A Transannular Polyene Tetracyclization for Rapid Construction of the Pimarane Framework

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A Transannular Polyene Tetracyclization for the Rapid Construction of the Pimarane Framework – Supporting Information

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1 General experimental details

All reactions were carried out with magnetic stirring and, if moisture or air sensitive, under nitrogen or argon atmosphere using standard Schlenk techniques in oven-dried glassware (100 °C oven temperature). If required glassware was further dried under vacuum with a heat-gun at 650 °C. External bath thermometers were used to record all reaction temperatures. Low temperature reactions were carried out in a Dewar vessel filled with acetone and dry ice (−78 °C) or equipped with an electronically regulated cryostat in acetone (between −78 °C and 0 °C) or with distilled water and ice (0 °C). High temperature reactions were conducted in reaction vessels equipped with a reflux condenser or in a pressure tube using a heated silicon oil bath or a metal block. Tetrahydrofuran (THF) was dried over molecular sieves (4Å) prior to use. All other solvents were purchased from Acros Organics as ‘extra dry’ reagents. If required solvents were degassed by bubbling argon through the solvent with a balloon under sonication. All other reagents with a purity > 95% were obtained from commercial sources (Sigma Aldrich, Acros, Alfa Aesar and others) and used without further purification unless otherwise stated.

Flash column chromatography (FCC) was carried out with Merck silica gel 60 (0.040–0.063 mm). Analytical thin layer chromatography (TLC) was carried out using Merck silica gel 60 F254 aluminum foils and visualized under UV light at 254 nm. Staining was performed with ceric ammonium molybdate (CAM) or by staining with an aqueous potassium permanganate solution and subsequent heating.

High pressure liquid chromatography (HPLC) was carried out on normal-phase Varian Dynamax columns. For semipreparative separations a 250 x 21.4 mm Microsorb 60–8 Si column and for preparative separations a 250 x 41.4 mm Microsorb 60-8 Si column was used.

NMR spectra (1H NMR and 13C NMR) were recorded in deuterated chloroform (chloroform-d), deuterated benzene (benzene-d6), deuterated dichloromethane (dichloromethane-d2) or deuterated pyridine (pyridine-d5) on a Bruker Avance Neo 400 MHz spectrometer, or a Bruker Avance II 600 MHz spectrometer and are reported as follows: chemical shift δ in ppm (multiplicity, coupling constant J in Hz, number of protons) for 1H NMR spectra and chemical shift δ in ppm for 13C NMR spectra. Multiplicities are abbreviated as follows: s = singlet, d = doublet, t = triplet, q = quartet, p = quintet, br = broad, m = multiplet, or combinations thereof. For 1H NMR the residual protic solvent peak served as internal reference (chloroform-d: 7.26 ppm, benzene-d6: 7.16 ppm, dichloromethane-d2: 5.32 ppm, pyridine-d5: 8.74 ppm for the signal with the highest shift). For 13C NMR the central carbon resonance of chloroform-d (77.16 ppm or 77.00 ppm for comparison of synthetic and isolated natural products), benzene-d6 (128.06 ppm), dichloromethane-d2 (54.00 ppm) or pyridine-d5 (150.35 ppm for the signal with the highest shift) served as internal reference. NMR spectra were assigned using information ascertained from COSY, HMBC, HSQC and NOESY experiments.

High resolution mass spectra (HRMS) were recorded on a Thermo Scientific™ LTQ Orbitrap XL™ Hybrid Ion Trap-Orbitrap Mass Spectrometer at the Institute of Organic Chemistry and Center for Molecular Biosciences, University of Innsbruck.

Infrared spectra (IR) were recorded from 4000 cm⁻¹ to 450 cm⁻¹ on a Bruker™ ALPHA FT-IR Spectrometer from Bruker. Samples were prepared as a neat film or a film by evaporation of a solution in Chloroform-d, Benzene-d6 or ethyl acetate. IR data in frequency of absorption (cm⁻¹) is reported as follows: w = weak, m = medium, s = strong, br = broad or combinations thereof.

Melting points were measured with a SRS MPA120 EZ-Melt Melting Point Apparatus in open glass capillaries and are uncorrected.
Optical rotation values were recorded on a Schmidt+Haensch UniPol L1000 Peltier polarimeter. The specific rotation is calculated as follows: \[ [\alpha]_{\lambda}^{T} = \frac{\alpha \times 100}{c \times d} \]. Thereby, the wavelength \(\lambda\) is reported in nm and the measuring temperature in °C. \(\alpha\) represents the recorded optical rotation, \(c\) the concentration of the analyte in 10 mg/mL and \(d\) the length of the cuvette in dm. Thus, the specific rotation is given in \(10^{-1}\cdot\text{deg} \cdot \text{cm}^2 \cdot \text{g}^{-1}\). Use of the sodium D line (\(\lambda = 589\) nm) is indicated by \(D\) instead of the wavelength in nm. The sample concentration as well as the solvent is reported in the relevant section of the experimental part.

X-Ray diffraction analysis was carried out by Dr. Klaus Wurst at the Institute of Inorganic and Theoretical Chemistry and Center for Molecular Biosciences, University of Innsbruck. The data collections were performed on a Bruker D8 Quest diffractometer (Photon 100 detector) equipped with a microfocus source generator (Incoatec GmbH, Geesthacht, Germany) combined with multi-layer optics (monochromatized Mo Kα radiation, \(\lambda = 71.073\) pm). The Bruker Apex III software was applied for the integration, scaling and multi-scan absorption correction of the data. The structure was solved with SHELXS\([1]\) (version 2013/1). Structure refinement (full-matrix least-squares against \(F^2\)) with SHELXL\([2]\) (version 2014/7). All non-hydrogen atoms were refined anisotropically. The hydrogen atoms were placed in ideal geometry riding on their parent atoms. Relevant details of the data collection and evaluation are listed in chapter 5. Supplementary crystallographic data for 8a, 8b, 19 and 25 may be obtained from the Cambridge Crystallographic Data Centre CCDC deposition service via www.ccdc.cam.ac.uk/structures on quoting the deposition number CCDC 1987621-1987624. Plotting of thermal ellipsoids in this document and in the main text was carried out using MERCURY for Windows at 50% probability level.

All yields are isolated, unless otherwise specified.
2 Experimental part

2.1 Synthesis of pimara-15-en-3α-8α-diol (7)

2.1.1 (E)-(6,10-dimethylundeca-5,9-dien-1-yn-1-yl)trimethylsilane (12)

To a solution of silane 11 (49.6 mL, 335 mmol, 2.00 equiv) in dry tetrahydrofuran (145 mL) was added tert-butyllithium (1.70 M in pentane, 187 mL, 1.90 equiv) at −20 °C. After 75 min, geranyl bromide (10) (35.4 mL, 167 mmol, 1 equiv) was added dropwise via syringe pump (100 mL/h). 30 min after the addition of 10 was complete, the reaction mixture was slowly allowed to warm to −5 °C over 80 min. After 15 min at −5 °C, the wine-red solution was poured into a 1:1 mixture of ice and water (800 mL). The mixture was extracted with pentane (3 x 500 mL), the combined organic layers were washed with saturated aqueous solution of sodium chloride (500 mL) and the washed solution was dried over magnesium sulfate. The dried solution was filtered, and the filtrate was concentrated. Purification of the residue by flash column chromatography on silica gel (0% grading to 2% diethyl ether in pentane) afforded the title compound 12 (29.1 g, 117 mmol, 70%) as a colorless liquid.[3]

**TLC** (pentane): Rf: 0.33.

**1H NMR** (400 MHz, Chloroform-d) δ 5.27 – 5.13 (m, 1H), 5.13 – 5.01 (m, 1H), 2.28 – 2.15 (m, 4H), 2.12 – 2.03 (m, 2H), 2.03 – 1.95 (m, 2H), 1.68 (d, J = 0.8 Hz, 3H), 1.62 (d, J = 1.3 Hz, 3H), 1.60 (s, 3H), 0.14 (s, 9H).

**13C NMR** (101 MHz, Chloroform-d) δ 136.7, 131.5, 124.4, 122.7, 107.6, 84.4, 39.8, 27.5, 26.8, 25.8, 20.5, 17.8, 16.3, 0.3.

**IR** (ATR, neat) νmax: 2962 (w), 2916 (w), 2856 (w), 2175 (w), 1445 (w), 1377 (w), 1248 (m), 1042 (w), 987 (w), 837 (s), 759 (m), 697 (w), 639 (w), 447 (w) cm⁻¹.

**HRMS** (ESI): calcd for C_{16}H_{29}Si⁺ [M+H]^+: 249.2033; found: 249.2025.
To a solution of silane 12 (22.4 g, 90.1 mmol, 1 equiv) in dry acetone (176 mL) was added AgNO$_3$ (7.66 g, 45.1 mmol, 0.500 equiv) and N-bromosuccinimide (19.3 g, 108 mmol, 1.20 equiv) successively at 0 °C.\(^1\) After 6 h, water (500 mL) was added and the mixture was extracted with pentane (1000 mL, 2 x 250 mL). The combined organic layers were washed with saturated aqueous solution of sodium chloride (400 mL), the washed solution was dried over magnesium sulfate and the dried solution was filtered. The filtrate was concentrated and the residue was purified by flash column chromatography on silica gel (pentane) to yield the title compound 13 (17.0 g, 66.6 mmol, 74%) as a colorless oil.\(^4\)

**TLC** (pentane): $R_f$: 0.74.

**$^1$H NMR** $^1$H NMR (400 MHz, Chloroform-$d$) $\delta$ 5.22 – 5.00 (m, 2H), 2.25 – 2.18 (m, 4H), 2.11 – 1.97 (m, 4H), 1.69 (s, 3H), 1.61 (d, $J = 4.2$ Hz, 6H).

**$^{13}$C NMR** (101 MHz, Chloroform-$d$) $\delta$ 137.1, 131.6, 124.3, 122.4, 80.4, 39.8, 37.8, 27.1, 26.8, 25.8, 20.3, 17.8, 16.2.

**IR** (ATR, neat) $\tilde{\nu}_{\text{max}}$: 2966 (m), 2914 (s), 2855 (m), 1668 (w), 1443 (s), 1376 (m), 1325 (w), 1250 (m), 1152 (w), 1108 (m), 1046 (w), 984 (w), 839 (s), 759 (w), 697 (w), 561 (w), 524 (w), 450 (m) cm$^{-1}$.

**HRMS** (ESI): calcd for C$_{13}$H$_{20}$Br$^+$ [M+H]$^+$: 255.0743; found: 255.0735.

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\(^1\) The reaction mixture was protected from light with aluminum foil.
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2.1.3 (Z)-aryl enol ether 14

To a suspension of caesium carbonate (9.00 g, 27.6 mmol, 3.00 equiv) in dry dimethylformamide (24 mL) was added 3-methoxyphenol (9.15 g, 73.7 mmol, 8.00 equiv) and alkyne 13 (2.35 g, 9.21 mmol, 1 equiv). The reaction mixture was heated at 80 °C in a sealed tube for 3 d before water (20 mL) was added to the thick brown suspension. The mixture was extracted with diethyl ether (3 x 40 mL) and the combined organic layers were washed with saturated aqueous solution of sodium chloride (40 mL), the washed solution dried over magnesium sulfate and the dried solution was filtered. The filtrate was concentrated and the residue purified by flash column chromatography on silica gel (0.5% grading to 1.0% diethyl ether in pentane) yielding the title compound 14 (1.55 g, 4.09 mmol, 44%) as a colorless oil.[5]

TLC (1% diethyl ether in pentane): R_f: 0.52.

^1H NMR (400 MHz, Chloroform-d) δ 7.25 – 7.16 (m, 1H), 6.68 – 6.50 (m, 3H), 5.76 (s, 1H), 5.17 – 5.02 (m, 2H), 3.80 (s, 3H), 2.35 – 2.23 (m, 2H), 2.23 – 2.14 (m, 2H), 2.11 – 2.04 (m, 2H), 2.02 – 1.94 (m, 2H), 1.69 (d, J = 0.6 Hz, 3H), 1.61 (s, 3H), 1.58 (s, 3H).

^13C NMR (101 MHz, Chloroform-d) δ 161.1, 156.3, 155.0, 136.9, 131.6, 130.1, 124.3, 122.4, 109.2, 108.4, 103.3, 92.0, 55.5, 39.8, 32.5, 26.8, 25.8, 25.1, 17.8, 16.1.

IR (ATR, neat) v_max: 2964 (w), 1915 (w), 2853 (w), 1645 (w), 1602 (m), 1590 (s), 1487 (s), 1451 (m), 1376 (w), 1330 (w), 1261 (m), 1192 (m), 1165 (m), 1146 (s), 1079 (w), 1042 (m), 969 (w), 837 (w), 765 (m), 744 (w), 686 (m), 568 (w), 455 (w) cm⁻¹.

HRMS (ESI): calcd for C_{20}H_{27}BrNaO_{2}^+ [M+Na]^+: 401.1087; found: 401.1039.
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2.1.4 Dienediol 16

Potassium carbonate (2.27 g, 16.4 mmol, 4.00 equiv) and \( \text{K}_3[\text{Fe(CN)}_6] \) (5.40 g, 16.4 mmol, 4.00 equiv) were ground to a fine powder in a mortar before adding Corey–Noe–Lin ligand\(^6\) 15 (93.4 mg, 82.0 µmol, 2.00 mol%), \( \text{K}_2\text{OsO}_4\cdot2\text{H}_2\text{O} \) (15.1 mg, 41.0 µmol, 1.00 mol%) and water (13 mL). After cooling the mixture to 0 °C, methanesulfonamide (390 mg, 4.10 mmol, 1 equiv) and a solution of alkene 14 (1.56 g, 4.10 mmol, 1 equiv) in tert-butanol (13 mL) were added. The biphasic suspension was sonicated at 0 °C for 15 min before stirring vigorously at 0 °C for 30 h.\(^2\) Sodium sulfite (5.17 g, 41.0 mmol, 10.0 equiv) was added and the slurry was allowed to reach 22 °C. After 30 min, 1 M aqueous solution of sodium hydroxide was added dropwise until all solids dissolved and the green mixture was extracted with ethyl acetate (4 x 100 mL). The combined organic layers were dried over sodium sulfate, the dried solution was filtered, and the filtrate concentrated. The residue was purified by flash column chromatography on silica gel (2% grading to 40% ethyl acetate in cyclohexane) yielding diol 16 (1.24 g, 3.00 mmol, 73%) as a yellowish oil along with starting material 14 (97.5 mg, 257 µmol, 6%).\(^3\)

Mosher ester analysis:

\(^2\) Without sonication the ligand often agglutinated leading to poor yields.
\(^3\) To avoid over-oxidation, the reaction was stopped prior to full conversion.
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To a mixture of (S)-α-methoxy-α-(trifluoromethyl)phenylacetic acid (S1) (32.5 mg, 139 µmol, 3.10 equiv) and N,N-dimethylpyridin-4-amine (17.0 mg, 139 µmol, 3.10 equiv) were added a solution of diol 16 (18.5 mg, 44.8 µmol, 1 equiv) in dry dichloromethane (1.0 mL) and dicyclohexylmethanediimine (28.6 mg, 139 µmol, 3.10 equiv) sequentially. After 18 h at 22 °C, the mixture was filtered through a plug of magnesium sulfate and the plug was washed with chloroform (5 mL). The filtrate was concentrated, and the residue purified by flash column chromatography on silica gel (20% ethyl acetate in pentane), yielding (S)-Mosher ester S2 (11.2 mg, 17.8 µmol, 40%) as a colorless oil. The enantiomeric ratio of the diol was determined by 1H NMR (400 MHz, Benzene-d₆) analysis of the corresponding mono-((S)-α-methoxy-α-(trifluoromethyl)phenylacetic acid esters. Comparison of the signals corresponding to the methyl group on the α-methoxy group of the ester δ 3.47 (q, J = 1.3 Hz) for the major (R)-enantiomer, δ 3.54 (q, J = 1.3 Hz) for the minor (S)-enantiomer revealed an enantiomeric ratio of 97:3, corresponding to an enantiomeric excess of 94%.7

To a mixture of (R)-α-methoxy-α-(trifluoromethyl)phenylacetic acid (S3) (17.6 mg, 75.0 µmol, 3.10 equiv) and N,N-dimethylpyridin-4-amine (9.16 mg, 75.0 µmol, 3.10 equiv) were added a solution of diol 16 (10.0 mg, 24.2 µmol, 1 equiv) in dry dichloromethane (0.50 mL) and dicyclohexylmethanediimine (15.5 mg, 75.0 µmol, 3.10 equiv) sequentially. After 27 h at 22 °C, the mixture was filtered through a plug of magnesium sulfate and the plug was washed with chloroform (5 mL). The filtrate was concentrated, and the residue purified by flash column chromatography on silica gel (10% ethyl acetate in pentane), yielding (R)-Mosher ester S4 (10.7 mg, 17.0 µmol, 70%) as a colorless oil. The enantiomeric ratio of the diol was determined by 1H NMR (400 MHz, Benzene-d₆) analysis of the corresponding mono-((R)-α-methoxy-α-(trifluoromethyl)phenylacetic acid esters. Comparison of the signals corresponding to the methyl group on the α-methoxy group of the ester: δ 3.54 (q, J = 1.3 Hz) for the major (R)-enantiomer, δ 3.47 (q, J = 1.3 Hz) for the minor (S)-enantiomer revealed an enantiomeric ratio of 97:3, corresponding to an enantiomeric excess of 94%.

Analytical data of dienediol 16:

TLC (50% ethyl acetate in pentane): Rf: 0.32.

1H NMR (400 MHz, Chloroform-d) δ 7.20 (t, J = 8.2 Hz, 1H), 6.61 (ddd, J = 8.3, 2.3, 0.8 Hz, 1H), 6.59 – 6.51 (m, 2H), 5.75 (s, 1H), 5.20 – 5.08 (m, 1H), 3.80 (s, 3H), 3.33 (dd, J = 10.5, 1.9 Hz, 1H), 2.30 – 2.15 (m, 5H), 1.95 – 1.99 (m, 2H), 1.92 (s, 1H), 1.62 – 1.53 (m, 4H), 1.39 (ddd, J = 13.9, 10.5, 8.7, 5.3 Hz, 1H), 1.20 (s, 3H), 1.15 (s, 3H).

13C NMR (101 MHz, Chloroform-d) δ 161.1, 156.2, 154.9, 136.8, 130.2, 123.1, 109.2, 108.4, 103.3, 92.1, 78.2, 73.2, 55.5, 36.8, 32.4, 29.8, 26.6, 25.1, 23.4, 16.1.

IR (ATR, neat) νmax: 3406 (br, w), 2927 (w), 1646 (w), 1602 (m), 1589 (m), 1488 (m), 1451 (m), 1382 (w), 1330 (w), 1261 (m), 1192 (m), 1165 (m), 1146 (s), 1076 (m), 1042 (m), 965 (m), 934 (w), 845 (w), 765 (m), 744 (m), 686 (m), 573 (w), 457 (w) cm⁻¹.

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HRMS (ESI): calcd for C_{20}H_{29}BrNaO_4^+ [M+Na]^+: 435.1141; found: 435.1145.

[\alpha]^0_D = +8.6 (c = 1.3, dichloromethane).

Analytical data of (S)-\(\alpha\)-methoxy-\(\alpha\)-(trifluoromethyl)phenylacetic acid ester S1:

TLC (20% ethyl acetate in pentane): R_f: 0.34.

\(^1\)H NMR (400 MHz, Benzene-\(d_6\)) \(\delta\) 7.83 – 7.75 (m, 2H), 7.14 – 7.09 (m, 2H), 7.08 – 7.03 (m, 1H), 6.99 (t, \(J = 8.2\) Hz, 1H), 6.69 (t, \(J = 2.3\) Hz, 1H), 6.59 (ddd, \(J = 8.2, 2.4, 0.9\) Hz, 1H), 6.48 (ddd, \(J = 8.4, 2.5, 0.9\) Hz, 1H), 5.52 (s, 1H), 5.09 – 5.02 (m, 2H), 3.47 (q, \(J = 1.3\) Hz, 3H), 3.25 (s, 3H), 2.12 – 1.96 (m, 6H), 1.71 (ddd, \(J = 14.4, 9.5, 7.4, 2.3\) Hz, 1H), 1.64 – 1.53 (m, 1H), 1.43 (d, \(J = 1.4\) Hz, 3H), 1.11 (s, 1H), 0.99 – 0.93 (m, 6H).

\(^1\)C NMR (101 MHz, Benzene-\(d_6\)) \(\delta\) 166.6, 161.7, 156.8, 155.0, 135.4, 132.9, 130.4, 129.8, 128.6, 128.0*, 124.2, 109.3, 108.7, 103.6, 92.6, 85.21 (d, \(J = 27.6\) Hz), 82.2, 72.0, 55.5, 54.9, 36.4, 32.3, 28.7, 25.9, 25.3, 25.1, 15.8. (The signal of the CF\(_3\)-group could not be detected; the signal marked with * overlapped with the solvent-peak, but could be assigned via the HSQC spectrum)

IR (ATR, neat) \(\tilde{\nu}_{\text{max}}\): 3536 (br, w), 2962 (w), 2935 (w), 2852 (w), 1743 (m), 1647 (w), 1604 (m), 1488 (m), 1451 (m), 1373 (w), 1261 (s), 1149 (s), 1018 (m), 924 (w), 845 (w), 765 (m), 716 (m), 688 (w) cm\(^{-1}\).

HRMS (ESI): calcd for C\(_{30}\)H\(_{36}\)BrO\(_6\)Na\(^+\) [M+Na]\(^+\): 651.1540; found: 651.1531.

[\alpha]^0_D = -10.5 (c = 0.75, dichloromethane).

Analytical data of (R)-\(\alpha\)-methoxy-\(\alpha\)-(trifluoromethyl)phenylacetic acid ester S4:

TLC (20% ethyl acetate in hexanes): R_f: 0.35.

\(^1\)H NMR (400 MHz, Benzene-\(d_6\)) \(\delta\) 7.86 (d, \(J = 7.8\) Hz, 2H), 7.15 – 7.11 (m, 2H), 7.09 – 7.04 (m, 1H), 6.99 (t, \(J = 8.2\) Hz, 1H), 6.69 (t, \(J = 2.4\) Hz, 1H), 6.58 (ddd, \(J = 8.1, 2.3, 0.9\) Hz, 1H), 6.48 (ddd, \(J = 8.3, 2.4, 0.9\) Hz, 1H), 5.52 (s, 1H), 5.05 – 4.94 (m, 2H), 3.54 (q, \(J = 1.3\) Hz, 3H), 3.25 (s, 3H), 2.10 – 1.98 (m, 4H), 1.88 (t, \(J = 7.7\) Hz, 2H), 1.56 – 1.42 (m, 2H), 1.38 (d, \(J = 1.3\) Hz, 3H), 1.14 (s, 1H), 1.02 (s, 3H), 0.93 (s, 3H).

\(^1\)C NMR (101 MHz, Benzene-\(d_6\)) \(\delta\) 167.2, 161.7, 156.8, 154.9, 135.4, 133.1, 130.4, 129.8, 128.6, 128.3*, 124.0, 109.3, 108.7, 103.6, 92.6, 85.37 (d, \(J = 27.2\) Hz), 82.0, 72.3, 55.6, 54.9, 36.1, 32.4, 28.8, 26.8, 25.2, 24.0, 15.8. (The signal of the CF\(_3\)-group could not be detected; the signal marked with * overlapped with the solvent-peak, but could be assigned via the HSQC spectrum)

IR (ATR, neat) \(\tilde{\nu}_{\text{max}}\): 3536 (br, w), 2962 (w), 2935 (w), 2852 (w), 1743 (m), 1647 (w), 1604 (m), 1488 (m), 1451 (m), 1373 (w), 1261 (s), 1149 (s), 1018 (m), 924 (w), 845 (w), 765 (m), 716 (m), 688 (w) cm\(^{-1}\).

HRMS (ESI): calcd for C\(_{30}\)H\(_{36}\)BrO\(_6\)Na\(^+\) [M+Na]\(^+\): 651.1540; found: 651.1526.

[\alpha]^0_D = +19.2 (c = 0.99, dichloromethane).
2.1.5  Epoxide fragment 17

To a solution of diol 16 (2.08 g, 5.03 mmol, 1 equiv) and dry pyridine (2.03 mL, 25.1 mmol, 5.00 equiv) in dry dichloromethane (20 mL) was added methanesulfonfyl chloride (584 µl, 7.54 mmol, 1.50 equiv) at 0 °C. The cooling bath was removed and the reaction mixture was allowed to warm to 22 °C. After 15.5 h, the solution was cooled to 0 °C, additional methanesulfonfyl chloride (118 µl, 1.51 mmol, 0.300 equiv) was added and the mixture was warmed to 22 °C. After 2.5 h, the mixture was concentrated, benzene (10 mL) was added to the residue and the solution was concentrated. Dry methanol (40 mL) and potassium carbonate (2.78 g, 20.1 mmol, 4.00 equiv) were added to the residue. After 17 h, the thick slurry was concentrated to about half of its volume. Water (30 mL) was added to the suspension and the mixture was extracted three times with dichloromethane (3 x 50 mL). The combined organic layers were dried over magnesium sulfate, the dried solution was filtered, and the filtrate was concentrated. The residue was purified by flash column chromatography on silica gel (5% ethyl acetate in cyclohexane) yielding epoxide 17 (1.60 g, 4.04 mmol, 80%) as a colorless oil.

TLC (20% ethyl acetate in cyclohexane): Rf: 0.50.

$^1$H NMR (400 MHz, Benzene-$d_6$) δ 7.08 (t, $J = 8.2$ Hz, 1H), 6.79 (t, $J = 2.3$ Hz, 1H), 6.68 (dq, $J = 8.2$, 0.9 Hz, 1H), 6.59 (ddd, $J = 8.3$, 2.4, 0.7 Hz, 1H), 5.55 (s, 1H), 5.20 – 4.96 (m, 1H), 3.35 (s, 3H), 2.62 (dd, $J = 6.7$, 5.6 Hz, 1H), 2.20 – 2.02 (m, 6H), 1.66 – 1.55 (m, 2H), 1.53 (d, $J = 1.0$ Hz, 3H), 1.25 (s, 3H), 1.19 (s, 3H).

$^{13}$C NMR (101 MHz, Benzene-$d_6$) δ 161.7, 156.8, 155.1, 136.1, 130.4, 123.3, 109.3, 108.7, 103.6, 92.4, 63.4, 57.4, 54.9, 36.8, 32.5, 27.9, 25.3, 25.0, 18.9, 16.0.

IR (ATR, neat) $\tilde{v}_{\text{max}}$: 3091 (w), 2960 (w), 2923 (w), 1646 (w), 1602 (m), 1590 (s), 1488 (s), 1452 (m), 1378 (w), 1262 (m), 1193 (m), 1166 (m), 1147 (s), 1079 (w), 1042 (m), 696 (w), 849 (w), 767 (m), 686 (w), 569 (w), 458 (w) cm$^{-1}$.

HRMS (ESI): calcd for C$_{20}$H$_{27}$BrKOs$^+$ [M+K]$^+$: 433.0775; found: 433.0772.

$[^{\alpha}]_{D}^0$ = -3.2 (c = 1.8, dichloromethane).

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$^4$ Methanesulfonfyl chloride was freshly distilled from P$_2$O$_5$ through a Vigreux column under a N$_2$ atmosphere.

$^5$ Potassium carbonate was ground to a fine powder in a mortar before use.
To a solution of iodide 18 (1.58 g, 8.08 mmol, 1.50 equiv) and 9-methoxy-9-borabicyclo[3.3.1]nonane (1.00 M in hexanes, 18.9 mL, 18.9 mmol, 3.50 equiv) in degassed dry tetrahydrofuran (75 mL) was added tert-butyllithium (1.70 M in pentane, 14.3 mL, 24.2 mmol, 4.50 equiv) dropwise at −78 °C. The solution turned yellow and then colorless.

After 60 min, the cooling bath was replaced by a water bath (22 °C) and the reaction mixture was warmed to 22 °C.

The reaction mixture was cooled to −78 °C after 5 min. A degassed 9:1 mixture of dimethylformamide and water (10 mL) was added to the clear solution. The cooling bath was replaced by a water bath (22 °C) and the reaction mixture was warmed to 22 °C.

A separate flask was charged with vinyl bromide 17 (2.13 g, 5.39 mmol, 1 equiv), caesium carbonate (3.51 g, 10.8 mmol, 2.00 equiv), 2-dicyclohexylphosphino-2′,6′-dimethoxybiphenyl (111 mg, 269 µmol, 5.00 mol%), chloro(2-dicyclohexylphosphino-2′,6′-dimethoxy-1,1′-biphenyl)[2-(2′-amino-1,1′-biphenyl)]palladium(II) (194 mg, 269 µmol, 5.00 mol%) and a degassed 9:1 mixture of dimethylformamide and water (136 mL). To the yellow suspension was added the preformed boronate-species via cannulation and the biphasic mixture was heated at 40 °C. After 6 h, water (75 mL) was added and the mixture was extracted with ethyl acetate (3 x 150 mL). The combined organic layers were washed with water (3 x 100 mL) and saturated aqueous solution of sodium chloride (100 mL). The solution was dried over magnesium sulfate, the dried solution filtered, and the filtrate concentrated. The residue was purified by flash column chromatography on silica gel (5% ethyl acetate in pentane) yielding cyclization precursor 9 (1.75 g, 4.55 mmol, 84%) as a colorless oil.

**TLC (10% ethyl acetate in hexanes): Rf: 0.46.**

**1H NMR** (400 MHz, Benzene-<d6>) δ 7.05 (t, J = 8.2 Hz, 1H), 6.75 (t, J = 2.3 Hz, 1H), 6.68 (ddd, J = 8.2, 2.3, 0.9 Hz, 1H), 6.48 (ddd, J = 8.3, 2.4, 0.9 Hz, 1H), 5.23 – 5.14 (m, 1H), 4.97 (t, J = 7.1 Hz, 1H), 4.86 – 4.71 (m, 2H), 3.31 (s, 3H), 2.54 (dd, J = 6.7, 5.7 Hz, 1H), 2.30 (q, J = 7.4 Hz, 2H), 2.26 – 2.16 (m, 4H), 2.15 – 1.97 (m, 4H), 1.62 – 1.46 (m, 8H), 1.14 (s, 3H), 1.09 (s, 3H).

**13C NMR** (101 MHz, Benzene-<d6>) δ 161.8, 158.6, 151.1, 145.2, 135.2, 130.4, 124.3, 116.0, 110.8, 108.7, 107.6, 102.9, 63.5, 57.4, 54.8, 37.8, 36.8, 32.9, 28.0, 25.9, 25.0, 23.8, 22.3, 18.9, 16.1.

**IR** (ATR, neat) ν<sub>max</sub>: 2959 (w), 2922 (w), 2852 (w), 1685 (w), 1649 (w), 1601 (m), 1591 (m), 1488 (m), 1452 (m), 1377 (w), 1327 (w), 1281 (m), 1263 (m), 1193 (m), 1165 (m), 1143 (s), 1078 (w), 1042 (m), 979 (w), 886 (m), 849 (w), 766 (m), 687 (m) cm<sup>−1</sup>.
HRMS (ESI): calcd for C_{25}H_{36}NaO_3^+ [M+Na]^+: 407.2557; found: 407.2560.

[α]_D^{20} = −2.1 (c = 1.7, dichloromethane).
To a solution of cyclization precursor 9 (100 mg, 260 µmol, 1 equiv) in dry dichloromethane (34 mL) was added SnCl₄ (100 mM in dichloromethane, 3.90 mL, 390 µmol, 1.50 equiv) dropwise over 130 sec at −78 °C. After 20 min, triethylamine (144 µl, 1.04 mmol, 4.00 equiv) was added to the yellow solution leading to decolorization and the reaction mixture was poured into 2 M aqueous solution of sodium hydroxide (34 mL). The aqueous layer was extracted with ethyl acetate (3 x 10 mL), and the combined organic layers were dried over magnesium sulfate. The dried solution was filtered, and the filtrate was concentrated. Purification of the residue by flash column chromatography on silica gel (7.5% grading to 10% ethyl acetate in pentane) yielded 58.5 mg of a mixture of tetracyclization products 8a, 8b, 8c and 8d along with other impurities. The mixture was separated by semipreparative normal-phase HPLC (1.5% grading to 2.5% i-propanol in n-hexane over 30 min) to yield 8a (15.8 mg, 41.1 µmol, 16%) as a colorless foam, 8b (10.2 mg, 26.5 µmol, 10%) as a colorless solid, a mixture of 8c with other impurities (12.8 mg) and a mixture of 8d with other impurities (19.4 mg).

To a solution of the impure fraction of 8c (12.8 mg, assuming 33.3 µmol, 1 equiv) in pyridine (890 µl) was sequentially added N,N-dimethylpyridin-4-amine (6.1 mg, 50 µmol, 1.5 equiv) and benzoyl chloride (7.7 µl, 67 µmol, 2.0 equiv) at 22 °C. After 29 h, the reaction mixture was concentrated, and the residue dissolved in ethyl acetate (10 mL). The solution was washed with 1 M aqueous solution of sodium hydroxide (5 mL), 1 M aqueous solution of hydrochloric acid (5 mL), saturated aqueous solution of sodium hydrogen carbonate (5 mL) and saturated aqueous solution of sodium chloride (5 mL). The solution was dried over magnesium sulfate, the dried solution was filtered, and the filtrate was concentrated. The residue was purified by flash column chromatography on silica gel (2% ethyl acetate in pentane) yielding diastereomer 19 (10.9 mg, 22.3 µmol, 9% over 2 steps) as a colorless solid.

To a solution of the impure fraction of 8d (19.4 mg, assuming 50.4 µmol, 1 equiv) in pyridine (1.35 mL) was sequentially added N,N-dimethylpyridin-4-amine (9.2 mg, 76 µmol, 1.5 equiv) and benzoyl chloride (12 µl, 0.10 mmol, 2.0 equiv) at 22 °C. After 27 h, the reaction mixture...
was concentrated and the residue was dissolved in ethyl acetate (10 mL). The solution was washed with 1 M aqueous solution of sodium hydroxide (5 mL), 1 M aqueous solution of hydrochloric acid (5 mL), saturated aqueous solution of sodium hydrogen carbonate (5 mL) and saturated aqueous solution of sodium chloride (5 mL). The solution was dried over magnesium sulfate, the dried solution was filtered, and the filtrate was concentrated. The residue was purified by flash column chromatography on silica gel (2% ethyl acetate in pentane) yielding diastereomer 20 (15.1 mg, 30.9 µmol, 12% over 2 steps) as a colorless oil.

Crystals suitable for X-RAY analysis were obtained by:
- **8a**: Recrystallisation from hot acetonitrile gave colorless crystals
- **8b**: Sublimation at 215 °C under N₂ atmosphere gave colorless crystals
- **19**: Slow evaporation of a solution in a 1:1 mixture of pentane and diethyl ether gave colorless crystals
- All attempts to crystallize 8d or 20 failed

**Cyclization with FeCl₃**

To a suspension of iron(III) chloride (84.4 mg, 520 µmol, 2.00 equiv) in dry dichloromethane (17 mL), cyclization precursor 9 (100 mg, 260 µmol, 1 equiv) in dry dichloromethane (17 mL) was added over 120 sec at −50 °C. The reaction mixture was slowly warmed to −20 °C over 2 h within the Dewar vessel by switching off the electronically regulated cryostat. Triethylamine (162 µl, 1.17 mmol, 4.50 equiv) was added to the orange suspension leading to a color change to yellow. The reaction mixture was poured into 1 M aqueous solution of sodium hydroxide (34 mL). The aqueous layer was extracted with dichloromethane (4 x 50 mL), and the combined organic layers were dried over magnesium sulfate. The dried solution was filtered, and the filtrate was concentrated. Purification of the residue by flash column chromatography on silica gel (10% ethyl acetate in pentane) yielded a mixture of tetracyclization products 8a, 8b, 8c and 8d along with other impurities. From the mixture the desired isomers 8a and 8b were separated by preparative normal-phase HPLC (1.0% grading to 2.0% i-propanol in n-hexane over 120 min) to yield 8a (12.5 mg, 32.5 µmol, 13%) as a colorless foam, 8b (13.1 mg, 34.1 µmol, 13%) as a colorless solid, a mixture of 8c with other impurities (14.8 mg) and a mixture of 8d with other impurities (18.6 mg).

**Large-Scale cyclization:**

To a solution of cyclization precursor 9 (742 mg, 1.93 mmol, 1 equiv) in dry dichloromethane (276 mL) in a 1-L round bottom flask equipped with a 40-mm olive-shaped magnetic stirring
bar was added SnCl₄ (100 mM in dichloromethane, 28.9 mL, 2.89 mmol, 1.50 equiv) via syringe pump (60 mL/h) at −78 °C under vigorous stirring (600 rpm). After the addition was complete, the solution was stirred for 20 min before triethylamine (1.20 mL, 8.68 mmol, 4.50 equiv) was added dropwise to the orange solution leading to decolorization. The reaction mixture was poured into 1 M aqueous solution of sodium hydroxide (280 mL). The aqueous layer was extracted with dichloromethane (2 x 400 mL) and the combined organic layers were dried over magnesium sulfate. The dried solution was filtered, and the filtrate was concentrated. The residue was purified by flash column chromatography on silica gel (3% grading to 7.5% ethyl acetate in pentane) yielding a mixture of tetracyclization products 8a, 8b, 8c and 8d along with other impurities. From the mixture the desired isomers 8a and 8b were isolated by preparative normal-phase HPLC (1.0% grading to 2.0% i-propanol in n-hexane over 120 min) yielding 8a (139 mg, 85% purity by NMR, 305 µmol, 16%) as mixture with other diastereomers, which could be further purified by recrystallization from refluxing acetonitrile (1 mL) to give clean pentacyclic product 8a (86.0 mg, 224 µmol, 12%). The regioisomer 8b was obtained as a mixture with other impurities (92.2 mg), which was used for the next step, after which the impurities could be removed by flash column chromatography on silica gel.

To a solution of impure 8b (92.2 mg, assuming 240 µmol, 1 equiv) in dry dimethylformamide (4.6 mL) was added a mixture of ethanethiol (36 µl, 480 µmol, 2.0 equiv) and sodium hydride (19 mg, 60% dispersion in mineral oil, 0.48 mmol, 2.0 equiv) in dimethylformamide (1.0 mL) and heated at 120 °C. After 9.5 h, a mixture of ethanethiol (36 µl, 480 µmol, 2.0 equiv) and sodium hydride (19 mg, 60% dispersion in mineral oil, 0.48 mmol, 2.0 equiv) in dimethylformamide (1.0 mL) was added. After 24 h, saturated aqueous solution of ammonium chloride (5 mL) was added to the reaction mixture. Water was added dropwise to the suspension until all solids dissolved. The mixture was extracted with ethyl acetate (3 x 10 mL) and the combined organic layers were washed with water (2 x 10 mL) and saturated aqueous solution of sodium chloride (10 mL). The solution was dried over magnesium sulfate, the dried solution was filtered and the filtrate was concentrated. The residue was purified by flash column chromatography on silica gel (15% grading to 20% ethyl acetate in pentane) yielding phenol 21b (71.7 mg, 194 µmol, 10% over 2 steps) as a colorless wax.

**Analytical data of pentacyle 8a**

**TLC** (20% ethyl acetate in cyclohexane): Rᵣ: 0.30.

**mp:** 173 °C.

**¹H NMR** (600 MHz, Chloroform-d) δ 7.02 (d, J = 8.5 Hz, 1H), 6.40 (dd, J = 8.5, 2.6 Hz, 1H), 6.32 (d, J = 2.6 Hz, 1H), 3.76 (s, 3H), 3.22 (dt, J = 11.5, 5.6 Hz, 1H), 1.93 – 1.82 (m, 2H), 1.67 (dd, J = 12.9, 2.8 Hz, 1H), 1.66 – 1.54 (m, 5H), 1.45 (tdd, J = 12.2, 7.2, 4.2 Hz, 3H), 1.40 (d, J = 12.7 Hz, 1H), 1.31 (s, 3H), 1.27 (d, J = 6.2 Hz, 1H), 1.13 (qd, J = 13.4, 12.2, 2.7 Hz, 1H), 1.08 – 1.02 (m, 4H), 1.01 – 0.95 (m, 4H), 0.90 (dd, J = 12.2, 2.3 Hz, 1H), 0.88 (s, 3H).

**¹³C NMR** (151 MHz, Chloroform-d) δ 159.2, 156.6, 125.4, 122.1, 105.8, 100.1, 79.2, 76.1, 57.7, 55.7, 55.4, 46.6, 42.0, 40.8, 39.2, 37.8, 37.3, 32.6, 28.5, 27.5, 26.9, 19.2, 18.0, 15.8, 15.2.

**IR** (ATR, neat) ν_max: 3402 (br, w), 2929 (s), 2869 (m), 2848 (m), 1738 (w), 1617 (m), 1582 (m), 1502 (s), 1442 (m), 1387 (w), 1319 (m), 1259 (m), 1202 (m), 1189 (m), 1162 (s), 1151 (s), 1151 (m), 1039 (m), 1004 (m), 984 (m), 935 (w), 882 (w), 831 (w), 786 (w), 729 (w), 633 (w), 468 (w), 445 (w) cm⁻¹.

**HRMS** (ESI): calcd for C₂₅H₃₆NaO₃⁺ [M+Na]⁺: 407.2557; found: 407.2546.

[α]_D^{20} = −11.1 (c = 0.41, dichloromethane).
Analytical data of pentacycle 8b:

**TLC** (20% ethyl acetate in cyclohexane): Rf: 0.33.

**mp**: 211–219 °C: sublimation and decomposition.

**1H NMR** (400 MHz, Chloroform-\(d\)) \(\delta\) 7.00 (t, \(J = 8.2\) Hz, 1H), 6.41 (dd, \(J = 8.2, 1.1\) Hz, 1H), 6.36 (dd, \(J = 8.1, 1.1\) Hz, 1H), 3.75 (s, 3H), 3.21 (dd, \(J = 10.3, 5.5\) Hz, 1H), 1.99 – 1.93 (m, 1H), 1.90 – 1.81 (m, 2H), 1.74 (dd, \(J = 13.0, 2.8\) Hz, 1H), 1.63 – 1.55 (m, 4H), 1.49 – 1.44 (m, 4H), 1.44 – 1.38 (m, 1H), 1.34 – 1.29 (m, 2H), 1.11 – 1.01 (m, 5H), 1.01 – 0.95 (m, 1H), 0.93 – 0.88 (m, 4H), 0.86 (s, 3H).

**13C NMR** (101 MHz, Chloroform-\(d\)) \(\delta\) 158.9, 157.3, 127.1, 117.5, 108.9, 102.6, 79.2, 75.1, 57.5, 55.7, 48.7, 40.9, 39.1, 38.5, 37.7, 37.3, 33.2, 28.5, 27.6, 27.4, 19.8, 17.9, 15.7, 15.1.

**IR** (ATR, neat) \(\tilde{\nu}_{\text{max}}\): 3401 (br, w), 2928 (m), 2869 (w), 2839 (w), 1599 (m), 1583 (m), 1464 (m), 1437 (m), 1387 (w), 1310 (w), 1264 (m), 1240 (m), 1190 (m), 1127 (w), 1087 (s), 1029 (m), 939 (w), 910 (w), 888 (w), 783 (m), 733 (w), 576 (w) cm\(^{-1}\).

**HRMS** (ESI): calcd for C\(_{25}\)H\(_{36}\)NaO\(_3\)\([\text{M}+\text{Na}]^+\): 407.2557; found: 407.2546.

\([\alpha]_D^{20} = -48.9\) (c = 0.92, dichloromethane).

Analytical data of diastereomer 19

**TLC** (20% ethyl acetate in cyclohexane): Rf: 0.79.

**mp**: 196–198 °C.

**1H NMR** (600 MHz, Chloroform-\(d\)) \(\delta\) 8.04 (dd, \(J = 8.2, 1.5\) Hz, 2H), 7.55 (t, \(J = 7.4\) Hz, 1H), 7.44 (t, \(J = 7.8\) Hz, 2H), 7.04 (t, \(J = 8.2\) Hz, 1H), 6.47 – 6.39 (m, 2H), 4.72 (dd, \(J = 10.6, 5.4\) Hz, 1H), 3.81 (s, 3H), 2.25 (dt, \(J = 14.5, 4.2\) Hz, 1H), 1.96 (ddd, \(J = 13.5, 10.4, 7.4\) Hz, 1H), 1.82 – 1.71 (m, 3H), 1.70 – 1.59 (m, 4H), 1.58 – 1.52 (m, 4H), 1.42 (s, 3H), 1.21 – 1.16 (m, 2H), 1.13 – 1.08 (m, 4H), 1.07 (s, 3H), 0.99 (s, 3H).

**13C NMR** (151 MHz, Chloroform-\(d\)) \(\delta\) 166.4, 158.8, 154.7, 132.9, 131.1, 129.7, 128.5, 127.3, 122.7, 110.8, 103.1, 81.9, 76.8, 55.3, 48.1, 48.0, 47.2, 38.6, 37.4, 36.4, 36.4, 36.3, 30.8, 28.9, 28.5, 24.0, 24.0, 19.5, 18.4, 17.6.

**IR** (ATR, neat) \(\tilde{\nu}_{\text{max}}\): 2950 (m), 2930 (m), 2866 (w), 1784 (w), 1715 (s), 1600 (w), 1580 (w), 1466 (m), 1450 (m), 1392 (w), 1365 (w), 1342 (w), 1314 (m), 1273 (s), 1221 (w), 1170 (w), 1113 (m), 1085 (w), 1026 (w), 970 (w), 929 (w), 891 (w), 856 (w), 784 (w), 761 (w), 712 (m) cm\(^{-1}\).

**HRMS** (ESI): calcd for C\(_{32}\)H\(_{40}\)NaO\(_4\)\([\text{M}+\text{Na}]^+\): 511.2819; found: 511.2800.

\([\alpha]_D^{20} = +52.4\) (c = 0.40, dichloromethane).

Analytical data of diastereomer 20

**TLC** (20% ethyl acetate in cyclohexane): Rf: 0.76.

**1H NMR** (400 MHz, Chloroform-\(d\)) \(\delta\) 8.07 – 8.03 (m, 2H), 7.59 – 7.53 (m, 1H), 7.45 (t, \(J = 7.6\) Hz, 2H), 7.12 (d, \(J = 8.5\) Hz, 1H), 6.47 (dd, \(J = 8.6, 2.6\) Hz, 1H), 6.31 (d, \(J = 2.6\) Hz,
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$^1$H NMR (400 MHz, Chloroform-\textit{d}) $\delta$ 6.86 (t, $J = 8.0$ Hz, 1H), 6.32 (dd, $J = 8.2, 1.2$ Hz, 1H), 6.17 (dd, $J = 8.0, 1.2$ Hz, 1H), 4.80 (s, 1H), 3.23 – 3.13 (m, 1H), 1.99 – 1.92 (m, 1H), 1.90 – 1.79 (m, 2H), 1.72 (dd, $J = 13.0, 2.8$ Hz, 1H), 1.63 – 1.55 (m, 4H), 1.52 – 1.40 (m, 5H), 1.39 – 1.30 (m, 3H), 1.10 – 0.96 (m, 6H), 0.93 – 0.89 (m, 4H), 0.83 (s, 3H).

$^{13}$C NMR (101 MHz, Chloroform-\textit{d}) $\delta$ 166.5, 159.2, 154.7, 132.9, 131.0, 129.7, 128.5, 126.0, 106.8, 101.6, 81.1, 77.9, 55.4, 49.9, 47.5, 44.7, 39.5, 38.9, 38.1, 37.7, 33.4, 28.6, 27.9, 27.7, 20.0, 18.3, 15.9, 15.3.

IR (ATR, neat) $\tilde{\nu}_{\text{max}}$: 3551 (w), 3238 (br, w), 3000 (w), 2941 (m), 2926 (m), 2871 (m), 2846 (m), 1606 (w), 1589 (m), 1454 (s), 1380 (w), 1349 (w), 1285 (m), 1243 (m), 1226 (w), 1204 (w), 1186 (m), 1126 (w), 1094 (w), 1066 (w), 1023 (s), 977 (w), 960 (w), 938 (w), 909 (m), 889 (w), 852 (w), 786 (m), 734 (s), 649 (w), 576 (w), 504 (w) cm$^{-1}$.

HRMS (ESI): calcd for C$_{26}$H$_{40}$NaO$_4$ $^{+}$ [M+Na]$^+$: 511.2819; found: 511.2804.

$[\alpha]_D^{20} = +52.8$ (c = 1.0, dichloromethane).

Analytical data of phenol 21b

TLC (20% ethyl acetate in cyclohexane): $R_f$: 0.53.

$^1$H NMR (400 MHz, Dichloromethane-\textit{d$_2$}) $\delta$ 6.86 (t, $J = 8.0$ Hz, 1H), 6.32 (dd, $J = 8.2, 1.2$ Hz, 1H), 6.17 (dd, $J = 8.0, 1.2$ Hz, 1H), 4.80 (s, 1H), 3.23 – 3.13 (m, 1H), 1.99 – 1.92 (m, 1H), 1.90 – 1.79 (m, 2H), 1.72 (dd, $J = 13.0, 2.8$ Hz, 1H), 1.63 – 1.55 (m, 4H), 1.52 – 1.40 (m, 5H), 1.39 – 1.30 (m, 3H), 1.10 – 0.96 (m, 6H), 0.93 – 0.89 (m, 4H), 0.83 (s, 3H).

$^{13}$C NMR (101 MHz, Dichloromethane-\textit{d$_2$}) $\delta$ 158.3, 155.2, 127.5, 116.4, 108.6, 107.5, 79.3, 75.7, 57.7, 56.0, 48.8, 41.2, 39.5, 38.9, 38.1, 37.7, 33.4, 28.6, 27.9, 27.7, 20.0, 18.3, 15.9, 15.3.

IR (ATR, neat) $\tilde{\nu}_{\text{max}}$: 3551 (w), 3238 (br, w), 3000 (w), 2941 (m), 2926 (m), 2871 (m), 2846 (m), 1606 (w), 1589 (m), 1454 (s), 1380 (w), 1349 (w), 1285 (m), 1243 (m), 1226 (w), 1204 (w), 1186 (m), 1126 (w), 1094 (w), 1066 (w), 1023 (s), 977 (w), 960 (w), 938 (w), 909 (m), 889 (w), 852 (w), 786 (m), 734 (s), 649 (w), 576 (w), 504 (w) cm$^{-1}$.

HRMS (ESI): calcd for C$_{24}$H$_{35}$O$_3$ $^{+}$ [M+H]$^+$: 371.2581; found: 371.2573.

$[\alpha]_D^{20} = -44.8$ (c = 0.47, dichloromethane).
To cyclization product 8a (83.0 mg, 216 μmol, 1 equiv) was added a mixture of ethanethiol (78 μl, 1.1 mmol, 5.0 equiv) and sodium hydride (43 mg, 60% dispersion in mineral oil, 1.1 mmol, 5.0 equiv) in dry dimethylformamide (4.3 mL) and the suspension was heated at 120 °C. After 16 h, a mixture of ethanethiol (78 μl, 1.1 mmol, 5.0 equiv) and sodium hydride (43 mg, 60% dispersion in mineral oil, 1.1 mmol, 5.0 equiv) in dry dimethylformamide (4.3 mL) was added. The mixture was heated at 120 °C for 21 h before saturated aqueous solution of ammonium chloride (20 mL) was added. Water was added dropwise until all solids dissolved and the mixture was extracted with ethyl acetate (3 x 20 mL). The combined organic layers were washed with water (3 x 10 mL) and saturated aqueous solution of sodium chloride (10 mL) and dried over magnesium sulfate. The dried solution was filtered, and the filtrate was concentrated. Purification of the residue by flash column chromatography on silica gel (20% grading to 30% ethyl acetate in pentane) afforded phenol 21a (75.2 mg, 203 μmol, 94%) as a colorless foam.

**TLC** (40% ethyl acetate in cyclohexane): Rf: 0.57.

**mp:** 194–196 °C.

**1H NMR** (400 MHz, Chloroform-d) δ 6.97 (d, J = 8.3 Hz, 1H), 6.32 (dd, J = 8.3, 2.6 Hz, 1H), 6.25 (d, J = 2.5 Hz, 1H), 5.12 (s, 1H), 3.25 (dd, J = 10.5, 5.3 Hz, 1H), 1.94 – 1.78 (m, 2H), 1.70 – 1.51 (m, 7H), 1.48 – 1.37 (m, 4H), 1.29 (s, 3H), 1.19 – 1.08 (m, 1H), 1.07 – 1.01 (m, 4H), 1.01 – 0.92 (m, 4H), 0.92 – 0.86 (m, 4H).

**13C NMR** (101 MHz, Chloroform-d) δ 156.7, 154.9, 125.7, 122.3, 106.6, 101.8, 79.2, 76.1, 57.6, 55.6, 46.4, 42.0, 40.7, 39.1, 37.8, 37.3, 32.6, 28.5, 27.4, 26.9, 19.1, 17.9, 15.8, 15.1.

**IR** (ATR, neat) $\tilde{\nu}_{max}$: 3368 (br, m), 2944 (s), 2871 (m), 1721 (m), 1619 (m), 1593 (m), 1504 (s), 1455 (s), 1374 (m), 1286 (m), 1258 (m), 1166 (s), 1145 (s), 1102 (m), 1068 (w), 1029 (m), 1005 (s), 988 (m), 963 (w), 935 (w), 883 (w), 844 (w), 799 (w), 747 (w), 632 (w), 613 (w), 509 (w), 418 (w) cm$^{-1}$.

**HRMS** (ESI): calcd for C₂₄H₃₅O₃$^{+}$ [M+H]$^{+}$: 371.2581; found: 371.2577.

$[\alpha]_{D}^{20}$ = −11.6 (c = 1.0, dichloromethane).
2.1.9 Phenol 21b

To cyclization product 8b (36.8 mg, 95.7 µmol, 1 equiv) was added a mixture of ethanethiol (14 µl, 0.19 mmol, 2.0 equiv) and sodium hydride (7.7 mg, 60% dispersion in mineral oil, 0.19 mmol, 2.0 equiv) in dry dimethylformamide (1.8 mL) and heated at 120 °C. After 20 h, a mixture of ethanethiol (7.1 µl, 96 µmol, 1.0 equiv) and sodium hydride (3.8 mg, 60% dispersion in mineral oil, 96 µmol, 1.0 equiv) in dry dimethylformamide (900 µL) was added. After 7 h at 120 °C, saturated aqueous solution of ammonium chloride (1 mL) was added. Water was added dropwise until all solids dissolved. The mixture was extracted with ethyl acetate (3 x 15 mL) and the combined organic layers were washed with water (10 mL) and saturated aqueous solution of sodium chloride (10 mL) and the washed solution dried over magnesium sulfate. The dried solution was filtered and the filtrate was concentrated. Flash column chromatography on silica gel (10% ethyl acetate in pentane) of the residue yielded phenol 21b (29.9 mg, 80.7 µmol, 84%) as a colorless wax.

Compare chapter 2.1.7 for analytical data
2.1.10 Protected pentacycle 22a

To a solution of phenol 21a (81.6 mg, 220 µmol, 1 equiv) in dry dichloromethane were sequentially added N,N-dimethylpyridin-4-amine (26.9 mg, 220 µmol, 1.00 equiv), acetic anhydride (62 µl, 0.66 mmol, 3.0 equiv) and pyridine (89 µl, 1.1 mmol, 5.0 equiv) at 22 °C. After 2 h, the mixture was concentrated and dry benzene (3 mL) was added to the residue. The mixture was concentrated before dry tetrahydrofuran (4.9 mL) and potassium tert-butoxide (906 mM in tert-butanol, 972 µl, 881 µmol, 4.00 equiv) were sequentially added to the residue at 22 °C sequentially. After 20 min, potassium tert-butoxide (906 mM in tert-butanol, 49 µl, 44 µmol, 0.20 equiv) was added. After 10 min, saturated aqueous solution of ammonium chloride (5 mL) was added and the mixture was extracted with ethyl acetate (3 x 10 mL). The combined organic layers were dried over magnesium sulfate, the dried solution was filtered and the filtrate was concentrated. The residue was purified by flash column chromatography on silica gel (7.5% grading to 10% ethyl acetate in pentane) yielding phenol 22a (77.2 mg, 187 µmol, 85%) as a colorless oil.

TLC (20% ethyl acetate in cyclohexane): Rf: 0.42.

1H NMR (400 MHz, Chloroform-d) δ 6.98 (d, J = 8.3 Hz, 1H), 6.32 (dd, J = 8.3, 2.6 Hz, 1H), 6.24 (d, J = 2.6 Hz, 1H), 4.65 (s, 1H), 4.50 (dd, J = 8.9, 7.1 Hz, 1H), 2.06 (s, 3H), 1.93 – 1.78 (m, 2H), 1.68 – 1.60 (m, 4H), 1.59 – 1.53 (m, 2H), 1.49 – 1.38 (m, 4H), 1.30 (s, 3H), 1.19 – 1.01 (m, 3H), 1.00 – 0.96 (m, 4H), 0.94 (s, 3H), 0.90 (s, 3H).

13C NMR (101 MHz, Chloroform-d) δ 171.3, 156.6, 154.9, 125.7, 122.4, 106.6, 101.8, 81.1, 76.0, 57.5, 55.7, 46.4, 41.9, 40.6, 38.0, 37.4, 37.2, 32.5, 28.5, 26.9, 23.7, 21.5, 19.1, 17.8, 16.9, 15.2.

IR (ATR, neat) νmax: 3396 (br, w), 2947 (m), 2873 (w), 2845 (w), 1705 (m), 1618 (m), 1593 (w), 1504 (m), 1450 (m), 1375 (m), 1248 (s), 1210 (m), 1167 (m), 1142 (s), 1103 (m), 1068 (w), 1014 (m), 988 (s), 907 (s), 883 (w), 844 (m), 800 (w), 729 (s), 648 (w), 558 (w), 511 (w) cm⁻¹.

HRMS (ESI): calcd for C26H36O4Na⁺ [M+Na⁺]: 435.2506; found: 435.2491.

[α]D 20 = +2.1 (c = 0.62, dichloromethane).
To a solution of phenol 21b (71.7 mg, 194 µmol, 1 equiv) in dry dichloromethane was added N,N-dimethylpyridin-4-amine (23.6 mg, 194 µmol, 1 equiv), acetic anhydride (55 µl, 0.58 mmol, 3.0 equiv) and pyridine (78 µl, 0.97 mmol, 5.0 equiv) at 22 °C. After 2 h, the mixture was concentrated and dry benzene (3 mL) was added to the residue. The mixture was concentrated again before dry tetrahydrofuran (4.3 mL) and potassium tert-butoxide (907 µl, 774 µmol, 4.00 equiv) were added to the residue at 22 °C. After 4 h, saturated aqueous solution of ammonium chloride (5 mL) was added and the mixture was extracted with ethyl acetate (3 x 10 mL). The combined organic layers were dried over magnesium sulfate, the dried solution was filtered, and the filtrate concentrated. The residue was purified by flash column chromatography on silica gel (10% ethyl acetate in pentane) yielding phenol 22b (60.0 mg, 145 µmol, 75%) as a yellow wax.

**TLC** (10% ethyl acetate in hexanes): Rf: 0.24.

**1H NMR** (400 MHz, Chloroform-d) δ 6.89 (t, J = 8.0 Hz, 1H), 6.36 (dd, J = 8.2, 1.2 Hz, 1H), 6.17 (dd, J = 7.9, 1.2 Hz, 1H), 4.75 (s, 1H), 4.53 – 4.45 (m, 1H), 2.06 (s, 3H), 1.98 (dt, J = 13.0, 3.1 Hz, 1H), 1.93 – 1.81 (m, 2H), 1.76 (dd, J = 13.0, 2.8 Hz, 1H), 1.67 – 1.55 (m, 4H), 1.54 (s, 3H), 1.50 – 1.39 (m, 2H), 1.39 – 1.31 (m, 2H), 1.16 – 1.02 (m, 3H), 1.01 – 0.95 (m, 4H), 0.93 (s, 3H), 0.90 (s, 3H).

**13C NMR** (101 MHz, Chloroform-d) δ 171.3, 157.8, 154.6, 127.2, 116.0, 108.4, 107.2, 81.1, 75.2, 57.3, 55.8, 48.4, 40.7, 38.5, 38.1, 37.4, 37.2, 33.1, 28.4, 27.4, 23.7, 21.5, 19.7, 17.8, 16.9, 15.1.

**IR** (ATR, neat) νmax: 3432 (br, w), 2925 (s), 2871 (m), 1732 (m), 1709 (s), 1608 (w), 1588 (m), 1456 (s), 1375 (m), 1320 (w), 1308 (w), 1267 (s), 1246 (s), 1203 (w), 1188 (m), 1144 (w), 1125 (w), 1088 (w), 1067 (m), 1033 (s), 1011 (m), 978 (m), 948 (w), 906 (w), 889 (w), 852 (w), 785 (m), 734 (m), 658 (w), 610 (w), 576 (w) cm⁻¹.

**HRMS** (ESI): calcd for C_{26}H_{37}O_{4}: [M+H]^+: 413.2686; found: 413.2642.

\[\alpha\]_D^0 = −35.2 (c = 0.39, dichloromethane).
2.1.12 Ketolactone 23

To a solution of phenol 22a (63.8 mg, 155 µmol, 1 equiv) in ethyl acetate (6.5 mL) was added KMnO₄ (489 mg, 3.09 mmol, 20.0 equiv) and water (13 mL). The mixture was heated at 70 °C and a solution of KMnO₄ (258 mM in water, 12.0 mL, 3.10 mmol, 20.0 equiv) was added via syringe pump (500 µl/h). After 24 h, saturated aqueous solution of sodium thiosulfate (16 mL) was added and the suspension was filtered. The filter cake was washed with water (5 mL) and ethyl acetate (5 mL). The aqueous layer of the filtrate was extracted with ethyl acetate (4 x 20 mL) and the combined organic layers were washed with saturated aqueous solution of sodium chloride (20 mL) and the washed solution was dried over sodium sulfate. The dried solution was filtered and the filtrate was concentrated. The residue was purified by flash column chromatography on silica gel (15% grading to 25% ethyl acetate in pentane) yielding ketolactone 23 (22.0 mg, 58.4 µmol, 38%) and lactone 24 (3.7 mg, 11 µmol, 7%) as colorless solids.

To a solution of phenol 22b (60.0 mg, 145 µmol, 1 equiv) in ethyl acetate (6.1 mL) was added KMnO₄ (460 mg, 2.91 mmol, 20.0 equiv) and water (12 mL). The mixture was heated at 70 °C and a solution of KMnO₄ (242 mM in water, 24.0 mL, 5.80 mmol, 40.0 equiv) was added via syringe pump (500 µl/h). After 48 h, saturated aqueous solution of sodium thiosulfate (30 mL) was added and the suspension was filtered. The filter cake was washed with water (10 mL) and ethyl acetate (10 mL). The aqueous layer of the filtrate was extracted with ethyl acetate (4 x 50 mL) and the combined organic layers were washed with saturated aqueous solution of sodium chloride (50 mL) and the washed solution was dried over sodium sulfate. The dried solution was filtered and the filtrate was concentrated. The residue was purified by flash column chromatography on silica gel (15% grading to 25% ethyl acetate in pentane) yielding ketolactone 23 (11.1 mg, 29.5 µmol, 20%) and lactone 24 (3.6 mg, 10 µmol, 7%) as colorless solids.

Analytical data of ketolactone 23

TLC (40% ethyl acetate in pentane): Rₓ: 0.61.

mp: decomposition above 191 °C.

¹H NMR (400 MHz, Chloroform-d) δ 4.48 (dd, J = 11.1, 4.7 Hz, 1H), 2.05 (s, 4H), 1.86 (dd, J = 11.5, 2.9 Hz, 1H), 1.80 – 1.72 (m, 2H), 1.70 – 1.55 (m, 7H), 1.53 – 1.40 (m, 2H), 1.17 (s, 4H), 1.12 – 1.04 (m, 1H), 1.00 (s, 3H), 0.96 – 0.91 (m, 4H), 0.89 (s, 3H).
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$^{13}$C NMR (101 MHz, Chloroform-$d$) δ 180.5, 171.2, 83.2, 80.8, 54.5, 52.5, 51.6, 43.9, 37.9, 37.6, 37.4, 36.7, 34.2, 28.7, 23.5, 21.5, 20.6, 19.6, 18.7, 17.2, 14.9.

IR (ATR, neat) $\tilde{\nu}_{\text{max}}$: 2923 (s), 2874 (w), 2851 (w), 1733 (s), 1456 (w), 1373 (w), 1246 (s), 1204 (w), 1171 (w), 1149 (w), 1085 (w), 1029 (w), 1010 (w), 982 (w), 949 (w), 927 (w), 899 (w) cm$^{-1}$.

HRMS (ESI): calcd for C$_{22}$H$_{32}$O$_{5}$Na$^+$ [M+Na$^+$]: 399.2142; found: 399.2121.

$[\alpha]_D^{20} = -1.6$ (c = 0.50, dichloromethane).

Analytical data of lactone 24

TLC (20% ethyl acetate in pentane): R$_f$: 0.47.

mp: 186–188 °C.

$^1$H NMR (400 MHz, Chloroform-$d$) δ 4.49 (dd, $J = 11.2, 4.8$ Hz, 1H), 2.22 (dd, $J = 14.4, 2.6$ Hz, 1H), 2.12 – 2.05 (m, 4H), 2.03 – 1.95 (m, 1H), 1.89 – 1.74 (m, 3H), 1.72 – 1.50 (m, 6H), 1.40 – 1.28 (m, 2H), 1.15 (s, 3H), 1.13 – 1.05 (m, 1H), 1.04 – 0.97 (m, 4H), 0.93 – 0.88 (m, 6H).

$^{13}$C NMR (101 MHz, Chloroform-$d$) δ 194.9, 171.2, 156.3, 83.1, 80.5, 55.1, 54.7, 46.0, 44.3, 40.1, 38.2, 38.0, 37.3, 37.1, 28.4, 23.5, 23.2, 21.4, 18.7, 17.5, 16.9, 15.0.

IR (ATR, neat) $\tilde{\nu}_{\text{max}}$: 2947 (m), 2927 (m), 2874 (m), 2857 (w), 1773 (s), 1732 (s), 1457 (m), 1395 (w), 1375 (m), 1366 (m), 1252 (s), 1245 (2), 1220 (m), 1208 (w), 1148 (m), 1128 (w), 1077 (m), 1028 (m), 1008 (m), 979 (w), 948 (w), 916 (w), 901 (w) cm$^{-1}$.

HRMS (ESI): calcd for C$_{21}$H$_{32}$O$_{4}$Na$^+$ [M+Na$^+$]: 371.2193; found: 371.2166.

$[\alpha]_D^{20} = +4$ (c = 0.15, dichloromethane).
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2.1.13 Tetraol 25

To a solution of keto lactone 23 (22.4 mg, 59.5 µmol, 1 equiv) in dry toluene (2.8 mL) was added sodium bis(2-methoxyethoxy)aluminium hydride (60 wt% in toluene, 0.39 mL, 1.2 mmol, 20 equiv) at 0 °C. The cooling bath was removed, and the reaction mixture was allowed to warm to 22 °C. After 14 h, the mixture was heated at 80 °C for 2 h before ethyl acetate (50 µl) was added dropwise at –78 °C. The reaction mixture was warmed to 22 °C, treated with 2 M aqueous solution of sodium hydroxide (5 mL) and extracted with ethyl acetate (4 x 10 mL). The combined organic layers were dried over sodium sulfate, the dried solution was filtered, and the filtrate was concentrated. The residue was purified by flash column chromatography on silica gel (5% methanol in dichloromethane) yielding tetraol 25 (18.1 mg, 53.2 mmol, 89%) as a colorless solid.

TLC (10% methanol in dichloromethane): Rf: 0.48.

mp: slow decomposition above 129 °C.

$^1H$ NMR (400 MHz, Pyridine-$d_5$) δ 6.64 (s, 1H), 5.72 (s, 1H), 5.38 (s, 1H), 4.39 (dd, $J$ = 8.4, 2.9 Hz, 1H), 4.19 – 3.98 (m, 2H), 3.55 (dd, $J$ = 11.1, 5.0 Hz, 1H), 2.29 – 2.11 (m, 2H), 2.10 – 1.87 (m, 5H), 1.74 (dt, $J$ = 12.9, 3.5 Hz, 1H), 1.63 (ddt, $J$ = 14.8, 6.5, 3.0 Hz, 1H), 1.51 (dq, $J$ = 13.0, 3.5 Hz, 1H), 1.44 – 1.36 (m, 1H), 1.30 (d, $J$ = 4.1 Hz, 7H), 1.16 – 1.08 (m, 4H), 1.05 (dd, $J$ = 12.9, 4.5 Hz, 1H), 1.02 – 0.99 (m, 3H), 0.96 (dd, $J$ = 12.0, 2.2 Hz, 1H), 0.84 (dd, $J$ = 12.6, 3.2 Hz, 1H).

$^{13}$C NMR (151 MHz, Pyridine-$d_5$) δ 79.2, 78.9, 71.1, 64.6, 57.5, 56.6, 50.6, 43.8, 40.1, 39.8, 38.9, 38.0, 37.0, 29.5, 29.0, 28.7, 19.8, 19.1, 17.1, 16.7.

IR (ATR, neat) $\tilde{\nu}_{max}$: 3402 (br, m), 2925 (m), 2872 (m), 2851 (m), 1737 (w), 1637 (w), 1442 (s), 1339 (s), 1192 (m), 1149 (m), 1087 (w), 1041 (m), 1011 (m), 833 (w) cm$^{-1}$.

HRMS (ESI): calcd for C$_{20}$H$_{37}$O$_4^+$ [M+H]$^+$: 341.2686; found: 341.2630.

$[\alpha]_D^{20} = -8.0$ (c = 0.57, methanol).
A solution of di(imidazol-1-yl)methanethione (3.7 mg, 21 µmol, 1.4 equiv) in dry dimethylformamide (1.3 mL) was added to tetraol 25 (5.0 mg, 15 µmol, 1 equiv) and the yellow solution was heated at 60 °C. After 42 h, di(imidazol-1-yl)methanethione (1.3 mg, 7.3 µmol, 0.50 equiv) was added and heated at 60 °C for 30 h, before water (5 mL) was added. The mixture was extracted with ethyl acetate (3 x 5 mL) and the combined organic layers washed with water (5 mL) and saturated aqueous solution of sodium chloride (5 mL) and the washed solution was dried over magnesium sulfate. The dried solution was filtered, and the filtrate was concentrated. The residue was purified by flash column chromatography on silica gel (30% grading to 40% ethyl acetate in pentane) yielding thiocarbonate 26 (3.1 mg, 8.1 µmol, 55%) as a colorless wax.

TLC (40% ethyl acetate in pentane): R<sub>f</sub>: 0.52.

<sup>1</sup>H NMR (400 MHz, Chloroform-<d>) δ 6.11 (dd, J = 8.7, 7.0 Hz, 1H), 4.58 (t, J = 8.9 Hz, 1H), 4.44 (dd, J = 8.8, 7.0 Hz, 1H), 3.20 (dd, J = 10.9, 5.3 Hz, 1H), 2.00 (dd, J = 14.7, 2.4 Hz, 1H), 1.75 – 1.60 (m, 5H), 1.59 – 1.50 (m, 4H), 1.48 – 1.44 (m, 2H), 1.39 (dd, J = 13.3, 4.8 Hz, 1H), 1.34 – 1.29 (m, 1H), 1.12 (d, J = 14.7 Hz, 1H), 1.00 (s, 3H), 0.98 – 0.93 (m, 4H), 0.87 – 0.84 (m, 4H), 0.84 – 0.80 (m, 4H).

<sup>13</sup>C NMR (151 MHz, Chloroform-<d>) δ 192.5, 85.1, 79.0, 72.5, 69.8, 56.5, 55.6, 49.0, 43.4, 39.1, 37.9, 37.1, 36.8, 35.6, 28.4, 27.3, 22.6, 17.6, 17.3, 15.8, 15.6.

IR (ATR, neat) 𝜈<sub>max</sub>: 3433 (br, w), 2938 (m), 2853 (w), 1451 (w), 1388 (w), 1348 (w), 1295 (s), 1173 (m), 1091 (w), 1031 (w), 1002 (w), 969 (w), 953 (w), 911 (w), 733 (w) cm<sup>-1</sup>.

HRMS (ESI): calcd for C<sub>21</sub>H<sub>34</sub>O<sub>4</sub>SNa<sup>+</sup> [M+Na]<sup>+</sup>: 405.2070; found:405.2030.

[α]<sup>D</sup> = +41 (c = 0.21, dichloromethane).
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2.1.15 Pimara-15-en-3α-8α-diol (7)

A solution of thiocarbonate 23 (3.1 mg, 8.1 µmol, 1 equiv) in trimethyl phosphite6 (960 µl) was heated at 110 °C for 32 h. The reaction mixture was concentrated, and the residue was purified by flash column chromatography on silica gel (10% ethyl acetate in pentane) yielding pimara-15-en-3α-8α-diol (7) (1.3 mg, 4.2 µmol, 52%) as an amorphous colorless solid.

TLC (20% ethyl acetate in hexanes): Rf: 0.63.

mp: 143 °C.7

$^1$H NMR (600 MHz, Chloroform-d) δ 5.98 (dd, $J = 17.9, 10.9$ Hz, 1H), 5.13 (d, $J = 17.9$ Hz, 1H), 5.08 (d, $J = 10.9$ Hz, 1H), 3.20 (dd, $J = 11.1, 5.2$ Hz, 1H), 2.00 (dq, $J = 13.6, 3.1$ Hz, 1H), 1.91 (s, 1H), 1.77 (dt, $J = 13.3, 3.2$ Hz, 1H), 1.73 – 1.66 (m, 2H), 1.64 – 1.56 (m, 3H), 1.50 – 1.43 (m, 3H), 1.24 – 1.18 (m, 3H), 0.99 (s, 3H), 0.99 – 0.95 (m, 1H), 0.93 (s, 3H), 0.90 (s, 3H), 0.85 – 0.81 (m, 2H), 0.80 (s, 3H).

$^{13}$C NMR (151 MHz, Chloroform-d) δ 147.5, 112.0, 79.1, 72.3, 56.2, 55.7, 53.4, 42.0, 39.0, 37.8, 37.0, 36.6, 36.1, 32.4, 28.3, 27.3, 17.8, 17.5, 15.51, 15.47.

IR (ATR, neat) $\tilde{v}_{\text{max}}$: 3570 (w), 3314 (br, w), 3078 (w), 2939 (s), 2926 (s), 2867 (m), 2852 (m), 1712 (w), 1633 (w), 1453 (m), 1411 (w), 1384 (w), 13133 (w), 1280 (w), 1201 (w), 1146 (w), 1127 (w), 1113 (w), 1085 (w), 1032 (m), 1001 (m), 978 (w), 959 (w), 943 (w), 920 (m), 846 (w), 734 (w), 703 (w), 685 (w) cm$^{-1}$.

HRMS (ESI): calcd for $\text{C}_{20}\text{H}_{34}\text{O}_{2}\text{Na}^+$ [M+Na]$^+$: 329.2451; found: 329.2440.

$[\alpha]_D^{29} = +6$ (c = 0.05, chloroform).

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6 Trimethyl phosphite was freshly distilled from sodium.
7 The amorphous sample was heated on a Kofler hot stage microscope where it revealed a broad melting range (95–139 °C). Upon cooling, crystals formed, which had a melting point of 143 °C.
2.2 Synthesis of other cyclization precursors
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13 + S20 → C$_6$H$_5$CO$_2$H, DMF, 80 °C (81%)

Cory-Nof–Lin ligand 18, methanesulfonylamide,
K$_2$CO$_3$, CuI, H$_2$O, K$_2$CO$_3$,
K$_3$Fe(CN)$_6$, t- BuOH, H$_2$O, 0 °C (38%)

18 → S21

MasCl, py, CH$_2$Cl$_2$,
then K$_2$CO$_3$, MeOH (85%)

1- BuLi, 8-Methoxy-8-BBN, THF,
then SPhos Pd Cl(I), SPhos,
C$_6$H$_5$CO$_2$H, DMF, H$_2$O (94%)

S22

S23

S24
2.2.1 (Z)-aryl enol ether S6

To a mixture of phenol S5 (4.86 g, 39.2 mmol, 10.0 equiv) and caesium carbonate (3.83 g, 11.8 mmol, 3.00 equiv) in dry dimethylformamide (5.0 mL) was added alkyne 13 (1.00 g, 3.92 mmol, 1 equiv) and the suspension was heated at 80 °C for 54 h. Water (20 mL) was added to the reaction mixture and extracted with diethyl ether (3 x 50 mL). The combined organic layers were dried over magnesium sulfate, the dried solution was filtered, and the filtrate was concentrated. Flash column chromatography on silica gel (0.3% grading to 1% diethyl ether in pentane) of the residue yielded enol ether S6 (617 mg, 1.63 mmol, 42%) as a colorless oil.

TLC (1% diethyl ether in pentane): Rf: 0.32.

1H NMR (400 MHz, Chloroform-d) δ 6.94 – 6.87 (m, 2H), 6.86 – 6.81 (m, 2H), 5.65 (s, 1H), 5.11 – 5.00 (m, 2H), 3.78 (s, 3H), 2.23 – 2.11 (m, 4H), 2.04 (q, J = 7.4 Hz, 2H), 1.99 – 1.93 (m, 2H), 1.69 – 1.65 (m, 3H), 1.59 (s, 3H), 1.55 (s, 3H).

13C NMR (101 MHz, Benzene-d6) δ 156.0, 155.8, 149.3, 136.6, 131.3, 124.8, 122.9, 118.7, 115.0, 90.7, 55.2, 40.1, 32.4, 27.1, 25.9, 25.4, 17.8, 16.0.

IR (ATR, neat) ν̃max: 2913 (w), 2854 (w), 1644 (w), 1501 (s), 1441 (m), 1376 (w), 1333 (w), 1296 (w), 1271 (w), 1245 (m), 1204 (s), 1180 (m), 1162 (w), 1133 (m), 1101 (w), 1036 (m), 1108 (w), 956 (w), 925 (w), 884 (w), 827 (m), 742 (m), 720 (w), 696 (w), 650 (w), 595 (w), 517 (m), 441 (w) cm⁻¹.

HRMS (ESI): calcd for C20H28BrO2⁺ [M+H]⁺: 379.1267; found: 379.1242.
Potassium carbonate (2.91 g, 21.1 mmol, 4.00 equiv) and K₃[Fe(CN)]₆ (6.94 g, 21.1 mmol, 4.00 equiv) were ground to a fine powder in a mortar before adding Corey–Noe–Lin ligand 15 (120 mg, 105 µmol, 2.00 mol%), K₂OsO₄•2H₂O (19.4 mg, 52.7 µmol, 1.00 mol%) and water (19.5 mL). After cooling the mixture to 0 °C, methanesulfonamide (502 mg, 5.27 mmol, 1 equiv) and a solution of alkene S6 (2.00 g, 5.27 mmol, 1 equiv) in tert-butanol (19.5 mL) were added and the biphasic suspension was sonicated at 0 °C for 15 min before stirring vigorously at 0 °C for 17.5 h. Sodium sulfite (6.65 g, 52.7 mmol, 10.0 equiv) was added, the cooling bath was removed and the slurry was allowed to reach 22 °C. After 20 min, 1 M aqueous solution of sodium hydroxide was added dropwise until all solids dissolved and the green mixture was extracted with ethyl acetate (4 x 50 mL). The combined organic layers were dried over sodium sulfate, the dried solution was filtered, and the filtrate was concentrated. The residue was purified by flash column chromatography on silica gel (2% grading to 35% ethyl acetate in cyclohexane) yielding diol S7 (1.62 g, 3.91 mmol, 74%) as a yellowish oil along with starting material S6 (80.0 mg, 211 µmol, 4%).

**TLC (40% ethyl acetate in cyclohexane):** Rₚ: 0.26.

**¹H NMR** (400 MHz, Benzene-d₆) δ 6.87 – 6.81 (m, 2H), 6.70 – 6.63 (m, 2H), 5.46 (s, 1H), 5.15 – 5.07 (m, 1H), 3.34 – 3.29 (m, 4H), 3.18 (s, 1H), 2.95 (s, 1H), 2.34 (ddd, J = 14.2, 9.4, 5.2 Hz, 1H), 2.15 – 1.99 (m, 5H), 1.55 – 1.36 (m, 5H), 1.13 (s, 6H).

**¹³C NMR** (101 MHz, Benzene-d₆) δ 155.9, 155.8, 149.2, 136.8, 123.1, 118.7, 115.1, 90.8, 78.3, 73.2, 55.3, 37.2, 32.3, 30.4, 26.7, 25.4, 23.6, 16.1.

**IR (ATR, neat)** ν max: 3411 (br, w), 2926 (w), 2854 (w), 1734 (w), 1644 (w), 1502 (s), 1464 (w), 1442 (w), 1382 (w), 1296 (w), 1246 (m), 1207 (s), 1180 (m), 1162 (w), 1135 (w), 1101 (w), 1076 (w), 1036 (m), 958 (w), 926 (w), 832 (w), 743 (w), 697 (w), 650 (w), 592 (w), 519 (w) cm⁻¹.

**HRMS** (ESI): calcd for C₂₀H₂₉BrO₄Na⁺ [M+Na]^⁺: 435.1141; found: 435.1145.

[α]₀° = +9.9 (c = 2.0, dichloromethane).

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8. Without sonication the ligand often agglutinated leading to poor yields.
9. The reaction was stopped before complete conversion was reached to avoid over-oxidation.
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2.2.3 Epoxide fragment S8

To a solution of diol S7 (1.60 g, 3.87 mmol, 1 equiv) and pyridine (1.56 mL, 19.4 mmol, 5.00 equiv) in dry dichloromethane (16 mL) was added methanesulfonyl chloride\(^{10}\) (449 µl, 5.8 mmol, 1.50 equiv) at 0 °C. The cooling bath was removed, and the reaction mixture was allowed to warm to 22 °C. After 19 h, water (40 mL) was added and the aqueous layer was extracted with dichloromethane (3 x 40 mL). The combined organic layers were dried over sodium sulfate, the dried solution was filtered, and the filtrate was concentrated. To the residue was added benzene (15 mL) and solution was concentrated.

The residue (assuming 1.90 g, 3.87 mmol, 1 equiv) was dissolved in dry methanol (50 mL) before potassium carbonate (1.07 g, 7.74 mmol, 2.00 equiv) was added.\(^{11}\) After 2 h, water (50 mL) was added and the aqueous layer was extracted with dichloromethane (100 mL, then 2 x 50 mL). The combined organic layers were washed with saturated aqueous solution of sodium chloride (50 mL), the washed solution was dried over magnesium sulfate, the dried solution was filtered, and the filtrate was concentrated. The residue was purified by flash column chromatography on silica gel (5% grading to 7.5% ethyl acetate in pentane) yielding epoxide S8 (1.16 g, 2.94 mmol, 76% over 2 steps) as a colorless oil.

**TLC** (20% ethyl acetate in cyclohexane): R\(_f\): 0.46.

\(^1\)H NMR (400 MHz, Chloroform-\(d\)) \(\delta\) 6.96 – 6.87 (m, 2H), 6.87 – 6.79 (m, 2H), 5.65 (s, 1H), 5.09 (t, \(J = 6.8\) Hz, 1H), 3.78 (s, 3H), 2.67 (t, \(J = 6.2\) Hz, 1H), 2.24 – 2.01 (m, 6H), 1.63 – 1.56 (m, 5H), 1.29 (s, 3H), 1.24 (s, 3H).

\(^{13}\)C NMR (101 MHz, Benzene-\(d_6\)) \(\delta\) 156.0, 155.7, 149.3, 136.0, 123.3, 118.7, 115.1, 90.8, 63.4, 57.4, 55.2, 36.8, 32.3, 27.9, 25.3, 25.0, 18.9, 16.0.

IR (ATR, neat) \(\tilde{\nu}_{\text{max}}\): 2958 (w), 2925 (w), 2836 (w), 1644 (w), 1502 (s), 1442 (w), 1378 (w), 1296 (w), 1246 (m), 1206 (s), 1180 (w), 1134 (w), 1102 (w), 1036 (m), 956 (w), 924 (w), 873 (w), 832 (m), 743 (w), 684 (w), 651 (w), 520 (w) cm\(^{-1}\).

**HRMS** (ESI): calcd for C\(_{20}\)H\(_{27}\)BrO\(_3\)Na\(^+\) [M+Na\(^+\)]: 417.1036; found: 417.1067.

\([\alpha]_D^{10} = -2.2\) (c = 2.5, dichloromethane).

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\(^{10}\) Methanesulfonyl chloride was freshly distilled from P\(_4\)O\(_10\) through a Vigreux column under a N\(_2\) atmosphere.

\(^{11}\) Potassium carbonate was ground to a fine powder in a mortar before use.
To a solution of iodide 18 (74.4 mg, 379 µmol, 1.50 equiv) and 9-methoxy-9-borabicyclo[3.3.1]nonane (1.00 M in hexanes, 885 µl, 885 µmol, 3.50 equiv) in degassed dry tetrahydrofuran (1.5 mL) was added tert-butyllithium (1.84 M in pentane, 619 µL, 1.14 mmol, 4.50 equiv) dropwise at −78 °C. The solution turned yellow and then colorless. After 5 min, the cooling bath was replaced by a water bath (22 °C) and the mixture was warmed to 22 °C. After 5 min, the reaction mixture was cooled to −78 °C. A degassed 9:1 mixture of dimethylformamide and water (100 µl) was added to the clear solution and the cooling bath was removed. The reaction mixture was allowed to warm to 22 °C.

A separate flask was charged with vinyl bromide S8 (100 mg, 253 µmol, 1 equiv), caesium carbonate (165 mg, 506 µmol, 2.00 equiv), 2,6-dicyclohexylphosphino-2′,6′-dimethoxybiphenyl (5.2 mg, 13 µmol, 5.0 mol%), chloro(2-dicyclohexylphosphino-2′,6′-dimethoxy-1,1′-biphenyl)[2-(2′-amino-1,1′-biphenyl)]palladium(II) (9.1 mg, 13 µmol, 5.0 mol%) and a degassed 9:1 mixture of dimethylformamide and water (2.7 mL). To the yellow suspension was added the preformed boronate-species via cannulation and the biphasic mixture was heated at 40 °C. After 16 h, water (5 mL) was added and the mixture was extracted with ethyl acetate (4 x 15 mL). The combined organic layers were washed with water (3 x 10 mL) and saturated aqueous solution of sodium chloride (10 mL). The solution was dried over magnesium sulfate, the dried solution was filtered, and the filtrate was concentrated. The residue was purified by flash column chromatography on silica gel (3% ethyl acetate in cyclohexane) yielding cyclization precursor S9 (90.0 mg, 234 µmol, 93%) as a colorless oil.

**TLC** (20% ethyl acetate in cyclohexane): Rf: 0.59.

**1H NMR** (400 MHz, Benzene-d6) δ 6.97 – 6.90 (m, 2H), 6.76 – 6.70 (m, 2H), 5.20 (dddd, J = 6.9, 5.6, 2.7, 1.4 Hz, 1H), 4.95 (dd, J = 7.5, 6.6 Hz, 1H), 4.84 – 4.77 (m, 2H), 3.31 (s, 3H), 2.55 (dd, J = 6.7, 5.7 Hz, 1H), 2.36 (q, J = 7.3 Hz, 2H), 2.27 – 2.16 (m, 4H), 2.14 – 1.97 (m, 4H), 1.63 – 1.50 (m, 8H), 1.14 (s, 3H), 1.10 (s, 3H).

**13C NMR** (101 MHz, Benzene-d6) δ 155.2, 151.7, 151.0, 145.3, 135.1, 124.3, 117.6, 115.1, 115.0, 110.7, 63.5, 57.4, 55.2, 38.0, 36.8, 32.7, 32.0, 26.0, 25.0, 23.8, 22.4, 18.9, 16.1.

**IR** (ATR, neat) νmax: 2924 (w), 2853 (w), 1683 (w), 1649 (w), 1503 (s), 1443 (w), 1377 (w), 1325 (w), 1296 (w), 1244 (w), 1208 (s), 1180 (w), 1131 (w), 1102 (w), 1038 (m), 975 (w), 886 (w), 828 (m), 733 (w), 678 (w), 521 (w) cm⁻¹.

**HRMS** (ESI): calcd for C25H36O3Na⁺ [M+Na⁺]: 407.2557; found: 407.2587.

[α]D = −2.0 (c = 1.8, dichloromethane).

S33
2.2.5 (Z)-aryl enol ether S11

To a suspension of caesium carbonate (3.83 g, 11.8 mmol, 3.00 equiv) in dry dimethylformamide (10 mL) was added phenol S10 (6.04 g, 39.2 mmol, 10.0 equiv) and alkyne 13 (1.00 g, 3.92 mmol, 1 equiv). The reaction mixture was heated at 80 °C in a sealed tube for 89 h before water (20 mL) was added to the thick brown suspension. The mixture was extracted with diethyl ether (3 x 30 mL) and the combined organic layers were washed with water (40 mL), saturated aqueous solution of sodium chloride (40 mL) and the solution was dried over magnesium sulfate. The dried solution was filtered, and the filtrate was concentrated. Purification of the residue by flash column chromatography on silica gel (0.5% grading to 5.0% diethyl ether in pentane) yielded the title compound S11 (700 mg, 1.71 mmol, 44%) as a colorless oil.

TLC (1% diethyl ether in cyclohexane): Rf: 0.27.

**1H NMR** (400 MHz, Benzene-d<sub>6** δ** 6.29 (d, J = 2.2 Hz, 2H), 6.22 (t, J = 2.2 Hz, 1H), 5.46 (s, 1H), 5.19 – 5.08 (m, 1H), 5.02 (tdd, J = 5.6, 3.1, 1.4 Hz, 1H), 3.30 (s, 6H), 2.19 – 2.03 (m, 6H), 2.03 – 1.94 (m, 2H), 1.66 (d, J = 0.8 Hz, 3H), 1.54 (s, 3H), 1.48 (s, 3H).

**13C NMR** (101 MHz, Benzene-d<sub>6** δ** 162.3, 157.5, 155.2, 136.7, 131.3, 124.8, 122.9, 96.0, 95.5, 92.5, 55.0, 40.1, 32.6, 27.1, 25.9, 25.4, 17.8, 16.1.

**IR** (ATR, neat) \(\tilde{\nu}\)max: 2917 (w), 1596 (m), 1474 (w), 1443 (w), 1377 (w), 1264 (w), 1205 (m), 1152 (s), 1126 (w), 1064 (w), 823 (w), 678 (w) cm\(^{-1}\).

**HRMS** (ESI): calcd for C\(_{21}\)H\(_{30}\)BrO\(_3\)\([M+H]^+\): 409.1373; found: 409.1355.
A Transannular Polyene Tetracyclization for the Rapid Construction of the Pimarane Framework – Supporting Information

2.2.6 Dienediol S12

Potassium carbonate (1.30 g, 9.43 mmol, 4.00 equiv) and K$_3$[Fe(CN)$_6$] (3.10 g, 9.43 mmol, 4.00 equiv) were ground to a fine powder in a mortar before adding Corey–Noe–Lin ligand 15 (53.7 mg, 47.1 µmol, 2.00 mol%), K$_2$OsO$_4$•2H$_2$O (8.7 mg, 24 µmol, 1.0 mol%) and water (8.7 mL). After cooling the mixture to 0 °C, methanesulfonamide (224 mg, 2.36 mmol, 1 equiv) and a solution of alkene S11 (965 mg, 2.36 mmol, 1 equiv) in tert-butanol (8.7 mL) were added and the biphasic suspension was sonicated at 0 °C for 15 min before stirring vigorously at 0 °C for 24 h.$^{12}$ Sodium sulfite (2.97 g, 23.6 mmol, 10.0 equiv) was added and the cooling bath was removed. The slurry was allowed to reach 22 °C. After 9 h, 1 M aqueous solution of sodium hydroxide was added dropwise until all solids dissolved and the green mixture was extracted with ethyl acetate (4 x 50 mL). The combined organic layers were dried over sodium sulfate, the dried solution was filtered, and the filtrate was concentrated. The residue purified by flash column chromatography on silica gel (2% grading to 35% ethyl acetate in cyclohexane) yielding diol S12 (770 mg, 1.74 mmol, 74%) as a yellowish oil along with starting material S11 (15.0 mg, 36.6 µmol, 2%).$^{13}$

**TLC** (50% ethyl acetate in cyclohexanes): $R_f$: 0.34.

$^1$H NMR (400 MHz, Benzene-$d_6$) δ 6.36 (d, $J = 2.2$ Hz, 2H), 6.26 (t, $J = 2.2$ Hz, 1H), 5.45 (s, 1H), 5.16 – 5.04 (m, 1H), 3.27 (s, 6H), 3.22 (dd, $J = 10.3$, 2.2 Hz, 1H), 2.27 (ddd, $J = 14.0$, 9.0, 5.2 Hz, 1H), 2.18 (s, 1H), 2.12 – 2.07 (m, 4H), 2.03 (dd, $J = 14.2$, 8.0 Hz, 1H), 1.74 (s, 1H), 1.50 (d, $J = 1.4$ Hz, 3H), 1.48 – 1.32 (m, 2H), 1.06 (s, 3H), 1.05 (s, 3H).

$^{13}$C NMR (101 MHz, Benzene-$d_6$) δ 162.4, 157.5, 155.1, 136.8, 123.2, 96.0, 95.5, 92.7, 78.1, 72.8, 55.0, 37.1, 32.5, 30.2, 26.5, 25.4, 23.6, 16.0.

**IR** (ATR, neat) $\tilde{\nu}_{max}$: 3412 (br, w), 2965 (w), 2934 (w), 2840 (w), 1596 (s), 1473 (m), 1383 (w), 1330 (w), 1267 (w), 1204 (m), 1151 (s), 1063 (m), 990 (w), 930 (w), 892 (w), 824 (w), 761 (w), 735 (w), 677 (w) cm$^{-1}$.

**HRMS** (ESI): calcd for C$_{21}$H$_{32}$BrO$_5$ $^{+}$ [M+H]$^+$: 443.1428; found: 443.1416.

$[\alpha]_D^{20}$ = +5.4 (c = 1.5, dichloromethane).

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12 Without sonication the ligand often agglutinated leading to poor yields.
13 The reaction was stopped before complete conversion was reached to avoid over-oxidation.
2.2.7 Epoxide fragment S13

To a solution of diol S12 (408 mg, 920 µmol, 1 equiv) and pyridine (371 µL, 4.60 mmol, 5.00 equiv) in dry dichloromethane (4.0 mL) was added methanesulfonyl chloride\(^{14}\) (107 µl, 1.38 mmol, 1.50 equiv) at 0 °C. The cooling bath was removed and the reaction mixture was allowed to warm to 22 °C. After 23 h, water (4.0 mL) was added and the aqueous layer was extracted with dichloromethane (3 x 4 mL). The combined organic layers were dried over sodium sulfate, the dried solution was filtered, and the filtrate was concentrated. To the residue was added benzene (15 mL) and the solution was concentrated.

The residue (assuming 480 mg, 920 µmol, 1 equiv) was dissolved in dry methanol (10 mL) before potassium carbonate (254 mg, 1.84 mmol, 2.00 equiv) was added.\(^{15}\) After 1.5 h, water (10 mL) was added and the mixture was extracted with dichloromethane (20 mL, then 2 x 10 mL). The combined organic layers were washed with saturated aqueous solution of sodium chloride (10 mL), the solution was dried over magnesium sulfate, the dried solution was filtered, and the filtrate was concentrated. The residue was purified by flash column chromatography on silica gel (5% ethyl acetate in pentane) yielding epoxide S13 (334 mg, 785 µmol, 85% over 2 steps) as a colorless oil.

**TLC** (10% ethyl acetate in cyclohexane): R\(_f\): 0.32.

\(^1\)H NMR (400 MHz, Benzene-\(d_6\)) \(\delta\) 6.35 (d, \(J = 2.2\) Hz, 2H), 6.26 (t, \(J = 2.2\) Hz, 1H), 5.46 (s, 1H), 5.06 – 4.98 (m, 1H), 3.27 (s, 6H), 2.56 – 2.48 (m, 1H), 2.11 – 1.93 (m, 6H), 1.54 – 1.46 (m, 2H), 1.45 (d, \(J = 1.4\) Hz, 3H), 1.15 (s, 3H), 1.09 (s, 3H).

\(^{13}\)C NMR (101 MHz, Benzene-\(d_6\)) \(\delta\) 162.4, 157.5, 155.1, 136.1, 123.3, 96.0, 95.5, 92.6, 63.4, 57.4, 55.0, 36.8, 32.5, 27.9, 25.4, 25.0, 18.9, 16.0.

IR (ATR, neat) \(\tilde{\nu}_{\text{max}}\): 2959 (w), 2928 (w), 2840 (w), 1596 (m), 1475 (w), 1377 (w), 1324 (w), 1267 (w), 1206 (m), 1153 (s), 1063 (w), 988 (w), 930 (w), 873 (w), 824 (w), 771 (w), 735 (w), 679 (w) cm\(^{-1}\).

**HRMS** (ESI): calcd for C\(_{21}\)H\(_{30}\)BrO\(_4\)\(^{+}\) [M+H]\(^{+}\): 425.1322; found: 425.1308.

\([\alpha]_D^{20} = -2.9\) (c = 2.0, dichloromethane).

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\(^{14}\) Methanesulfonyl chloride was freshly distilled from P\(_4\)O\(_{10}\) through a Vigreux column under a N\(_2\) atmosphere.

\(^{15}\) Potassium carbonate was ground to a fine powder in a mortar before use.
A Transannular Polyene Tetracyclization for the Rapid Construction of the Pimarane Framework – Supporting Information

2.2.8 Cyclization precursor S14

To a solution of iodide 18 (39.4 mg, 201 µmol, 1.50 equiv) and 9-methoxy-9-borabicyclo[3.3.1]nonane (1.00 M in hexanes, 469 µL, 469 µmol, 3.50 equiv) in degassed dry tetrahydrofuran (875 µL) was added tert-butyllithium (1.60 M in pentane, 377 µL, 603 µmol, 4.50 equiv) dropwise at −78 °C. The solution turned yellow and then colorless. After 5 min, the cooling bath was replaced by a water bath (22 °C) and the mixture was warmed to 22 °C. After 5 min the reaction mixture was cooled to −78 °C. A degassed 9:1 mixture of dimethylformamide and water (50 µl) was added to the clear solution and the cooling bath was removed. The reaction mixture was allowed to warm to 22 °C.

A separate flask was charged with vinyl bromide S13 (57.0 mg, 134 µmol, 1 equiv), caesium carbonate (87.3 mg, 268 µmol, 2.00 equiv), 2-dicyclohexylphosphino-2′,6′-dimethoxybiphenyl (2.8 mg, 7.0 µmol, 5.0 mol%), chloro(2-dicyclohexylphosphino-2′,6′-dimethoxy-1,1′-biphenyl)[2-(2′-amino-1,1′-biphenyl)]palladium(II) (4.8 mg, 7.0 µmol, 5.0 mol%) and a degassed 9:1 mixture of dimethylformamide and water (1.6 mL). To the yellow suspension was added the preformed boronate-species via cannulation and the biphasic mixture was heated at 40 °C. After 3.5 h, water (5 mL) was added and the mixture was extracted with ethyl acetate (4 x 15 mL). The combined organic layers were washed with water (3 x 10 mL) and saturated aqueous solution of sodium chloride (10 mL). The solution was dried over magnesium sulfate, the dried solution was filtered, and the filtrate was concentrated. The residue was purified by flash column chromatography on silica gel (3% ethyl acetate in pentane) yielding cyclization precursor 14 (45.1 mg, 109 µmol, 81%) as a colorless oil.

*TLC* (20% ethyl acetate in cyclohexane): *Rf*: 0.53.

**1H NMR** (400 MHz, Benzene-d₆) δ 6.44 (d, *J* = 2.2 Hz, 2H), 6.27 (t, *J* = 2.2 Hz, 1H), 5.24 – 5.17 (m, 1H), 4.98 (t, *J* = 7.1 Hz, 1H), 4.79 (s, 2H), 3.31 (s, 6H), 2.58 – 2.53 (m, 1H), 2.30 – 2.22 (m, 4H), 2.15 – 1.97 (m, 4H), 1.61 – 1.50 (m, 8H), 1.14 (s, 3H), 1.10 (s, 3H).

**13C NMR** (101 MHz, Benzene-d₆) δ 162.5, 159.3, 151.1, 145.2, 135.2, 124.3, 116.2, 110.8, 95.4, 94.5, 63.5, 57.4, 54.9, 37.8, 36.8, 33.0, 28.0, 26.0, 25.0, 23.9, 22.3, 18.9, 16.1.

**IR** (ATR, neat) 𝜈 max: 3071 (w), 2924 (w), 2853 (w), 1685 (w), 1594 (s), 1459 (m), 1377 (w), 1324 (w), 1239 (w), 1204 (m), 1145 (s), 1057 (m), 1004 (w), 930 (w), 886 (w), 824 (m), 753 (w), 728 (w), 682 (w) cm⁻¹.

**HRMS** (ESI): calcd for C₂₆H₃₉O₄Na⁺ [M+Na⁺]: 437.2662; found: 437.2650.

[𝛼]D° = −1.9 (c = 0.74, dichloromethane).
A Transannular Polyene Tetracyclization for the Rapid Construction of the Pimarane Framework – Supporting Information

2.2.9 (Z)-aryl enol ether S16

To a suspension of caesium carbonate (8.70 g, 26.7 mmol, 3.00 equiv) in dry dimethylformamide (5.5 mL) was added phenol S15 (4.12 g, 26.7 mmol, 3.00 equiv) and alkyne 13 (2.27 g, 8.90 mmol, 1 equiv). The reaction mixture was heated at 80 °C in a sealed tube for 24 h before water (100 mL) was added to the thick brown suspension. The mixture was extracted with diethyl ether (4 x 100 mL) and the combined organic layers were washed with saturated aqueous solution of sodium chloride (100 mL), the solution was dried over magnesium sulfate, the dried solution was filtered, and the filtrate was concentrated. Purification of the residue by flash column chromatography on silica gel (3% grading to 4% diethyl ether in pentane) yielded the title compound S16 (990 mg, 2.42 mmol, 27%) as a colorless oil.

TLC (10% ethyl acetate in pentane): Rf: 0.78.

$^1$H NMR (600 MHz, Benzene-$d_6$) δ 6.73 (t, $J = 8.3$ Hz, 1H), 6.62 (dd, $J = 8.3$, 1.4 Hz, 1H), 6.31 (dd, $J = 8.3$, 1.4 Hz, 1H), 5.35 (s, 1H), 5.17 (ddt, $J = 8.5$, 7.0, 1.5 Hz, 1H), 5.03 – 4.96 (m, 1H), 3.84 (s, 3H), 3.29 (s, 3H), 2.11 – 2.06 (m, 6H), 1.97 (t, $J = 7.7$ Hz, 2H), 1.67 (d, $J = 1.6$ Hz, 3H), 1.54 (s, 3H), 1.47 (s, 3H).

$^{13}$C NMR (151 MHz, Benzene-$d_6$) δ 156.2, 154.8, 149.3, 141.0, 136.5, 131.2, 124.8, 123.7, 123.0, 111.9, 108.0, 88.5, 61.0, 55.6, 40.1, 32.5, 27.1, 25.9, 25.4, 17.8, 16.0.

IR (ATR, neat) $\tilde{\nu}_{\text{max}}$: 3095 (w), 2965 (w), 2930 (m), 2853 (w), 1647 (w), 1594 (m), 1471 (s), 1439 (m), 1375 (w), 1277 (m), 1247 (s), 1171 (w), 1141 (m), 1090 (s), 1008 (m), 886 (w), 837 (w), 790 (w), 739 (m), 653 (w) cm$^{-1}$.

HRMS (ESI): calcd for C$_{21}$H$_{29}$BrO$_3$Na$^+$ [M+Na]$^+$: 431.1192; found: 431.1186.

S38
A Transannular Polyene Tetracyclization for the Rapid Construction of the Pimarane Framework – Supporting Information

2.2.10 Dienediol S17

Potassium carbonate (689 mg, 4.98 mmol, 4.00 equiv) and K$_3$[Fe(CN)$_6$] (1.64 g, 4.98 mmol, 4.00 equiv) were ground to a fine powder in a mortar before adding Corey–Noe–Lin ligand 15 (28.4 mg, 24.9 µmol, 2.00 mol%), K$_2$OsO$_4$•2H$_2$O (4.6 mg, 13 µmol, 1.0 mol%) and water (4.0 mL). After cooling the mixture to 0 °C, methanesulfonamide (119 mg, 1.25 mmol, 1 equiv) and a solution of alkene S16 (510 mg, 1.25 mmol, 1 equiv) in tert-butanol (4.0 mL) were added. The biphasic suspension was sonicated at 0 °C for 15 min before stirring vigorously at 0 °C for 38 h. Sodium sulfite (1.57 g, 12.5 mmol, 10.0 equiv) was added and the cooling bath was removed. The slurry was allowed to warm to 22 °C. After 30 min, 2 M aqueous solution of sodium hydroxide was added dropwise until all solid dissolved and the green mixture was extracted with ethyl acetate (4 x 50 mL). The combined organic layers were dried over sodium sulfate, the dried solution was filtered, and the filtrate was concentrated. The residue was purified by flash column chromatography on silica gel (2% grading to 35% ethyl acetate in cyclohexane) yielding diol S17 (208 mg, 470 mmol, 38%) as a yellowish oil along with starting material S16 (281 mg, 686 µmol, 55%).

**TLC (80% ethyl acetate in pentane):** R$_f$: 0.55.

**$^1$H NMR** (400 MHz, Benzene-d$_6$) δ 6.73 (t, J = 8.3 Hz, 1H), 6.61 (dd, J = 8.3, 1.4 Hz, 1H), 6.31 (dd, J = 8.3, 1.4 Hz, 1H), 5.34 (s, 1H), 5.10 – 4.99 (m, 1H), 3.84 (s, 3H), 3.29 (s, 3H), 3.17 (ddd, J = 10.4, 4.0, 2.1 Hz, 1H), 3.21 (ddd, J = 14.3, 9.1, 5.2 Hz, 1H), 2.13 – 2.04 (m, 4H), 2.04 – 1.95 (m, 1H), 1.90 (d, J = 4.2 Hz, 1H), 1.48 (d, J = 1.4 Hz, 4H), 1.45 – 1.39 (m, 1H), 1.32 (ddd, J = 13.8, 10.3, 8.9, 5.3 Hz, 1H), 1.03 (s, 3H), 1.03 (s, 3H).

**$^{13}$C NMR** (101 MHz, Benzene-d$_6$) δ 156.2, 154.8, 149.2, 140.9, 136.7, 123.7, 123.3, 111.8, 108.0, 88.7, 78.1, 72.6, 61.0, 55.6, 37.0, 32.4, 30.1, 26.5, 25.4, 23.6, 15.9.

**IR** (ATR, neat) $\tilde{\nu}_{max}$: 3426 (w), 3099 (w), 2932 (m), 2855 (w), 1647 (w), 1594 (m), 1471 (s), 1381 (w), 1277 (m), 1247 (s), 1141 (m), 1086 (s), 1006 (m), 935 (w), 884 (w), 794 (w), 739 (w) cm$^{-1}$.

**HRMS (ESI):** calcd for C$_{21}$H$_{31}$BrO$_3$Na$^+$ [M+Na$^+$]: 465.1247; found: 465.1246. 

[α]$^D_{20}$ = +8.6 (c = 0.57, dichloromethane).

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16 Without sonication the ligand often agglutinated leading to poor yields.
17 The reaction was stopped before complete conversion was reached to avoid over-oxidation.
2.2.11 Epoxide fragment S18

To a solution of diol S17 (171 mg, 386 µmol, 1 equiv) and pyridine (155 µL, 1.93 mmol, 5.00 equiv) in dry dichloromethane (1.7 mL) was added methanesulfonyl chloride\(^{18}\) (45.1 µl, 579 µmol, 1.50 equiv) at 0 °C. The cooling bath was removed, and the reaction mixture was allowed to warm to 22 °C. After 17 h, water (2 mL) was added and the aqueous layer was extracted with dichloromethane (3 x 4 mL). The combined organic layers were dried over sodium sulfate, the dried solution was filtered, and the filtrate was concentrated. To the residue was added benzene (15 mL) and the solution was concentrated.

The residue (assuming 201 mg, 386 µmol, 1 equiv) was dissolved in dry methanol (3.9 mL) before potassium carbonate (107 mg, 771 µmol, 2.00 equiv) was added.\(^{19}\) After 1.5 h, water (5 mL) was added and the aqueous layer was extracted with dichloromethane (3 x 10 mL). The combined organic layers were dried over magnesium sulfate, the dried solution was filtered, and the filtrate was concentrated. The residue was purified by flash column chromatography on silica gel (5% ethyl acetate in cyclohexane) yielding epoxide S18 (100 mg, 235 µmol, 61% over 2 steps) as a colorless oil.

\[ \text{TLC} \) (20% ethyl acetate in cyclohexane): \( R_f \) 0.42.

\[ \text{\(^1H\ NMR\)} \) (400 MHz, Benzene-\(d_6\)) \( \delta \) 6.74 (t, \( J = 8.3 \) Hz, 1H), 6.61 (dd, \( J = 8.3, 1.5 \) Hz, 1H), 6.32 (dd, \( J = 8.3, 1.4 \) Hz, 1H), 5.36 (s, 1H), 4.96 (qt, \( J = 4.4, 2.1 \) Hz, 1H), 3.83 (s, 3H), 3.30 (s, 3H), 2.50 (dd, \( J = 6.7, 5.6 \) Hz, 1H), 2.06 (d, \( J = 3.2 \) Hz, 4H), 2.03 – 1.89 (m, 2H), 1.55 – 1.41 (m, 5H), 1.14 (s, 3H), 1.08 (s, 3H).

\[ \text{\(^{13C\ NMR\)} \) (101 MHz, Benzene-\(d_6\)) \( \delta \) 156.1, 154.8, 149.2, 141.0, 135.9, 123.7, 123.4, 111.9, 108.0, 88.5, 63.5, 61.0, 57.4, 55.7, 36.8, 32.4, 27.9, 25.4, 25.0, 18.9, 15.9.

\[ \text{IR\ (ATR, neat)} \) \( \tilde{\nu}_{\text{max}} \) 3095 (w), 2934 (w), 2836 (w), 1647 (w), 1592 (m), 1469 (s), 1377 (w), 1277 (m), 1245 (s), 1171 (m), 1139 (m), 1086 (s), 1006 (m), 871 (w), 775 (w), 737 (m) \( \text{cm}^{-1} \).

\[ \text{HRMS\ (ESI)} \) : calcd for C\(_2\)\(_{20}\)Br\(_4\)O\(_4\)Na\(^+\) [M+Na\(^+\)]: 447.1141; found: 447.1111.

\[^{[\alpha]}_D^{20} = -2.2 \) (c = 1.77, dichloromethane).

\(^{18}\) Methanesulfonyl chloride was freshly distilled from P\(_4\)O\(_{10}\) through a Vigreux column under a N\(_2\) atmosphere.

\(^{19}\) Potassium carbonate was ground to a fine powder in a mortar before use.
To a solution of iodide 18 (34.6 mg, 176 µmol, 1.50 equiv) and 9-methoxy-9-borabicyclo[3.3.1]nonane (1.00 M in hexanes, 411 µl, 411 µmol, 3.50 equiv) in degassed dry tetrahydrofuran (718 µL) was added tert-butyllithium (1.84 M in pentane, 287 µL, 529 µmol, 4.50 equiv) dropwise at −78 °C. The solution turned yellow and then colorless. After 5 min, the cooling bath was replaced by a water bath (22 °C) and the reaction mixture was warmed to 22 °C. After 5 min the reaction mixture was cooled to −78 °C. A degassed 9:1 mixture of dimethylformamide and water (50 µl) was added to the clear solution and the cooling bath was removed. The reaction mixture was allowed to warm to 22 °C.

A separate flask was charged with vinyl bromide S18 (50.0 mg, 118 µmol, 1 equiv), caesium carbonate (76.6 mg, 235 µmol, 2.00 equiv), 2-(dicyclohexylphosphino)-2′,6′-dimethoxybiphenyl (2.4 mg, 5.9 µmol, 5.0 mol%), chloro(2-(dicyclohexylphosphino)-2′,6′-dimethoxy-1,1′-biphenyl)[2-(2′-amino-1,1′-biphenyl)]palladium(II) (4.2 mg, 5.9 µmol, 5.0 mol%) and a degassed 9:1 mixture of dimethylformamide and water (1.2 mL). To the yellow suspension was added the preformed boron species via cannulation and the biphasic mixture was heated at 40 °C. After 18 h, water (5 mL) was added and the mixture was extracted with ethyl acetate (3 x 10 mL). The combined organic layers were dried over magnesium sulfate, the dried solution was filtered, and the filtrate was concentrated. The residue was purified by flash column chromatography on silica gel (5% ethyl acetate in pentane) yielding cyclization precursor S19 (23.5 mg, 56.7 µmol, 48%) as a colorless oil.

**TLC** (20% ethyl acetate in cyclohexane): Rf: 0.49.

**1H NMR** (400 MHz, Benzene-d_6) δ 6.81 (t, J = 8.3 Hz, 1H), 6.68 (dd, J = 8.3, 1.5 Hz, 1H), 6.34 (dd, J = 8.3, 1.4 Hz, 1H), 5.22 – 5.12 (m, 1H), 4.95 (t, J = 7.1 Hz, 1H), 4.84 – 4.77 (m, 2H), 3.88 (s, 3H), 3.36 (s, 3H), 2.54 (dd, J = 6.6, 5.8 Hz, 1H), 2.39 – 2.32 (m, 2H), 2.30 – 2.19 (m, 4H), 2.11 – 1.95 (m, 4H), 1.62 – 1.49 (m, 8H), 1.14 (s, 3H), 1.09 (s, 3H).

**13C NMR** (101 MHz, Benzene-d_6) δ 154.9, 151.7, 151.0, 145.4, 140.4, 135.1, 124.3, 123.5, 114.6, 110.7, 109.7, 106.8, 63.5, 60.7, 57.4, 55.7, 38.0, 36.8, 32.9, 28.0, 26.0, 25.0, 23.8, 22.4, 18.9, 16.1.

**IR** (ATR, neat) ν~max: 3073 (w), 2926 (m), 2853 (w), 1685 (w), 1649 (w), 1594 (m), 1471 (s), 1377 (w), 1286 (m), 1247 (s), 1171 (w), 1135 (m), 1094 (s), 1010 (m), 886 (w), 777 (w), 737 (w) cm⁻¹.

**HRMS** (ESI): calcld for C_{26}H_{38}O_{4}⁺ [M+Na]⁺: 437.2662; found: 437.2651.

[α]_D²⁰ = −1.2 (c = 0.85, dichloromethane).
A Transannular Polyene Tetracyclization for the Rapid Construction of the Pimarane Framework – Supporting Information

2.2.13 (Z)-aryl enol ether S21

![Chemical Structure](image)

To a suspension of caesium carbonate (14.0 g, 42.9 mmol, 3.00 equiv) in dry dimethylformamide (38 mL) was added phenol S20 (10.8 g, 114 mmol, 8.00 equiv) and alkyne 13 (3.65 g, 14.3 mmol, 1 eqiv). The reaction mixture was heated at 80 °C in a sealed tube for 65 h before water (50 mL) was added to the thick brown suspension. The mixture was extracted with diethyl ether (4 x 50 mL) and the combined organic layers were washed with water (100 mL) and saturated aqueous solution of sodium chloride (2 x 50 mL). The solution was dried over magnesium sulfate, the dried solution was filtered, and the filtrate was concentrated. Purification of the residue by flash column chromatography on silica gel (1% diethyl ether in pentane) yielded the title compound S21 (2.54 g, 7.27 mmol, 51%) as a yellowish oil.

TLC (1% diethyl ether in pentane): Rf: 0.67.

$^1$H NMR (400 MHz, Benzene-d$_6$) δ 7.08 – 7.00 (m, 2H), 6.95 – 6.86 (m, 2H), 6.86 – 6.77 (m, 1H), 5.43 (s, 1H), 5.19 (ddp, J = 6.8, 5.5, 1.3 Hz, 1H), 5.01 (ddt, J = 6.9, 5.6, 1.3 Hz, 1H), 2.11 (q, J = 7.1 Hz, 2H), 2.07 – 1.96 (m, 6H), 1.69 (d, J = 1.4 Hz, 3H), 1.56 (s, 3H), 1.46 (s, 3H).

$^{13}$C NMR (101 MHz, Benzene-d$_6$) δ 155.7, 155.2, 136.6, 131.3, 129.9, 124.8, 122.9, 122.8, 117.2, 92.2, 40.1, 32.5, 27.1, 25.9, 25.2, 17.8, 16.0.

IR (ATR, neat) $\tilde{\nu}_{\text{max}}$: 2965 (w), 2914 (w), 2855 (w), 1645 (w), 1592 (m), 1490 (s), 1445 (w), 1377 (w), 1332 (w), 1267 (w), 1214 (s), 1163 (m), 1132 (m), 1073 (w), 1024 (w), 955 (w), 922 (w), 890 (w), 830 (w), 749 (s), 690 (s), 565 (w), 496 (m) cm$^{-1}$.

HRMS (ESI): calcd for C$_{19}$H$_{25}$BrONa$^+$ [M+Na]$^+$: 471.0981; found: 471.0973.
A Transannular Polyene Tetracyclization for the Rapid Construction of the Pimarane Framework – Supporting Information

2.2.14 Dienediol S22

Potassium carbonate (6.12 g, 44.3 mmol, 4.00 equiv) and K3[Fe(CN)6] (14.6 g, 44.1 mmol, 4.00 equiv) were ground to a fine powder in a mortar before adding Corey–Noe–Lin ligand 15 (315 mg, 277 µmol, 2.50 mol%), K2OsO4•2H2O (40.8 mg, 111 µmol, 1.00 mol%) and water (30 mL). After cooling the mixture to 0 °C, methanesulfonamide (1.05 g, 11.1 mmol, 1 equiv) and a solution of alkene S21 (3.87 g, 11.1 mmol, 1 equiv) in tert-butanol (30 mL) were added and the biphasic suspension was sonicated at 0 °C for 15 min before stirring vigorously at 0 °C for 46 h. Sodium sulfite (14.0 g, 111 mmol, 10.0 equiv) was added and the cooling bath was removed. The slurry was allowed to warm to 22 °C. After 30 min, 1 M aqueous solution of sodium hydroxide was added dropwise until all solids dissolved and the green mixture was extracted with ethyl acetate (4 x 100 mL). The combined organic layers were dried over sodium sulfate, the dried solution was filtered, and the filtrate was concentrated. The residue purified by flash column chromatography on silica gel (2% grading to 30% ethyl acetate in cyclohexane) yielding diol S22 (1.60 g, 4.19 mmol, 38%) as a yellowish oil along with starting material S21 (1.27 g, 3.65 mmol, 33%).

**TLC** (50% ethyl acetate in cyclohexane): Rf: 0.38.

**1H NMR** (400 MHz, Benzene-d6) δ 7.08 – 7.02 (m, 2H), 6.94 – 6.89 (m, 2H), 6.85 – 6.79 (m, 1H), 5.43 (s, 1H), 5.09 – 5.00 (m, 1H), 3.18 (ddt, J = 10.4, 3.9, 2.1 Hz, 1H), 2.25 (ddt, J = 14.3, 9.2, 5.3 Hz, 1H), 2.06 – 1.96 (m, 5H), 1.87 (d, J = 4.1 Hz, 1H), 1.49 – 1.41 (m, 4H), 1.37 – 1.29 (m, 1H), 1.03 (s, 3H), 1.02 (s, 3H).

**13C NMR** (101 MHz, Benzene-d6) δ 155.6, 155.1, 136.9, 129.9, 123.1, 122.9, 117.2, 92.3, 78.1, 72.6, 37.1, 32.4, 30.1, 26.5, 25.2, 23.6, 16.0.

**IR** (ATR, neat) $\tilde{\nu}_{\text{max}}$: 3465 (br, w), 2977 (w), 2928 (w), 2855 (w), 1736 (m), 1647 (w), 1592 (m), 1490 (m), 1447 (w), 1373 (m), 1214 (s), 1163 (m), 1135 (m), 1045 (s), 924 (m), 892 (w), 847 (w), 751 (s), 692 (m), 635 (w), 608 (m), 582 (w), 498 (m) cm⁻¹.

**HRMS** (ESI): calcd for C19H27BrO3Na⁺ [M+Na]⁺: 405.1036; found: 405.1025.

$[\alpha]_D^{20} = +8.1$ (c = 0.92, dichloromethane).

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20. Without sonication the ligand often agglutinated leading to poor yields.

21. The reaction was stopped before complete conversion was reached to avoid over-oxidation.
2.2.15 Epoxide fragment S23

![Reaction Scheme](image)

To a solution of diol S22 (1.35 g, 3.51 mmol, 1 equiv) and dry pyridine (1.42 mL, 17.6 mmol, 5.00 equiv) in dry dichloromethane (15 mL) was added methanesulfonyl chloride (408 µl, 5.27 mmol, 1.50 equiv) at 0 °C. The cooling bath was removed and the reaction mixture was allowed to warm to 22 °C. After 15.5 h, the solution was cooled to 0 °C, methanesulfonyl chloride (118 µl, 1.51 mmol, 0.30 equiv) was added and the cooling bath was removed. The mixture was allowed to warm to 22 °C. After 21 h, the mixture was concentrated, benzene (7 mL) was added to the residue and the solution was concentrated before dry methanol (30 mL) and potassium carbonate (1.94 g, 14.1 mmol, 4.00 equiv) were added. After 1 h, the thick slurry was concentrated to about half of its volume. Water (15 mL) was added and the mixture was extracted with dichloromethane (3 x 50 mL). The combined organic layers were dried over magnesium sulfate, the dried solution was filtered, and the filtrate was concentrated. The residue was purified by flash column chromatography on silica gel (5% ethyl acetate in cyclohexane) yielding epoxide S23 (1.09 g, 2.99 mmol, 85%) as a colorless oil.

**TLC** (10% ethyl acetate in cyclohexane): Rf: 0.46.

**1H NMR** (400 MHz, Benzene-d$_6$) δ 7.08 – 7.02 (m, 2H), 6.94 – 6.87 (m, 2H), 6.86 – 6.80 (m, 1H), 5.45 (s, 1H), 4.99 (tdd, J = 5.7, 2.7, 1.3 Hz, 1H), 2.52 (dd, J = 6.7, 5.6 Hz, 1H), 2.10 – 1.93 (m, 6H), 1.56 – 1.45 (m, 2H), 1.42 (d, J = 1.3 Hz, 3H), 1.16 (s, 3H), 1.09 (s, 3H).

**13C NMR** (101 MHz, Benzene-d$_6$) δ 155.6, 155.1, 136.0, 129.9, 123.2, 122.9, 117.2, 92.2, 63.4, 57.4, 36.8, 32.4, 27.9, 25.2, 25.0, 18.9, 15.9.

**IR** (ATR, neat) $\tilde{\nu}_{\text{max}}$: 2959 (w), 2924 (w), 2855 (w), 1645 (w), 1592 (m), 1490 (s), 1455 (w), 1377 (m), 1332 (w), 1267 (w), 1214 (s), 1163 (m), 1132 (m), 1073 (w), 1022 (w), 955 (w), 922 (w), 873 (m), 749 (s), 690 (s), 575 (w), 498 (m) cm$^{-1}$.

**HRMS** (ESI): calcd for C$_{19}$H$_{25}$Br$_2$O$_2$Na$^+$ [M+Na$^+$]: 387.0930; found: 387.0918.

$[\alpha]_D^{20} = -2.0$ (c = 0.99, dichloromethane).

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22 Methanesulfonyl chloride was freshly distilled from P$_4$O$_{10}$ through a Vigreux column under a N$_2$ atmosphere.

23 Potassium carbonate was ground to a fine powder in a mortar before use.
A Transannular Polyene Tetracyclization for the Rapid Construction of the Pimarane Framework – Supporting Information

2.2.16 Cyclization precursor S24

To a solution of iodide 18 (80.5 mg, 411 µmol, 1.50 equiv) and 9-methoxy-9-borabicyclo[3.3.1]nonane (1.00 M in hexanes, 958 µL, 958 µmol, 3.50 equiv) in degassed dry tetrahydrofuran (1.7 mL) was added tert-butyllithium (1.60 M in pentane, 770 µL, 1.23 mmol, 4.50 equiv) dropwise at −78 °C. The solution turned yellow and then colorless. After 30 min, the cooling bath was replaced by a water bath (22 °C) and the mixture was warmed to 22 °C. After 5 min the mixture was cooled to −78 °C. A degassed 9:1 mixture of dimethylformamide and water (1 mL) was added to the clear solution and the cooling bath was removed. The reaction mixture was allowed to warm to 22 °C.

A separate flask was charged with vinyl bromide S23 (100 mg, 274 µmol, 1 equiv), caesium carbonate (178 mg, 547 µmol, 2.00 equiv), 2,2′-dicyclohexylphosphino-2′,6′-dimethoxybiphenyl (5.6 mg, 14 µmol, 5.0 mol%), Chloro(2-dicyclohexylphosphino-2′,6′-dimethoxy-1,1′-biphenyl)[2-(2′-amino-1′-biphenyl)]palladium(II) (9.9 mg, 14 µmol, 5.0 mol%) and a degassed 9:1 mixture of dimethylformamide and water (4 mL). To the yellow suspension was added the preformed boronate-species via cannulation and the biphasic mixture was heated at 40 °C. After 5 h, water (5 mL) was added and the mixture was extracted with ethyl acetate (3 x 15 mL). The combined organic layers were washed with water (15 mL) and saturated aqueous solution of sodium chloride (15 mL). The solution was dried over magnesium sulfate, the dried solution was filtered, and the filtrate was concentrated. The residue was purified by flash column chromatography on silica gel (5% ethyl acetate in pentane) yielding cyclization precursor S24 (81.5 mg, 230 µmol, 84%) as a colorless oil.

TLC (10% ethyl acetate in cyclohexane): Rf: 0.75.

1H NMR (400 MHz, Benzene-d6) δ 7.14 – 7.08 (m, 2H), 7.03 – 6.96 (m, 2H), 6.83 (tt, J = 7.3, 1.2 Hz, 1H), 5.17 (ddt, J = 6.8, 5.5, 1.4 Hz, 1H), 4.97 (t, J = 7.1 Hz, 1H), 4.78 (d, J = 1.1 Hz, 2H), 2.54 (dd, J = 6.7, 5.6 Hz, 1H), 2.32 – 2.24 (m, 2H), 2.23 – 2.13 (m, 4H), 2.13 – 1.96 (m, 4H), 1.61 – 1.47 (m, 8H), 1.14 (s, 3H), 1.09 (s, 3H).

13C NMR (101 MHz, Benzene-d6) δ 157.3, 151.0, 145.2, 135.2, 129.9, 124.3, 121.9, 116.5, 115.8, 110.8, 63.5, 57.4, 37.8, 36.8, 32.8, 28.0, 25.9, 25.0, 23.8, 22.3, 18.9, 16.1.

IR (ATR, neat) νmax: 2961 (m), 2924 (m), 2853 (w), 1683 (w), 1651 (w), 1596 (m), 1490 (s), 1455 (w), 1377 (m), 1324 (w), 1292 (w), 1220 (s), 1163 (w), 1130 (w), 1073 (w), 1026 (w), 973 (w), 888 (m), 828 (w), 751 (m), 692 (m) cm⁻¹.

HRMS (ESI): calcd for C24H34O2Na⁺ [M+Na⁺]: 377.2451; found: 377.2448.

[α]D 30 = −2.1 (c = 1.0, dichloromethane).
2.3 Isomerization experiment

In order to examine, if isomerization of the (Z)-aryl enol ether occurs during polyene cyclization, the following variant of the cyclization precursor without the epoxide was prepared:

To a solution of iodide 18 (233 mg, 1.19 mmol, 1.50 equiv) and 9-methoxy-9-borabicyclo[3.3.1]nonane (1.00 M in hexanes, 2.77 mL, 2.77 mmol, 3.50 equiv) in degassed dry tetrahydrofuran (4.6 mL) was added tert-butyl lithium (1.70 M in pentane, 2.09 mL, 3.54 mmol, 4.50 equiv) dropwise at −78 °C. The solution turned yellow and then colorless. After 10 min, the cooling bath was replaced by a water bath (22 °C) and the mixture was warmed to 22 °C. After 25 min the reaction mixture was cooled to −78 °C. A degassed 9:1 mixture of dimethylformamide and water (1 mL) was added to the clear solution and the cooling bath was removed. The reaction mixture was allowed to warm to 22 °C.

A separate flask was charged with vinyl bromide 14 (300 mg, 791 µmol, 1 equiv), caesium carbonate (515 mg, 1.58 mmol, 2.00 equiv), 2-dicyclohexylphosphino-2′,6′-dimethoxybiphenyl (16.2 mg, 39.5 µmol, 5.00 mol%), Chloro(2-dicyclohexylphosphino-2′,6′-dimethoxy-1,1′-biphenyl)[2-(2′-amino-1,1′-biphenyl)]palladium(II) (28.5 mg, 39.5 µmol, 5.00 mol%) and a degassed 9:1 mixture of dimethylformamide and water (8 mL). To the yellow suspension was added the preformed boronate-species via cannulation and the biphasic mixture was heated at 40 °C. After 20 h, water (30 mL) was added and the mixture was extracted with diethyl ether (3 x 30 mL). The combined organic layers were washed with water (30 mL) and saturated aqueous solution of sodium chloride (30 mL). The solution was dried over magnesium sulfate, the dried solution was filtered, and the filtrate was concentrated. 1H NMR analysis of the residue revealed (Z)-S25 as the major component (75% NMR purity) along with decomposition products.
Therefore, we conclude, that isomerization of the (Z)-enol ether is at most a minor side-reaction.

Analytical data of (Z)-S25:

**TLC** (2% ethyl acetate in pentane): Rf: 0.34.

**1H NMR** (400 MHz, Benzene-d6) δ 7.04 (t, J = 8.2 Hz, 1H), 6.77 (t, J = 2.3 Hz, 1H), 6.69 (ddd, J = 8.1, 2.3, 0.9 Hz, 1H), 6.49 (ddd, J = 8.2, 2.4, 0.9 Hz, 1H), 5.27 – 5.17 (m, 2H), 4.98 (t, J = 7.1 Hz, 1H), 4.78 (s, 2H), 3.30 (s, 3H), 2.35 – 2.19 (m, 6H), 2.18 – 2.12 (m, 2H), 2.10 – 1.99 (m, 4H), 1.67 (d, J = 0.9 Hz, 3H), 1.59 (s, 3H), 1.55 (s, 6H).

**13C NMR** (101 MHz, Benzene-d6) δ 161.8, 158.7, 151.2, 145.2, 135.8, 131.2, 130.3, 124.9, 123.9, 115.9, 110.8, 108.7, 107.6, 102.8, 54.8, 40.2, 37.9, 33.0, 27.2, 25.9, 23.8, 22.3, 17.8, 16.1.

**IR** (ATR, neat) ν_{max}: 2965 (w), 2916 (m), 2855 (w), 2916 (w), 1649 (w), 1592 (m), 1488 (m), 1451 (m), 1375 (w), 1328 (w), 1281 (m), 1194 (m), 1145 (s), 1077 (w), 1043 (w), 979 (w), 888 (w), 835 (w), 765 (w), 688 (w) cm^{-1}.

**HRMS (ESI)**: calcd for C_{25}H_{37}O_{2}^{+} [M+H]^{+}: 369.2788; found: 369.2785.
3 NMR comparison data for pimara-15-en-3α-8α-diol (7)

| position | ¹H NMR (600 MHz, Chloroform-d₆) isolated 7 [ppm] | ¹H NMR (600 MHz, Chloroform-d₆) synthetic 7 [ppm] | Δ ppm | ¹³C NMR (50.32 MHz, Chloroform-d₆) isolated 7 [ppm] | ¹³C NMR (151 MHz, Chloroform-d₆) synthetic 7 [ppm] | Δ ppm |
|----------|--------------------------------------------------|--------------------------------------------------|-------|--------------------------------------------------|--------------------------------------------------|-------|
| 1α       | 1.71 (dt, J = 13.1, 3.5 Hz)                      | 1.71*                                             | 0.00  | 37.8                                             | 37.8                                             | 0.0   |
| 1β       | 0.98                                             | 0.99 – 0.95 (m, 1H)                               | --    | --                                               | --                                               | --    |
| 2α       | 1.61 (m)                                         | 1.62*                                             | +0.01 | 27.2                                             | 27.3                                             | +0.1  |
| 2β       | 1.61 (m)                                         | 1.62*                                             | +0.01 | 79.1                                             | 79.1                                             | 0.0   |
| 3β       | 3.21 (dd, J = 11.1, 5.2 Hz)                      | 3.20 (dd, J = 11.1, 5.2 Hz)                       | −0.01 | --                                               | --                                               | --    |
| 4        | 38.9                                             | 39.0                                              | +0.1  | --                                               | --                                               | --    |
| 5β       | 0.82                                             | 0.85 – 0.81 (m, 2H)                               | --    | 55.6                                             | 55.7                                             | +0.1  |
| 6α       | 1.63 (qd, J = 13.4, 3.7 Hz)                      | 1.63*                                             | 0.00  | 17.8                                             | 17.8                                             | 0.0   |
| 6β       | 1.49                                             | 1.50 – 1.43 (m, 3H)                               | --    | --                                               | --                                               | --    |
| 7α       | 1.78 (dt, J = 13.4, 3.2 Hz)                      | 1.77 (dt, J = 13.3, 3.2 Hz)                       | −0.01 | 42.0                                             | 42.0                                             | 0.0   |
| 7β       | 1.22                                             | 1.24 – 1.18 (m, 3H)                               | --    | --                                               | --                                               | --    |
| 8        | 72.3                                             | 72.3                                              | 0.0   | --                                               | --                                               | --    |
| 9β       | 0.85                                             | 0.85 – 0.81 (m, 2H)                               | --    | 56.2                                             | 56.2                                             | 0.0   |
| 10       | 37.0                                             | 37.0                                              | 0.0   | --                                               | --                                               | --    |
| 11α      | 1.47 (qd, J = 13.4, 3.1 Hz)                      | 1.50 – 1.43 (m, 3H)                               | --    | 17.4                                             | 17.5                                             | +0.1  |
| 11β      | 1.47 (m)                                         | 1.50 – 1.43 (m, 3H)                               | --    | --                                               | --                                               | --    |
| 12α      | 2.01 (dd, J = 13.7, 3.1 Hz)                      | 2.00 (dd, J = 13.8, 3.1 Hz)                       | −0.01 | 36.1                                             | 36.1                                             | 0.0   |
| 12β      | 1.21 (dd, J = 13.7, 4.4 Hz)                      | 1.22*                                             | +0.01 | --                                               | --                                               | --    |
| 13       | 36.5                                             | 36.6                                              | +0.1  | --                                               | --                                               | --    |
| 14α      | 1.68 (dd, J = 14.0, 3.1 Hz)                      | 1.68*                                             | 0.00  | 53.4                                             | 53.4                                             | 0.0   |
| 14β      | 1.23                                             | 1.24 – 1.18 (m, 3H)                               | --    | --                                               | --                                               | --    |
| 15       | 5.98 (dd, J = 17.9, 11.0 Hz)                     | 5.98 (dd, J = 17.9, 10.9 Hz)                      | 0.00  | 147.5                                            | 147.5                                            | 0.0   |
| 16A      | 5.09 (dd, J = 11.0, 1.2 Hz)                      | 5.08 (dd, J = 10.9, 1.2 Hz)                       | −0.01 | 112.0                                            | 112.0                                            | 0.0   |
| 16B      | 5.14 (dd, J = 17.9, 12.9 Hz)                     | 5.13 (dd, J = 17.9, 12.9 Hz)                      | −0.01 | --                                               | --                                               | --    |
| 17       | 0.91 (s)                                         | 0.90 (s)                                          | −0.01 | 28.3                                             | 28.3                                             | 0.0   |
| 18       | 0.99 (s)                                         | 0.99 (s)                                          | 0.00  | 32.4                                             | 32.4                                             | 0.0   |
| 19       | 0.81 (s)                                         | 0.80 (s)                                          | −0.01 | 15.5                                             | 15.51                                            | 0.0   |
| 20       | 0.93 (s)                                         | 0.93 (s)                                          | 0.00  | 15.5                                             | 15.47                                            | 0.0   |

* The signal overlapped with at least one other signal, but the chemical shift could be assigned via the HSQC spectrum.
4 NMR spectra

\[ \text{\textsuperscript{1}H NMR, Chloroform-}d \]
\[ 400 \text{ MHz} \]

\[ \text{\textsuperscript{13}C NMR, Chloroform-}d \]
\[ 101 \text{ MHz} \]
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$^1\text{H NMR, Chloroform-d}$
$400 \text{ MHz}$

$^{13}\text{C NMR, Chloroform-d}$
$101 \text{ MHz}$
A Transannular Polyene Tetracyclization for the Rapid Construction of the Pimarane Framework – Supporting Information

$^{1}H$ NMR, Chloroform-d
400 MHz

$^{13}C$ NMR, Chloroform-d
101 MHz
A Transannular Polyene Tetracyclization for the Rapid Construction of the Pimarane Framework – Supporting Information

1H NMR, Chloroform-d
400 MHz

1H NMR, Chloroform-d
101 MHz

13C NMR, Chloroform-d
101 MHz
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S2
HSQC, Benzene-\(d_6\)
400 MHz

\{7.79,128.04\}
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S4
HSQC, Benzene-d$_6$
400 MHz

(7.86, 128.26)
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\[
\begin{align*}
\text{Br} & \quad \text{O} \\
\text{O} & \quad \text{OMe}
\end{align*}
\]

\[1^H \text{ NMR, Benzene-}d_6\]

400 MHz

\[13^C \text{ NMR, Benzene-}d_6\]

101 MHz

S58
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$^{1}$H NMR, Benzene-$d_{6}$

$^{13}$C NMR, Benzene-$d_{6}$

S59
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8a
$^1$H NMR, Chloroform-$d$
600 MHz

8a
$^{13}$C NMR, Chloroform-$d$
151 MHz
A Transannular Polyene Tetracyclization for the Rapid Construction of the Pimarane Framework – Supporting Information

**8b**

$^1$H NMR, Chloroform-d
400 MHz

**8c**

$^{13}$C NMR, Chloroform-d
101 MHz
A Transannular Polyene Tetracyclization for the Rapid Construction of the Pimarane Framework – Supporting Information

19

$^1$H NMR, Chloroform-$d$
600 MHz

$^{13}$C NMR, Chloroform-$d$
151 MHz
A Transannular Polyene Tetracyclization for the Rapid Construction of the Pimarane Framework – Supporting Information

20

$^1$H NMR, Chloroform-$d$
400 MHz

13C NMR, Chloroform-$d$
101 MHz
A Transannular Polyene Tetracyclization for the Rapid Construction of the Pimarane Framework – Supporting Information

21b

$^1$H NMR, Dichloromethane-$d_2$

400 MHz

$^{13}$C NMR, Dichloromethane-$d_2$

101 MHz
A Transannular Polyene Tetracyclization for the Rapid Construction of the Pimarane Framework – Supporting Information

21a
$^1$H NMR, Chloroform-$d$
400 MHz

21a
$^{13}$C NMR, Chloroform-$d$
101 MHz
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22a
$^1$H NMR, Chloroform-$d$
400 MHz

22a
$^{13}$C NMR, Chloroform-$d$
101 MHz
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22b
\[ ^1H \text{ NMR, Chloroform-d} \]
400 MHz

22b
\[ ^{13}C \text{ NMR, Chloroform-d} \]
101 MHz
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$\text{AcO}^-$

![Chart 1: H NMR, Chloroform-d, 400 MHz]

$^1\text{H NMR, Chloroform-d, 400 MHz}$

![Chart 2: C NMR, Chloroform-d, 101 MHz]

$^{13}\text{C NMR, Chloroform-d, 101 MHz}$

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**24**

$^1$H NMR, Chloroform-$d$

400 MHz

$^{13}$C NMR, Chloroform-$d$

101 MHz
A Transannular Polyene Tetracyclization for the Rapid Construction of the Pimarane Framework – Supporting Information

26
$^1$H NMR, Chloroform-$_d$
400 MHz

13C NMR, Chloroform-$_d$
151 MHz

S71
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pimara-15-en-3α,8α-diol (7)

$^1$H NMR, Chloroform-d
600 MHz

$^1$C NMR, Chloroform-d
151 MHz

S72
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Extension of the HSQC spectrum above:
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^1^H NMR, Chloroform-d
400 MHz

^13^C NMR, Benzene-d_6
10^1^ MHz
A Transannular Polyene Tetracyclization for the Rapid Construction of the Pimarane Framework – Supporting Information

$^1$H NMR, Benzene-d$_6$
400 MHz

$^1$H NMR, Benzene-d$_6$
101 MHz

$^{13}$C NMR, Benzene-d$_6$
101 MHz

S7

S75
A Transannular Polyene Tetracyclization for the Rapid Construction of the Pimarane Framework – Supporting Information

**H NMR, Chloroform-d**

400 MHz

**C NMR, Benzene-d$_6$**

101 MHz
A Transannular Polyene Tetracyclization for the Rapid Construction of the Pimarane Framework – Supporting Information
A Transannular Polyene Tetracyclization for the Rapid Construction of the Pimarane Framework – Supporting Information

S9
$^1$H NMR, Benzene-<sub>d6</sub>
400 MHz

150.2 101.0 173.1
148.9 110.5
148.6 110.5
140.9 110.2
61.5
38.0
35.8
32.2
22.7
18.4

S9
$^{13}$C NMR, Benzene-<sub>d6</sub>
101 MHz

S78
A Transannular Polyene Tetracyclization for the Rapid Construction of the Pimarane Framework – Supporting Information

$\text{S11}$

$^1$H NMR, Benzene-$d_6$
400 MHz

$^13$C NMR, Benzene-$d_6$
101 MHz
A Transannular Polyene Tetracyclization for the Rapid Construction of the Pimarane Framework – Supporting Information
A Transannular Polyene Tetracyclization for the Rapid Construction of the Pimarane Framework – Supporting Information

S12

$^1$H NMR, Benzene-$d_6$
400 MHz

S12

$^{13}$C NMR, Benzene-$d_6$
101 MHz
A Transannular Polyene Tetracyclization for the Rapid Construction of the Pimarane Framework – Supporting Information

S13

$^1$H NMR, Benzene-$d_6$
400 MHz

S13

$^{13}$C NMR, Benzene-$d_6$
101 MHz
A Transannular Polyene Tetracyclization for the Rapid Construction of the Pimarane Framework – Supporting Information

**S14**

$^1$H NMR, Benzene-$d_6$

400 MHz

$^{13}$C NMR, Benzene-$d_6$

101 MHz
A Transannular Polyene Tetracyclization for the Rapid Construction of the Pimarane Framework – Supporting Information

S16

NOESY, Benzene-d$_6$

600 MHz
A Transannular Polyene Tetracyclization for the Rapid Construction of the Pimarane Framework – Supporting Information

S17
$^1$H NMR, Benzene-$d_6$
400 MHz

S17
$^{13}$C NMR, Benzene-$d_6$
101 MHz
A Transannular Polyene Tetracyclization for the Rapid Construction of the Pimarane Framework – Supporting Information

S18

$^1$H NMR, Benzene-$d_6$
400 MHz

S18

$^{13}$C NMR, Benzene-$d_6$
101 MHz
A Transannular Polyene Tetracyclization for the Rapid Construction of the Pimarane Framework – Supporting Information

S19

$^1$H NMR, Benzene-$d_6$
400 MHz

S19

$^{13}$C NMR, Benzene-$d_6$
101 MHz
A Transannular Polyene Tetracyclization for the Rapid Construction of the Pimarane Framework – Supporting Information

S21
NOESY, Benzene-d6
600 MHz
A Transannular Polyene Tetracyclization for the Rapid Construction of the Pimarane Framework – Supporting Information

S22
$^1$H NMR, Benzene-$d_6$
400 MHz

S22
$^{13}$C NMR, Benzene-$d_6$
101 MHz
A Transannular Polyene Tetracyclization for the Rapid Construction of the Pimarane Framework – Supporting Information

S23
$^1$H NMR, Benzene-$d_6$
400 MHz

S23
$^{13}$C NMR, Benzene-$d_6$
101 MHz
A Transannular Polyene Tetracyclization for the Rapid Construction of the Pimarane Framework – Supporting Information

S24
$^1$H NMR, Benzene-$d_6$
400 MHz

S24
$^{13}$C NMR, Benzene-$d_6$
101 MHz
A Transannular Polyene Tetracyclization for the Rapid Construction of the Pimarane Framework – Supporting Information

(Z)-S25
$^1$H NMR, Benzene-$d_6$
400 MHz

(Z)-S25
$^{13}$C NMR, Benzene-$d_6$
101 MHz
5 X–Ray data

5.1 Minor regioisomer 8b

| Identification code       | compound_8b |
|---------------------------|-------------|
| Empirical formula         | C_{25}H_{39}O_{3} |
| Formula weight            | 384.54      |
| Temperature               | 297(2) K    |
| Wavelength                | 0.71073 Å   |
| Crystal system            | Orthorhombic|
| Space group               | P2_12_12_1 (no. 19) |
| Unit cell dimensions      |             |
| a                         | 7.1860(5) Å |
| b                         | 13.4417(10) Å |
| c                         | 21.8077(17) Å |
| Volume                    | 2106.5(3) Å³ |
| Z                         | 4           |
| Density (calculated)      | 1.213 Mg/m³ |
| Absorption coefficient    | 0.077 mm⁻¹ |
| F(000)                    | 840         |
| Crystal size              | 0.180 x 0.060 x 0.030 mm³ |
| Theta range for data collection | 2.405 to 21.521° |
| Index ranges              | -7<=h<=7, -13<=k<=13, -22<=l<=22 |
| Reflections collected     | 12758       |
| Independent reflections   | 2431 [R(int) = 0.0685] |
| Completeness to theta     | 99.8 %      |
| Absorption correction     | Semi-empirical from equivalents |
| Max. and min. transmission| 0.992 and 0.931 |
| Refinement method         | Full-matrix least-squares on F² |
| Data / restraints / parameters | 2431 / 1 / 258 |
| Goodness-of-fit on F²     | 1.050       |
| Final R indices [I>2sigma(I)] | R1 = 0.0410, wR2 = 0.0871 |
| R indices (all data)      | R1 = 0.0576, wR2 = 0.0931 |
| Absolute structure parameter | 0.5(10) |
| Extinction coefficient    | 0.017(2)    |
| Largest diff. peak and hole | 0.132 and -0.130 eÅ³ |
5.2 Major regioisomer 8a

| Identification code | compound_8a |
|---------------------|-------------|
| Empirical formula   | C_{25}H_{36}O_{3} |
| Formula weight      | 384.54      |
| Temperature         | 183(2) K    |
| Wavelength          | 0.71073 Å   |
| Crystal system      | Monoclinic  |
| Space group         | P2_{1} (no. 4) |
| Unit cell dimensions| a = 11.1048(12) Å, α = 90°, b = 7.3792(7) Å, β = 97.516(3)°, c = 13.0067(14) Å, γ = 90° |
| Volume              | 1056.67(19) Å³ |
| Z                   | 2           |
| Density (calculated) | 1.209 Mg/m³ |
| Absorption coefficient | 0.077 mm⁻¹ |
| F(000)              | 420         |
| Crystal size        | 0.300 x 0.200 x 0.200 mm³ |
| Theta range for data collection | 2.270 to 26.000° |
| Index ranges        | -13<=h<=13, -9<=k<=9, -15<=l<=16 |
| Reflections collected | 18571 |
| Independent reflections | 4144 [R(int) = 0.0201] |
| Completeness to theta = 21.521° | 99.7 % |
| Absorption correction | Semi-empirical from equivalents |
| Max. and min. transmission | 0.959 and 0.937 |
| Refinement method   | Full-matrix least-squares on F² |
| Data / restraints / parameters | 4144 / 2 / 258 |
| Goodness-of-fit on F² | 1.012 |
| Final R indices [l>2sigma(l)] | R1 = 0.0296, wR2 = 0.0794 |
| R indices (all data) | R1 = 0.0301, wR2 = 0.0800 |
| Absolute structure parameter | 0.15(17) |
| Extinction coefficient | 0.070(9) |
| Largest diff. peak and hole | 0.212 and -0.156 eÅ³ |
5.3 Undesired diastereomer 19

| Property                        | Value                                      |
|--------------------------------|--------------------------------------------|
| Identification code            | compound_19                                |
| Empirical formula              | C_{32}H_{40}O_{4}                          |
| Formula weight                 | 488.64                                     |
| Temperature                    | 296(2) K                                   |
| Wavelength                     | 0.71073 Å                                  |
| Crystal system                 | Orthorhombic                               |
| Space group                    | P2\_12\_12 (no. 19)                        |
| Unit cell dimensions           | a = 7.3804(4) Å, b = 13.3089(8) Å, c = 27.5773(16) Å, α = 90°, β = 90°, γ = 90° |
| Volume                         | 2708.8(3) Å^3                             |
| Z                              | 4                                          |
| Density (calculated)           | 1.198 Mg/m^3                               |
| Absorption coefficient         | 0.077 mm\(^{-1}\)                         |
| F(000)                         | 1056                                       |
| Crystal size                   | 0.180 x 0.180 x 0.120 mm^3                |
| Theta range for data collection| 2.693 to 24.998°                           |
| Index ranges                   | -8<=h<=8, -15<=k<=15, -32<=l<=32           |
| Reflections collected          | 29271                                      |
| Independent reflections        | 4756 [R(int) = 0.0325]                     |
| Completeness to theta = 21.521°| 99.7%                                      |
| Absorption correction          | Semi-empirical from equivalents            |
| Max. and min. transmission     | 0.971 and 0.934                           |
| Refinement method              | Full-matrix least-squares on F^2          |
| Data / restraints / parameters  | 4756 / 0 / 327                             |
| Goodness-of-fit on F^2         | 1.077                                      |
| Final R indices [l>2\(\sigma(l)\)] | R1 = 0.0477, wR2 = 0.1226                   |
| R indices (all data)           | R1 = 0.0565, wR2 = 0.1271                  |
| Absolute structure parameter   | -0.4(3)                                    |
| Extinction coefficient         | 0.0132(19)                                 |
| Largest diff. peak and hole    | 0.151 and -0.141 e.Å^3                    |
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5.4 Tetraol 25

| Identification code         | compound_25               |
|-----------------------------|---------------------------|
| Empirical formula           | C_{20}H_{36}O_{4}         |
| Formula weight              | 340.49                    |
| Temperature                 | 183(2) K                  |
| Wavelength                  | 0.71073 Å                 |
| Crystal system              | Orthorhombic              |
| Space group                 | P2_{1}2_{1}2_{1} (no. 19) |
| Unit cell dimensions        |                           |
| a                           | 7.415(2) Å                |
| b                           | 11.049(3) Å               |
| c                           | 22.726(7) Å               |
| α                           | 90°                       |
| β                           | 90°                       |
| γ                           | 90°                       |
| Volume                      | 1861.8(10) Å³             |
| Z                           | 4                         |
| Density (calculated)        | 1.215 Mg/m³               |
| Absorption coefficient      | 0.082 mm⁻¹                |
| F(000)                      | 752                       |
| Crystal size                | 0.120 x 0.060 x 0.020 mm³ |
| Theta range for data collection | 2.571 to 20.497°.     |
| Index ranges                |                           |
| -7<=h<=7, -10<=k<=10, -22<=l<=22 |
| Reflections collected       | 21214                     |
| Independent reflections     | 1860 [R(int) = 0.1168]    |
| Completeness to theta       | 21.521°                   |
| 99.8 %                      |
| Absorption correction       | Semi-empirical from equivalents |
| Max. and min. transmission  | 0.956 and 0.901           |
| Refinement method           | Full-matrix least-squares on F² |
| Data / restraints / parameters | 1860 / 4 / 237          |
| Goodness-of-fit on F²       | 1.086                     |
| Final R indices [>2sigma(I)]| R1 = 0.0395, wR2 = 0.0731 |
| R indices (all data)        | R1 = 0.0553, wR2 = 0.0780 |
| Absolute structure parameter| 0.4(10)                   |
| Extinction coefficient      | 0.0058(12)                |
| Largest diff. peak and hole | 0.178 and -0.128 eÅ⁻³    |
6 References

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