9 (CH), 128.2 (CH), 128.1 (CH), 118.6 (CH), 84.8 (CH), 78.1 (CH, C-2), 57.0 (CH, C-7a), 36.3 (CH$_2$), 35.4 (CH$_2$), 29.0 (CH$_2$), 27.0 (CH$_3$), 26.0 (3xCH$_3$, Me$_3$C-Si), 24.2 (CH$_3$), 18.2 (C, CSi), -1.6 (CH$_3$, Me-Si), -3.0 (CH$_3$, Me-Si), -3.9 (CH$_3$, Me-Si), -4.3 (CH$_3$, Me-Si).
$^1$H-NMR (250 MHz, CDCl$_3$): $\delta = 7.20$ (t, $J = 7.7$, 2H, H$_2$), 7.07 (t, $J = 7.5$, 1H, H$_4$), 7.01 (d, $J = 6.8$, 2H, H$_8$), 6.02 (bs, 1H, H-2), 3.78 (td, $J_1 = 10.5$, $J_2 = 4.5$, 1H, H-7), 2.33 (m, 1H, H-7a), 2.18 (s, 2H, CH$_2$Si), 2.08 (m, 1H), 1.94 (m, 1H), 1.78 (m, 1H), 1.61 (4H, m), 1.36 (td, $J_1 = 10.5$, $J_2 = 4.5$, 1H), 0.91 (s, 9H, Me$_3$C-Si), 0.80 (s, 3H, H-8), 0.08 (s, 6H, 2xMe-Si), 0.06 (s, 3H, Me-Si), 0.03 (s, 3H, Me-Si).

$^{13}$C-NMR (63 MHz, CDCl$_3$): $\delta = 155.0$ (C, C-3), 141.8 (CH, C-2), 140.2 (C), 128.5 (CH), 128.2 (CH), 124.1 (CH), 70.5 (CH, C-7), 58.6 (CH, C-7a), 51.9 (C, C-3a), 37.0 (CH$_2$), 36.1 (CH$_2$), 34.2 (CH$_2$), 26.6 (CH$_2$), 26.0 (3xCH$_3$, Me$_3$C-Si), 22.1 (CH$_3$), 18.4 (C, C-Si), 17.3 (CH$_3$, C-8'), -2.1 (CH$_3$, Me-Si), -2.5 (CH$_3$, Me-Si), -4.1 (CH$_3$, Me-Si), -4.5 (CH$_3$, Me-Si).
$^{1}$H-NMR (400 MHz, CDCl$_3$): $\delta = 7.18$ (t, $J = 7.5$, 2H, H$_{ar}$), 7.04 (t, $J = 7.3$, 1H, H$_{ar}$), 6.98 (d, $J = 7.5$, 2H, H$_{ar}$), 5.90 (s, 1H), 3.55 (m, 1H), 2.40 (ddd, $J_1 = 16.6$, $J_2 = 7.0$, $J_3 = 1.9$, 1H), 2.17 (s, 2H, CH$_2$Ph), 2.14 (ddd, $J_1 = 6.0$, $J_2 = 2.0$, 1H), 1.72 (dd, $J_1 = 12.2$, $J_2 = 6.2$, 1H), 1.63 (m, 2H), 1.53 (m, 2H), 1.37 (m, 2H), 1.15 (s, 3H), 0.87 (s, 9H, Me$_3$C-Si), 0.01 (s, 6H, 2xMe-Si).

$^{13}$C-NMR (100 MHz, CDCl$_3$) $\delta = 153.5$ (C, C-3), 141.1 (C, C-2), 140.2 (C), 128.4 (CH), 128.0 (CH), 123.9 (CH), 71.7 (CH, C-7), 54.5 (CH, C-7a), 51.7 (C, C3a), 37.0 (CH$_2$), 35.7 (CH$_2$), 32.2 (CH$_2$), 27.9 (CH$_3$, Me-3a), 26.6 (CH$_2$), 25.9 (3xCH$_2$, Me$_3$C-Si), 18.5 (CH$_2$), 18.0 (C, CSI), -2.1 (CH$_3$, Me-Si), -2.1 (CH$_3$, Me-Si), -4.3 (CH$_3$, Me-Si), -4.8 (CH$_3$, Me-Si).
$^1$H-NMR (400 MHz, CDCl$_3$): $\delta$ = 7.15 (t, $J = 7.5$, 2H, H$_{2a}$), 7.02 (t, $J = 7.3$, 1H, H$_{b}$), 6.95 (d, $J = 7.4$, 2H, H$_{3e}$), 3.10 (td, $J_1 = 10.5$, $J_2 = 4.1$, 1H), 2.66 (q, $J = 8$, 1H), 2.53 (c, $J = 8.4$, 1H), 2.35 (dd, $J_1 = 15.5$, $J_2 = 5.1$, 1H), 2.14 (s, 2H, CH$_2$Ph), 1.89-1.74 (m, 2H), 1.74-1.66 (m, 2H), 1.65-1.54 (m, 2H), 1.42-1.28 (m, 1H), 1.18-1.03 (m, 2H), 0.87 (s, 9H, Me$_3$C-Si), 0.80 (d, $J = 6.9$, 3H), 0.08 (s, 3H, 2xMe$_2$Si), 0.06 (s, 3H, 2xMe$_2$Si), 0.03 (s, 6H, 2xMe$_2$Si).

$^{13}$C-NMR (63 MHz, CDCl$_3$) $\delta$ = 154.0 (C, C-3), 140.2 (C), 137.3 (C), 128.2 (CH), 127.9 (CH), 123.8 (CH), 79.1 (CH, C-7), 55.7 (CH, C-7a), 43.1 (CH), 39.0 (CH$_2$), 35.3 (CH$_2$), 28.7 (CH$_2$), 26.8 (CH$_2$), 25.8 (3xCH$_3$, Me$_3$C-Si), 23.9 (CH$_2$), 21.9 (CH$_3$, Me-C-2), 18.1 (C, CSI), -1.9 (CH$_3$, Me-Si), -2.1 (CH$_3$, Me-Si), -4.0 (CH$_3$, Me-Si), -4.5 (CH$_3$, Me-Si).
$^{1}$H-NMR (250 MHz, CDCl$_3$): $\delta$ = 3.70 (td, $J_1 = 10.5, J_2 = 4.5$, 1H, H-4), 2.42 (m, 1H, H-3a), 2.10 (m, 3H), 1.69-1.50 (m, 5H), 1.20 (m, 2H), 0.88 (s, 9H, Me$_3$C-Si), 0.86 (s, 3H, H-8), 0.08 (s, 6H, 2xMe-Si).

$^{13}$C-NMR (63 MHz, CDCl$_3$): $\delta$ = 220.5 (C, C-1), 70.8 (CH, C-4), 52.5 (CH, C-3a), 49.5 (C, C-7a), 36.8 (CH$_2$), 35.6 (CH$_2$), 31.1 (CH$_2$), 25.9 (3xCH$_3$, Me$_3$C-Si), 22.1 (CH$_2$) 21.0 (CH$_2$), 18.3 (C, CSi), 13.8 (CH$_3$, C-8), -4.1 (CH$_3$, Me-Si), -4.6 (CH$_3$, Me-Si).
$^1$H NMR (250 MHz, CDCl$_3$): $\delta = 7.77$ (d, $J = 8.5$, 2H, H$_{ar}$), 7.32 (d, $J = 8.5$, 2H, H$_{ar}$), 4.55 (td, $J_1 = 10.6$, $J_2 = 4.7$, 1H, H-4), 2.42 (s, 3H, Me-Ph), 2.35 (m, 1H, H-3a), 2.00 (m, 3H), 1.67 (m, 3H), 1.55-1.07 (m, 4H), 0.81 (s, 3H, H-8).

$^{13}$C NMR (63 MHz, CDCl$_3$): $\delta = 218.5$ (C, C-1), 144.8 (C), 134.4 (C), 129.9 (CH), 127.7 (CH), 81.7 (CH, C-4), 50.1 (CH, C-3a), 49.6 (C, C-7a), 35.0 (CH$_2$), 33.4 (CH$_2$), 30.5 (CH$_2$), 21.7 (CH$_3$, Me-Ph) 21.3 (CH$_3$), 20.8 (CH$_2$), 13.6 (CH$_3$, C-8).
\[ \delta = 5.58 \text{ (m, 1H, H-2)}, 3.73 \text{ (td, } J_1 = 10.5, J_2 = 4.5, \text{ 1H, H-7)}, 2.36 \text{ (m, 1H)}, 2.09 \text{ (m, 1H)}, 1.93 \text{ (m, 2H)}, 1.77 \text{ (m, 2H)}, 1.34 \text{ (m, 3H)}, 0.98 \text{ (s, 3H, H-8)}, 0.88 \text{ (s, 9H, Me_3Si)}, 0.05 \text{ (s, 6H, 2xMe-Si)}. \]

\[ \delta = 158.5 \text{ (C, C-3)}, 118.3 \text{ (C, q, CF_3)}, 114.4 \text{ (CH, C-2)}, 69.0 \text{ (CH, C-7)}, 55.3 \text{ (CH, C-7a)}, 46.5 \text{ (C, C-3a)}, 36.8 \text{ (CH_3)}, 32.1 \text{ (CH_2)}, 29.9 \text{ (CH_3)}, 25.9 \text{ (3xCH_3, Me_3C-Si)}, 21.3 \text{ (CH_2)}, 18.3 \text{ (C, Csi)}, 15.1 \text{ (CH_3, C-8)}, -4.1 \text{ (CH_3, Me-Si)}, -4.6 \text{ (CH_3, Me-Si)}. \]
$^1$H-NMR (250 MHz, CDCl₃): $\delta = 6.11$ (m, 1H, H-2'), 5.86 (s, 1H, H-2), 4.14 (q, $J = 7.1$, 2H, OCH₂CH₃), 3.75 (td, $J_1 = 10.4$, $J_2 = 5.3$, 1H, H-7'), 2.35 (m, 1H), 2.29 (s, 3H, H-4), 1.97 (m, 3H), 1.67 (m, 4H), 1.27 (t, $J = 7.1$, 3H, OCH₂CH₃), 0.96 (s, 3H, H-8'), 0.88 (s, 9H, Me₃C-Si), 0.05 (s, 6H, 2xCH₃-Si).

$^{13}$C-NMR (63 MHz, CDCl₃): $\delta = 168.8$ (C, C-1), 155.8 (C, C-3), 150.5 (C, C-3'), 133.9 (CH, C-2'), 114.7 (CH, C-2), 69.8 (CH, C-7'), 59.7 (CH₂, OCH₂CH₃), 58.4 (CH, C-7a'), 48.8 (C, C-3a'), 36.7 (CH₂), 34.9 (CH₂), 31.9 (CH₂), 26.0 (3xCH₃, Me₃C-Si), 21.9 (CH₃), 18.3 (C, CSi), 17.2 (CH₃, C-4), 16.1 (CH₃, C-8'), 14.5 (CH₃, OCH₂CH₃), -4.1 (CH₃, Me-Si), -4.6 (CH₃, Me-Si).
$^1$H-NMR (500 MHz, CDCl$_3$): $\delta = 5.34$ (m, 1H, H-2'), 4.09 (m, 2H, OCH$_2$CH$_3$), 3.73 (td, $J_1 = 10.4, J_2 = 4.4$, 1H, H-7'), 2.63 (m, 1H), 2.5 (dd, $J_1 = 14.9, J_2 = 7.5$, 1H, H-2), 2.35 (dd, $J_1 = 14.9, J_2 = 7.8$, 1H, H-2), 2.20 (m, 1H, H-7a'), 1.91 (m, 2H), 1.63 (m, 4H), 1.31 (m, 1H), 1.19 (m, 1H), 1.23 (t, $J = 7.2$, 3H, OCH$_2$CH$_3$), 1.04 (d, $J = 6.7$, 3H, H-4), 0.87 (s, 9H, Me$_3$C-Si), 0.76 (s, 3H, H-8'), 0.04 (s, 6H, 2xCH$_3$-Si).

$^{13}$C-NMR (126 MHz, CDCl$_3$): $\delta = 172.9$ (C, C-1), 159.0 (C, C-3'), 121.4 (CH, C-2'), 70.2 (CH, C-7'), 60.3 (CH$_2$, OCH$_2$CH$_3$), 58.1 (CH, C-7a'), 49.2 (C, C-3a'), 41.8 (CH$_2$), 37.1 (CH$_2$), 34.5 (CH$_2$), 31.6 (CH$_2$), 29.4 (CH$_3$, OCH$_2$CH$_3$), 26.0 (3xCH$_3$, Me$_3$C-Si), 21.9 (CH$_3$), 21.8 (CH, C-20), 18.3 (C, CSi), 15.9 (CH$_3$, C-8'), 14.4 (CH$_3$, C-4'), -4.1 (CH$_3$, Me-Si), -4.6 (CH$_3$, Me-Si).
$^1$H-NMR (400 MHz, CDCl$_3$): $\delta = 5.31$ (m, 1H, H-2'), 3.74 (td, $J_1 = 10.4$, $J_2 = 4.6$, 1H, H-7'), 3.60 (td, $J_1 = 6.7$, $J_2 = 2.8$, 2H, H-1), 2.20 (m, 2H), 1.74 (m, 8H), 1.01 (d, $J = 6.9$, 3H, H-4), 0.87 (s, 9H, Me$_3$C-Si), 0.76 (s, 3H, H-8'), 0.04 (s, 6H, 2xMe-Si).

$^{13}$C-NMR (63 MHz, CDCl$_3$): $\delta = 159.8$ (C, C-3'), 121.0 (CH, C-2'), 70.2 (CH, C-7'), 61.5 (CH$_2$, C-1), 58.3 (CH, C-7a'), 49.0 (C, C-3a'), 39.4 (CH$_2$), 37.1 (CH$_2$), 34.3 (CH$_2$), 31.5 (CH$_2$), 29.0 (CH, C-20), 26.0 (3xCH$_3$, Me$_3$CSi), 22.4 (CH$_3$, C-4), 21.9 (CH$_2$), 18.3 (C, Csi), 16.0 (CH$_3$, C-8'), -4.1 (CH$_3$, Me-Si), -4.6 (CH$_3$, Me-Si).
\[ ^1H-NMR \, (400 \, MHz, \, CDCl_3) : \delta = 3.59 \, (m, \, 3H, \, H-4, \, 2xH-1), \, 1.65 \, (m, \, 8H), \, 1.20 \, (m, \, 7H), \, 0.92 \, (d, \, J = 6.9, \, 3H, \, H-4), \, 0.86 \, (s,9H, \, Me_2C-Si), \, 0.66 \, (s, \, 3H, \, H-8'), \, 0.00 \, (s, \, 6H, \, 2xMe-Si). \]

\[ ^13C-NMR \, (63 \, MHz, \, CDCl_3) : \delta = 71.8 \, (CH, \, C-4'), \, 60.9 \, (CH_2, \, C-1), \, 57.3 \, (CH), \, 57.0 \, (CH), \, 44.6 \, (C, \, C-7a'), \, 39.4 \, (CH_2), \, 39.0 \, (CH_2), \, 36.6 \, (CH_3), \, 32.7 \, (CH), \, 27.9 \, (CH_2), \, 26.0 \, (3xCH_3, \, Me_2C-Si), \, 24.5 \, (CH_3), \, 22.0 \, (CH_2), \, 18.9 \, (CH_3, \, C-4), \, 18.2 \, (C, \, CSI), \, 12.1 \, (CH_3, \, C-8'), \, -4.0 \, (CH_3, \, Me-Si), \, -4.5 \, (CH_3, \, Me-Si). \]
$^1$H-NMR (400 MHz, CDCl$_3$): $\delta = 3.55 \text{ (td, } J_1 = 9.7, J_2 = 4.2, 1\text{H, H-4')}, 3.30 \text{ (td, } J_1 = 9.5, J_2 = 4.8, 1\text{H, H-1)}, 3.10 \text{ (m, } 1\text{H, H-1)}, 2.05 \text{ (m, } 1\text{H, H-3a')}, 1.80 \text{ (m, } 4\text{H}), 1.55 \text{ (m, } 6\text{H}), 1.15 \text{ (m, } 4\text{H}), 0.90 \text{ (d, } J = 6.9, 3\text{H, H-4)}, 0.88 \text{ (s, } 9\text{H, Me$_3$C-Si}), 0.68 \text{ (s, } 3\text{H, H-8')}, 0.04 \text{ (s, } 6\text{H, 2xCH$_3$Si}).$

$^{13}$C-NMR (63 MHz, CDCl$_3$): $\delta = 71.7 \text{ (CH, C-4')}, 57.3 \text{ (CH)}, 56.3 \text{ (CH)}, 44.7 \text{ (C, C-7a')}, 40.4 \text{ (CH$_2$)}, 39.4 \text{ (CH$_2$)}, 37.0 \text{ (CH)}, 36.6 \text{ (CH$_2$)}, 27.7 \text{ (CH$_2$)}, 26.0 \text{ (3xCH$_3$, Me$_3$C-Si)}, 22.0 \text{ (CH$_2$)}, 18.3 \text{ (C, CSi)}, 17.9 \text{ (CH$_3$, C-4)}, 12.2 \text{ (CH$_3$, C-8')}, 5.4 \text{ (CH$_2$, C-1)}, -4.0 \text{ (CH$_3$, Me-Si)}, -4.5 \text{ (CH$_2$, Me-Si)}.$
$^1$H-NMR (400 MHz, CDCl$_3$): $\delta = 3.52$ (td, $J_1 = 9.8, J_2 = 4.4$, 1H, H-4'), 2.16 (td, $J_1 = 7.6, J_2 = 3.0$, 2H, H-2), 1.70 (m, 9H), 1.43 (s, 9H, tBuO), 1.20 (m, 8H), 0.90 (d, $J = 6.5$, 3H, H-6), 0.88 (s, 9H, Me$_3$C-Si), 0.65 (s, 3H, H-8'), 0.03 (s, 6H, 2xMe-Si).

$^{13}$C-NMR (63 MHz, CDCl$_3$): $\delta = 173.4$ (C, C-1), 80.0 (C, OCtBu), 71.8 (CH, C-4'), 57.3 (CH), 56.6 (CH), 44.6 (C, C-7a'), 39.4 (CH$_2$), 36.7 (CH$_2$), 36.2 (CH$_2$), 35.4 (CH$_2$), 28.3 (3xCH$_3$, Me$_3$CO) 27.8 (CH$_2$), 26.0 (3xCH$_3$, Me$_3$C-Si), 24.6 (CH$_2$), 22.0 (CH$_2$), 21.9 (CH$_2$), 18.7 (CH$_3$, C-6), 18.3 (C, CSi), 12.1 (CH$_3$, C-8'), -4.0 (CH$_3$, Me-Si), -4.5 (CH$_3$, Me-Si).
\textbf{$^1$H-RMN (500 MHz, CDCl$_3$):} $\delta = 3.53$ (td, $J_1 = 10.3, J_2 = 5.1$, 1H, H-4'), 2.14 (td, $J_1 = 7.5, J_2 = 5.8$, 2H, H-1), 1.43 (s, 9H, tBuO), 0.90 (d, $J = 6.4$, 3H, H-6), 0.65 (s, 3H, H-8').

\textbf{$^{13}$C-RMN (63 MHz, CDCl$_3$):} $\delta =$ 173.4 (C, C-1), 80.0 (C, OC$\text{tBu}$), 71.1 (CH, C-4'), 57.3 (CH), 56.4 (CH), 44.8 (C, C-7a'), 39.3 (CH$_2$), 36.1 (CH$_2$), 36.0 (CH$_2$), 35.4 (CH$_2$), 28.1 (3xCH$_3$, Me$_3$CO), 28.0 (CH$_2$), 23.5 (CH$_2$), 21.9 (CH$_2$), 21.8 (CH$_2$), 18.6 (CH$_3$, C-6), 12.1 (CH$_3$, C-8').
$^1$H-NMR (400 MHz, CDCl$_3$): $\delta = 2.44$ (dd, $J_1 = 11.7$, $J_2 = 7.5$, 1H, C-3a’), 1.44 (s, 9H, tBuO), 0.90 (d, $J = 5.8$, 3H, H-6), 0.63 (s, 3H, H-8’).

$^{13}$C-NMR (63 MHz, CDCl$_3$): $\delta = 212.1$ (C, C-4’), 173.2 (C, C-1), 150.0 (C, O$t$Bu), 62.0 (CH), 56.4 (CH), 49.9 (C, C-3a’), 41.0 (CH$_3$), 39.0 (CH$_2$), 35.9 (CH$_2$), 35.3 (CH), 35.1 (CH$_2$), 28.1 (3xCH$_3$, Me$_3$CO), 27.5 (CH$_2$), 24.1 (CH$_2$), 21.6 (CH$_2$), 19.1 (CH$_2$), 18.7 (CH$_3$, C-6), 12.5 (CH$_3$, C-8’).
$^1$H-NMR (400 MHz, CDCl$_3$): $\delta = 5.63$ (s, 1H, HBr), 2.85 (m, 1H, H-5'), 2.16 (m, 2H, H-2), 1.44 (s, 9H, tBuO), 0.93 (d, J = 5.8, 3H, H-6), 0.63 (s, 3H, H-8').

$^{13}$C-NMR (63 MHz, CDCl$_3$): $\delta = 173.4$ (C, C-1), 145.2 (C, C-4'), 97.5 (CH, HBr), 80.0 (C, OCtBu), 56.0 (CH), 55.6 (CH), 45.6 (C, C-7a'), 39.9 (CH$_3$), 36.1 (CH$_2$), 35.9 (CH), 35.3 (CH$_2$), 31.1 (CH$_2$), 28.2 (3xCH$_3$, Me$_3$CO), 27.7 (CH$_2$), 22.7 (CH$_2$), 22.1 (CH$_3$), 21.8 (CH$_2$), 18.8 (CH$_3$, C-6), 11.8 (CH$_3$, C-8').
^1^H-RMN (400 MHz, CDCl₃): δ = 4.89 (s, 1H, HCB), 3.15 (m, 1H, H-5'), 2.16 (m, 2H, H-2), 1.43 (s, 9H, tBuO), 1.25 (s, 12H, 4xCH₃-pinacol), 0.92 (d, J = 6.1, 3H, H-6), 0.53 (s, 3H, H-8').

^1^3C-RMN (63 MHz, CDCl₃): δ = 173.4 (C, C-1), 166.3 (C, C-4'), 82.6 (C, C-pinacol), 80.0 (C, OCtBu), 58.1 (CH), 56.6 (CH), 46.3 (C, C-7a'), 40.5 (CH₂), 36.1 (CH₂), 35.9 (CH), 35.3 (CH₂), 33.4 (CH₂), 32.8 (3xCH₃, Me₃CO), 27.5 (CH₂), 25.0 (2xCH₃, CH₃-pinacol), 24.9 (2xCH₃, CH₃-pinacol), 24.4 (CH₂), 22.4 (CH₂), 21.8 (CH₂), 18.8 (CH₃, C-6), 11.8 (CH₃, C-8').
$^1$H-NMR (400 MHz, CDCl$_3$): $\delta$ = 6.24 (d, $J$ = 11.3, 1H, H-6), 6.04 (d, $J$ = 11.2, 1H, H-7), 5.21 (s, 1H, H-19), 4.88 (s, 1H, H-19), 4.39 (m, 1H, H-1), 4.20 (m, 1H, H-3), 2.82 (m, 1H), 2.45 (m, 1H), 2.18 (m, 4H), 1.97 (m, 2H), 1.87 (m, 3H), 1.64 (m, 7H), 1.44 (s, 9H, tBuO), 1.25 (m, 4H), 0.95 (t, $J$ = 7.9, 6H, CH$_3$-TES), 0.95 (d, 3H, H-21, overlaped), 0.60 (q, $J$ = 7.9, 2H, CH$_2$-TES), 0.59 (q, $J$ = 7.9, 2H, CH$_2$-TES), 0.54 (s, 3H, H-18).

$^{13}$C-NMR (63 MHz, CDCl$_3$): $\delta$=173.5 (C, C-25), 148.5 (C, C-10), 141.3 (C, C-8), 135.1 (C, C-5), 123.3 (CH, C-6), 118.0 (CH, C-7), 111.4 (CH$_2$, C-19), 80.1 (CH, C-1), 67.3 (CH, C-3), 56.5 (CH, C-17), 46.2 (CH$_2$), 45.9 (CH$_2$), 45.2 (CH$_2$), 40.7 (CH$_2$), 36.1 (CH$_2$), 36.0 (CH), 35.4 (CH$_2$), 29.1 (CH$_2$), 28.2 (3xCH$_3$, Me$_3$CO), 27.8 (CH$_2$), 23.7 (CH$_2$), 22.2 (CH$_2$), 21.9 (CH$_2$), 18.9 (CH$_3$, C-21), 12.0 (CH$_2$, C-18), 7.04 (3xCH$_3$, TES), 4.99 (3xCH$_3$, TES).
$^1$H-NMR (500 MHz, CD$_3$OD): $\delta = 6.32$ (d, $J = 11.0$, 1H, H-6), 6.09 (d, $J = 11.1$, 1H, H-7), 5.29 (s, 1H, H-19), 4.90 (s, 1H, H-19), 4.35 (m, 1H, H-1), 4.14 (m, 1H, H-3), 2.90 (m, 1H), 2.55 (m, 1H), 2.30 (m, 1H), 2.04 (m, 2H), 1.92 (m, 2H), 1.72 (m, 2H), 1.47 (m, 13H), 1.17 (s, 6H, H-26 and H-27), 0.97 (d, $J = 6.8$, 3H, H-21), 0.57 (3H, s, H-18).

$^{13}$C-NMR (126 MHz, CDCl$_3$): $\delta = 149.7$ (C, C-10), 142.5 (C, C-8), 135.6 (C, C-5), 124.9 (CH, C-6), 118.9 (CH, C-7), 112.0 (CH$_3$, C-19), 79.4 (C, C-25), 71.5 (CH, C-1), 67.4 (CH, C-3), 58.0 (CH), 57.6 (CH), 46.9 (CH$_2$), 46.1 (CH$_2$), 45.3 (CH$_2$), 43.7 (CH$_2$), 41.9 (CH$_2$), 37.7 (CH$_2$), 37.4 (CH), 29.9 (CH$_3$), 29.3 (CH$_3$, C-26), 29.2 (CH$_3$, C-27), 28.7 (CH$_2$), 24.6 (CH$_2$), 23.3 (CH$_2$), 21.9 (CH$_2$), 19.4 (CH$_3$, C-21), 12.4 (CH$_3$, C-18).
X-RAY data

Compound 14 (CCDF 999113)

Crystals file available from the Cambridge Crystallographic Data Centre: CCDC 999113.
http://www.ccdc.cam.ac.uk/Community/Requestastructure/Pages/DataRequest.aspx

Table 1. Crystal data and structure refinement for compound 18.

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<td>Crystal system</td>
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Compound 19 (CCDF 1534334)


Table 1. Crystal data and structure refinement for compound 19.

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