Stereoselective total synthesis of the parthenolides indicates target selectivity for tubulin carboxypeptidase activity

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Supporting Information

Table of content

1 Correct molecular structure of (–)-parthenolide

2 General information

2.1 Instrumentation (Chemistry)

2.2 Methods and materials (Chemistry)

2.3 Methods and materials (biology)

2.3.1 DRG neuron cultures and immunocytochemical stainings

2.3.2 Monocyte isolation and polarization of macrophages

2.3.3 Determination of cell viability

2.3.4 SDS-PAGE and Western blot

2.3.5 Determination of cytokine levels

2.4 Abbreviations

3 Experimental

3.1 Preparation of 2-(silyloxymethyl)allylborationes

3.2 Preparation of carbonyl compounds and allylboration reactions

3.3 Structure elucidation of allylboration products

3.4 Synthesis of parthenolides
3.5 Single-crystal X-ray structure analysis of bromide (±)-9

4 References

5 NMR spectra of new compounds

Figures, Schemes and Tables

Fig. S1. Molecular structure of bromide (±)-9 obtained from single-crystal X-ray analysis. Only the (R,R,R,R)-enantiomer is depicted. Most of the H atoms are omitted for clarity reasons. C = grey, H = white, Br = orange, O = red, S = bright yellow, Si = pale yellow.

Scheme S1. Correct and wrong stereochemistry depiction of parthenolide.


Scheme S3. Epoxide opening and oxidative cyclization of an allylboration product for structure elucidation by NMR.

Table S1. ¹H NMR data in comparison to published data of (±)-22.

Table S2. ¹³C{¹H} NMR data in comparison to published data of (±)-22.

Table S3. ¹H NMR data of (–)-1 in comparison with commercial material (TCI).

Table S4. ¹³C{¹H} NMR data of (–)-1 in comparison with commercial material (TCI).
1 Correct molecular structure of \((-\)-parthenolide

There are several reported molecular structures of \((-\)-parthenolide varying in the epoxide’s stereochemistry, although the published X-ray crystal structures show the stereochemistry clearly to be \(4R,5R,6S,7S\) (see also manuscript).\(^{S1}\) Beside molecular structure A (see Scheme S1 below), which is used throughout this manuscript and by others,\(^{S1c,2}\) the wrong variant B frequently occurs and was also featured in Wikipedia.\(^{S3}\) It may be that the depiction issue arose from projecting the 3D (crystal) structure that features basically all rings in the same plane to a 2D representation without losing the appearance of the characteristic all-\(trans\) stereochemistry.\(^{S1b}\) For a step by step construction of the correct epoxide’s stereochemistry depiction, the starting point is the epoxidation of a \(trans\) alkene \(X1\) from the backside (Scheme S1), as realized during the biosynthesis of \((-\)-parthenolide from \((+\)-costunolide.\(^{S4}\) The molecular structure of the epoxide \(X2\) shown is close to a 3D representation and includes the carbon chain’s \(trans\) geometry as well as the right epoxide geometry, drawn with the oxygen above the carbon chain. More commonly, the oxygen atom is placed below the carbon chain (\(X3\)), as shown in the correct parthenolide structure A. Another variant which we ourselves used in a previous publication (\(X4\))\(^{S5}\) shows even more clearly the correct stereochemistry (see \(X5\)), but with an impossible conformation. Therefore, we chose structure A for using in this manuscript and recommend its usage furtheron. The entry in Wikipedia has been adapted accordingly.

The common structure B uses an epoxide depiction (\(X6\)) which would also correspond to an impossible conformation (\(X7\), but in fact resolving to a \(cis\) stereochemistry (\(X8\)) with incorrect \(5S\) configuration.
Scheme S1. Correct and wrong stereochemistry depictions of parthenolide.
2 General information

2.1 Instrumentation (Chemistry)

NMR spectra were recorded on one of the following Bruker spectrometers: Avance I (250 MHz, probe: BBO), Fourier (300 MHz, probe: Dual $^1$H/$^{13}$C), Avance I (400 MHz, probe: BBO), Avance II [400 MHz, probes: BBFO, BBO (+ATM)], Avance III HD [500 MHz, probe: BBO (Prodigy)] or Avance III [600 MHz, probes: TCPI (+ATM), PAQXI (+ATM), BBO (+ATM)]. $^1$H/$^{13}$C ASAP–HSQC and Multiplicity-edited ASAP–HSQC (denoted as HSQC/DEPT) spectra were recorded as described by Luy and co-workers. Chemical shifts (δ) are expressed in parts per million (ppm) with respect to the solvent signal ($^{13}$C NMR, δ: $^6$C$_6$D$_6$ 128.06, CDCl$_3$ 77.16), the residual nondeuterated solvent signal ($^1$H NMR, δ: $^6$C$_6$D$_5$H 7.16, CHCl$_3$ 7.26) or an external standard ($^{11}$B NMR: BF$_3$×OEt$_2$, $^{119}$Sn: SnMe$_4$ in CDCl$_3$).

Signals were assigned on the basis of 2D NMR experiments.

RP-HPLC analyses were conducted on a Shimadzu system fitted with a Macherey-Nagel EC 125/4 Nucleodur C18 Gravity column (5 µm, 125 × 10 mm ID). Linear MeCN/H$_2$O gradients were employed at 1 mL/min flow rate. Chiral HPLC analyses and separations were conducted on a Shimadzu system with an analytical Daicel Chiralpak-IA (5 µm, 250 × 4.6 mm ID) or a semi-preparative Daicel Chiralpak-OJ column (10 µm, 250 × 10 mm ID), eluting with isocratic n-hexane/EtOH mixtures (see experimental procedures for details).

GC–MS (low resolution) analyses were conducted on a HP 6890 system with a SGE BPX5 column (0.25µm, 25 m×0.22 mm ID) and a HP 5973 mass selective detector (single quadrupol) in EI mode, using He as carrier gas (1 mL/min flow rate). High resolution mass spectra (HRMS) were recorded on one of the following machines: Bruker Maxis Impact (QTOF) in ESI mode, Thermo Scientific Q Exactive Plus (Orbitrap) in ESI or APCI mode or Thermo Q Exactive GC (Orbitrap) in EI mode.

FT-IR spectra were recorded on a Shimadzu IRAffinity-1 machine in ATR mode. The following notations indicate the intensity of the absorption bands: $s$ = strong, $m$ = medium, $w$ = weak.

Melting points were determined with a Büchi B-540 apparatus.

Optical rotations were recorded with a Jasco P-2000 polarimeter at 589 nm. The path length of the cuvette was $d$ = 10 mm. Specific rotations ([α]) are expressed in deg × mL × g$^{-1}$ × dm$^{-1}$, but reported without the unit. Corresponding concentrations (c) are given in g/(100mL).
2.2 Methods and materials (Chemistry)

Unless otherwise stated, all reactions were carried out using standard Schlenk techniques under a positive pressure of nitrogen or argon. Analytical thin layer chromatography (TLC) was performed on silica gel 60 F254 on aluminum sheets. Substances were detected by UV quenching (254 nm) or staining (KMnO4 in aq. K2CO3 solution). Silica gel 60 (40–63 μm) was used for flash column chromatography (approx. 0.3 bar positive pressure).S8 (-)-Parthenolide was purchased from Tokyo Chemical Industry Co., Ltd. as a reference (Lot. NM8FA-CT).

Reagents available from commercial sources were used without further purification, with the following exceptions: Anhydrous amines (Et3N, pyridine, 2,6-lutidine) and anhydrous TMSCl were obtained by distillation from CaH2. Anhydrous CH2Cl2 and 1,2-dibromoethane were obtained by distillation from CaH2 or by treating HPLC grade material with 3 Å molecular sieves (MS 3 Å) for min. 24 h. Anhydrous DMF and PhMe were obtained from a solvent purification system prior to use (HPLC grade solvents, N2 atmosphere, MS 3 Å or activated alumina, respectively). Anhydrous Et2O and THF were obtained by distilling peroxide free (KOH) and pre-dried (CaCl2) material from purple Na/benzophenone. MeOH, EtOH, and MeCN (HPLC grade) were dehydrated by treatment with MS 3 Å (min. 48 h). CDCl3 was passed through a short plug of activated basic Al2O3 (63–200 μm, activity grade I) directly before use. C6D6 was stored with MS 3 Å. LiBr was dried under vacuum by slowly heating the solid to 160 °C (20°C/h) and keeping it at this temperature for 5 h.

pH 7 phosphate buffer (0.5 M) was prepared by dissolving 58.8 g Na3PO4×12 H2O (144 mmol), 42.7 g NaH2PO4 (356 mmol) and 113 mg NaN3 (1.74 mmol) in 900 mL water and filling up to a total volume of 1 L. Na2EDTA (0.5 M, pH 8) solution was prepared by suspending 186 g Na2EDTA×3H2O in 900 mL water and slowly adding NaOH pellets until dissolution was complete and pH 8 was reached. It was filled up to a total volume of 1 L. The concentration of BuLi solutions was determined by threefold titration using 4-biphenyl acetic acid in anhydrous THF at room temperature.S9

The following substances were prepared according to the published procedures:

Homoallyloxy acetaldehyde SI-1, allyl alcohol SI-2, MgBr2×OEt2 (as 0.8 M solution in 4:1 Et2O/C6H6), aldehyde (±)-SI-3, aldehyde (±)-SI-4 and PMB–Br.
2.3 Methods and materials (biology)

2.3.1 DRG neuron cultures and immunocytochemical stainings

Cultures were prepared as described previously. DRG neurons were harvested from adult C57BL/6j mice as described previously. Isolated DRGs (T8–L6) were incubated in 0.25% trypsin/EDTA (GE Healthcare, Chalfont St Giles, UK) and 0.3% collagenase type IA (Sigma) in DMEM (Life Technologies, Carlsbad, US-CA) at 37 °C and 5% CO₂ for 45 min and mechanically dissociated. Cells were resuspended in DMEM containing 10% fetal bovine serum (GE Healthcare) and penicillin/streptomycin (500 U/mL; Merck Millipore, Billerica, US-MA) and cultured at 37 °C and 5% CO₂ on poly-D-lysine (PDL, 0.1 mg/mL, molecular weight <300,000 kDa; Sigma) and laminin (20 µg/mL; Sigma)-coated plates (Sarstedt, Germany). Cells were either treated with vehicle (DMSO), 1 nM (−)-parthenolide (Sigma-Aldrich, USA, MO), 0.5–50 nM (−)-1, 0.5–50 nM (+)-1, 0.5–50 nM (−)-22 or 0.5–50 nM (+)-22.

Axonal growth was determined 48 h upon incubation by fixation in 4% PFA (Sigma) and immunocytochemical staining with antibodies against βIII-tubulin (1:2,000; Covance, Princeton, US-NJ). Imaging and quantification of total axon length and neuron numbers per well were automatically performed with the Olympus VS120 microscope system (BD, Franklin Lakes, US-NJ) and ImageJ NeuriteTracer plugin, avoiding experimenter-induced quantification bias. Average axon length per neuron and neuron counts per experimental group were normalized to control groups. Data represent means ± SEM of 3 replicate wells per experiment and two independent experiments. Significances of intergroup differences were evaluated using either one- or two-way analysis of variance (ANOVA) followed by the Holm-Sidak post hoc test.

Microtubule detyrosination in axon tips was evaluated two days in culture using antibodies against βIII-tubulin (1:2,000; Covance) and detyrosinated tubulin (1:2,000; Millipore) as described previously. Axon tips were defined as the last 15 µm of βIII-tubulin positive neurite extensions and determined positive with a gray value above 30 after background subtraction. Data represent means ± SEM of three replicate wells with 20 tips per well from at least two independent experiments. Significances of intergroup differences were evaluated using either one-way analysis of variance (ANOVA) followed by Holm-Sidak post hoc test.
2.3.2 Monocyte isolation and polarization of macrophages

Leukocyte concentrates from freshly withdrawn peripheral blood of male and female healthy adult human donors (age 18–65 years) with written informed consent were provided by the Institute of Transfusion Medicine at the University Hospital Jena, Germany. The experimental protocol was approved by the ethical committee of the University Hospital Jena. All methods were performed in accordance with the relevant guidelines and regulations. Peripheral blood mononuclear cells (PBMC) were separated using dextran sedimentation, followed by centrifugation on lymphocyte separation medium (Histopaque®-1077, Sigma-Aldrich). PBMC were seeded in RPMI 1640 (Sigma-Aldrich) containing 10% (v/v) heat-inactivated fetal calf serum (FCS), 100 U/mL penicillin, and 100 µg/mL streptomycin in cell culture flasks (Greiner Bio-one, Frickenhausen, Germany) for 1.5 h at 37 °C and 5% CO₂ for adherence of monocytes. For differentiation of monocytes to macrophages and polarization towards M₁, published criteria were used. M₁ were generated by incubating monocytes with 20 ng/mL granulocyte-macrophage colony-stimulating factor (GM-CSF; Peprotech, Hamburg, Germany) for 6 days in RPMI 1640 supplemented with 10% FCS, 2 mmol/L glutamine (Biochrom/Merck, Berlin, Germany), and penicillin-streptomycin (Biochrom/Merck), followed by treatment with 100 ng/mL lipopolysaccharide (LPS) and 20 ng/mL interferone (INF)-γ (Peprotech).

2.3.3 Determination of cell viability

The viability of M₁ macrophages was assessed by MTT assay as described. Briefly, macrophages after 6 days of differentiation of monocytes were pre-incubated with test compounds for 15 min at 37 °C (5% CO₂), LPS (100 ng/mL, Peprotech) and INF-γ (20 ng/mL, Peprotech) were added, and cells were incubated for 48 h. Staurosporine (1 µM, Sigma-Aldrich), a pan-kinase inhibitor and inducer of apoptosis, was used as positive control. MTT solution was added, cells were further incubated for 4 h, and lysed in a buffer containing 10% (w/v) SDS.

2.3.4 SDS-PAGE and Western blot

Unpolarized macrophages were treated with test compounds or vehicle (0.1% DMSO) 15 min before cells were polarized to M₁ for 6 h. Cell lysates, corresponding to 2 × 10⁶ macrophages, were separated on 10% polyacrylamide gels, and blotted onto nitrocellulose membranes (Amersham Protran Supported 0.45 µm nitrocellulose, GE Healthcare, Freiburg, Germany). The membranes were incubated with the primary antibodies: rabbit polyclonal anti-COX-2,
1:1000 (4842S, Cell Signaling) and mouse monoclonal anti-β-actin, 1:1000 (3700S, Cell Signaling). Immunoreactive bands were stained with IRDye 800CW Goat anti-Rabbit IgG (H+L), 1:15,000 (926 32211, LI-COR Biosciences) and IRDye 680LT Goat anti-Mouse IgG (H+L), 1:40,000 (926-68020, LI-COR Biosciences), and visualized by an Odyssey infrared imager (LI-COR Biosciences). Data from densitometric analysis were background corrected.

2.3.5 **Determination of cytokine levels**

Unpolarized macrophages were treated with test compounds or vehicle (0.1% DMSO) 15 min before cells were polarized to M1 for 48 h. For measurement of extracellular cytokine levels, supernatants were collected by centrifugation (2000 g, 4 °C, 10 min). TNF-α was analyzed by in-house made ELISA kits (R&D system, Bio-Techne, MN, USA).

2.4 **Abbreviations**

15-c-5 = 15-crown-5, acac = acetylacetonate, αMγB = α-methylene-γ-butyrolactone, Ar = aryl, brsm = (yield) based on recovered starting material, COX = cyclooxygenase, CSA = camphorsulfonic acid, DDQ = 2,3-dichloro-5,6-dicyano-1,4-benzoquinone, detyr = detyrosinated, DIPT = diisopropyl tartrate, DMP = Dess–Martin periodinane, dr = diastereomeric ratio, DRG = dorsal root ganglion, EWG = electron withdrawing group, IFN = interferone, Im = imidazole, KHMDS = potassium hexamethyldisilazide, LPS = lipopolysaccharide, MS = molecular sieves, Ms = methanesulfonyl, MTBE = methyl tert-butyl ether, NBS = N-bromosuccinimide, PE = petroleum ether (bp. 35–70 °C), pin = pinacolate [2,3-dimethylbutane-2,3-bis(olate)], PMB = p-methoxy benzyl, PTL = parthenolide, rt = room temperature (20–25 °C), SEM = standard error mean, stau = staurosporine, TBAF = tetra-n-butylammonium fluoride, TBS = tert-butyl(dimethyl)silyl, TCP = tubulin carboxypeptidase, TEMPO = 2,2,6,6-Tetramethylpiperidine-1-oxyl, Tf = trifluoromethanesulfonate, TNF = tumor necrosis factor, tub = tubulin, unpol = unpolarized, veh = vehicle.
3 Experimental

3.1 Preparation of 2-(silyloxy methyl)allylboronates

\((E)-4\text{-Hydroxy-3-(tri-\text{-}n\text{-}butylstannyl)}\text{-but-2-en-1-yl acetate (SI-5)}\)

\[
\begin{align*}
\text{HO} & \quad \text{OH} & \quad \text{HO} & \quad \text{OH} & \quad \text{AcO} \\
\begin{array}{c}
\text{12} \\
\text{13} \\
\text{SI-5}
\end{array} & \quad \begin{array}{c}
\text{cat. [Pd(PPh\text{\textsubscript{3}})]}_4, \text{\textsuperscript{t}Bu\textsubscript{3}SnH, THF,} \\
0 \degree \text{C, 2 h}
\end{array} & \quad \begin{array}{c}
\text{Sn\textsuperscript{t}Bu\textsubscript{3}} \\
25 \degree \text{C}
\end{array} & \quad \begin{array}{c}
\text{AcO}, \text{Et\textsubscript{3}N,} \\
\text{CH\textsubscript{2}Cl\textsubscript{2}}, 5 \degree \text{C, 24 h}
\end{array} & \quad \begin{array}{c}
\text{SI-5} \\
\text{SI-6}
\end{array}
\end{align*}
\]

To a stirred solution of 2-butyn-1,4-diol (12, 5.0 g, 58.0 mmol, 1 equiv.) in anhydrous THF (100 mL) at 0 °C was added [Pd(PPh\text{\textsubscript{3}})_4] (670 mg, 0.58 mmol, 0.01 equiv.), followed by dropwise addition of \text{"Bu\textsubscript{3}SnH} (15.9 mL, 17.2 g, 59.0 mmol, 1.02 equiv.) over the course of 1.5 h (0.18 mL/min) by using a syringe pump. After additional 30 min (TLC control, PE/EtOAc, 1:1) the solvent was evaporated. Column chromatography of the residue (PE/EtOAc, 10:1→5:1→1:1, 8 × 15 cm) provided the stannane 13 (21.3 g, 56.6 mmol, 98%) as a slightly yellow oil.

**TLC:** \(R_f = 0.45\) (PE/EtOAc, 1:1).

Stannane 13 was dissolved in anhydrous CH\textsubscript{2}Cl\textsubscript{2} (180 mL) and cooled to 0 °C with stirring. \text{Et\textsubscript{3}N} (10.2 mL, 7.44 g, 73.5 mmol, 1.3 equiv.) was added, followed by Ac\textsubscript{2}O (6.95 mL, 7.50 g, 73.5 mmol, 1.3 equiv.). The solution was kept at 5 °C. After 24 h (TLC control, PE/EtOAc, 2:1) MeOH (20 mL) was added and the mixture was stirred at rt for 1 h. The solution was then washed with a 1.0 M HCl solution (2 × 100 mL), sat. NaHCO\textsubscript{3} solution (100 mL) and brine (100 mL), dried with MgSO\textsubscript{4}, filtered and concentrated in vacuo. Column chromatography of the residue (PE/Et\textsubscript{2}O, 4:1→2:1, 8 × 20 cm) provided the acetoxy stannane SI-5 (16.1 g, 38.4 mmol, 68%) as a colorless oil, which slowly isomerizes partially to acetoxy stannane SI-6 at ~25 °C\textsuperscript{19}. Evaporation was carried out at 0–10 °C, in order to suppress isomerization.
SI-5:
TLC: $R_f = 0.51$ (PE/Et$_2$O, 3:2).

$^1$H NMR (400 MHz, C$_6$D$_6$, mixture of SI-5 (major) and SI-6, SI-5 assigned): $\delta = 5.81$ ($tt$, 1H, $^3J_{HH} = 6.3$, $^2J_{HH} = 2.2$ Hz, $=$CH), $^3J_{HH} = 67.0$ Hz), 4.57–4.48 ($m$, 2H, CH$_2$O), 4.21–4.07 ($m$, 2H, CH$_2$O; $^3J_{HH} = 34.7$ Hz), 1.68–1.53 ($m$, 9H, 3 × CH$_2$), 1.46–1.31 ($m$, 6H, 3 × CH$_2$), 1.15–0.90 ($m$, 15H, 3 × CH$_2$ + 3 × CH$_3$).

$^{13}$C($^1$H) NMR (101 MHz, C$_6$D$_6$, mixture of SI-5 (major) and SI-6, SI-5 assigned): $\delta = 170.2$ (C=O), 153.1 ($=CSn$, $^1J_{C,Sn} = 370.8$ Hz), 131.7 ($=CH$, $^2J_{C,Sn} = 22.5$ Hz), 63.4 (CH$_2$O, $^3J_{C,Sn} = 17.2$ Hz), 61.4 (CH$_2$O, $^3J_{C,Sn} = 61.7$ Hz), 29.6 (CH$_2$, $^3J_{C,Sn} = 19.5$ Hz), 27.8 (CH$_2$, $^2J_{C,Sn} = 57.6$ Hz), 20.5 (C(O)CH$_3$), 14.0 (CH$_3$), 10.6 (CH$_2$, $^1J_{C,Sn} = 326.8$ Hz).

$^{119}$Sn($^1$H) (149 MHz, C$_6$D$_6$): $\delta = -40.2$ (s).

IR (ATR): $\tilde{\nu} = 3441$ (w), 3000–2800 (m), 1744 (s), 1728 (m), 1458 (m), 1377 (m), 1226 (s), 1026 (s), 1038 (s), 690 (m), 864 (m), 663 (m) cm$^{-1}$.

HRMS (ESI, TOF): m/z calc’d for C$_{18}$H$_{36}$O$_3$Sn[M+Na]$^+$ 443.1579; observed 443.1584.

SI-6
TLC: $R_f = 0.30$ (PE/Et$_2$O, 3:2).

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**(E)-4-Hydroxy-3-iodobut-2-en-1-yl acetate (SI-7)**

![Diagram](image)

To a stirred solution of stannane SI-5 (9.51 g, 22.7 mmol, 1.0 equiv.) in anhydrous CH$_2$Cl$_2$ (70 mL) at $–78$ °C I$_2$ (6.04 g, 23.8 mmol, 1.05 equiv.) was added in one portion. After 3 h at this temperature (TLC control, Et$_2$O/PE, 3:1) the cooling bath was removed and semi-sat. Na$_2$S$_2$O$_3$ solution (70 mL) was added. Stirring was continued for 10 min. The colorless organic layer was separated, washed with sat. NaHCO$_3$ solution (70 mL) and brine (70 mL), dried with MgSO$_4$, filtered and concentrated in vacuo. The residue was taken up in MeCN (100 mL) and washed with PE (100 mL). The PE layer was then extracted with MeCN (3 × 30 mL). The combined MeCN extracts were concentrated in vacuo. After column
chromatography (PE/MTBE, 1:1, 6 × 20 cm) the vinyl iodide SI-7 (5.35 g, 20.9 mmol, 92%) was obtained as a colorless oil.

**TLC:** \( R_f = 0.30 \) (PE/MTBE, 1:1).

**\(^{1}H\) NMR** (300 MHz, C\(_6\)D\(_6\)): \( \delta = 6.19 \) (\( t t \), 1H, \( ^{3}J_{H,H} = 7.2 \), 0.9 Hz, \( =CH \)), 4.25 (\( d \), 2H, \( ^{3}J_{H,H} = 7.3 \) Hz, CH\(_2\)), 4.02 (\( d \), 2H, \( ^{3}J_{H,H} = 4.4 \) Hz, CH\(_2\)), 2.77 (\( brs \), 1H, OH), 1.54 (\( s \), 3H, CH\(_3\)).

**\(^{13}C\)\(^{1}H\) NMR** (75 MHz, C\(_6\)D\(_6\)): \( \delta = 170.6 \) (C=O), 136.2 (\( =CH \)), 109.6 (\( =Cl \)), 66.5 (CH\(_2\)OH), 61.2 (CH\(_2\)OAc), 20.4 (CH\(_3\)).

**IR** (ATR): \( \tilde{\nu} = 3433 \) (w), 3000–2800 (m), 1736 (s), 1636 (w), 1439 (w), 1377 (m), 1362 (m), 1223 (s), 1115 (m), 1026 (s), 964 (m), 814 (w), 737 (w), 606 (m) cm\(^{-1}\).

**HRMS** (ESI, TOF): m/z calc’d for C\(_6\)H\(_9\)IO\(_3\) [M+Na\(^+\)] 278.9489; observed 278.9492.

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(E)-4-[(tert-Butyldimethylsilyl)oxy]-3-iodobut-2-en-1-ol (14)

![Chemical Structure](image)

To a stirred solution of alcohol SI-7 (7.46 g, 29.1 mmol, 1.0 equiv.) in anhydrous CH\(_2\)Cl\(_2\) (100 mL) at 0 °C was added imidazole (2.97 g, 43.7 mmol, 1.5 equiv.), followed by TBSCI (6.14 g, 40.7 mmol, 1.4 equiv.). After 10 min the cooling bath was removed and the suspension was stirred for 3 h at rt (TLC control, PE/MTBE, 1:1). The mixture was filtered through a plug of silica (6 × 6 cm, PE/MTBE, 3:1). The solvent was removed in vacuo and the residual oil (SI-8) was taken to the next step.

**TLC:** \( R_f = 0.79 \) (PE/MTBE, 3:1).

The crude protected diol SI-8 was dissolved in anhydrous MeOH (100 mL) and cooled to 0 °C with stirring. K\(_2\)CO\(_3\) (8.04 g, 58.2 mmol, 2.0 equiv.) was added and after 10 min the cooling bath was removed. The suspension was stirred at rt for 2 h (TLC control, PE/MTBE, 5:1), then filtered through a plug of Celite, followed by addition of sat. NH\(_4\)Cl solution (100 mL). The mixture was extracted with MTBE (200 mL). The organic layer was separated
and washed with brine (100 mL), dried with MgSO₄, filtered and concentrated in vacuo. Column chromatography of the residue (PE/MTBE, 3:1→2:1, 8 × 15 cm) provided the allyl alcohol 14 (7.93 g, 24.2 mmol, 83% over 2 steps) as a colorless oil.

**TLC**: $R_f = 0.26$ (PE/MTBE, 5:1).

$^1$H NMR (300 MHz, C₆D₆): $\delta = 6.31$ (t, 1H, $^3J_{HH} = 6.5$ Hz, CH), 4.08 (s, 2H, CH₂OSi), 3.77 (d, 2H, $^3J_{HH} = 6.0$ Hz, CH₂OH), 1.68 (br s, 1H, OH), 0.94 (s, 9H, SiC(CH₃)₃), 0.04 (s, 6H, Si(CH₃)₂).

$^{13}$C{¹H} NMR (75 MHz, C₆D₆): $\delta = 142.0$ (CH), 105.1 (Cl), 66.7 (CH₂OSi), 60.5 (CH₂OH), 26.1 (SiC(CH₃)₃), 18.5 (SiC(CH₃)₃), −5.0 (Si(CH₃)₂).

IR (ATR): $\tilde{\nu} = 3379$ (w), 3000–2800 (m), 2280 (w), 1634 (w), 1470 (w), 1362 (w), 1254 (m), 1107 (m), 1003 (m), 941 (w), 833 (s), 814 (m), 775 (s), 741 (w), 671 (w) cm⁻¹.

HRMS (ESI, TOF): m/z calc’d for C₁₀H₂₁IO₂Si [M+Na]$^+$ 351.0248; observed 351.0251.

(E)-[(4-Bromo-2-iodobut-2-en-1-yl)oxy](tert-butyl)dimethylsilane (15)

![Chemical Structure](image)

To a stirred solution of alcohol 14 (7.93 g, 24.2 mmol, 1.0 equiv.) in anhydrous CH₂Cl₂ (100 mL) at $-40$ °C was added PPh₃ (9.52 g, 36.3 mmol, 1.5 equiv.). After 10 min NBS (6.03 g, 33.9 mmol, 1.4 equiv.) was added in 6 portions at 3 min intervals. The mixture was stirred at this temperature for 6 h (TLC control, PE/MTBE, 3:1). Anhydrous MeOH (1 mL) was added and stirring was continued for 20 min. The cooling bath was removed, the mixture was diluted with PE (50 mL) and filtered through a plug of silica (d × h = 7 × 5 cm, PE/CH₂Cl₂, 3:1). The filtrate was concentrated and purified by column chromatography (PE/CH₂Cl₂, 15:1, 7 × 15 cm). Allyl bromide 15 (8.48 g, 21.7 mmol, 90%) was obtained as slightly pink oil, which was stored at $-25$ °C for months without detectable decomposition.

**TLC**: $R_f = 0.38$ (PE/CH₂Cl₂, 9:1).
\( ^1H \) NMR (300 MHz, CD\(_6\)D\(_6\)): \( \delta = 6.22 \) (tt, 1H, \( ^3J_{HH} = 8.6, 1.2 \text{ Hz, } \text{H} \)), 4.03 (s, 2H, CH\(_2\)OSi), 3.42 (d, 2H, \( ^3J_{HH} = 8.7 \text{ Hz, CH}_2\)Br), 0.93 (s, 9H, SiC(CH\(_3\))\(_3\)), 0.01 (s, 6H, Si(CH\(_3\))\(_2\)).

\( ^{13}C\{^1H\} \) NMR (75 MHz, CD\(_6\)D\(_6\)): \( \delta = 136.9 \) (=CH), 109.3 (=Cl), 66.2 (CH\(_2\)OSi), 27.1 (CH\(_2\)Br), 26.0 (SiC(CH\(_3\))\(_3\)), 18.4 (SiC(CH\(_3\))\(_3\)), –5.1 (Si(CH\(_3\))\(_2\)).

IR (ATR): \( \bar{\nu} = 3000 – 2800 \) (m), 2280 (w), 1620 (w), 1470 (w), 1330 (w), 1261 (m), 1203 (w), 1103 (m), 1064 (m), 1007 (w), 833 (s), 813 (m), 779 (m), 737 (s), 706 (w) cm\(^{-1}\).

HRMS (ESI, TOF): m/z calc’d for C\(_{10}\)H\(_{20}\)BrIOSi [M+Na]\(^+\) 412.9404; observed 412.9406.

\((E)\)-tert-Butyl[[2-iodo-4-(phenylthio)but-2-en-1-yl]oxy]dimethylsilane (SI-9)

To a stirred solution of PhSH (1.11 mL, 1.20 g, 10.9 mmol, 1.05 equiv.) in anhydrous MeOH (80 mL) at –20 °C was added a NaOMe solution (2.50 mL, 10.9 mmol, 1.05 equiv., 4.36 m in MeOH). After stirring for 10 min a solution of the allyl bromide 15 (4.06 g, 10.4 mmol, 1.0 equiv.) in anhydrous MeOH (20 mL) was added and the reaction mixture was allowed to warm to 0 °C over 2 h and stirred at 0 °C for another hour (TLC control, PE/CH\(_2\)Cl\(_2\), 4:1). After completion of the reaction the cooling bath was removed, pH 7 phosphate buffer (150 mL, 0.5 m) and MTBE (150 mL) were added, and the organic layer was separated. The organic extract was washed with sat. NaHCO\(_3\) solution (2 × 50 mL) and brine (100 mL), dried with MgSO\(_4\), filtered and concentrated in vacuo. Column chromatography of the residue (PE/CH\(_2\)Cl\(_2\), 8:1→4:1→2:1, 6 × 15 cm) provided the allyl sulfide SI-9 (4.18 g, 9.94 mmol, 96%) as a slightly yellow oil.

**TLC:** \( R_t = 0.22 \) (PE/CH\(_2\)Cl\(_2\), 8:1).

\( ^1H \) NMR (300 MHz, CD\(_6\)D\(_6\)): \( \delta = 7.26 – 7.21 \) (m, 2H, CH, Ph), 6.99–6.87 (m, 3H, CH, Ph), 6.28 (tt, 1H, \( ^3J_{HH} = 8.1, 1.0 \text{ Hz, H} \)), 3.81 (s, 2H, CH\(_2\)O), 3.16 (d, 2H, \( ^3J_{HH} = 8.1 \text{ Hz, S} \))

0.95 (s, 9H, SiC(CH\(_3\))\(_3\)), 0.02 (s, 6H, Si(CH\(_3\))\(_2\)).
\(^{13}\text{C}\{^1\text{H}\}\ \text{NMR}\ (75 \text{ MHz, } \text{C}_6\text{D}_6): \ \delta = 137.1 \ (\text{SC}_{\text{quart}}), 135.5 \ (\text{HC}═), 132.0 \ (\text{CH, Ph}), 129.2 \ (\text{CH, Ph}), 127.3 \ (\text{CH, Ph}), 106.5 \ (=\text{Cl}), 65.5 \ (\text{CH}_2\text{O}), 34.8 \ (\text{CH}_2\text{S}), 26.1 \ (\text{Si}((\text{CH}_3)_3)), 18.5 \ (\text{Si}((\text{CH}_3)_3)),\ -5.0 \ (\text{Si}(\text{CH}_3)_2)\). 

\text{IR (ATR): } \tilde{\nu} = 3902 \ (\text{w}), 3855 \ (\text{w}), 3749 \ (\text{w}), 3650 \ (\text{w}), 3567 \ (\text{w}), 2928 \ (\text{m}), 2855 \ (\text{m}), 2362 \ (\text{w}), 1745 \ (\text{w}), 1622 \ (\text{w}), 1469 \ (m), 1363 \ (m), 1254 \ (s), 1098 \ (s), 939 \ (w), 835 \ (s), 749 \ (s), 691 \ (m) \ \text{cm}^{-1}.

\text{HRMS (ESI, Orbitrap): } m/z \text{ calc’d for } \text{C}_{16}\text{H}_{25}\text{IOSSi}[\text{M}–\text{H}]^- 419.0356; \text{ observed } 419.0348.

\text{(E)-tert-Butyl[2-iodohepta-2,6-dien-1-yl]oxy]dimethylsilane (SI-10)}

![Chemical structure]

To a stirred solution of allyl bromide 15 (170 mg, 0.43 mmol, 1.0 equiv.) in anhydrous THF (3.6 mL) at \(-40^\circ\text{C}\) was added a solution of methallylmagnesium bromide (0.75 mL, 0.52 mmol, 1.2 equiv, 0.7 M in THF), prepared from methallyl bromide and Mg (3.0 equiv.) in anhydrous THF at 0 \(^\circ\text{C}\). After 1.5 h at \(-40^\circ\text{C}\) (TLC control, PE/Et\(_2\)O, 20:1) the cooling bath was removed, sat. \text{NH}_4\text{Cl} solution (20 mL) was added and the mixture was extracted with MTBE (20 mL). The organic layer was separated, washed with brine (20 mL), dried with MgSO\(_4\), filtered and all volatiles were removed \textit{in vacuo}. Column chromatography of the residue (PE/MTBE, 99:1, 1 \times 18 cm) gave the vinyl iodide SI-10 (148 mg, 0.40 mmol, 94%) as a colorless oil.

\text{TLC: } R_f = 0.25 \ (\text{PE}).

\(^1\text{H NMR}\ (300 \text{ MHz, } \text{C}_6\text{D}_6): \ \delta = 6.17 \ (t, \ 1\text{H}, \ ^3J_{\text{H,H}} = 7.5 \text{ Hz, } =\text{CH}), 4.78–4.68 \ (m, \ 1\text{H, } =\text{C(\text{H})H}^+), 4.70–4.58 \ (m, \ 1\text{H, } =\text{C(\text{H})H}^+), 4.14 \ (s, \ 2\text{H, } \text{CH}_2\text{OSi}), 2.10–1.90 \ (m, \ 2\text{H, } \text{CH}_2), 1.85–1.68 \ (m, \ 2\text{H, } \text{CH}_2), 1.51 \ (s, \ 3\text{H, } =\text{C(\text{R})CH}_3), 1.00 \ (s, \ 9\text{H, } \text{Si}((\text{CH}_3)_3)), 0.09 \ (s, \ 6\text{H, } \text{Si}(\text{CH}_3)_2)).

\(^{13}\text{C}\{^1\text{H}\}\ \text{NMR}\ (75 \text{ MHz, } \text{C}_6\text{D}_6): \ \delta = 144.2 \ (=\text{C}_q), 142.1 \ (=\text{CH}), 111.1 \ (=\text{CH}_2), 103.1 \ (=\text{Cl}), 65.7 \ (\text{CH}_2\text{OSi}), 37.0 \ (\text{CH}_2), 29.5 \ (\text{CH}_2), 26.1 \ (\text{Si}((\text{CH}_3)_3)), 22.3 \ (\text{CH}_3), 18.6 \ (\text{Si}((\text{CH}_3)_3)),\ -4.9 \ (\text{Si}(\text{CH}_3)_2)\).
IR (ATR): $\tilde{\nu} = 3300–3000 \text{ (w)}$, 3000–2800 (m), 1651 (w), 1632 (m), 1369 (w), 1253 (m), 1107 (m), 1080 (m), 941 (w), 887 (m), 775 (s), 667 (m), 613 (w) cm$^{-1}$.

HRMS (ESI, TOF): m/z calc’d for C$_{14}$H$_{27}$IOSi [M+Na]$^+$ 389.0768; observed 389.0769.

(E)-tert-Butyl[(2-iodohepta-2,6-dien-1-yl)oxy]dimethylsilane (SI-11)

![Chemical structure]

To a stirred solution of allyl bromide 15 (3.0 g, 7.67 mmol, 1.0 equiv.) in anhydrous THF (70 mL) at $-40 ^\circ$C was added a solution of allylmagnesium bromide (14.0 mL, 11.5 mmol, 1.5 equiv., 0.82 M in Et$_2$O), prepared from allyl bromide and Mg (3.0 equiv.) in anhydrous Et$_2$O at 0 °C. After 2 h at $-40 ^\circ$C (TLC control, PE/Et$_2$O, 20:1) EtOH (1 mL) was added and the cooling bath was removed. Sat. NH$_4$Cl solution (100 mL) was added and the mixture was extracted with MTBE (100 mL). The organic layer was separated, washed with brine (100 mL), dried with MgSO$_4$, filtered and all volatiles were removed in vacuo. Column chromatography of the residue (PE/CH$_2$Cl$_2$, 9:1, 4 × 15 cm) gave the vinyl iodide SI-11 (2.59 g, 7.35 mmol, 96%) as a colorless oil.

TLC: $R_f = 0.36$ (PE/CH$_2$Cl$_2$, 8:1),

$^1$H NMR (300 MHz, C$_6$D$_6$): $\delta = 6.14$ (t, 1H, $^3J_{HH} = 7.4$ Hz, HC=Cl), 5.62–5.48 (m, 1H, HC=), 4.93–4.91 (m, 1H, $\equiv$C(H)H$^+$), 4.89–4.85 (m, 1H, $\equiv$C(H)H$^+$), 4.11 (s, 2H, CH$_2$OSi), 1.95–1.85 (m, 2H, CH$_2$), 1.82–1.74 (m, 2H, CH$_2$), 0.99 (s, 9H, SiC(CH$_3$)$_3$), 0.08 (s, 6H, Si(CH$_3$)$_2$).

$^{13}$C($^1$H) NMR (101 MHz, C$_6$D$_6$): $\delta = 141.8$ (HC=), 137.3 (HC=), 115.6 ($\equiv$CH$_2$), 103.4 ($\equiv$Cl), 65.7 (CH$_2$OSi), 33.2 (CH$_2$), 30.7 (CH$_2$), 26.1 (SiC(CH$_3$)$_3$), 18.5 (SiC(CH$_3$)$_3$), 4.9 (Si(CH$_3$)$_2$).

IR (ATR): $\tilde{\nu} = 3078$ (w), 2929 (m), 2856 (m), 2194 (w), 2045 (w), 1926 (w), 1710 (w), 1639 (w), 1465 (m), 1361 (m), 1254 (s), 1099 (s), 1002 (s), 913 (m), 835 (s), 777 (s), 670 (s) cm$^{-1}$.

MS (GC, EI): m/z 295.0 [M–Bu]$^+$. 

HRMS: No molecular ion peak detectable (collected HPLC fraction, ionization modes: ESI, APCI, EI).
2-Isopropoxy-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (SI-12)

\[
\text{B(O'Pr)}_3 + \begin{array}{c}
\text{H} \\
\text{HO}
\end{array} \rightarrow \begin{array}{c}
\text{PrO} \\
\text{B}
\end{array} \quad \text{120 °C, 5 h} \quad 92\% \quad \text{SI-12}
\]

A published procedure was modified in the following way:\textsuperscript{S20} Pinacol (10.0 g, 84.2 mmol, 1.0 equiv.) and B(O’Pr)\textsubscript{3} (19.4 mL, 15.8 g, 84.2 mmol, 1.0 equiv.) were stirred in a distillation apparatus at 120 °C and 900 mbar for 5 h. After that time the pressure was reduced to 100 mbar over 30 min followed by increasing the heating to 150 °C. After vacuum distillation \textsuperscript{1}PrOB(pin) (14.4 g, 77.5 mmol, 92%) was obtained as colorless oil, which was stored under anhydrous N\textsubscript{2} atmosphere.

\textbf{Bp.}: 104–106 °C (100 mbar).

\textsuperscript{1}H NMR (400 MHz, C\textsubscript{6}D\textsubscript{6}): \(\delta = 4.47\) (sept, 1H, \(^3J_{HH} = 6.2\) Hz, \(\text{H(CH}_3_2\)), 1.17 (d, 6H, \(^3J_{HH} = 6.2\) Hz, CH\textsubscript{3}), 1.06 (s, 12H, CH\textsubscript{3}, pin).

\textsuperscript{13}C\{\textsuperscript{1}H\} NMR (101 MHz, C\textsubscript{6}D\textsubscript{6}): \(\delta = 82.2\) (OC\textsubscript{quart}), 67.3 (\(\text{C(CH}_3_2\)), 24.7 (CH\textsubscript{3}), 24.6 (CH\textsubscript{3}), 24.6 (CH\textsubscript{3}).

\textsuperscript{11}B\{\textsuperscript{1}H\} NMR (128 MHz, C\textsubscript{6}D\textsubscript{6}): \(\delta = 22.2\) (s).

The NMR data matched published data.\textsuperscript{S21}

2-(Iodomethyl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (SI-13)

\[
\text{CH}_2\text{I}_2 + \begin{array}{c}
\text{PrO} \\
\text{B}
\end{array} \rightarrow \begin{array}{c}
\text{BuLi, THF, 1.5 h, –78 °C} \\
\text{then TMSO, –78 °C to rt, 1 h}
\end{array} \quad 73\% \quad \text{SI-13}
\]

A published procedure was modified in the following way:\textsuperscript{S21} To a stirred solution of CH\textsubscript{2}I\textsubscript{2} (5.62 mL, 18.7 g, 69.7 mmol, 1.0 equiv., dehydrated by passing through a plug of activated neutral alumina before usage) and \textsuperscript{1}PrOB(pin) (SI-12, 15.0 mL, 13.0 g, 69.7 mmol, 1.0 equiv.) in anhydrous THF (50 mL) at –78 °C was added a \textsuperscript{1}BuLi solution (27.9 mL, 69.7 mmol, 1.0 equiv., 2.5 M in hexanes) dropwise over 1 h using a syringe pump. The initially yellow
suspension was stirred for a further 30 min at –78 °C, then TMSCl (8.87 mL, 7.57 g, 69.7 mmol, 1.0 equiv.) was added, the cooling bath was removed and the solution was allowed to reach rt and stirred for an additional hour. Hexane (80 mL) was added and the suspension was filtered through Celite (PE). All volatiles were removed in vacuo. The residual oil was rapidly filtered through a plug of silica (d × h = 5 × 4 cm; MTBE/PE, 1:1) and the filtrate was concentrated in vacuo. After distillation of the residue (3–4 mbar, bath temperature: 110 °C) the boronate SI-13 (13.7 g, 51.1 mmol, 73%) was obtained as a colorless oil, which solidifies below –25 °C.

**TLC:** $R_f = 0.33$ (PE/MTBE, 9:1).

**Bp.** 60–64 °C (3–4 mbar).

$^1$H NMR (400 MHz, C$_6$D$_6$): $\delta = 1.96$ (s, 2H, CH$_2$), 1.00 (s, 12H, CH$_3$).

$^{13}$C{$^1$H} NMR (75 MHz, C$_6$D$_6$): $\delta = 82.0$ (C$_{quat}$), 22.5 (CH$_3$).

The carbon (CH$_2$) adjacent to boron was not observed, due to quadrupolar coupling with $^{11}$B ($I = 3/2$) and $^{10}$B ($I = 3$), resulting in very weak signals and fast relaxation.

$^{11}$B{$^1$H} NMR (128 MHz, C$_6$D$_6$): $\delta = 31.8$ (s).

The NMR data matched published data.$^{22}$

[(4,4,5,5-Tetramethyl-1,3,2-dioxaborolan-2-yl)methyl]zinc(II) iodide [IZnCH$_2$B(pin), SI-14]

According to Knochel’s procedure,$^{23}$ zinc powder (5.17 g, 79.1 mmol, 2.0 equiv.) was suspended in anhydrous THF (30 mL) and anhydrous 1,2-dibromoethane (0.34 mL, 744 mg, 3.96 mmol, 0.1 equiv.) was added under vigorous stirring. The solution was brought to reflux for a minute and then allowed to cool to rt. TMSCl (0.10 mL, 86.0 mg, 0.80 mmol, 0.02 equiv.) was added and the mixture was again refluxed for a minute and cooled to rt. After 15 min a solution of ICH$_2$B(pin) (SI-13, 10.6 g, 39.6 mmol, 1.0 equiv.) in anhydrous THF (10 mL) was added over 30 min. The stirring was stopped after additional 2 h and the solids were allowed to settle over 36–48 h at 5 °C. The clear, colorless supernatant containing
**SI-14** was titrated against I₂ (1.0 equiv.) in THF to determine its concentration (0.76 M, ~90% yield).

The reagent solution with the settled, excess zinc was stored at 5 °C under nitrogen for 2–3 weeks without noticeable decomposition and decrease in concentration.

(Z)-**tert-Butyldimethyl[(4-(phenylthio)-2-[(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)methyl]but-2-en-1-yl]oxy]silane** [(Z)-**11a**]

![Chemical structure diagram](attachment:structure.png)

To a stirred solution of [Pd(PPh₃)₄] (274 mg, 0.24 mmol, 0.1 equiv.) in anhydrous THF (15 mL) at rt was added a solution of alkylzinc reagent SI-14 (7.60 mL, 4.76 mmol, 2.0 equiv., 0.62 M in THF), followed by a solution of vinyl iodide SI-9 (1.00 g, 2.38 mmol, 1.0 equiv.) in anhydrous THF (10 mL). The flask was immersed in a preheated 60 °C oil bath and stirred for 3 h (GC–MS control). The oil bath was removed and the mixture was cooled to 0 °C whereupon it was added to a stirred pH 6 phosphate buffer (75 mL, 0.5 M) at 0 °C. The mixture was extracted with MTBE (70 mL) and the extract was washed with brine (70 mL). The organic extract was dried with MgSO₄, filtered and the solvent was removed in vacuo. Rapid (10 min) column chromatography of the residue (PE/Et₂O, 40:1, 4 × 10 cm) provided the allylboronate (Z)-**11a** (680 mg, 1.56 mmol, 66%) as a colorless oil which solidified below –25 °C.

[Note: The allylboronate decomposes on silica gel, therefore prolonged contact (>15 min) should be avoided]

**TLC**: Rᵣ = 0.26 (PE/CH₂Cl₂, 6:1).

**¹H NMR** (300 MHz, C₆D₆): δ = 7.36–7.27 (m, 2H, CH, Ph), 7.07–6.96 (m, 2H, CH, Ph), 6.94–6.85 (m, 1H, CH, Ph), 5.47 (t, 1H, J₃H₂H = 7.8 Hz, HC=), 4.27 (s, 2H, CH₂O), 3.47 (d, 2H, J₃H₂H = 7.8 Hz, PhSCH₂), 1.98 (s, 2H, CH₂B), 1.02 (s, 12H, CH₃, pin), 0.96 (s, 9H, SiC(CH₃)₃), 0.06 (s, 6H, Si(CH₃)₂).

**¹³C{¹H} NMR** (75 MHz, C₆D₆): δ = 140.6 (SC_quart), 137.8 (R₂C=), 130.1 (CH, Ph), 129.0 (CH, Ph), 126.1 (CH, Ph), 120.7 (HC=), 83.1 (C(CH₃)₂, pin), 61.9 (CH₂O), 31.9 (CH₂S), 26.2 (SiC(CH₃)₃), 24.9 (CH₃, pin), 18.6 (SiC(CH₃)₃), –5.1 (Si(CH₃)₂).
The carbon atom (CH$_2$) adjacent to boron was concealed, due to quadrupolar coupling with $^{11}$B ($I = 3/2$) and $^{10}$B ($I = 3$).

$^{11}$B{H} NMR (128 MHz, C$_6$D$_6$): $\delta = 33.4$ (s).

IR (ATR): $\tilde{\nu} = 3947$ (w), 3903 (w), 3855 (w), 3748 (w), 3650 (w), 3567 (w), 3059 (w), 2929 (w), 2856 (w), 2362 (w), 1745 (w), 1651 (w), 1471 (w), 1317 (m), 1260 (m), 1143 (m), 1072 (m), 966 (m), 835 (s), 749 (s), 690 (m) cm$^{-1}$.

HRMS (APCI, Orbitrap): m/z calc’d for C$_{23}$H$_{39}$BO$_3$SSi[M+H]$^+$ 435.2555; observed 435.2553.

(Z)-tert-Butyldimethyl(6-methyl-2-[(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)methyl]hepta-2,6-dien-1-yl)oxy)silane [(Z)-11b]

Following the procedure described for the synthesis of boronate (Z)-11a the reaction of vinyl iodide SI-10 (1.38 g) and IZnCH$_2$B(pin) (SI-14, 14.3 mL, 0.53 M) in the presence of [Pd(PPh$_3$)$_4$] (563 mg) in anhydrous THF (50 mL) at 60 °C for 2 h yielded 54% of boronate (Z)-11b (770 mg) after rapid column chromatography.

[Note: The allylboronate decomposes on silica gel, therefore prolonged contact (>15 min) should be avoided]

TLC: $R_f = 0.22$ (PE/CH$_2$Cl$_2$, 4:1).

$^1$H NMR (400 MHz, C$_6$D$_6$): $\delta = 5.34$ (t, 1H, $^3$J$_{H,H} = 7.0$ Hz, HC=), 4.79 (s, 2H, =CH$_2$), 4.46 (s, 2H, CH$_2$O), 2.27–2.19 (m, 2H, CH$_2$), 2.11 (s, 2H, CH$_2$B), 2.05–2.02 (m, 2H, CH$_2$), 1.62 (s, 3H, CH$_3$), 1.07 (s, 12H, CH$_3$, pin), 1.01 (s, 9H, SiC(CH$_3$)$_3$), 0.14 (s, 6H, Si(CH$_3$)$_2$).

$^{13}$C{H} NMR (101 MHz, C$_6$D$_6$): $\delta = 145.1$ (R$_2$C=), 136.2 (R$_2$C=), 124.9 (RC(H)=), 110.2 (=CH$_2$), 82.5 (C(CH$_3$)$_2$, pin), 61.7 (CH$_2$O), 38.1 (CH$_2$), 26.1 (CH$_3$), 25.8 (SiC(CH$_3$)$_3$), 24.6 (CH$_3$, pin), 22.2 (CH$_3$C=), 18.7 (CH$_2$B, B-decoupled, from HSQC), 18.6 (SiC(CH$_3$)$_3$), $-$5.4 (Si(CH$_3$)$_2$).

The carbon atom (CH$_2$) adjacent to boron was concealed, due to quadrupolar coupling with $^{11}$B ($I = 3/2$) and $^{10}$B ($I = 3$).

$^{11}$B{H} NMR (128 MHz, C$_6$D$_6$): $\delta = 33.6$ (s).
IR (ATR): $\tilde{\nu} = 3000$--$2800$ (m), 1651 (w), 1462 (w), 1344 (m), 1319 (m), 1253 (m), 1215 (w), 1146 (s), 1072 (m), 1066 (w), 968 (m), 883 (m), 837 (s), 775 (s), 671 (m) cm$^{-1}$.

HRMS (ESI, TOF): m/z calc’d for C$_{21}$H$_{41}$BO$_3$Si [M+Na]$^+$ 403.2810; observed 408.2813.

(Z)-tert-butyldimethyl[[2-[(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)methyl]hepta-2,6-dien-1-yl]oxy]silane [(Z)-11c]

\[
\begin{align*}
\text{Si-11} & \quad \text{OTBS} & \quad \text{[Pd(PPh$_3$_4],} \\
& \quad [\text{IzB(pin)},] \\
& \quad \text{THF, 60 °C, 2 h} \\
\rightarrow & \quad \text{OTBS} & \quad \text{B(pin)}
\end{align*}
\]

Following the procedure described for the synthesis of boronate (Z)-11a the reaction of vinyl iodide SI-11 (774 mg) and [IzCH$_2$B(pin) (SI-14, 2.95 mL, 0.82 M) in the presence of [Pd(PPh$_3$_4)] (127 mg, 5 mol-%) in anhydrous THF (11 mL) at 60 °C for 4 h yielded 50% of boronate (Z)-11c (403 mg) after rapid (10 min) column chromatography (PE/Et$_2$O, 30:1, 5 × 10 cm).

TLC: $R_f = 0.29$ (PE/CH$_2$Cl$_2$/Et$_2$O, 29:5:1).

$^1$H NMR (400 MHz, C$_6$D$_6$): $\delta$ = 5.78 (ddt, 1H, $^3$J$_{H,H}$ = 16.7, 10.2, 6.5 Hz, C(H)==), 5.29 (t, 1H, $^3$J$_{H,H}$ = 7.1 Hz, HC==C$_{\text{quat}}$), 5.04–4.93 (m, 2H, ==CH$_2$), 4.41 (s, 2H, CH$_2$OSi), 2.18–1.96 (m, 6H, 3 × CH$_2$), 1.06 (s, 12H, CH$_3$, pin), 0.99 (s, 9H, SiC(CH$_3$_3), 0.12 (s, 6H, Si(CH$_3$_2)$_2$).

$^{13}$C($^1$H) NMR (75 MHz, C$_6$D$_6$): $\delta$ = 138.7 (HC==), 136.9 (R$_2$C==), 125.0 (R$_2$C(H)==), 114.8 (==CH$_2$), 82.9 (C(CH$_3$_2), pin), 62.1 (CH$_2$O), 34.6 (CH$_2$), 27.6 (CH$_2$), 26.3 (SiC(CH$_3$_3), 25.0 (CH$_3$, pin), 18.6 (SiC(CH$_3$_3), 5.0 (Si(CH$_3$_2)$_2$).

The carbon atom (CH$_2$) adjacent to boron was concealed, due to quadrupolar coupling with $^{11}$B ($I = 3/2$) and $^{10}$B ($I = 3$).

$^{11}$B($^1$H) NMR (128 MHz, C$_6$D$_6$): $\delta$ = 33.5 (s).

IR (ATR): $\tilde{\nu} = 2932$ (m), 2859 (m), 2363 (w), 1735 (m), 1641 (w), 1437 (s), 1373 (m), 1301 (m), 1256 (m), 1148 (s), 952 (m), 833 (s), 782 (s), 674 (s) cm$^{-1}$.

HRMS (ESI, TOF): m/z calc’d for C$_{20}$H$_{39}$BO$_3$Si [M+Na]$^+$ 389.2654; observed 389.2658.
3.2 Preparation of carbonyl compounds and allylboration reactions

(1R*,2R*)-2-{3-[tert-Butyldimethylsilyl]oxy]prop-1-yl-2-yl}-1-phenylhex-5-en-1-ol [(±)-16a]

Freshly distilled benzaldehyde (7.0 μl, 7.3 mg, 68.8 μmol, 1.2 equiv.) was added to a stirred solution of boronate (Z)-11c (21.0 mg, 57.3 μmol, 1.0 equiv.) in anhydrous Et₂O (0.6 mL) at 0 °C. The solution was allowed to reach rt over 2 h. After 24 h at this temperature (TLC control, PE/Et₂O, 6:1) the complete mixture was directly subjected to column chromatography (PE/Et₂O, 8:1, 1.5 × 20 cm) to obtain the homoallyl alcohol (±)-16a (16.1 mg, 46.5 μmol, 81%) as a colorless oil.

TLC: Rf = 0.39 (PE/Et₂O, 6:1).

1H NMR (300 MHz, C₆D₆): δ = 7.35–7.30 (m, 2H, 2 × CH, Ph), 7.22–7.06 (m, 3H, 3 × CH, Ph, overlapped with solvent signal), 5.59 (ddt, 1H, 3J_H,H = 16.9, 10.2, 6.6 Hz, C(H)═), 5.31 (d, 1H, 2J_H,H = 1.4 Hz, ÑC(H)H'), 4.97–4.87 (m, 3H, ÑC(H)H' + ÑCH₂), 4.53 (dd, 1H, 3J_H,H = 7.6, 3.7 Hz, C(H)OH), 4.05 (d, 1H, 3J_H,H = 13.1 Hz, C(H)H’OSi), 3.93 (d, 1H, 3J_H,H = 13.1 Hz, C(H)H’OSi), 2.75 (d, 1H, 3J_H,H = 3.7 Hz, OH), 2.45–2.33 (m, 1H, C(H)C(R)═CH₂), 2.09–1.91 (m, 1H, C(H)H’), 1.91–1.72 (m, 1H, C(H)H’), 1.58–1.37 (m, 2H, CH₂), 0.98 (s, 9H, SiC(CH₃)₃), 0.08–0.04 (m, 6H, Si(CH₃)(CH₃)’).

13C[1H] NMR (75 MHz, C₆D₆): δ = 148.1 (C_quad. Ph), 144.4 (R₂C═), 138.7 (C(H)═), 128.2 (CH, Ph), 127.6 (CH, Ph), 127.2 (CH, Ph), 114.9 (═CH₂), 114.1 (═CH₂), 77.4 (C(H)OH), 66.3 (CH₂OSi), 51.9 (C(H)C(R)═CH₂), 31.9 (CH₂), 30.4 (CH₂), 26.1 (SiC(CH₃)₃), 18.5 (SiC(CH₃)₃), −5.3 (Si(CH₃)(CH₃)’), −5.3 (Si(CH₃)(CH₃)’).

IR (ATR): ν̃ = 3904 (w), 3737 (w), 3422 (w), 3070 (w), 2929 (m), 2856 (m), 1641 (w), 1452 (m), 1390 (m), 1253 (m), 1191 (w), 1048 (s), 908 (s), 836 (s), 776 (s), 700 (s) cm⁻¹.

HRMS (ESI, TOF): m/z calc’d for C₂₁H₃₄O₂Si[M+Na]⁺ 369.2220; observed 369.2222.
(1R*,2R*)-2-[3-[(tert-Butyldimethylsilyl)oxy]prop-1-en-2-yl]-1-(3-methoxyphenyl)hex-5-en-1-ol [(±)-16b]

\[
\text{(Z)-11c} \xrightarrow{\text{Et}_2\text{O},
0^\circ\text{C to rt, 24 h}} \text{(±)-16b}
\]

\[\begin{align*}
\text{OMe} & \quad \text{OTBS} \\
& \quad \text{B(pin)} \\
& \quad \text{OH} \\
\end{align*}\]

\[m\text{-Anisaldehyde (6.8 \mu l, 7.62 mg, 56.0 \mu mol, 1.2 equiv.) was added to a stirred solution of boronate (Z)-11c (17.1 mg, 46.7 \mu mol, 1.0 equiv.) in anhydrous Et}_2\text{O (0.6 mL) at 0 }^\circ\text{C. The solution was allowed to reach rt over 2 h. After 24 h at this temperature (TLC control, PE/Et}_2\text{O, 5:1) the complete mixture was directly subjected to column chromatography (PE/Et}_2\text{O, 7:1, 1.5 × 20 cm) to obtain the homoallyl alcohol (±)-16b (14.7 mg, 39.0 \mu mol, 84%) as a colorless oil.}\]

**TLC:** \(R_f = 0.34\) (PE/Et\(_2\)O, 7:1).

**\(1^H\text{ NMR}\) (300 MHz, C\(_6\)D\(_6\)):** \(\delta = 7.14–7.10 (m, 2H, \text{CH, Ar})\), 6.95 \((d, 1H, ^3J_{HH} = 7.6 \text{ Hz, CH, Ar})\), 6.73 \((dd, 1H, ^3J_{HH} = 8.1, 2.5 \text{ Hz, CH, Ar})\), 5.61 \((ddt, 1H, ^3J_{HH} = 16.9, 10.2, 6.6 \text{ Hz, C(H)═})\), 5.31 \((d, 1H, ^2J_{HH} = 1.1 \text{ Hz, } =C(H)H')\), 4.99–4.86 \((m, 3H, =C(H)H' + =CH_2)\), 4.55 \((dd, 1H, ^3J_{HH} = 7.5, 3.5 \text{ Hz, C(H)OH})\), 4.06 \((d, 1H, ^3J_{HH} = 13.1 \text{ Hz, C(H)H'OSi})\), 3.94 \((d, 1H, ^3J_{HH} = 13.1 \text{ Hz, C(H)H'})\), 3.37 \((s, 3H, \text{OCH}_3)\), 2.78 \((d, 1H, ^3J_{HH} = 3.7 \text{ Hz, OH})\), 2.48–2.40 \((m, 1H, C(H)C(R)═CH_2)\), 1.55–1.45 \((m, 2H, \text{CH}_2)\), 0.98 \((s, 9H, \text{SiC(CH}_3)_3)\), 0.07–0.05 \((m, 6H, \text{Si(CH}_3)(\text{CH}_3)')\).

**\(13^C\{^1H\}\text{ NMR}\) (75 MHz, C\(_6\)D\(_6\)):** \(\delta = 160.3 \text{ (COMe, Ar)}\), 148.2 \((\text{C}_{\text{quart}, \text{Ar}})\), 146.1 \((\text{R}_2\text{C═})\), 138.7 \((\text{C(\text{H})═})\), 129.3 \((\text{CH, Ar})\), 119.6 \((\text{CH, Ar})\), 114.9 \((=\text{CH}_2)\), 114.0 \((=\text{CH}_2)\), 113.0 \((\text{CH, Ar})\), 113.0 \((\text{CH, Ar})\), 77.4 \((\text{C(H)OH})\), 66.4 \((\text{CH}_2\text{OSi})\), 54.7 \((\text{COCH}_3, \text{ Ar})\), 51.7 \((\text{C(H)C(R)═CH}_2)\), 31.9 \((\text{CH}_2)\), 30.5 \((\text{CH}_2)\), 26.1 \((\text{SiC(CH}_3)_3)\), 18.5 \((\text{SiC(CH}_3)_3)\), −5.3 \((\text{Si(CH}_3)(\text{CH}_3)')\), −5.3 \((\text{Si(CH}_3)(\text{CH}_3)')\).

**IR (ATR):** \(\tilde{\nu} = 3437 \text{ (w), 3075 (w), 2930 (m), 2857 (m), 2358 (w), 1600 (m), 1461 (m), 1254 (s), 1043 (s), 908 (m), 836 (s), 775 (s), 699 (m) cm}^{-1}\).

**HRMS (ESI, TOF):** \(m/z\) calc’d for C\(_{22}\)H\(_{36}\)O\(_3\)Si [M+Na]\(^+\) 399.2326; observed 399.2326.
Freshly distilled cyclohexanecarboxaldehyde (7.61 μl, 7.05 mg, 62.9 μmol, 1.2 equiv.) was added to a stirred solution of boronate (Z)-11c (19.2 mg, 52.4 μmol, 1.0 equiv.) in anhydrous Et₂O (0.6 mL) at 0 °C. The solution was allowed to reach rt over 2 h. After 24 h at this temperature (TLC control, PE/Et₂O, 20:1) the complete mixture was directly subjected to column chromatography (PE/Et₂O, 20:1, 1.5 × 20 cm) to obtain the homoallyl alcohol (±)-16c (15.9 mg, 45.1 μmol, 86%) as a colorless oil.

**TLC:** \( R_f = 0.32 \) (PE/Et₂O, 20:1).

**\(^1\)H NMR** (300 MHz, C₆D₆): \( \delta = 5.78 \) (ddt, 1H, \( 3J_{HH} = 17.0, 10.2, 6.6 \) Hz, C(H)=), 5.25 (d, 1H, \( 2J_{HH} = 1.5 \) Hz, \( \equiv \text{C}(\text{H})\text{H}' \)), 5.10–4.92 (m, 3H, \( \equiv \text{C}(\text{H})\text{H}' + \equiv \text{CH}_2 \)), 4.15 (d, 1H, \( 3J_{HH} = 13.0 \) Hz, \( \text{C}(\text{H})\text{H}'\text{OSi} \)), 3.98 (d, 1H, \( 3J_{HH} = 13.0 \) Hz, \( \text{C}(\text{H})\text{H}'\text{OSi} \)), 3.27 (dd, 1H, \( 3J_{HH} = 6.2, 6.0 \) Hz, \( \text{C}(\text{H})\text{OH} \)), 2.46–2.35 (m, 1H, OH), 2.14–1.88 (m, 3H, \( \text{C}(\text{H})\text{C}(\text{R})\equiv \text{CH}_2 + \text{CH}_2 \)), 1.83–1.14 (m, 13H, 6 × \( \text{CH}_2 + \text{R}_2\text{CH} \)), 0.96 (s, 9H, SiC(CH₃)₃), 0.07–0.03 (m, 6H, Si(CH₃)(CH₃)')

**\(^{13}\)C\({^1}\)H NMR** (75 MHz, C₆D₆): \( \delta = 148.6 \) (R₂C=), 139.0 (C(H)=), 115.1 (=CH₂), 114.9 (=CH₂), 77.8 (C(H)OH), 65.6 (CH₂OSi), 47.1 (C(H)C(R)=CH₂), 41.3 (CH), 32.1 (CH₂), 30.9 (CH₂), 30.4 (CH₂), 27.5 (CH₂), 27.1 (CH₂), 26.9 (CH₂), 26.7 (CH₂), 26.1 (SiC(CH₃)₃), 18.5 (SiC(CH₃)₃), −5.3 (Si(CH₃)(CH₃)'), −5.3 (Si(CH₃)(CH₃)').

**IR** (ATR): \( \tilde{\nu} = 3442 \) (w), 3076 (w), 2926 (s), 2855 (m), 2712 (w), 2543 (w), 2361 (w), 1641 (w), 1450 (w), 1392 (w), 1254 (m), 1186 (w), 1050 (m), 908 (m), 836 (s), 775 (s), 667 (m) cm⁻¹.

**HRMS** (ESI, TOF): m/z calc’d for C₂₁H₄₆O₂Si[Na]⁺ 375.2690; observed 375.2694.
(2R*,3R*)-1-(But-3-en-1-yloxy)-3-{3-[(tert-butyldimethylsilyl)oxy]prop-1-en-2-yl}hept-6-en-2-ol [±]-16d

Homoallyloxy acetaldehyde SI-1 (90.2 mg, 0.79 mmol, 1.84 equiv., used as a 2:1 molar mixture with CH₂Cl₂) was added to a stirred solution of boronate (Z)-11c (160 mg, 0.43 mmol, 1.0 equiv.) in anhydrous Et₂O (3.0 mL) at 0 °C. The solution was allowed to reach rt over 6 h. After 24 h at this temperature (TLC control, PE/Et₂O, 7:1) the complete mixture was directly subjected to column chromatography (PE/Et₂O, 7:1, 3 × 15 cm) to obtain the homoallyl alcohol (±)-16d (105 mg, 0.30 mmol, 70%) as a colorless oil.

**TLC:** Rᵣ = 0.27 (PE/Et₂O, 7:1).

**¹H NMR** (300 MHz, C₆D₆): δ = 5.87–5.66 (m, 2H, 2 × C(H)=), 5.37 (s, 1H, =C(H)H’), 5.09–4.96 (m, 5H, 2 × =CH₂ + =C(H)H’), 4.25 (d, 1H, 3J₁,₂H₁ = 13.9 Hz, C(H)H’OSi), 4.10 (d, 1H, 3J₁,₂H₁ = 13.9 Hz, C(H)H’OSi), 3.84–3.73 (m, 1H, OCH₂C(H)OH), 3.38–3.19 (m, 4H, C₂H₅OCH₂), 2.72 (d, 1H, 3J₁,₂H₁ = 4.7 Hz, OH), 2.38–2.29 (m, 1H, C(H)C(R)=CH₂), 2.25–1.90 (m, 4H, 2 × CH₂), 1.72–1.59 (m, 2H, CH₂), 0.98 (s, 9H, SiC(CH₃)₃), 0.08 (s, 6H, Si(CH₃)₂).

**¹³C{¹H} NMR** (75 MHz, C₆D₆): δ = 148.1 (R₂C=), 139.0 (C(H)=), 135.7 (C(H)=), 116.4 (==CH₂), 114.8 (==CH₂), 113.4 (==CH₂), 74.0 (OCH₂C(H)OH), 72.5 (OCH₂C(H)OH), 70.7 (CH₂OCH₂), 65.5 (CH₂OSi), 46.5 (C(H)C(R)=CH₂), 34.6 (CH₂), 32.0 (CH₂), 29.8 (CH₂), 26.1 (SiC(CH₃)₃), 18.6 (SiC(CH₃)₃), −5.2 (Si(CH₃)(CH₃)'), −5.3 (Si(CH₃)(CH₃')).

**IR** (ATR): ʋ = 3903 (w), 3854 (w), 3737 (w), 3568 (w), 3422 (w), 3078 (w), 2930 (m), 2859 (m), 2361 (w), 1641 (w), 1461 (w), 1362 (w), 1254 (m), 1103 (s), 994 (m), 907 (s), 836 (s), 774 (s), 668 (m) cm⁻¹.

**HRMS** (ESI, TOF): m/z calc’d for C₂₀H₃₈O₃Si [M+Na]^+ 377.2482; observed 377.2482.
Synthesis scheme for the $\alpha,\beta$-unsaturated aldehyde SI-15 and $\alpha,\beta$-epoxy aldehydes ($-$)/($\pm$)-SI-16.

Experimental conditions see below scheme.

**Scheme S2.** Synthesis of $\alpha,\beta$-unsaturated aldehyde SI-15 and $\alpha,\beta$-epoxy aldehydes ($-$)/($\pm$)-SI-16.
(2E,6E)-8-Hydroxy-3,7-dimethylocta-2,6-dien-1-yl acetate (SI-17)

Salicylic acid (544 mg, 3.94 mmol, 0.1 equiv.), SeO$_2$ (131 mg, 1.18 mmol, 0.03 equiv.) and $^{t}$BuOOH (13.5 mL, 98.5 mmol, 2.5 equiv, ~70w-% in water) were dissolved in CH$_2$Cl$_2$ (50 mL) open to air and stirred for 15 min. Then geranyl acetate$^{524}$ (SI-18, 7.74 g, 39.4 mmol, 1.0 equiv.) was added as a solution in CH$_2$Cl$_2$ (50 mL). After 18 h (TLC control, PE/acetone, 6:1) the solution was washed with a 1.0 M NaOH solution (4 × 30 mL) and brine (50 mL). The organic extract was dried with MgSO$_4$, filtered and concentrated in vacuo.

Column chromatography of the residue (PE/acetone, 6:1→2:1, 7 × 25 cm) gave in order of elution remaining starting material (2.32 g, 11.8 mmol, 30%) and the allyl alcohol SI-17 (3.54 g, 16.7 mmol, 42%, 61% brsm), both as colorless oils.

**TLC:** $R_f$ = 0.24 (PE/acetone, 6:1).

**$^1$H NMR** (300 MHz, C$_6$D$_6$): $\delta$ = 5.51–5.44 (m, 1H, C(H)═), 5.41–5.34 (m, 1H, C(H)═), 4.67 (d, 2H, $^3$J$_{H,H}$ = 7.1 Hz, CH$_2$OAc), 3.92 (s, 2H, ==C(CH$_2$)OH), 2.18–2.09 (m, 2H, CH$_2$), 2.06–1.98 (m, 2H, CH$_2$), 1.80 (s, 3H, OC(O)CH$_3$), 1.62 (s, 3H, CH$_3$), 1.59 (s, 3H, CH$_3$), 1.42 (br s, 1H, OH).

**$^{13}$C{($^1$H)} NMR** (75 MHz, C$_6$D$_6$): $\delta$ = 170.4 (OC(O)CH$_3$), 141.3 (R$_2$C═), 135.9 (R$_2$C═), 124.6 (HC═), 119.7 (HC═), 68.7 (CH$_2$OH), 61.3 (CH$_2$OAc), 39.4 (CH$_2$), 25.9 (CH$_2$), 20.6 (OC(O)CH$_3$), 16.3 (CH$_3$), 13.7 (CH$_3$).

The NMR data matched published data.$^{525}$

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4-Methoxybenzyl 2,2,2-trichloroacetimidate (SI-19)

**TLC:** $R_f$ = 0.24 (PE/acetone, 6:1).

**$^1$H NMR** (300 MHz, C$_6$D$_6$): $\delta$ = 5.51–5.44 (m, 1H, C(H)═), 5.41–5.34 (m, 1H, C(H)═), 4.67 (d, 2H, $^3$J$_{H,H}$ = 7.1 Hz, CH$_2$OAc), 3.92 (s, 2H, ==C(CH$_2$)OH), 2.18–2.09 (m, 2H, CH$_2$), 2.06–1.98 (m, 2H, CH$_2$), 1.80 (s, 3H, OC(O)CH$_3$), 1.62 (s, 3H, CH$_3$), 1.59 (s, 3H, CH$_3$), 1.42 (br s, 1H, OH).

**$^{13}$C{($^1$H)} NMR** (75 MHz, C$_6$D$_6$): $\delta$ = 170.4 (OC(O)CH$_3$), 141.3 (R$_2$C═), 135.9 (R$_2$C═), 124.6 (HC═), 119.7 (HC═), 68.7 (CH$_2$OH), 61.3 (CH$_2$OAc), 39.4 (CH$_2$), 25.9 (CH$_2$), 20.6 (OC(O)CH$_3$), 16.3 (CH$_3$), 13.7 (CH$_3$).

The NMR data matched published data.$^{525}$

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4-Methoxybenzyl 2,2,2-trichloroacetimidate (SI-19)
A published procedure was modified in the following way: NaH (1.20 g, 30.0 mmol, 0.14 equiv., 60w-% in mineral oil) was suspended in anhydrous Et₂O (200 mL) at 0 °C under stirring. After 10 min p-methoxybenzyl alcohol (27.0 mL, 30.0 g, 217 mmol, 1.0 equiv.) was added and stirring was continued for 15 min. Then trichloroacetonitrile (24.0 mL, 34.5 g, 239 mmol, 1.1 equiv.) was added dropwise over 30 min using a syringe pump (0.8 mL/min). The solution was allowed to warm to rt over 1 h and kept at rt for additional 30 min. All volatiles were removed in vacuo and the residual oil was taken up in n-hexane (25 mL). MeOH (1.40 mL, 32.6 mmol, 0.15 equiv.) was added and the mixture was stirred vigorously for 15 min, followed by filtration of the suspension through Celite (n-hexane). The filtrate was concentrated in vacuo and purified by column chromatography (PE/EtOAc, 9:1 + 2% Me₂NEt, 9 × 15 cm) to obtain the PMB trichloroacetimidate SI-19 (55.6 g, 197 mmol, 91%) as a slightly yellow oil, which solidified below –25 °C.

**TLC:** **Rₜ = 0.41** (PE/EtOAc, 4:1)

**¹H NMR** (300 MHz, CDCl₃): δ = 8.37 (br s, 1H, NH), 7.42–7.33 (m, 2H, CH, Ar), 6.97–6.84 (m, 2H, CH, Ar), 5.28 (s, 2H, CH₂O), 3.82 (s, 3H, OCH₃).

**¹³C⁷(H) NMR** (75 MHz, CDCl₃): δ = 162.7 (C=NH), 159.8 (COCH₃), 129.8 (CH, Ar), 127.6 (OCH₂C, Ar), 114.0 (CH, Ar), 91.6 (CCl₃), 70.8 (CH₂O), 55.4 (CH₃).

The NMR data matched published data.

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(2E,6E)-8-[(4-Methoxybenzyl)oxy]-3,7-dimethylocta-2,6-dien-1-yl acetate (SI-20)

To a stirred solution of allyl alcohol SI-17 (3.32 g, 15.6 mmol, 1.0 equiv.) in anhydrous CH₂Cl₂ (60 mL) at 0 °C was added PMB trichloroacetimidate (5.30 g, 18.8 mmol, 1.2 equiv.), followed by (+)-CSA (725 mg, 3.12 mmol, 0.2 equiv.). The solution was stirred at 0 °C for 1 h and then allowed to warm to rt. After 19 h (TLC control, PE/acetone, 6:1) the brown suspension was filtered. The filtrate was washed with sat. NaHCO₃ solution (60 mL) and brine (60 mL), dried with MgSO₄, filtered and the solvent was removed in vacuo. Column
chromatography of the residue (PE/MTBE, 4:1, 7 × 20 cm) provided the PMB ether SI-20 (3.58 g, 10.8 mmol, 69%) as a slightly yellow oil.

**TLC:** \( R_f = 0.34 \) (PE/MTBE, 4:1).

**\(^1\)H NMR** (300 MHz, C\(_6\)D\(_6\)): \( \delta = 7.30–7.23 \) (m, 2H, CH, Ar), 6.85–6.79 (m, 2H, CH, Ar), 5.44–5.34 (m, 2H, 2 × C(H)=), 4.59 (d, 2H, \(^3\)J\(_{HH}\) = 6.7 Hz, CH\(_2\)OAc), 4.35 (s, 2H, OCH\(_2\)Ar), 3.84 (s, 2H, OCH\(_2\)Ar), 3.32 (s, 3H, OCH\(_3\)), 2.12–2.01 (m, 2H, CH\(_2\)), 1.96–1.90 (m, 2H, CH\(_2\)), 1.69 (s, 3H, OC(O)CH\(_3\)), 1.63 (s, 3H, CH\(_3\)), 1.49 (s, 3H, CH\(_3\)).

**\(^{13}\)C\({^1}\)H NMR** (75 MHz, C\(_6\)D\(_6\)): \( \delta = 170.1 \) (OCC(O)CH\(_3\)), 159.7 (COCH\(_3\), Ar), 141.3 (R\(_2\)C=), 133.2 (R\(_2\)C=), 131.4 (OCH\(_2\)C, Ar), 129.4 (CH, Ar), 127.0 (HC=), 119.7 (HC=), 114.1 (CH, Ar), 75.9 (CH\(_2\)OR), 71.4 (CH\(_2\)OR), 61.2 (CH\(_2\)OAc), 54.8 (OCH\(_3\)), 39.4 (CH\(_2\)), 26.1 (CH\(_2\)), 20.6 (OC(O)CH\(_3\)), 16.3 (CH\(_3\)), 14.0 (CH\(_3\)).

**IR** (ATR): \( \tilde{\nu} = 2913 \) (w), 2841 (w), 2361 (m), 2060 (w), 1869 (w), 1735 (m), 1612 (m), 1512 (m), 1442 (m), 1364 (m), 1231 (s), 1031 (s), 952 (m), 819 (s), 751 (s), 607 (m) cm\(^{-1}\).

**HRMS** (ESI, TOF): m/z calc’d for C\(_{20}\)H\(_{28}\)O\(_4\)[M+Na]\(^+\) 355.1880; observed 355.1878.

(2\(E\),6\(E\))-8-[(4-Methoxybenzyl)oxy]-3,7-dimethylocta-2,6-dien-1-ol (SI-21)

To a stirred solution of acetate SI-20 (3.48 g, 10.5 mmol, 1.0 equiv.) in anhydrous MeOH (40 mL) at rt was added K\(_2\)CO\(_3\) (2.90 g, 21.0 mmol, 2.0 equiv.). After 2 h (TLC control, PE/MTBE, 1:1) the suspension was cooled to 0 \(^\circ\)C, a NaCl saturated 1.0 M HCl solution (45 mL) was added and after 10 min the mixture was extracted with EtOAc (80 mL). The organic layer was separated and washed with brine (80 mL). The organic extract was dried with MgSO\(_4\), filtered and concentrated in vacuo. Column chromatography of the residue (PE/MTBE, 1:1, 7 × 12 cm) provided the alcohol SI-21 (2.82 g, 9.71 mmol, 92%) as a colorless oil.

**TLC:** \( R_f = 0.44 \) (PE/MTBE, 1:1).
$^1$H NMR (300 MHz, $CD_6$): $\delta = 7.32–7.22$ (m, 2H, CH, Ar), 6.86–6.78 (m, 2H, CH, Ar), 5.46–5.37 (m, 2H, 2 × C(H)═), 4.35 (s, 2H, OCH$_2$Ar), 4.02 (d, 2H, $^3J_{H,H} = 6.7$ Hz, CH$_2$OH), 3.84 (s, 2H, =C(CH$_2$)O), 3.32 (s, 3H, OCH$_3$), 2.15–2.06 (m, 2H, CH$_2$), 2.01–1.93 (m, 2H, CH$_2$), 1.66 (s, 3H, CH$_3$), 1.47 (s, 3H, CH$_3$), 1.34 (s, 1H, OH).

$^{13}$C($^1$H) NMR (75 MHz, $CD_6$): $\delta = 159.7$ (COCH$_3$), 137.5 (R$_2$C═), 133.1 (R$_2$C═), 131.4 (OCH$_2$C, Ar), 129.5 (CH, Ar), 127.4 (HC═), 125.4 (HC═), 114.1 (CH, Ar), 76.0 (CH$_2$O), 71.5 (CH$_2$O), 59.3 (CH$_2$O), 54.8 (OCH$_3$), 39.4 (CH$_2$), 26.3 (CH$_2$), 16.1 (CH$_3$), 14.1 (CH$_3$).

IR (ATR): $\tilde{\nu} = 3736$ (w), 3393 (w), 2914 (m), 2851 (m), 2361 (m), 2137 (w), 1944 (w), 1869 (w), 1669 (w), 1612 (s), 1457 (m), 1361 (m), 1302 (m), 1245 (s), 1173 (m), 1032 (s), 819 (s), 751 (s), 616 (m) cm$^{-1}$.

HRMS (ESI, TOF): m/z calc’d for C$_{18}$H$_{26}$O$_3$ [M+Na]$^+$ 313.1774; observed 313.1775.

$^{(2E,6E)}$-8-[(4-Methoxybenzyl)oxy]-3,7-dimethylocta-2,6-dienal (SI-15)

To a stirred solution of allyl alcohol SI-21 (200 mg, 0.69 mmol, 1.0 equiv.) and NaHCO$_3$ (290 mg, 3.45 mmol, 5.0 equiv.) in anhydrous CH$_2$Cl$_2$ (7.0 mL) at rt was added DMP (352 mg, 0.83 mmol, 1.2 equiv.) in one portion. After 1.5 h (TLC control, MTBE/PE, 2:1) the suspension was poured into a mixture of sat. NaHCO$_3$ (10 mL) and sat. Na$_2$SO$_4$ (10 mL) and stirred for 30 min. The organic layer was separated, washed with sat. NaHCO$_3$ (20 mL) and brine (20 mL), dried with MgSO$_4$, filtered and concentrated in vacuo. Column chromatography of the residue (PE/MTBE, 3:1→2:1, 2.5 × 30 cm) provided the α,β-unsaturated aldehyde SI-15 (174 mg, 0.60 mmol, 87%) as a colorless oil.

**TLC:** $R_f = 0.34$ (PE/MTBE, 2:1)

$^1$H NMR (300 MHz, $CD_6$): $\delta = 9.86$ (d, 1H, $^3J_{H,H} = 7.7$ Hz, CHO), 7.33–7.24 (m, 2H, CH, Ar), 6.88–6.80 (m, 2H, CH, Ar), 5.81 (dq, 1H, $^3J_{H,H} = 7.7$, 2.4, 1.2 Hz, =C(H)CHO), 5.30–5.20 (m, 1H, C(H)═), 4.34 (s, 2H, CH$_2$O), 3.79 (s, 2H, CH$_2$O), 3.32 (s, 3H, OCH$_3$), 1.90 (dt,
2H, $^3J_{HH} = 7.7, 7.2$ Hz, CH$_2$C(H) —), 1.78–1.70 (m, 2H, CH$_2$), 1.56 (s, 3H, CH$_3$), 1.50 (d, 3H, $^4J_{HH} = 1.2$ Hz, CH$_3$).

$^{13}$C($^1$H) NMR (75 MHz, C$_6$D$_6$): $\delta = 189.8$ (CHO), 161.2 (C$_{quart}$), 159.8 (C$_{quart}$), 131.3 (OCH$_2$C, Ar), 129.4 (CH, Ar), 125.6 (HC=), 114.2 (CH, Ar), 75.6 (CH$_2$O), 71.6 (CH$_2$O), 54.8 (OCH$_3$), 40.0 (CH$_2$), 25.4 (CH$_2$), 16.9 (CH$_3$), 14.0 (CH$_3$).

IR (ATR): $\tilde{\nu} = 2914$ (m), 2849 (m), 2342 (w), 2109 (w), 2008 (w), 1669 (s), 1612 (m), 1512 (s), 443 (m), 1380 (m), 1303 (m), 1245 (s), 1176 (m), 1033 (s), 818 (s), 614 (m) cm$^{-1}$.

HRMS (ESI, TOF): m/z calc’d for C$_{18}$H$_{24}$O$_3$ [M+Na]$^+$ 311.1618; observed 311.1619.

{(2R,3R)-3-[(E)-5-[(4-Methoxybenzyl)oxy]-4-methylpent-3-en-1-yl]-3-methyloxiran-2-yl}methanol [(+)-SI-22 and (±)-SI-22]

Racemic conditions:
To a stirred solution of allyl alcohol SI-21 (4.00 g, 13.8 mmol, 1.0 equiv.) in anhydrous CH$_2$Cl$_2$ (100 mL) at 0 °C was added [VO(acac)$_2$] (729 mg, 2.75 mmol, 0.2 equiv.), followed by an anhydrous tBuOOH solution (3.32 mL, 16.6 mmol, 1.2 equiv., 5.0 M in decane with 4 Å molecular sieves). The deep red solution was stirred at 0 °C for 2.5 h (TLC control, MTBE/PE, 2:1) after which a 1:1 mixture of sat. Na$_2$SO$_3$ solution and sat. NaHCO$_3$ solution (50 mL) was added. The cooling bath was removed and the mixture was stirred for 30 min until the color changed to light green. The organic layer was separated, washed with sat. NaHCO$_3$ solution (100 mL), brine (100 mL), dried with MgSO$_4$, filtered and concentrated in vacuo. Column chromatography of the residue (MTBE/PE, 1:1→2:1, 6 × 15 cm) provided the epoxy alcohol (±)-SI-22 (3.18 g, 10.4 mmol, 75%) as a colorless oil.

Enantioselective conditions for (2R,3R)-(+)‐SI-22:
Freshly activated powdered 4 Å molecular sieves (1.60 g) were suspended in anhydrous (MeOH-free) CH$_2$Cl$_2$ (40 mL) with stirring. d-(-)-DIPT (0.41 mL, 464 mg, 1.98 mmol, 0.25 equiv.) was added and the mixture was stirred for 20 min after which it was cooled to –20 °C. Ti(O'Pr)$_4$ (0.47 mL, 449 mg, 1.58 mmol, 0.20 equiv.) was added and stirring was
continued for 15 min. Anhydrous ¹BuOOH solution (3.16 mL, 15.8 mmol, 2.0 equiv., 5.0 M in decane with 4 Å molecular sieves) was added and after additional 30 min the mixture was cooled to −50 °C. Then allyl alcohol SI-21 (2.30 g, 7.92 mmol, 1.0 equiv.) was added as a solution in anhydrous CH₂Cl₂ (10 mL). After 17 h at this temperature (TLC control, MTBE/PE, 2:1) the cooling bath was removed and the mixture was filtered through a plug of silica (d × h = 5 × 4 cm, Et₂O). The filtrate was washed with a 1:1 mixture of sat. Na₂SO₃ solution and sat. NaHCO₃ solution (80 mL), followed by brine (80 mL), dried with MgSO₄, filtered and concentrated in vacuo. Column chromatography of the residue (MTBE/PE, 1:1→2:1, 4 × 20 cm) gave the enantioenriched epoxy alcohol (+)-SI-22 (2.31 g, 7.54 mmol, 95%) as a colorless oil (92% ee, chiral HPLC see below).

**TLC:** $R_f = 0.43$ (MTBE/PE, 2:1).

$[\alpha]^{25}_D = +4.64$ (c = 1.0, THF, 92% ee).

**¹H NMR** (300 MHz, C₆D₆): $\delta = 7.30$−7.24 (m, 2H, CH, Ar), 6.85−6.79 (m, 2H, CH, Ar), 5.37 (t, 1H, $^3J_{H,H} = 7.2$ Hz, C(H)==), 4.35 (s, 2H, CH₂O), 3.80 (s, 2H, CH₂O), 3.55−3.49 (m, 2H, CH₂O), 3.11 (s, 3H, OCH₃), 2.83 (t, 1H, $^3J_{H,H} = 5.5$ Hz, C(O)CH, epoxide), 2.03 (dt, 2H, $^3J_{H,H} = 7.5$, 7.5 Hz, CH₂), 1.87 (br s, 1H, OH), 1.62 (s, 3H, CH₃), 1.60−1.51 (m, 1H, C(H)H'), 1.36 (dt, 1H, $^2,3J_{H,H} = 13.7$, 8.2 Hz, C(H)H'), 1.06 (s, 3H, CH₃).

**¹³C{¹H} NMR** (75 MHz, C₆D₆): $\delta = 159.8$ (COCH₃), 133.2 (R₂C==), 131.2 (OCH₂C, Ar), 129.6 (CH, Ar), 127.0 (HC==), 114.1 (CH, Ar), 75.9 (CH₂O), 71.7 (CH₂O), 63.0 (C(O)CH, epoxide), 61.4 (C(O)CH, epoxide), 60.2 (CH₂O), 54.8 (OCH₃), 38.4 (CH₂), 23.7 (CH₂), 16.7 (CH₃), 14.1 (CH₃).

**IR** (ATR): $\tilde{\nu} = 3738$ (w), 3649 (w), 3420 (w), 2918 (m), 2853 (m), 2361 (m), 1611 (m), 1512 (m), 1456 (m), 1383 (m), 1245 (s), 1174 (m), 1031 (s), 818 (s), 751 (s), 686 (m), 614 (m) cm⁻¹.

Chiral HPLC [Daicel Chiralcel-IA column (5 μm, 253 × 4.6 mm ID) with guard cartridge, n-Hexan/EtOH, 95:5, 1 mL/min, 25 °C, 203 nm]:

a. (±)-SI-22

<table>
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<tr>
<th>No.</th>
<th>Ret. time / min</th>
<th>Area / mAU×min</th>
<th>Height / mAU</th>
<th>Rel. area / %</th>
<th>Resolution</th>
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<td>12.5</td>
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<tr>
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<td>122.5</td>
<td>90.9</td>
<td>50.5</td>
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</tr>
</tbody>
</table>

b. (2R,3R)-(+) -SI-22; \( t_R = 26.1, 44.0 \) min (major), \( er = 96:4, ee = 92\% \).

<table>
<thead>
<tr>
<th>No.</th>
<th>Ret. time / min</th>
<th>Area / mAU×min</th>
<th>Height / mAU</th>
<th>Rel. area / %</th>
<th>Resolution</th>
</tr>
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<td>43.1</td>
<td>684.9</td>
<td>345.0</td>
<td>96.14</td>
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</tr>
</tbody>
</table>

\((2R,3R)-3-\{(E)-5-[(4-Methoxybenzyl)oxy]-4-methylpent-3-en-1-yl\}-3-methyloxirane-2-carbaldehyde \[\text{[(-)-SI-16 and (±)-SI-16]}\]

\[
\begin{align*}
\text{OPMB} & \quad \text{OPMB} \\
\begin{array}{c}
\text{(±)-SI-22} \\
\text{(±)-SI-22}
\end{array} & \quad \begin{array}{c}
\text{DMP, NaHCO}_3, \\
\text{CH}_2\text{Cl}_2, 0^\circ\text{C to rt, 3 h}
\end{array} & \quad \begin{array}{c}
\text{OPMB} \\
\text{OPMB}
\end{array}
\end{align*}
\]

To a stirred solution of epoxy alcohol \((±)-\text{SI-22} \) (1.06 g, 3.46 mmol, 1.0 equiv.) and NaHCO\(_3\) (581 mg, 6.92 mmol, 2.0 equiv.) in anhydrous CH\(_2\)Cl\(_2\) (30 mL) at 0 °C was added DMP
(1.91 g, 4.50 mmol, 1.3 equiv.) in one portion. The mixture was allowed to warm to rt over 1 h. After additional stirring at rt for 2 h (TLC control, MTBE/PE, 2:1) the complete mixture was directly subjected to column chromatography (PE/MTBE, 2:1, 4 × 20 cm) to give epoxy aldehyde (±)-SI-16 (928 mg, 3.05 mmol, 88%) as a colorless oil. The product slowly decomposed at rt and was stored at −25 °C until usage.

Under the same conditions epoxy alcohol (+)-SI-22 (2.30 g, 7.50 mmol) was converted to epoxy aldehyde (−)-SI-16, yielding 2.12 g (6.96 mmol, 93%) of a colorless oil.

**TLC:** $R_f = 0.32$ (PE/MTBE, 2:1).

$[\alpha]_D^{25} = -48.5$ (c = 1.0, THF, 92% ee).

$^1H$ NMR (300 MHz, C$_6$D$_6$): $\delta = 9.13$ (d, 1H, $^3J_{H,H} = 5.0$ Hz, C(O)H), 7.32–7.24 (m, 2H, CH$_2$O), 6.87–6.78 (m, 2H, CH$_2$O), 6.03–5.91 (m, 2H, CH$_2$O), 4.36 (s, 2H, CH$_2$O), 3.81 (s, 2H, CH$_2$O), 3.31 (s, 3H, OCH$_3$), 2.84 (d, 1H, $^3J_{H,H} = 5.0$ Hz, C(O)CH, epoxide), 1.86 (dt, 2H, $^3J_{H,H} = 7.6$ Hz, CH$_2$O), 1.56 (s, 3H, CH$_3$), 1.37–1.15 (m, 2H, CH$_2$), 0.95 (s, 3H, CH$_3$).

$^{13}C$_{($^1H$)} NMR (75 MHz, C$_6$D$_6$): $\delta = 198.6$ (CHO), 159.8 (COCH$_3$), 153.8 (R$_2$C═), 129.4 (CH, Ar), 125.7 (HC═), 114.1 (CH, Ar), 75.7 (CH$_3$O), 71.7 (CH$_2$O), 63.4 (C(O)CH, epoxide), 54.8 (O(O)CH, epoxide), 37.9 (CH$_2$), 23.2 (CH$_2$), 16.9 (CH$_3$), 14.0 (CH$_3$).

IR (ATR): $\tilde{\nu} = 3735$ (w), 3649 (w), 3567 (w), 3421 (w), 2915 (m), 2841 (m), 2361 (m), 2061 (w), 1989 (w), 1719 (m), 1611 (m), 1512 (s), 1456 (m), 1383 (m), 1244 (s), 1174 (m), 1032 (s), 818 (s), 751 (s), 613 (m) cm$^{-1}$.

HRMS (APCI, Orbitrap): m/z calc’d for C$_{18}$H$_{24}$O$_4$[M–H]$^–$ 303.1602; observed 303.1601.

(3R*,4S*,5E,9E)-2-[[[(tert-Butyldimethylsilyl)oxy]methyl]-11-[(4-methoxybenzyl)oxy]-6,10-dimethyl-3-[(phenylthio)methyl]undeca-1,5,9-trien-4-ol [(±)-16e]
Borane (Z)-11a (135 mg, 0.31 mmol, 1.0 equiv.) was added to a stirred solution of aldehyde SI-15 (100 mg, 0.35 mmol, 1.10 equiv.) and NaHCO₃ (1.30 mg, 15.5 μmol, 0.05 equiv.) in anhydrous Et₂O (2.0 mL) at 0 °C. After 48 h at this temperature (TLC control, PE/MTBE, 3:1) the complete mixture was directly subjected to column chromatography (PE/MTBE, 3:1, 2.5 × 20 cm), to obtain the isomerically pure allyl/homoallyl alcohol (±)-16e (175 mg, 0.29 mmol, 94%) as a colorless oil. A second isomer was detected by HPLC–MS (19:1 dr major:minor), but not isolated.

**TLC:** *R*ᵣ = 0.37 (PE/MTBE, 3:1).

**¹H NMR** (300 MHz, C₆D₆): δ = 7.38–7.31 (m, 2H, CH, Ar), 7.31–7.25 (m, 2H, CH, Ar), 7.07–6.98 (m, 2H, CH, Ar), 6.95–6.86 (m, 1H, CH, Ar), 6.85–6.78 (m, 2H, CH, Ar), 5.43 (td, 1H, 34 JHH = 6.9, 1.1 Hz, CH₂C(H)=CR₂), 5.36 (d, 1H, 3 JHH = 1.4 Hz, =C(H)H'), 5.30 (dd, 1H, 3 JHH = 8.7, 1.1 Hz, C(H)=C(H)OH), 5.06 (d, 1H, 3 JHH = 0.7 Hz, =C(H)H'), 4.61 (ddd, 1H, 3 JHH = 8.7, 5.7, 4.9 Hz, C(H)OH), 4.37 (s, 2H, CH₂O), 4.23 (d, 1H, 3 JHH = 13.2 Hz, C(H)H'OOSi), 4.10 (d, 1H, 3 JHH = 13.2 Hz, C(H)H'OOSi), 3.85 (s, 2H, CH₂O), 3.39–3.25 (m, 4H, OCH₃ + C(H)H'OOSi), 3.13–2.99 (m, 1H, C(H)H'OOSi), 2.53 (ddd, 1H, 3 JHH = 9.2, 5.9, 5.9 Hz, C(H)C(R)=CH₂), 2.41 (d, 1H, 3 JHH = 4.9 Hz, OH), 2.17–2.07 (m, 2H, CH₂), 2.01–1.93 (m, 2H, CH₂), 1.66 (s, 3H, CH₃), 1.56 (d, 3H, 4 JHH = 1.2 Hz, CH₃), 0.95 (s, 9H, Si(CH₃)₃), 0.06 (m, 6H, Si(CH₃)(CH₃)'), 0.06 (m, 6H, Si(CH₃)(CH₃)').

**¹³C{¹H} NMR** (75 MHz, C₆D₆): δ = 159.7 (C(OCH₃)), 147.2 (R₂C=), 138.0 (R₂C=), 137.7 (R₂C=), 133.3 (Cquart, Ar), 131.4 (Cquart, Ar), 129.5 (CH, Ar), 129.2 (CH, Ar), 129.1 (CH, Ar), 127.7 (C(H)=CR₂, overlayed by C₆D₃H (HMBC)), 127.2 (C(H)=CR₂), 125.9 (CH, Ar), 115.1 (=CH₂), 114.1 (CH, Ar), 76.0 (CH₂O), 71.6 (CH₂O), 69.8 (C(H)OH), 66.3 (CH₂OSi), 54.8 (OCH₃), 50.2 (C(H)C(R)=CH₂), 39.6 (CH₂), 35.1 (CH₂S), 26.3 (CH₂), 26.1 (SiC(CH₃)₃), 18.5 (SiC(CH₃)₃), 16.8 (CH₃), 14.2 (CH₃), −5.2 (Si(C₃H₃)(CH₃)'), −5.3 (Si(CH₃)(CH₃)').

**IR** (ATR): ν = 3738 (w), 3442 (w), 2928 (m), 2854 (m), 2361 (w), 1612 (m), 1512 (s), 1440 (m), 1360 (m), 1247 (s), 1173 (m), 1036 (s), 835 (s), 745 (s), 690 (s) cm⁻¹.

**HRMS** (ESI, TOF): m/z calc’d for C₃₅H₅₂O₄SSi[M+Na]+ 619.3248; observed 619.3249.
(1R*,2R*)-1-[(2R*,3R*)-3-(But-3-en-1-yl)-3-methyloxiran-2-yl]-2-{3-[(tert-butyldimethylsilyl)oxy]prop-1-en-2-yl}hex-5-en-1-ol [(±)-16f]

Borane (Z)-11c (20 mg, 54.6 µmol, 1.0 equiv.) was added to a stirred solution of aldehyde (±)-Si-3 (8.42 mg, 60.1 µmol, 1.1 equiv.) and NaHCO₃ (0.23 mg, 2.73 µmol, 0.05 equiv.) in anhydrous Et₂O (0.5 mL) at 0 °C. After 48 h at this temperature (TLC control, PE/MTBE, 5:1) the complete mixture was directly subjected to column chromatography (PE/MTBE, 10:1, 2 × 20 cm), to obtain the isomerically pure homoallyl alcohol (±)-16f (19.1 mg, 50.2 µmol, 92%) as a colorless oil. A second isomer was detected by GC–MS (18:1 dr major:minor), but not isolated.

**TLC:** Rᵣ = 0.36 (PE/MTBE, 10:1).

**¹H NMR** (300 MHz, CD₆): δ = 5.85–5.70 (m, 2H, 2 × C(H)=), 5.21 (s, 1H, =C(H)H'), 5.10–4.99 (m, 3H, =C(H)H' + =CH₂), 4.97–4.92 (m, 2H, =CH₂), 4.08 (d, 1H, J₃H,H = 12.3 Hz, C(H)H'OSi), 3.95 (d, 1H, J₃H,H = 12.3 Hz, C(H)H'OSi), 3.54–3.41 (m, 1H, C(H)OH), 3.22 (d, 1H, J₃H,H = 5.5 Hz, C(H)OH), 2.76 (d, 1H, J₃H,H = 8.4 Hz, C(O)CH, epoxide), 2.58–2.48 (m, 1H, C(H)C(R)=CH₂), 2.17–1.84 (m, 5H, 2 × CH₂ + C(H)H'), 1.80–1.42 (m, 3H, CH₂ + C(H)H'), 1.32 (s, 3H, CH₃), 0.93 (s, 9H, SiC(CH₃)₃), 0.06–0.00 (m, 6H, Si(CH₃)(CH₃)').

**¹³C(¹H) NMR** (75 MHz, CD₆): δ = 147.1 (R₂C=C), 138.8 (C(CH)=), 138.5 (C(H)=), 116.9 (=CH₂), 115.0 (==CH₂), 114.8 (==CH₂), 72.8 (C(H)OH), 65.8 (CH₂OSi), 64.9 (C(O)CH, epoxide), 60.2 (C(O)CH, epoxide), 49.9 (C(H)C(R)==CH₂), 38.4 (CH₂), 32.0 (CH₂), 30.0 (CH₂), 29.4 (CH₂), 26.0 (SiC(CH₃)₃), 18.5 (SiC(CH₃)₃), 17.2 (CH₃), −5.4 (Si(CH₃)(CH₃)'), −5.4 (Si(CH₃)(CH₃)').

**IR (ATR):** ν = 3102 (w), 3088 (w), 2911 (m), 2877 (m), 2352 (w), 1532 (w), 1470 (m), 1366 (m), 1381 (m), 1244 (m), 1088 (m), 1078 (m), 990 (m), 912 (s), 827 (s), 769 (s), 673 (m) cm⁻¹.

**HRMS** (ESI, TOF): m/z calc’d for C₂₂H₄₀O₅Si [M+Na]⁺ 403.2639; observed 403.2642.
(1R,2R)-3-[(tert-Butyldimethylsilyl)oxy]methyl]-1-((2R,3R)-3-[(E)-5-[(4-methoxy-benzyl)oxy]-4-methylpent-3-en-1-yl]-3-methyloxiran-2-yl]-2-[(phenylthio)methyl]but-3-en-1-ol [(+)-16g and (±)-16g]

Boronate (Z)-11a (1.51 g, 3.48 mmol, 1.00 equiv.) was added to a stirred solution of aldehyde (±)-SI-16 (1.16 g, 3.82 mmol, 1.10 equiv.) and NaHCO₃ (14.3 mg, 0.17 mmol, 0.05 equiv.) in anhydrous Et₂O (18 mL) at 0 °C. After 48 h at this temperature (TLC control, PE/MTBE, 4:1) sat. NaHCO₃ solution (30 mL) and Et₂O (15 mL) were added and the biphasic mixture was stirred for 5 min. Then the organic layer was separated and washed with brine (30 mL). The organic extract was dried with MgSO₄, filtered and concentrated in vacuo.

Column chromatography of the residue (PE/MTBE, 3:1, 7 × 35 cm) provided the isomerically pure homoallyl alcohol (±)-16g (2.02 g, 3.29 mmol, 94%) as colorless oil. A second isomer was detected by HPLC–MS (19:1 dr major:minor), but not isolated.

Under the same conditions the reaction of boronate (Z)-11a (1.65 g, 3.79 mmol) and epoxy aldehyde (−)-SI-16 (1.27 g, 4.18 mmol) gave 2.11 g (3.44 mmol, 91%) of the homoallyl alcohol (+)-16g as a colorless oil.

TLC: Rᵣ = 0.60 (PE/MTBE, 2:1).

[α]D²³ = +6.44 (c = 1.0, THF, 92% ee).

¹H NMR (300 MHz, C₆D₆): δ = 7.39–7.34 (m, 2H, CH, Ar), 7.31–7.25 (m, 2H, CH, Ar), 7.05–6.98 (m, 2H, CH, Ar), 6.93–6.86 (m, 1H, CH, Ar), 6.85–6.80 (m, 2H, CH, Ar), 5.41 (t, 1H, J₁H,₂H = 6.8 Hz, CH₂C(H)═CR₂), 5.30 (d, 1H, J₁H,₂H = 0.9 Hz, C(CH₂)═CH), 4.35 (s, 1H, CH₂O), 4.21 (d, 1H, J₁H,₂H = 12.4 Hz, C(CH)H'OSi), 4.06 (d, 1H, J₁H,₂H = 12.3 Hz, C(CH)H'OSi), 3.81 (s, 3H, OCH₃), 3.78–3.69 (m, 1H, C(CH)H'OSi), 3.54–3.43 (m, 1H, C(CH)H'S), 3.31 (s, 3H, OCH₃), 3.18 (dd, 1H, J₁H,₂H = 12.8, 9.4 Hz, C(CH)H'S), 2.93–2.85 (m, 1H, C(CH)C(R)═CH₂), 2.79 (d, 1H, J₁H,₂H = 8.5 Hz, C(O)CH, epoxide), 2.12 (td, 2H, J₁H,₂H = 7.5, 7.4 Hz, CH₂), 1.70–1.56 (m, 4H, CH₃ + C(CH)H'), 1.51–
1.38 (m, 1H, C(H)H'), 1.31 (s, 3H, CH₃), 0.92 (s, 9H, SiC(CH₃)₃), 0.02 (m, 6H, Si(CH₃)(CH₃)').

¹³C{¹H} NMR (75 MHz, C₆D₆): δ = 159.8 (COCH₃), 146.0 (R₂C═), 137.4 (R₂C═), 133.2 (C(=CH₂)), 129.5 (CH, Ar), 129.5 (CH, Ar), 129.2 (CH, Ar), 127.2 (CH₂C(H)═CR₂), 126.1 (CH, Ar), 117.5 (＝CH₂), 114.1 (CH, Ar), 76.0 (CH₂O), 71.6 (CH₂O), 71.3 (C(H)OH), 66.0 (CH₂OSi), 64.5 (C(O)(CH), epoxide), 60.8 (C(O)CH, epoxide), 54.8 (OCH₃), 49.0 (C(H)(R)═CH₂), 38.6 (CH₂), 34.8 (CH₂S), 26.0 (SiC(CH₃)₃), 23.9 (CH₂), 18.5 (SiC(CH₃)₃), 17.1 (CH₃), 14.1 (CH₃), −5.4 (Si(CH₃)(CH₃)'), −5.4 (Si(CH₃)(CH₃)').

IR (ATR): ν̃ = 3855 (w), 3739 (w), 3650 (w), 3567 (w), 3383 (w), 3072 (w), 2929 (m), 2855 (m), 2362 (m), 2166 (w), 1990 (w), 1921 (w), 1869 (w), 1612 (m), 1512 (m), 1460 (m), 1362 (m), 1248 (s), 1173 (m), 1035 (s), 908 (m), 836 (s), 748 (s), 691 (m) cm⁻¹.

HRMS (ESI, TOF): m/z calc’d for C₃₅H₅₂O₅SSi[M+H]+ 613.3377; observed 613.3378.

[(2S*,3S*)-2-methyl-3-(2-methylthiazol-4-yl)oxiran-2-yl]methanol [(±)-SI-23]

The allyl alcohol SI-2 (97.0 mg, 0.57 mmol, 1.0 equiv.) and [VO(acac)₂] (29.2 mg, 0.1 mmol, 0.2 equiv.) were dissolved in anhydrous CH₂Cl₂ (6.0 mL). The turquoise-green solution was cooled to 10 °C and an anhydrous 'BuOOH solution (178 μl, 0.89 mmol, 1.5 equiv., 5.0 M in decane with 4 Å molecular sieves) was added. After 18 h at this temperature (TLC control, EtOAc/PE, 4:1) the red solution was concentrated in vacuo. Column chromatography of the residue (EtOAc/PE, 4:1, 3 × 20 cm) delivered epoxide (±)-SI-23 (50.0 mg, 0.27 mmol, 47%) as a slightly yellow oil.

TLC: Rf = 0.30 (EtOAc/PE, 4:1).

¹H NMR (300 MHz, CDCl₃): δ = 6.98 (d, 1H, J_H,H = 0.8 Hz, CH, Ar), 4.25 (s, 1H, HC(O)C, epoxide), 3.86–3.70 (m, 2H, CH₂OH), 2.71 (s, 3H, CH₃, Ar), 2.39 (s, 1H, OH), 1.21 (s, 3H, C(O)C(CH₃)).
$^{13}$C($^1$H) NMR (75 MHz, CDCl$_3$): $\delta = 166.7$ (C$_{quart}$, Ar), 151.5 (C$_{quart}$, Ar), 115.3 (CH, Ar), 65.1 (CH$_2$OH), 64.0 (HC(O)C, epoxide), 58.2 (HC(O)C, epoxide), 19.3 (CH$_3$), 13.7 (CH$_3$).

IR (ATR): $\tilde{\nu} =$ 3339 (m), 3122 (m), 2927 (m), 2865 (m), 2362 (w), 2234 (w), 2143 (w), 2002 (w), 1944 (w), 1870 (w), 1715 (w), 1653 (w), 1439 (m), 1381 (m), 1275 (m), 1188 (s), 1136 (m), 1035 (s), 904 (m), 758 (s), 651 (s) cm$^{-1}$.

HRMS (ESI, TOF): m/z calc’d for C$_8$H$_{11}$NO$_2$S [M+H]$^+$ 186.0583; observed 186.0584.

(2S*,3R*)-2-Methyl-3-(2-methylthiazol-4-yl)oxirane-2-carbaldehyde [(±)-SI-24]

To a stirred solution of epoxy alcohol (±)-SI-23 (41.0 mg, 0.22 mmol, 1.0 equiv.) and NaHCO$_3$ (37.0 mg, 0.44 mmol, 2.0 equiv.) in anhydrous CH$_2$Cl$_2$ (2.5 mL) at rt was added DMP (113 mg, 0.27 mmol, 1.2 equiv.). After 1 h (TLC control, EtOAc/PE, 4:1) a 1:1 mixture of sat. Na$_2$S$_2$O$_3$ solution and sat. NaHCO$_3$ solution (4 mL) was added and the biphasic mixture was stirred for 10 min. Then the organic layer was separated and washed with brine (4 mL). The organic extract was dried with MgSO$_4$, filtered and concentrated in vacuo. Column chromatography of the residue (PE/EtOAc, 1:1, 2 × 15 cm) provided the aldehyde (±)-SI-24 (25.0 mg, 0.14 mmol, 64%) as colorless oil.

TLC: $R_t =$ 0.28 (PE/EtOAc, 2:1).

$^1$H NMR (300 MHz, CDCl$_3$): $\delta = 9.05$ (s, 1H, CHO), 7.07 (d, 1H, $^4$J$_{H,H} =$ 0.7 Hz, CH, Ar), 4.40 (s, 1H, HC(O)C, epoxide), 2.72 (s, 3H, CH$_3$), 1.33 (s, 3H, CH$_3$).

$^{13}$C($^1$H) NMR (75 MHz, CDCl$_3$): $\delta = 198.4$ (CHO), 167.3 (C$_{quart}$, Ar), 148.8 (C$_{quart}$, Ar), 116.6 (CH, Ar), 65.0 (HC(O)C, epoxide), 58.2 (HC(O)C, epoxide), 19.3 (CH$_3$), 9.5 (CH$_3$).

IR (ATR): $\tilde{\nu} =$ 3903 (w), 3735 (w), 3119 (w), 2931 (w), 2851 (w), 2362 (w), 2112 (w), 1944 (w), 1870 (w), 1726 (s), 1439 (m), 1380 (m), 1272 (m), 1184 (m), 1134 (m), 1031 (s), 893 (m), 753 (s), 662 (s) cm$^{-1}$.

HRMS (EI, Orbitrap): m/z calc’d for C$_8$H$_9$NO$_2$S [M–H]$^+$ 182.0270; observed 182.071.
(1S*,2S*)-2-[3-((tert-Butyldimethylsilyl)oxy)prop-1-en-2-yl]-1-[(2R*,3R*)-2-methyl-3-(2-methylthiazol-4-yl)oxiran-2-yl]hex-5-en-1-ol [(±)-16ha] and (1R*,2R*)-2-[3-((tert-Butyldi-methylsilyl)oxy)prop-1-en-2-yl]-1-[(2R*,3R*)-2-methyl-3-(2-methylthiazol-4-yl)oxiran-2-yl]hex-5-en-1-ol [(±)-16hb]

Aldehyde (±)-SI-24 (27.5 mg, 150 μmol, 1.1 equiv.) was added to a stirred solution of boronate (Z)-11c (50.0 mg, 136 μmol, 1.0 equiv.) and NaHCO₃ (0.57 mg, 6.82 μmol, 0.05 equiv.) in anhydrous Et₂O (0.7 mL) at 0 °C. After 48 h at this temperature (TLC control, PE/EtOAc, 2:1) the complete mixture was directly subjected to column chromatography (PE/EtOAc, 3:1, 3 × 25 cm), to obtain the following products in order of elution: Homoallyl alcohol (±)-16ha (21.0 mg, 49.6 μmol, 36%) and (±)-16hb (29.0 mg, 68.4 μmol, 50%), both as colorless oils.

Major isomer was assigned as Felkin product, referring to the configuration assignment described in the main text.

16ha:

TLC: \( R_f = 0.45 \) (PE/EtOAc, 3:1).

\(^1\)H NMR (300 MHz, C₆D₆): \( \delta = 6.77 \) (s, 1H, CH, thiazole), 5.82 (ddt, 1H, \( ^3J_{HH} = 16.8, 10.2, 6.5 \) Hz, C(H)=), 5.40 (d, 1H, \( ^4J_{HH} = 1.3 \) Hz, =C(H)H'), 5.13–4.96 (m, 3H, =C(H)H' + =CH₂), 4.29–4.23 (m, 2H, C(H)H'OSi + HC(O)C, epoxide), 4.17 (d, 1H, \( ^4J_{HH} = 13.6 \) Hz, C(H)H'OSi), 3.51 (d, 1H, J = 6.8 Hz, C(H)OH), 3.17 (br s, 1H, OH), 2.49 (ddd, 1H, \( ^3J_{HH} = 10.7, 6.8, 4.3 \) Hz, C(H)C(R)≡CH₂), 2.24 (s, 3H, CH₃), 2.20–2.09 (m, 1H, C(H)H'), 2.08–1.90 (m, 2H, C(H)H' + C(H)H'), 1.87–1.72 (m, 1H, C(H)H'), 1.30 (s, 3H, CH₃), 0.98 (s, 9H, SiC(CH₃)₃), 0.08 (s, 6H, Si(CH₃)₂).

\(^{13}\)C\(^{1}\)H NMR (75 MHz, C₆D₆): \( \delta = 166.0 \) (C₅, thiazole), 152.8 (C₅, thiazole), 148.1 (R₂C=), 138.9 (C(H)=), 115.3 (=CH₂), 115.1 (CH, thiazole), 113.6 (=CH₂), 77.9
(C(H)OH), 66.4 (CH₂O), 64.9 (HC(O)C, epoxide), 59.2 (H(C(O)C, epoxide), 45.8 (C(H)C(R)=CH₂), 31.9 (CH₂), 30.3 (CH₂), 26.2 (SiC(CH₃)₃), 18.8 (Si(C(CH₃)₃), 18.6 (CH₃), 12.5 (CH₃), −5.2 (Si(CH₃)(CH₃)'), −5.3 (Si(CH₃)(CH₃)').

IR (ATR): \( \tilde{\nu} = 3077 \) (w), 2930 (m), 2857 (m), 2362 (w), 1717 (w), 1642 (w), 1459 (m), 1387 (m), 1254 (m), 1186 (m), 1053 (m), 907 (s), 774 (s), 668 (m) cm⁻¹.

HRMS (ESI, TOF): m/z calc’d for C₂₂H₃₇NO₅SSi[M+Na]⁺ 446.2156; observed 446.2158.

16hb:

TLC: \( R_f = 0.35 \) (PE/EtOAc, 3:1).

\(^1\)H NMR (300 MHz, C₆D₆): \( \delta = 6.75 \) (d, 1H, \( ^4J_{H,H} = 0.8 \) Hz, CH, thiazole), 5.82 (ddt, 1H, \( ^3J_{H,H} = 16.7 \), 10.3, 6.3 Hz, C(H)=), 5.33 (d, 1H, \( ^4J_{H,H} = 1.3 \) Hz, \( =C(H)H' \)), 5.14 (dd, 1H, \( ^3J_{H,H} = 17.2 \), 1.6 Hz, \( =C(H)H' \)), 5.05–4.98 (m, 1H, \( =C(H)H' \)), 4.95 (s, 1H, \( =C(H)H' \)), 4.26 (s, 1H, HC(O)C, epoxide), 4.13 (s, 2H, CH₂OSi), 3.38 (d, 1H, \( ^3J_{H,H} = 8.7 \) Hz, C(H)OH), 2.82 (br s, 1H, OH), 2.33 (ddd, 1H, \( ^3J_{H,H} = 8.9 \), 8.8, 3.5 Hz, C(H)C(R)=CH₂), 2.23 (s, 3H, CH₃), 2.18–2.05 (m, 1H, C(H)H'), 2.01–1.85 (m, 2H, C(H)H' + C(H)H'), 1.70–1.55 (m, 1H, C(H)H'), 1.28 (s, 3H, CH₃), 0.98 (s, 9H, SiC(CH₃)₃), 0.07 (s, 6H, Si(CH₃)₂).

\(^{13}\)C\(^{1\)H\}) NMR (75 MHz, C₆D₆): \( \delta = 166.2 \) (C₄(C), thiazole), 152.6 (C₃(C), thiazole), 148.5 (R₂C=), 138.7 (C(H)=), 115.1 (=CH₂), 115.1 (CH, thiazole), 113.0 (=CH₂), 80.0 (C(H)OH), 66.5 (CH₂O), 65.6 (HC(O)C, epoxide), 60.4 (H(C(O)C, epoxide), 46.5 (C(H)C(R)=CH₂), 31.5 (CH₂), 29.8 (CH₂), 26.1 (SiC(CH₃)₃), 18.8 (Si(C(CH₃)₃), 18.5 (CH₃), 11.3 (CH₃), −5.3 (Si(CH₃)(CH₃)'), −5.3 (Si(CH₃)(CH₃)').

IR (ATR): \( \tilde{\nu} = 3567 \) (w), 3395 (w), 3123 (w), 3076 (w), 2929 (m), 2855 (m), 2362 (w), 1795 (w), 1731 (w), 1641 (w), 1458 (m), 1385 (m), 1253 (m), 1185 (m), 1063 (s), 906 (s), 835 (s), 773 (s), 668 (m) cm⁻¹.

HRMS (ESI, TOF): m/z calc’d for C₂₂H₃₇NO₅SSi[M+Na]⁺ 446.2156; observed 446.2155.

Aldehyde (±)-SI-4 (14.0 µl, 13.8 mg, 61.9 µmol, 1.2 equiv.) was added to a stirred solution of boronate (Z)-11c (18.9 mg, 51.6 µmol, 1.0 equiv.) in anhydrous Et2O (0.6 mL) at 0 °C. The solution was allowed to reach rt over 8 h. After 24 h at this temperature (TLC control, PE/Et2O, 20:1) the complete mixture was directly subjected to column chromatography (PE/MTBE, 4:1, 1.5 × 20 cm), to obtain the homoallyl alcohols (±)-16ia,b (16.7 mg, 36.1 µmol, 70%) as a colorless oil and as an inseparable 1.2:1 mixture of diastereomers. Major isomer was assigned as Felkin product, referring to the configuration assignment described in the main text.

**TLC:** $R_f = 0.41$ (PE/MTBE, 2:1).

**$^1$H NMR** (300 MHz, C6D6; mixture of diastereomers, integrals given for each): $\delta = 7.25$–$7.20$ (m, 4H, CH, Ar), 6.83–6.76 (m, 4H, CH, Ar), 5.84–5.67 (m, 2H, $2 \times =C(H)H'$), 5.09–4.89 (m, 6H, $2 \times =C(H)H'$ + $2 \times =CH_2$), 4.40 (s, $2H$, CH2O), 4.36 (d, $2H$, $^3J_{H,H} = 4.0$ Hz, CH2O), 4.15–3.96 (m, 6H, $2 \times =CH_2OSi$), 3.60 (dd, $1H$, $^3J_{H,H} = 11.4$, 2.7 Hz, OC(H)H'C(O)C), 3.49 (dd, $1H$, $^3J_{H,H} = 11.3$, 3.3 Hz, OC(H)H'C(O)C), 3.45–3.27 (m, 10H, OCH2C(O)C, $2 \times =C(H)OH$, 2 × OCH3), 3.23–3.13 (m, 4H, $2 \times =HC(O)CH$, epoxide), 2.90–2.84 (m, 2H, $2 \times =HC(O)CH$, epoxide), 2.75 (d, $1H$, $^3J_{H,H} = 6.4$ Hz, OH), 2.44–2.34 (m, 1H, $C(H)C(R) = CH_2$), 2.27 (dt, $1H$, $^3J_{H,H} = 10.7$, 5.5 Hz, $C(H)C(R) = CH_2$), 2.11–1.83 (m, 4H, $2 \times =CH_2$), 1.80–1.50 (m, 4H, $2 \times =CH_2$), 0.99–0.93 (m, 18H, $2 \times =Si(CH_3)3$), 0.10–0.06 (m, 6H, Si(CH3)(CH3)'), 0.04 (s, 6H, Si(CH3)2).
13C{2H} NMR (75 MHz, C6D6; mixture of diastereomers, assignment: * or #): δ = 159.5* (COMe, Ar), 159.4# (COMe, Ar), 147.4* (R2C=), 146.9# (R2C=), 138.4# (C(H)=), 130.4* (Cquart, Ar), 130.4# (Cquart, Ar), 129.2* (CH, Ar), 129.1# (CH, Ar), 114.6* (=CH2), 114.6# (=CH2), 113.8* (CH, Ar), 113.7# (CH, Ar), 113.2#* (=CH2), 72.7# (OCH2Ar), 72.8* (C=H)OH), 72.6# (C=H)OH), 69.7# (OCH2), 69.6# (OCH2), 65.6* (OCH2), 65.3# (OCH2), 57.6* (C(O)C, epoxide), 56.8# (C(O)C, epoxide), 55.3* (C(O)C, epoxide), 54.4* (C(O)C, epoxide), 54.7# (COCH3, aryl), 47.7* (C(H)C(R)=CH2), 47.3# (C(H)C(R)=CH2), 31.5# (CH2), 31.4# (CH2), 29.3# (CH2), 29.0# (CH2), 25.7* (SiC(CH3)3), 25.7# (SiC(CH3)3), 18.2* (SiC(CH3)3), 18.1# (SiC(CH3)3), −5.6# (Si(CH3)(CH3)''), −5.7# (Si(CH3)(CH3)''), −5.8# (Si(CH3)2).

IR (ATR): ν = 3073 (w), 2929 (m), 2856 (m), 2712 (w), 2542 (w), 2361 (w), 2213 (w), 2033 (w), 1990 (w), 1612 (m), 1512 (s), 1460 (m), 1362 (m), 1248 (s), 1174 (m), 1096 (s), 1036 (s), 905 (s), 836 (s), 774 (s), 670 (m) cm⁻¹.

HRMS (ESI, TOF): m/z calc’d for C26H21O5Si [M+Na]⁺ 485.2694; observed 485.2693.

1-[(2S*,3R*)-3-(But-3-en-1-yl)-3-methyloxiran-2-yl]ethanone [(±)-SI-25]

Epoxy aldehyde (±)-SI-3 (200 mg, 1.43 mmol, 1.0 equiv.) was added dropwise over 30 min to a solution of MeMgBr (0.52 mL, 1.57 mmol, 1.1 equiv., 3.0 mL in Et2O) in anhydrous THF (14 mL) at −78 °C. After 2 h at −78 °C (TLC control, PE/MTBE, 2:1) the cooling bath was removed and a sat. NH4Cl solution (20 mL) was added and the mixture was stirred for 10 min. Then brine (20 mL) and MTBE (40 mL) were added and the organic layer was separated after extraction. The organic extract was dried with MgSO4, filtered and the solvent was removed in vacuo.

The residual oil (SI-26) was dissolved in anhydrous CH2Cl2 (15 mL). NaHCO3 (140 mg, 1.67 mmol, 1.2 equiv.) was added at rt, followed by DMP (667 mg, 1.57 mmol, 1.1 equiv.). The mixture was stirred for 4 h (TLC control, heptanes/MTBE, 2:1). Semi-sat. Na2S2O3 (10 mL) was added and the suspension was stirred until all solids dissolved (15–30 min). The organic layer was separated, washed with brine (40 mL), dried with MgSO4, filtered and
concentrated in vacuo. Column chromatography of the residue (PE/MTBE, 8:3, 3 × 25 cm) provided the epoxy ketone (±)-**SI-25** (126 mg, 0.82 mmol, 57% over 2 steps) as a colorless oil.

**TLC:** $R_t = 0.35$ (PE/MTBE, 4:1).

**$^1$H NMR** (400 MHz, C$_6$D$_6$): $\delta = 5.65$–5.54 ($m$, 1H, C(H)=), 4.94–4.92 ($m$, 1H, \(=\text{C(H)H'}\)), 4.91–4.87 ($m$, 1H, \(=\text{C(H)H'}\)), 2.95 ($s$, 1H, C(O)CH, epoxide), 1.93–1.82 ($m$, 2H, CH$_2$), 1.74 ($s$, 3H, CH$_3$), 1.50–1.36 ($m$, 1H, C(H)H'), 1.32–1.21 ($m$, 1H, C(H)H'), 0.96 ($s$, 3H, CH$_3$).

**$^{13}$C($^1$H) NMR** (101 MHz, C$_6$D$_6$): $\delta = 203.0$ (C=O), 137.7 (RC(H)=), 115.2 (==CH$_2$), 64.5 (C(O)CH, epoxide), 62.2 (C(O)CH, epoxide), 37.5 (CH$_2$), 29.5 (CH$_2$), 27.5 (CH$_3$), 16.4 (CH$_3$).

**IR** (ATR): $\tilde{\nu} = 3078$ (w), 2926 (m), 2858 (m), 2361 (m), 2195 (w), 2113 (w), 2066 (w), 1719 (s), 1641 (m), 1355 (m), 1243 (m), 1184 (m), 1071 (m), 995 (m), 914 (s), 836 (m), 750 (s), 611 (s) cm$^{-1}$.

**HRMS** (ESI, TOF): m/z calc’d for C$_9$H$_{14}$O$_2$ [M+Na]$^+$ 177.0886; observed 177.0888.
3.3 Structure elucidation of allylboration products

To determine the stereochemistry of the epoxy alcohol (±)-16f we planned to transform it to a bicyclic compound by intramolecular epoxide opening and by bridging the newly formed alcohol moiety with the existing (protected) one. This bicycle (±)-SI-27 should be rigid enough for $^1$H,$^1$H-NOESY experiments.

The synthesis is depicted in Scheme S3. Epoxy alcohol (±)-SI-28 underwent a clean, regioselective epoxide opening during an overnight NMR measurement to form (±)-SI-29. The connectivity was determined by a $^1$H,$^{13}$C-HMBC experiment and shown to be the product of a formal acid induced opening, with attack of the nucleophile at the higher substituted position.

After signal assignment by HSQC/DEPT and HMBC experiments, the NOESY analysis of (±)-SI-27 (see below reaction conditions) confirmed the configuration that corresponds to Felkin control in the allylboration. (Additional confirmation of the formation of the Felkin product was gained by X-ray crystal structure analysis of allyl bromide (±)-2).

Scheme S3. Epoxide opening and oxidative cyclization of an allylboration product for structure elucidation by NMR

$$\text{NaH, PMB-Br}$$

$$\text{DMF, rt}$$

$$71\%$$

$$\text{TBAF \times 3H}_2\text{O, THF, rt}$$

$$87\%$$

$$\text{"C}_2\text{D}_6", \text{rt, 12 h}$$

$$99\%$$

$$\text{DDQ, 3 Å M.S., CH}_2\text{Cl}_2, 0^\circ\text{C}$$

$$62\%$$
To a stirred solution of alcohol (±)-16f (48.0 mg, 126 μmol, 1.0 equiv.) in anhydrous DMF (1.2 mL) at 0 °C was added NaH (7.60 mg, 190 μmol, 1.5 equiv., 60% w-% in mineral oil) in 5 portions. After 20 min freshly purified PMB–Br (38.2 mg, 190 μmol, 1.5 equiv.) was added and the suspension was allowed to warm to rt. After 19 h (TLC control, heptanes/MTBE, 7:1) the mixture was cooled to 0 °C, pH 7 phosphate buffer (10 mL) and MTBE (10 mL) were added and the organic layer was separated. The organic extract was washed with brine (2 × 20 mL), dried with MgSO₄, filtered and concentrated in vacuo. Column chromatography of the residue (PE/Et₂O, 15:1, 2 × 20 cm) provided the PMB ether (±)-SI-30 (45.0 mg, 89.9 μmol, 71%) as a colorless oil.

**TLC:** $R_f = 0.34$ (PE/Et₂O, 15:1).

**¹H NMR** (300 MHz, C₆D₆): $\delta = 7.27–7.21$ (m, 2H, CH, Ar), 6.85–6.78 (m, 2H, CH, Ar), 5.87–5.60 (m, 3H, 2 × C(H)= + =C(H)H⁺), 5.44 (d, 1H, $^2J_HH = 1.9$ Hz, =C(H)H⁺), 5.06 (dd, 1H, $^3J_HH = 17.1$, 1.8 Hz, =C(H)H⁺), 5.01–4.90 (m, 3H, =C(H)H⁺ + =CH₂), 4.52–4.36 (m, 3H, OCH₂Ar + OC(H)H⁺C=), 4.24 (d, 1H, $^2J_HH = 11.3$ Hz, OC(H)H⁺C=), 3.34–3.28 (m, 4H, C(H)OPMB + OCH₃), 2.85 (d, 1H, $^3J_HH = 8.6$ Hz, C(O)CH, epoxide), 2.54–2.46 (m, 1H, OCH₂C(=C)CH), 2.24–2.09 (m, 1H, C(H)H⁺), 2.08–1.85 (m, 4H, C(H)H⁺ + CH₂ + C(H)H⁺), 1.80–1.67 (m, 1H, C(H)H⁺), 1.60–1.48 (m, 1H, C(H)H⁺), 1.46–1.34 (m, 1H, C(H)H⁺), 1.13 (s, 3H, CH₃), 1.00 (s, 9H, Si(C(CH₃))₃), 0.12–0.11 (m, 6H, Si(CH₃)(CH₃)⁺).

**¹³C(¹H) NMR** (75 MHz, C₆D₆): $\delta = 159.8$ (COCH₃, Ar), 148.0 (OCH₂C=), 139.0 (C(H)=), 138.3 (C(H)=), 131.2 (Cquart, Ar), 129.2 (CH, Ar), 114.9 (≡CH₂), 114.9 (≡C=CH₂), 114.1 (CH, Ar), 111.8 (OCH₂C≡C=CH₂), 78.8 (C(H)OPMB), 71.8 (OCH₂C=), 65.9 (OCH₂Ar), 62.9 (C(O)CH, epoxide), 61.1 (C(O)CH, epoxide), 54.8 (OCH₃), 46.0 (OCH₂C≡C=CH), 38.0 (CH₂), 32.1 (CH₂), 30.9 (CH₂), 29.7 (CH₂), 26.2 (Si(C(CH₃))₃), 18.7 (Si(C(CH₃))₃), 17.7 (CH₃), −5.2 (Si(CH₃)₂).
IR (ATR): $\tilde{\nu} = 3075$ (w), 2929 (m), 2855 (m), 2362 (w), 2169 (w), 2066 (w), 1944 (w), 1828 (w), 1612 (w), 1512 (m), 1458 (m), 1385 (m), 1248 (s), 1172 (s), 835 (s), 774 (s), 669 (m) cm$^{-1}$.

HRMS (APCI, Orbitrap): m/z calc’d for C$_{30}$H$_{48}$O$_4$Si [M+H]$^+$ 501.3395; observed 501.3397.

(2S*,3R*,4R*,5R*)-2,5-Di(but-3-en-1-yl)-4-[(4-methoxybenzyl)oxy]-2-methyl-6-methyleneoxepan-3-ol [(±)-SI-29]

![Chemical Structure]

To a stirred solution of TBS protected alcohol (±)-SI-30 (40.2 mg, 80.3 μmol, 1.0 equiv.) in anhydrous THF (1.0 mL) at 0 °C was added a TBAF×3H$_2$O solution (0.08 mL, 84.3 μmol, 1.05 equiv., 1.0 M in THF). After 15 min at 0 °C to solution was allowed to stir at rt for 2 h (TLC control, PE/MTBE, 3:1, SI-28: $R_f = 0.30$). Then the solution was diluted with MTBE (10 mL) and added to a sat. NH$_4$Cl solution (10 mL). The organic layer was separated and washed with brine (2 × 10 mL). The organic extract was dried with MgSO$_4$, filtered and the solvent was removed in vacuo. Column chromatography of the residue (PE/MTBE, 3:1, 2 × 15 cm) gave alcohol SI-28 (27.1 mg, 70.1 μmol, 87%) as a colorless oil. During NMR measurements (rt, 14 h) the solution of the alcohol (±)-SI-28 in C$_6$D$_6$ (0.6 mL) rearranged quantitatively to alcohol (±)-SI-29.

(±)-SI-29:

**TLC:** $R_f = 0.43$ (PE/MTBE, 5:1).

$^1$H NMR (300 MHz, C$_6$D$_6$): $\delta = 7.21$–7.13 (m, 2H, CH, Ar, overlap with C$_6$D$_3$H, see HSQC), 6.82–6.75 (m, 2H, CH, Ar), 5.95–5.68 (m, 2H, 2 × C(H)═), 5.14–4.96 (m, 4H, 2 × =CH$_2$), 4.88 (s, 1H, OCH$_2$C═C(H)H'), 4.79 (s, 1H, OCH$_2$C═C(H)H'), 4.48 (d, 1H, $^2J_{H,H} = 11.3$ Hz, OC(H)H'-Ar), 4.40–4.29 (m, 2H, OC(H)H'Ar + OC(H)H'C═), 4.18 (d, 1H, $^3J_{H,H} = 14.9$ Hz, OC(H)H'C═), 3.65 (dd, 1H, $^3J_{H,H} = 3.8$, 2.5 Hz, C(H)OPMB), 3.55 (d, 1H, $^3J_{H,H} = 3.8$ Hz, C6H-3-ol).
C(HOH), 3.30 (s, 3H, OCH₃), 2.72–2.65 (m, 1H, OCH₂C(==C)CH), 2.38–2.13 (m, 2H, CH₂), 2.12–1.84 (m, 4H, 2 × CH₂), 1.82–1.64 (m, 2H, CH₂), 1.31 (s, 3H, CH₃).

¹³C{¹H} NMR (75 MHz, C₆D₆): δ = 159.9 (COCH₃, Ar), 148.0 (OCH₂C==), 139.6 (C(H)==), 138.9 (C(H)==), 131.1 (C₄veled, Ar), 129.3 (CH, Ar), 115.0 (==CH₂), 114.3 (==CH₂), 114.3 (CH, Ar), 110.1 (OCH₂C==CH₂), 82.9 (C(H)OPMB), 79.2 (C₄veledCH₃), 77.9 (C(H)OH), 74.4 (OCH₂Ar), 69.1 (OCH₂C==), 54.8 (OCH₃), 44.1 (OCH₂C(==C)CH), 40.0 (CH₂), 32.5 (CH₂), 29.9 (CH₂), 28.2 (CH₂), 18.7 (CH₃).

IR (ATR): ν̃ = 3567 (w), 3075 (w), 2927 (m), 2362 (m), 1944 (w), 1828 (w), 1612 (m), 1513 (m), 1457 (m), 1360 (m), 1248 (s), 1172 (m), 1094 (s), 1033 (s), 906 (s), 821 (s), 753 (s), 634 (m) cm⁻¹.

HRMS (ESI, TOF): m/z calc’d for C₂₄H₃₄O₄[M+H]⁺ 387.2530; observed 387.2532.

For the corresponding 2D spectra see section 5.

(2R*,3aR*,4S*,8R*,8aR*)-4,8-Di(but-3-en-1-yl)-2-(4-methoxyphenyl)-4-methyl-7-methylenehexahydro-[1,3]dioxolo[4,5-c]oxepine [(±)-SI-27]

(±)-SI-29

DDQ, 4 Å MS, CH₂Cl₂, 0 °C, 2 h

62%

(±)-SI-29

(±)-SI-27

To a stirred solution of alcohol (±)-SI-29 (26.0 mg, 67.3 μmol, 1.0 equiv.) and activated powdered 3 Å molecular sieves (70 mg) in anhydrous CH₂Cl₂ (1.5 mL) at 0 °C was added
DDQ (18.3 mg, 80.7 μmol, 1.2 equiv.), whereupon the colorless solution turned first yellow and later green. After 2 h at this temperature (TLC control, PE/MTBE, 10:1) the brown suspension was directly subjected to column chromatography (PE/Et₂O, 10:1, 2 × 15 cm). The acetal (±)-SI-27 (14.5 mg, 41.6 μmol, 62%) was obtained as colorless oil.

**TLC:** \( R_f = 0.30 \) (PE/Et₂O, 10:1).

**\(^1\)H NMR** (300 MHz, C₆D₆): \( \delta = 7.60–7.53 \) (m, 2H, CH, Ar), 6.84–6.77 (m, 2H, CH, Ar), 5.92–5.67 (m, 2H, 2 × C(H)==), 5.64 (s, 1H, (RO)₂CHAr), 5.14–4.95 (m, 4H, 2 × =CH₂), 4.89–4.85 (m, 2H, OCH₂C==CH₂), 4.58 (d, 1H, \(^2\)J\(_{H,H} = 15.2\) Hz, OC(H)H'C==), 4.24–4.14 (m, 2H, CH₂O), 3.76 (d, 1H, \(^3\)J\(_{H,H} = 7.1\) Hz, C₉O₄C=), 3.27 (s, 3H, OCH₃).

**\(^{13}\)C\(^{1}\)H NMR** (75 MHz, C₆D₆): \( \delta = 160.8 \) (COCH₃, Ar), 148.4 (OCH₂C==), 139.2 (C(H)==), 139.0 (C(H)==), 130.2 (C₉H₈Ar), 128.8 (CH, Ar), 115.0 (=CH₂), 114.6 (=CH₂), 113.8 (CH, Ar), 109.4 (OCH₂C==CH₂), 102.7 (RO)₂CHAr), 84.0 (C₉H₈CHO), 79.2 (C₉H₈CHO), 77.6 (C₉H₈CHO), 68.2 (OCH₂C==), 54.8 (OCH₃), 41.4 (C₉H₈CHO), 40.5 (OCH₂C(−C)CH₃), 31.8 (OCH₂C(−C)CH₂CH₂CH₃), 28.8 (OCH₂C(−C)CH₂CH₂CH₃), 28.2 (C₉H₈CHO), 20.6 (CH₃).

**IR** (ATR): \( \tilde{\nu} = 3650 \) (w), 3568 (w), 3076 (w), 2924 (m), 2362 (m), 1920 (w), 1829 (w), 1717 (w), 1615 (m), 1514 (m), 1399 (m), 1304 (m), 1251 (s), 1171 (m), 1071 (s), 1002 (s), 908 (s), 827 (s), 634 (cm\(^{-1}\)).

**HRMS** (APCI, Orbitrap): m/z calc’d for C₂₄H₃₂O₄[+M+]\(^{+}\) 385.2373; observed 385.2376.

For the corresponding 2D spectra see section 5.
3.4 Synthesis of parthenolides

\[ (5R,6R)-5-((2R,3R)-3-\{[(E)-5-[(4-Methoxybenzyl)oxy]-4-methylpent-3-en-1-yl]-3-methyl-oxiran-2-yl]-2,2,3,3,10,11,11-octamethyl-7-methylene-6-[(phenylthio)methyl]-4,9-dioxa-3,10-disiladodecanec [(+)-17 and (±)-17] \]

TBSOTf (0.55 mL, 637 mg, 2.41 mmol, 1.0 equiv.) was added to a stirred solution of 2,6-lutidine (0.84 mL, 776 mg, 7.24 mmol, 3.0 equiv.) in anhydrous MeCN (18 mL) at −30 °C. After 10 min a solution of alcohol (±)-16g (1.48 g, 2.41 mmol, 1.0 equiv.) in anhydrous MeCN (6.0 mL) was added dropwise and the solution was allowed to stir for 3 h at this temperature (TLC control, PE/MTBE, 4:1). The solution was added to a stirred sat. NaHCO₃ solution (120 mL) at 0 °C and extracted with MTBE (100 mL). The combined organic layers were washed consecutively with sat. CuSO₄ solution (3 × 30 mL), a Na₂EDTA solution (2 × 50 mL, 0.2 M, pH 8) and brine (2 × 50 mL). The organic extract was dried with MgSO₄, filtered and concentrated in vacuo. Column chromatography of the residue (PE/Et₂O, 9:1, 4 × 25 cm) provided TBS ether (±)-17 (1.74 g, 2.39 mmol, 99%) as a colorless oil.

Under the same conditions alcohol (+)-16g (2.09 g, 3.41 mmol) was converted to the TBS ether (+)-17, yielding 2.09 g (2.87 mmol, 84%) of a colorless oil.

**TLC:** \( R_f = 0.30 \) (PE/Et₂O, 9:1).

\[ [\alpha]_{D}^{23} = +14.8 \quad (c = 1.0, \text{THF}, 92\% \, ee) \]

**¹H NMR** (300 MHz, C₆D₆): δ = 7.38–7.32 (m, 2H, CH, Ar), 7.31–7.25 (m, 2H, CH, Ar), 7.05–6.97 (m, 2H, CH, Ar), 6.93–6.86 (m, 1H, CH, Ar), 6.84–6.79 (m, 2H, CH, Ar), 5.69 (d, 1H, \( J_{HH} = 1.8 \text{ Hz} \)), 5.53 (d, 1H, \( J_{HH} = 1.8 \text{ Hz} \)), 5.40 (t, 1H, \( J_{HH} = 6.6 \text{ Hz} \)), 4.42 (s, 2H, CH₂O), 4.36 (s, 2H, CH₂O), 4.22 (dd, 1H, \( J_{HH} = 7.9 \text{ Hz} \), C(H)OSi), 3.84 (s, 2H, CH₂O), 3.39–3.21 (m, 5H, OCH₃ + CH₂S), 2.86 (d, 1H, \( J_{HH} = 7.9 \text{ Hz} \), C(O)CH, epoxide), 2.76–2.67 (m, 1H, C(H)C(R)═CH₂), 2.19–2.08 (m, 2H, CH₂), 1.66 (s, 3H, CH₃), 1.64–1.51 (m, 1H, C(H)H'), 1.48–1.26 (m, 1H, C(H)H'), 1.20 (s,
3H, CH₃), 1.00 (s, 9H, SiC(CH₃)₃), 0.98 (s, 9H, SiC(CH₃)₃), 0.17 (s, 3H, Si(CH₃)(CH₃)’), 0.13 (m, 6H, Si(CH₃)₂), 0.08 (s, 3H, Si(CH₃)(CH₃)’).

¹³C{¹H} NMR (75 MHz, C₆D₆): δ = 159.7 (COCH₃), 147.5 (R₂C═), 137.1 (R₂C═), 133.3 (C_q(═C(H)═CR₂), 126.2 (CH, Ar), 114.1 (CH, Ar), 112.7 (=CH₂), 75.9 (CH₂O), 71.5 (CH₂O), 69.3 (C(H)OSi), 66.1 (CH₂O), 64.3 (C(O)CH, epoxide), 61.7 (C(O)CH, epoxide), 54.8 (OCH₃), 45.1 (C(H)C(R)═CH₂), 38.0 (CH₂), 36.0 (CH₂S), 26.2 (SiC(CH₃)₃), 26.1 (SiC(CH₃)₃), 23.4 (CH₂), 18.6 (SiC(CH₃)₃), 17.6 (CH₃), 14.0 (CH₃), −3.8 (Si(CH₃)(CH₃)'), −4.4 (Si(CH₃)(CH₃)'), −5.1 (Si(CH₃)₂).

IR (ATR): ν̃ = 3855 (w), 3735 (w), 3650 (w), 3568 (w), 3063 (w), 2929 (m), 2855 (m), 2361 (m), 1700 (w), 1612 (w), 1512 (w), 1460 (m), 1360 (w), 1252 (s), 1171 (m), 1090 (s), 938 (m), 835 (s), 773 (s), 690 (m) cm⁻¹.

HRMS (APCI, Orbitrap): m/z calc’d for C₄₁H₆₆O₅SSi₂ [M+H]+ 727.4242; observed 727.4238.

(5R,6R)-5-[(2R,3R)-3-[(E)-5-[(4-Methoxybenzyl)oxy]-4-methylpent-3-en-1-yl]-3-methyl-oxiran-2-yl]-2,2,3,3,10,10,11,11-octamethyl-7-methylene-6-[(phenylsulfonyl)-methyl]-4,9-dioxo-3,10-disiladodecane [(+)-18 and (–)-18]

Thioether (±)-17 (1.74 g, 2.39 mmol, 1.0 equiv.) was dissolved in 'BuOH (12 mL) and pyridine (3.0 mL) open to air and cooled to 0 °C. (NH₄)₆Mo₇O₂₄·4H₂O (1.77 g, 1.43 mmol, 0.6 equiv.) was added in one portion, followed by aq. H₂O₂ (3.0 mL, ~30w-%). The suspension was allowed to warm to rt over 6 h. After additional 10 h (TLC control, PE/EtOAc, 3:1) a mixture of sat. Na₂SO₃ solution (20 mL) and sat. NaHCO₃ solution (10 mL) was added slowly to the yellow suspension at 0 °C. EtOAc (40 mL) was added and the biphasic mixture was stirred for 10 min. The organic layer was separated and washed consecutively with sat. CuSO₄ solution (2 × 30 mL), a Na₂EDTA solution (2 × 30 mL, 0.2 m, pH 8) and brine (2 × 30 mL). The organic extract was dried with MgSO₄, filtered and
concentrated in vacuo. Column chromatography of the residue (PE/EtOAc, 7:1→5:1, 3×15 cm) provided the sulfone (±)-18 (1.49 g, 1.96 mmol, 82%) as a colorless oil.

Under the same conditions thioether (+)-17 (2.07 g, 2.85 mmol) was converted to sulfone (+)-18, yielding 2.07 g (2.72 mmol, 95%) of a colorless oil.

**TLC:** $R_f = 0.39$ (PE/EtOAc, 5:1).

$[α]_D^{23} = +20.1$ (c = 1.0, THF, 92% ee).

**$^1$H NMR** (300 MHz, C$_6$D$_6$): $δ = 7.87–7.80$ (m, 2H, CH, Ar), 7.32–7.23 (m, 2H, CH, Ar), 6.96–6.86 (m, 3H, CH, Ar), 6.86–6.79 (m, 2H, CH, Ar), 5.53 (d, 1H, $^2$J$_{H,H} = 1.7$ Hz, $\equiv$C(H)H$^+$), 5.44–5.34 (m, 2H, CH$_2$C(H)$\equiv$CR$_2$ + $\equiv$C(H)H$^+$), 4.49 (dd, 1H, $^3$J$_{H,H} = 7.8, 2.7$ Hz, C(H)OSi), 4.37 (s, 2H, CH$_2$O), 4.35–4.21 (m, 2H, CH$_2$OSi), 3.84 (s, 2H, CH$_2$O), 3.83–3.73 (m, 1H, C(H)H$^+$S), 3.31 (s, 3H, OCH$_3$), 3.24–3.14 (m, 2H, C(H)H$^+$S + C(H)C(R)$\equiv$CH$_2$), 2.80 (d, 1H, $^3$J$_{H,H} = 7.8$ Hz, C(O)CH, epoxide), 2.19–2.08 (m, 2H, CH$_2$), 1.66 (s, 3H, CH$_3$), 1.62–1.52 (m, 1H, C(H)H$^+$S), 1.46–1.35 (m, 1H, C(H)$^+$H$^+$), 1.30 (s, 3H, CH$_3$), 0.99 (s, 9H, Si(CH$_3$)$_3$), 0.96 (s, 9H, SiC(CH$_3$)$_3$), 0.29 (s, 3H, Si(CH$_3$)(CH$_3$)$_3$)$'$, 0.11 (s, 3H, Si(CH$_3$)(CH$_3$)$_3$)$'$, 0.08–0.07 (m, 6H, Si(CH$_3$)(CH$_3$)$_3$)$'$.

**$^{13}$C($^1$H) NMR** (75 MHz, C$_6$D$_6$): $δ = 159.7$ (C(OCH$_3$), 146.6 (R$_2$C═), 140.8 (SC$_{\text{quan}}$), 133.3 (C$_{\text{quart}}$, Ar), 133.2 (CH, Ar), 131.4 (R$_3$C═), 129.5 (CH, Ar), 129.2 (CH, Ar), 127.9 (CH, Ar), 126.9 (CH$_2$C(H)$\equiv$CR$_2$), 114.1 (CH, Ar), 113.5 (═CH$_2$), 75.9 (CH$_2$O), 71.5 (CH$_2$O), 69.9 (C(H)OSi), 65.8 (CH$_2$OSi), 64.3 (C(O)CH, epoxide), 62.0 (C(O)CH, epoxide), 57.4 (CH$_2$S), 54.8 (OCH$_3$), 40.7 (C(H)C(R)$\equiv$CH$_2$), 37.9 (CH$_3$), 26.2 (SiC(CH$_3$)$_3$), 26.1 (SiC(CH$_3$)$_3$), 23.4 (CH$_2$), 18.6 (SiC(CH$_3$)$_3$), 18.4 (SiC(CH$_3$)$_3$), 17.6 (CH$_3$), 14.0 (CH$_3$), −3.9 (Si(CH$_3$)(CH$_3$)$_3$)$'$, −4.3 (Si(CH$_3$)(CH$_3$)$_3$)$'$, −5.3 (Si(CH$_3$)$_2$).

**IR** (ATR): $\tilde{v} = 3855$ (w), 3736 (w), 3649 (w), 3567 (w), 2930 (m), 2855 (m), 2361 (m), 1612 (w), 1512 (m), 1458 (m), 1387 (m), 1304 (m), 1252 (m), 1086 (m), 908 (m), 835 (s), 750 (s), 689 (m) cm$^{-1}$.

**HRMS** (APCI, Orbitrap): m/z calc’d for C$_{41}$H$_{56}$O$_7$SSi$_2$[M+H]$^+$ 759.4141; observed 759.4117.

To a stirred solution of PMB ether (±)-18 (1.49 g, 1.96 mmol, 1.0 equiv.) in a mixture of CH₂Cl₂ (36 mL), 'BuOH (4.0 mL), MeCN (4.0 mL) and pH 7 phosphate buffer (4.0 mL, 0.5 M) was added DDQ (890 mg, 3.92 mmol, 2.0 equiv.) in 6 portions, every 2 min at 0 °C. After 6 h at this temperature (TLC control, PE/EtOAc, 3:1) the mixture was filtered and the filtrate was stirred with sat. NaHCO₃ solution (20 mL) for 20 min until all solids dissolved and the solution turned completely red. Additional sat. NaHCO₃ solution (100 mL) was added and the mixture was extracted with MTBE/PE (2:1, 300 mL). The organic layer was washed with sat. NaHCO₃ solution (100 mL) and brine (200 mL), dried with MgSO₄, filtered and the solvent was removed in vacuo. The residual oil was taken up in anhydrous MeOH/CH₂Cl₂ (5:2, 40 mL) and cooled to 0 °C. NaBH₄ (111 mg, 2.94 mmol, 1.5 equiv.) was added in one portion under stirring and the mixture was kept at this temperature for 1 h (TLC control, PE/EtOAc, 2:1) followed by addition of sat. NH₄Cl solution (100 mL) and CH₂Cl₂ (100 mL). The organic layer was separated, washed with sat. NaHCO₃ solution (100 mL) and brine (100 mL), dried with MgSO₄, filtered and concentrated in vacuo. Column chromatography of the residue (PE/MTBE, 2:1, 4 × 35 cm) provided the allyl alcohol (±)-SI-31 (1.15 g, 1.80 mmol, 92%) as a colorless oil.

Under the same conditions PMB protected alcohol (+)-18 (2.0 g, 2.63 mmol) was converted to alcohol (–)-SI-31, yielding 1.54 g (2.41 mmol, 92%) of a colorless oil.

**TLC:** \( R_f = 0.26 \) (PE/EtOAc, 3:1).
\[
[\alpha]_{D}^{23} = -15.3 \ (c = 1.0, \ THF, \ 92\% \ ee).
\]

**¹H NMR** (300 MHz, C₆D₆): \( \delta = 7.90-7.77 \) (m, 2H, CH, Ph), 6.97–6.82 (m, 3H, CH, Ph), 5.53 (s, 1H, \( =\mathrm{C(H)}\mathrm{H}^+ \)), 5.36 (s, 1H, \( =\mathrm{C(H)}\mathrm{H}^+ \)), 5.26 (t, 1H, \( ^3J_{\mathrm{H,H}} = 7.0 \) Hz, CH₂C(H)=CR₂).
4.51 (dd, 1H, $^2$J$_{HH} = 7.8$, 2.4 Hz, C(H)OSi), 4.33 (d, 1H, $^2$J$_{HH} = 15.0$ Hz, C(H)H’OSi), 4.25 (d, 1H, $^2$J$_{HH} = 15.0$ Hz, C(H)H’OSi), 3.86–3.69 (m, 3H, C(H)H’S + CH$_2$OH), 3.24–3.11 (m, 2H, C(H)H’S + OH), 2.81 (d, 1H, $^3$J$_{HH} = 7.8$ Hz, C(O)CH, epoxide), 2.17–1.99 (m, 2H, CH$_2$), 1.61–1.50 (m, 4H, CH$_3$ + C(H)H’), 1.47–1.35 (m, 1H, C(H)H’), 1.31 (s, 3H, CH$_3$), 0.99 (s, 9H, SiC(CH$_3$)$_3$), 0.96 (s, 9H, SiC(CH$_3$)$_3$), 0.30 (s, 3H, Si(CH$_3$)(CH$_3$)’), 0.12 (s, 3H, Si(CH$_3$)(CH$_3$)’), 0.08 (s, 6H, Si(CH$_3$)$_2$).

$^{13}$C$^{[2]}$H NMR (75 MHz, C$_6$D$_6$): $\delta = 146.6$ (R$_2$C=), 140.8 (SC$_{quat}$), 135.8 (R$_2$C=), 133.2 (CH, Ph), 129.2 (CH$_2$C(H)=CR$_2$), 128.2 (CH, Ph), 124.6 (CH, Ph), 113.5 (=CH$_2$), 69.9 (C(H)OSi), 68.5 (CH$_2$OH), 65.8 (CH$_2$OSi), 64.3 (C(O)CH, epoxide), 62.0 (C(O)CH, epoxide), 57.4 (CH$_2$S), 40.7 (C(H)C(R)=CH$_2$), 37.9 (CH$_2$), 26.2 (SiC(CH$_3$)$_3$), 26.1 (SiC(CH$_3$)$_3$), 23.3 (CH$_2$), 18.6 (SiC(CH$_3$)$_3$), 18.4 (SiC(CH$_3$)$_3$), 17.7 (CH$_3$), 13.5 (CH$_3$), –3.9 (Si(CH$_3$)(CH$_3$)’), –4.3 (Si(CH$_3$)(CH$_3$)’), –5.3 (Si(CH$_3$)$_2$).

IR (ATR): $\tilde{\nu} = 3735$ (w), 3649 (w), 3567 (w), 2930 (m), 2856 (m), 2361 (m), 2060 (w), 1920 (m), 1649 (m), 1458 (m), 1387 (m), 1305 (m), 1254 (m), 1087 (s), 1003 (m), 909 (m), 836 (s), 751 (s), 689 (m) cm$^{-1}$.

HRMS (ESI, Orbitrap): m/z calc’d for C$_{33}$H$_{58}$O$_6$SSi$_2$ [M+Na]$^+$ 661.3385; observed 661.3370.

(5R,6R)-5-[(2R,3R)-3-[(E)-5-Bromo-4-methylpent-3-en-1-yl]-3-methyloxiran-2-yl]-2,2,3,10,10,11,11-octamethyl-7-methylene-6-[(phenylsulfonyl)methyl]-4,9-dioxa-3,10-disiladodecane [(−)-9 and (±)-9]

\[\begin{array}{c}
\text{OH} \quad \text{SO}_2\text{Ph} \\
\text{OTBS} \quad \text{OTBS} \\
\begin{array}{c}
\text{(−)-Si-31} \\
\text{(±)-Si-31}
\end{array}
\end{array}\]

\[\begin{array}{c}
\text{Br} \quad \text{SO}_2\text{Ph} \\
\text{OTBS} \quad \text{OTBS} \\
\begin{array}{c}
\text{(−)-9} \\
\text{(±)-9}
\end{array}
\end{array}\]

To a stirred solution of anhydrous Et$_3$N (0.24 mL, 178 mg, 1.76 mmol, 1.20 equiv.) in anhydrous THF (10 mL) at 0 °C was added MsCl (0.12 mL, 177 mg, 1.54 mmol, 1.05 equiv.). After 5 min a solution of allyl alcohol (±)-Si-31 (940 mg, 1.47 mmol, 1.0 equiv.) in anhydrous THF (5.0 mL) was added and the suspension was stirred for 2 h. Then anhydrous LiBr (1.28 g, 14.7 mmol, 10.0 equiv.) in anhydrous THF (14.7 mL; stored as 1.0 M stock solution with 4 Å molecular sieves) was added at 0 °C and the mixture was stirred for another 1.5 h (TLC control, PE/EtOAc, 3:1). pH 7 phosphate buffer (30 mL, 0.5 m) was added to
terminate the reaction. The mixture was extracted with MTBE (60 mL) and the extract was washed with brine (2 × 30 mL), dried with MgSO₄ and filtered. Toluene (3.0 mL) was added and the solution was concentrated in vacuo. Column chromatography of the residue (PE→PE/MTBE, 7:1, 3 × 15 cm) provided the allyl bromide (±)-9 (922 mg, 1.31 mmol, 89%) as a colorless oil which solidified slowly upon storage at −25 °C to give a colorless solid. Crystals suitable for X-ray analysis were obtained by slow (complete) evaporation of a saturated solution in n-heptane/C₆H₆ (5:1) at rt.

Under the same conditions alcohol (−)-SI-31 (1.43 g, 2.24 mmol) was converted to bromide (−)-9, yielding 1.38 g (1.96 mmol, 88%) of a colorless oil.

**TLC:** $R_t = 0.34$ (PE/MTBE, 9:1).

**Mp.:** 88–90 °C [MTBE, (±)-9].

$[\alpha]_D^{13} = -10.9 \ (c = 1.0, \ \text{THF}, \ 92\% \ \text{ee}).$

**¹H NMR** (300 MHz, C₆D₆): $\delta = 7.82 \ (dd, 2H, 3^4J_{H,H} = 7.6, \ 1.6 \ Hz, \ CH, \ Ph), \ 6.98–6.86 \ (m, \ 3H, \ CH, \ Ph), \ 5.51 \ (d, \ 1H, \ 4^3J_{H,H} = 1.6 \ Hz, \ CH, \ Ph), \ 5.19 \ (t, \ 1H, \ 3^3J_{H,H} = 7.0 \ Hz, \ CH_{2}C(H)═CR_{2}), \ 4.46 \ (dd, \ 1H, \ 3^3J_{H,H} = 7.8, \ 2.7 \ Hz, \ C(H)OSi), \ 4.30 \ (d, \ 1H, \ 2^3J_{H,H} = 15.0 \ Hz, \ C(H)H′OSi), \ 4.22 \ (d, \ 1H, \ 2^3J_{H,H} = 15.0 \ Hz, \ C(H)H′OSi), \ 3.75 \ (dd, \ 1H, \ 2^3J_{H,H} = 14.8, \ 10.3 \ Hz, \ C(H)H′S), \ 3.61 \ (s, \ 2H, \ CH_{2}Br), \ 3.22–3.11 \ (m, \ 2H, \ C(H)H′S + C(H)C(R)═CH_{2}), \ 2.73 \ (d, \ 1H, \ 3^3J_{H,H} = 7.8 \ Hz, \ C(O)CH, \ epoxide), \ 1.97–1.85 \ (m, \ 2H, \ CH_{2}), \ 1.55 \ (s, \ 3H, \ CH_{3}), \ 1.48–1.33 \ (m, \ 1H, \ C(H)H′), \ 1.29–1.14 \ (m, \ 4H, \ CH_{3} + C(H)H′), \ 0.99–0.93 \ (m, \ 18H, \ 2 × SiC(CH_{3})_{2}), \ 0.28 \ (s, \ 3H, \ Si(C(CH_{3})CH_{3})^{′}), \ 0.11–0.04 \ (m, \ 9H, \ Si(C(CH_{3})CH_{3})^{′} + Si(CH_{3})_{2}).$

**¹³C (¹H) NMR** (75 MHz, C₆D₆): $\delta = 146.5 \ (R_2C═), \ 140.7 \ (SC_{\text{quat}}), \ 133.3 \ (CH, \ Ph), \ 132.6 \ (R_2C═), \ 130.4 \ (CH_{2}C(H)═CR_{2}), \ 129.3 \ (CH, \ Ph), \ 128.2 \ (CH, \ Ph), \ 113.5 \ (═CH_{2}), \ 69.9 \ (C(H)OSi), \ 65.8 \ (CH_{2}OSi), \ 64.3 \ (C(O)CH, \ epoxide), \ 61.8 \ (C(O)CH, \ epoxide), \ 57.4 \ (CH_{2}S), \ 41.2 \ (CH_{2}Br), \ 40.6 \ (C(H)C(R)═CH_{2}), \ 37.1 \ (CH_{2}), \ 26.2 \ (SiC(CH_{3})_{3}), \ 26.1 \ (SiC(CH_{3})_{3}), \ 23.8 \ (CH_{2}), \ 18.6 \ (SiC(CH_{3})_{3}), \ 18.4 \ (SiC(CH_{3})_{3}), \ 17.6 \ (CH_{3}), \ 14.5 \ (CH_{3}), \ −3.9 \ (Si(C(CH_{3})CH_{3})^{′}), −4.4 \ (Si(CH_{3})_{2}(CH_{3})^{′}), −5.2 \ (Si(CH_{3})_{2}).$

**IR (ATR):** $\tilde{\nu} = 3839 \ (w), \ 3736 \ (w), \ 3649 \ (w), \ 3567 \ (w), \ 2932 \ (m), \ 2857 \ (m), \ 2712 \ (w), \ 2361 \ (m), \ 1699 \ (w), \ 1653 \ (w), \ 1460 \ (m), \ 1391 \ (m), \ 1253 \ (m), \ 1150 \ (s), \ 1085 \ (s), \ 1001 \ (m), \ 936 \ (m), \ 840 \ (s), \ 774 \ (s) \ \text{cm}^{-1}.$
**HRMS** (ESI, TOF): m/z calc’d for C_{33}H_{57}BrO_5SSi_2 [M+Na]^+ 725.2526 (100%), 723.2541 (83%); observed 725.2525 (100%), 723.2539 (83%).

**tert-Butyl[2-�{(1R*,2R*,3R*,10R*,E)-2-[(tert-butyldimethylsilyl)oxy]-6,10-dimethyl-11-oxabicyclo[8.1.0]undec-6-en-3-yl}allyloxy]dimethylsilane [(+)-20 and (±)-20]**

To a stirred solution of a KHMDS solution (0.57 mL, 0.57 mmol, 4.0 equiv., 1.0 M in THF) in anhydrous THF (33 mL) at 0 °C was added a solution of sulfone (+/-9 (110 mg, 0.16 mmol, 1.0 equiv.) in anhydrous THF (7.0 mL) over 15 min using a syringe pump (0.46 mL/min). After another 15 min (TLC control, PE/MTBE, 4:1) the reaction was terminated by addition of sat. NH_4Cl solution (30 mL), followed by Et_2O (90 mL). The organic layer was separated, washed with sat. NaHCO_3 solution (90 mL) and brine (90 mL), dried with MgSO_4, filtered, and concentrated in vacuo. After column chromatography (PE/MTBE, 4:1, 2 × 30 cm) the separable diastereomeric sulfones (+/-19a and (+/-19b were combined to yield a colorless glass, which was taken further to the next step. Yield in total: 77.8 mg, 0.13 mmol, 80%.

Under the same conditions, but divided into 9 separate transformation, sulfone (-/-9 (1.37 g, 1.95 mmol) was converted to the ten-membered ring sulfones 19a,b, yielding 762 mg (1.22 mmol, 63%) of a colorless glass.

**19a:** TLC: R_f = 0.67 (PE/MTBE, 4:1).

**19b:** TLC: R_f = 0.31 (PE/MTBE, 4:1).

**HRMS** (ESI, Orbitrap): m/z calc’d for C_{33}H_{56}NaO_5SSi_2 [M+Na]^+ 643.3279; observed 643.3274.

To a strongly stirred suspension of the diastereomeric sulfones (+/-19a and (+/-19b (230 mg, 0.37 mmol, 1.0 equiv.) in a 5:1 mixture of anhydrous MeOH and THF (2.0 mL) at rt was
added 5% Na(Hg) (1.71 g, 3.70 mmol Na, 10.0 equiv.) in one portion [Note: Consistent yields were obtained with Na(Hg) pieces <3 mm size (hammered)]. After 1.5 h (TLC control, PE/MTBE, 6:1) the suspension was filtered through a plug of Celite (MTBE, 20 mL) into stirred pH 7 phosphate buffer (20 mL, 0.5 M) at 0 °C. After 5 min the organic layer was separated, washed with sat. NaHCO₃ solution (20 mL) and brine (20 mL), dried with MgSO₄, filtered and concentrated in vacuo. Column chromatography of the residue (PE/MTBE, 15:1, 3 × 25 cm) provided the protected epoxy alcohol (±)-20 (120 mg, 0.25 mmol, 68%) as a colorless oil.

Under the same conditions sulfones 19a,b (762 mg, 1.22 mmol) were converted to protected epoxy alcohol (+)-20, yielding 411 mg (0.85 mmol, 70%) of a colorless oil.

**TLC:** $R_f = 0.40$ (PE/MTBE, 20:1).

$[\alpha]_D^{22} = +34.4 \quad (c = 1.0, \text{THF, } 92\% \text{ ee}).$

$^1\text{H} \text{NMR} \quad (300 \text{ MHz, } C_6D_6): \quad \delta = 5.40 \ (s, 1H, \text{H})$, 5.06 (br s, 1H, C(H)=), 4.95 (s, C=H'), 4.29 (d, 1H, $^2J_{HH} = 13.7 \text{ Hz}$, C(H)H'OSi), 4.21 (d, 1H, $^2J_{HH} = 13.7 \text{ Hz}$, C(H)H'OSi), 3.94 (dd, 1H, $^3J_{HH} = 10.6, 3.3 \text{ Hz}$, C(H)OSi), 2.51 (d, 1H, $^3J_{HH} = 3.3 \text{ Hz}$, C(O)CH, epoxide), 2.14–1.95 (m, 3H, CH₂ + C(H)C(R)=CH₂), 1.93–1.83 (m, 1H, C(H)H'), 1.80–1.68 (m, 1H, C(H)H'), 1.54 (s, 3H, CH₃), 1.48–1.38 (m, 4H, C(H)H' + CH₃), 1.09–0.99 (m, 19H, C(H)H' + 2 × SiC(CH₃)₃), 0.33 (s, 3H, Si(CH₃)(CH₃)'), 0.17 (s, 3H, Si(CH₃)(CH₃)'), 0.12 (s, 6H, Si(CH₃)₂).

The signal for one CH₂ group could not be detected.

$^{13}\text{C}(^1\text{H}) \text{NMR} \quad (75 \text{ MHz, } C_6D_6): \quad \delta = 153.7 \ (R_2C=), 135.1 \ (br, R_2C=), 125.2 \ (br, C(H)=CR₂), 110.1 \ (=CH₂), 74.3 \ (C(H)OSi), 67.9 \ (CH₂OSi), 64.9 \ (C(O)CH, epoxide), 59.6 \ (C(O)CH, epoxide), 45.6 \ (C(H)C(R)=CH₂), 38.7 \ (br, CH₂), 32.9 \ (br, CH₂), 26.6 \ (SiC(CH₃)₃), 26.2 \ (SiC(CH₃)₃), 24.2 \ (br, CH₂), 20.1 \ (br, C(R)C(CH₃)), 18.9 \ (SiC(CH₃)₃), 18.6 \ (SiC(CH₃)₃), 15.8 \ (CH₃), −3.3 \ (Si(CH₃)(CH₃)'), −4.8 \ (Si(CH₃)(CH₃)'), −5.1 \ (Si(CH₃)(CH₃)'), −5.2 \ (Si(CH₃)(CH₃)')).

The signal for one CH₂ group could not be detected.

**IR** (ATR): $\tilde{\nu} = 3855 \ (w), 3736 \ (w), 3649 \ (w), 3567 \ (w), 2929 \ (m), 2856 \ (m), 2709 \ (w), 2362 \ (m), 2165 \ (w), 1919 \ (w), 1651 \ (m), 1459 \ (m), 1361 \ (m), 1251 \ (m), 1099 \ (m), 963 \ (m), 835 \ (s), 772 \ (s), 669 \ (m) \ cm^{-1}.$

**MS** (GC, EI): m/z 423.3 [M−Bu]+.
HRMS: No molecular ion peak detectable (collected HPLC fraction, ionization modes: ESI, APCI, EI).

\[ (4R,5R,6R,7R)\text{-dia-Parthenolide} \ [(+)\text{-22 and } (\pm)\text{-22}] \]

To a stirred solution of TBS protected diol \((\pm)\text{-20}\) (30.0 mg, 62.4 \(\mu\)mol, 1.0 equiv.) in anhydrous THF (2.0 mL) at rt was added a TBAF\(\times\)3H\(_2\)O solution (0.13 mL, 0.13 mmol, 2.0 equiv., 1.0 M in THF). After 18 h (TLC control, MTBE/PE, 2:1) the mixture was diluted with Et\(_2\)O (20 mL) and washed with pH 7 phosphate buffer (20 mL), sat. NaHCO\(_3\) solution (20 mL) and brine (3 \(\times\) 10 mL). The organic layer was then dried with MgSO\(_4\), filtered and concentrated \(\text{in vacuo}\). Column chromatography of the residue (MTBE/PE, 3:1, 2 \(\times\) 20 cm) gave the unstable epoxy diol \((\pm)\text{-21}\) (11.0 mg, 43.6 \(\mu\)mol, 70\%) as a colorless oil.

TLC: \(R_f = 0.25\) (MTBE/PE, 2:1).

The diol \(\textbf{21}\) was dissolved in anhydrous CH\(_2\)Cl\(_2\) (0.5 mL) and TEMPO (2.05 mg, 13.1 \(\mu\)mol, 0.3 equiv.) was added at rt with stirring, followed by PhI(OAc)\(_2\) (41.9 mg, 0.13 mmol, 3.0 equiv.). After 18 h (TLC control, PE/EtOAc, 2:1) the mixture was diluted with PE (1 mL) and directly subjected to column chromatography (PE/EtOAc, 3:1, 2 \(\times\) 20 cm), obtaining \((4R^*,5R^*,6R^*,7R^*)\text{-dia-parthenolide}\)\(^{\text{SS}}\) \((\pm)\text{-22}\) (9.3 mg, 37.5 \(\mu\)mol, 86\%) as a colorless solid.

Milligram amounts of the pure enantiomers \((4R,5R,6R,7R)\text{-22}\) and \((4S,5S,6S,7S)\text{-22}\) were obtained by multi-run separation on a HPLC system using an analytical Daicel Chiralcel-IA column, like described below.

Under the same conditions epoxide \((+)\text{-20}\) (30.0 mg, 62.4 \(\mu\)mol) was converted to diol \(\textbf{21}\) (13.1 mg, 51.5 \(\mu\)mol), which was directly transformed to \((4R,5R,6R,7R)\text{-}(+)\text{-parthenolide}\) \((+)\text{-22}\), yielding 10.2 mg (41.4 \(\mu\)mol, 80\%) of a colorless solid.
**TLC:** $R_f = 0.43$ (PE/EtOAc, 2:1); 0.34 (CH$_2$Cl$_2$/PhMe/MTBE, 10:5:1)$^\text{ss}$. 

$[\alpha]^\text{D}_22 = +5.4$ ($c = 1.0$, THF, $>99$% ee), $+4.6$ ($c = 1.0$, THF, 92% ee) for (4R,5R,6R,7R)-22. 

$[\alpha]^\text{D}_22 = -4.9$ ($c = 1.0$, THF, $>99$% ee) for (4S,5S,6S,7S)-22.

**NMR:**

**Table S1.** $^1$H NMR data in comparison to published data of ($\pm$)-22.$^\text{ss}$

<table>
<thead>
<tr>
<th>300 MHz, CDCl$_3$ (Ref. $^\text{ss}$)</th>
<th>Assignment</th>
<th>400 MHz, CDCl$_3$ (this work)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.23 ($d$, 1H, $^2J_{H,H} = 3.4$ Hz)</td>
<td>$\equiv$$C$(H)H'</td>
<td>6.23 ($d$, 1H, $^2J_{H,H} = 3.4$ Hz)</td>
</tr>
<tr>
<td>5.56 ($d$, 1H, $^2J_{H,H} = 3.4$ Hz)</td>
<td>$\equiv$$C$(H)H'</td>
<td>5.56 ($d$, 1H, $^2J_{H,H} = 3.4$ Hz)</td>
</tr>
<tr>
<td>5.44–5.30 (m, 1H)</td>
<td>$\equiv$$C$(H)CH$_2$</td>
<td>5.37 (br s, 1H), 3.6 Hz</td>
</tr>
<tr>
<td>4.37 ($dd$, 1H, $^3J_{H,H} = 10.2$, 3.5 Hz)</td>
<td>C(H)OCO</td>
<td>4.37 ($dd$, 1H, $^3J_{H,H} = 10.2$, 3.5 Hz)</td>
</tr>
<tr>
<td>2.90–2.79 (m, 1H)</td>
<td>C(H)C═CH$_2$</td>
<td>2.89–2.80 (m, 1H)</td>
</tr>
<tr>
<td>2.75 (br s, 1H)</td>
<td>(H)C(O)C, epoxide</td>
<td>2.74 (br s, 1H)</td>
</tr>
<tr>
<td>2.48–2.36 (m, 1H)</td>
<td>C(H)H'</td>
<td>2.47–2.36 (m, 1H)</td>
</tr>
<tr>
<td>2.34–2.25 (m, 1H)</td>
<td>C(H)H'</td>
<td>2.35–2.26 (m, 1H),</td>
</tr>
<tr>
<td>2.23–2.01 (m, 4H)</td>
<td>2 × C(H)H' + 2 × C(H)H'</td>
<td>2.23–2.02 (m, 4H),</td>
</tr>
<tr>
<td>1.70–1.55 (m, 4H)</td>
<td>$\equiv$$C$(CH$_2$)CH$_3$ + C(H)H'</td>
<td>1.70–1.57 (m, 4H)</td>
</tr>
<tr>
<td>1.43–1.24 (m, 4H)</td>
<td>CH$_3$ + C(H)H'</td>
<td>1.45–1.28 (m, 4H)</td>
</tr>
</tbody>
</table>

**Table S2.** $^{13}$C($^1$H) NMR data in comparison to published data of ($\pm$)-22.$^\text{ss}$

<table>
<thead>
<tr>
<th>75 MHz, CDCl$_3$ (Ref. $^\text{ss}$)</th>
<th>Assignment</th>
<th>101 MHz, CDCl$_3$ (this work)</th>
</tr>
</thead>
<tbody>
<tr>
<td>169.1</td>
<td>CO$_2$</td>
<td>169.1</td>
</tr>
<tr>
<td>139.5</td>
<td>$\equiv$$C$CH$_2$</td>
<td>139.5</td>
</tr>
<tr>
<td>136.7 (br)</td>
<td>$\equiv$$C$(CH$_2$)CH$_3$</td>
<td>137.0 (br)</td>
</tr>
<tr>
<td>125.0 (br)</td>
<td>$\equiv$$C$(H)CH$_2$</td>
<td>124.8 (br)</td>
</tr>
<tr>
<td>119.1</td>
<td>$\equiv$CH$_2$</td>
<td>119.1</td>
</tr>
<tr>
<td>79.6</td>
<td>$\equiv$$C$(H)OCO</td>
<td>79.5</td>
</tr>
<tr>
<td>62.4</td>
<td>(H)C(O)C, epoxide</td>
<td>62.3</td>
</tr>
<tr>
<td>60.4</td>
<td>(H)C(O)C, epoxide</td>
<td>60.4</td>
</tr>
</tbody>
</table>
The NMR data matched previously published data.\textsuperscript{55}

<table>
<thead>
<tr>
<th>75 MHz, CDCl\textsubscript{3} (Ref. \textsuperscript{55})</th>
<th>Assignment</th>
<th>101 MHz, CDCl\textsubscript{3} (this work)</th>
</tr>
</thead>
<tbody>
<tr>
<td>44.2</td>
<td>$\text{C}(\text{H})\text{C}=\text{CH}_2$</td>
<td>44.3</td>
</tr>
<tr>
<td>39.4 (br)</td>
<td>CH\textsubscript{2}</td>
<td>39.4 (br)</td>
</tr>
<tr>
<td>36.5 (br)</td>
<td>CH\textsubscript{2}</td>
<td>36.5 (br)</td>
</tr>
<tr>
<td>25.7 (br)</td>
<td>CH\textsubscript{2}</td>
<td>25.7 (br)</td>
</tr>
<tr>
<td>22.5 (br)</td>
<td>CH\textsubscript{2}</td>
<td>22.5 (br)</td>
</tr>
<tr>
<td>17.0</td>
<td>$=\text{C(\text{CH}_2)}\text{CH}_3$</td>
<td>17.0</td>
</tr>
<tr>
<td>16.6</td>
<td>CH\textsubscript{3}</td>
<td>16.6</td>
</tr>
</tbody>
</table>
Chiral HPLC [Daicel Chiralcel-IA column (5 μm, 253 × 4.6 mm ID) with guard cartridge, n-Hexan/EtOH, 95:5, 1 mL/min, 25 °C, 203 nm]:

a. (±)-22

<table>
<thead>
<tr>
<th>No.</th>
<th>Ret. time / min</th>
<th>Area / mAU×min</th>
<th>Height / mAU</th>
<th>Rel. area / %</th>
<th>Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>31.6</td>
<td>788.3</td>
<td>482.5</td>
<td>50.8</td>
<td>13.0</td>
</tr>
<tr>
<td>2</td>
<td>114.5</td>
<td>763.4</td>
<td>99.9</td>
<td>49.2</td>
<td>–</td>
</tr>
</tbody>
</table>

b. (4R,5R,6R,7R)-(+)-22; $t_R = 31.2, 110.2$ min (major), $er = 97:3$, ee = 94%.

<table>
<thead>
<tr>
<th>No.</th>
<th>Ret. time / min</th>
<th>Area / mAU×min</th>
<th>Height / mAU</th>
<th>Rel. area / %</th>
<th>Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>31.2</td>
<td>65.6</td>
<td>52.3</td>
<td>2.78</td>
<td>10.1</td>
</tr>
<tr>
<td>2</td>
<td>110.2</td>
<td>2297</td>
<td>232.2</td>
<td>97.2</td>
<td>–</td>
</tr>
</tbody>
</table>

c. (4S,5S,6S,7S)-(−)-22, >99% ee after preparative chiral HPLC.

d. (4R,5R,6R,7R)-(−)-22, >99% ee after preparative chiral HPLC.
Fresh, blue WCl₆ (333 mg, 0.84 mmol, 4.0 equiv.) was added in one portion to stirred anhydrous THF (2.5 mL) at −78 °C. After 5 min a (alkoxide/hydroxide free) n-BuLi solution (1.05 mL, 2.52 mmol, 12.0 equiv., 2.4 M in hexane) was added dropwise over 10 min. The suspension was kept at −78 °C for 10 min and then allowed to warm to 15 °C over 1.5 h, during which several color changes were observed (red, green, yellow, brown, dark brown). The solution was kept at 15 °C for 2 min, cooled again to 0 °C (10 min) and added to a solution of epoxide (±)-20 (108 mg, 0.21 mmol, 1.0 equiv.) in anhydrous THF (0.5 mL) at 0 °C. The dark brown suspension was kept at this temperature for 3 h and then kept at 10 °C for 15 h (TLC control, PE/CH₂Cl₂, 6:1). The mixture was added into stirred sat. NaHCO₃ solution (30 mL) at 0 °C. Et₂O (30 mL) was added and stirring was continued for 10 min. The organic layer was separated and washed sequentially with sat. NaHCO₃ solution (2 × 30 mL), a Na₂EDTA solution (30 mL, 0.2 M, pH 8) and brine (30 mL). The extract was dried with MgSO₄, filtered and concentrated in vacuo. Column chromatography of the residue (PE/CH₂Cl₂, 10:1 + 0.5% Me₂NEt, 3 × 35 cm) provided the germacrene (±)-23 (69.0 mg, 0.15 mmol, 71%) as a colorless oil.

Under the same conditions epoxide (+)-20 (200 mg, 0.42 mmol) was converted to germacrene (–)-23, yielding 168 mg (0.36 mmol, 86%) of a colorless oil.

**TLC:** \( R_t = 0.48 \) (PE/CH₂Cl₂, 5:1).

\[ \alpha \]D²² = −24.5 (c = 1.0, THF, 92% ee).

**¹H NMR** (300 MHz, C₆D₆): \( \delta = 5.43–5.27 \) (m, 1H, \( \equiv \text{C} (\text{H}) \text{H} \)), 5.02–4.87 (m, 1H, \( \equiv \text{C} (\text{H}) \text{H} \)), 4.75–4.61 (m, 2H, 2 × C(H)\( \equiv \)), 4.44–4.15 (m, 3H, C(H)OSi + CH₂OSi), 2.40–2.22 (m, 1H, C(H)\( \equiv \)), 2.18–1.91 (m, 5H, C(H)C(R)\( \equiv \))CH₂ + 2 × C(H)\( \equiv \)+ 2 × C(H)\( \equiv \)), 1.89–1.75 (m, 2H, C(H)\( \equiv \)+ C(H)\( \equiv \)), 1.72–1.52 (m, 1H, C(H)\( \equiv \)), 1.44 (d, 3H, 4J_H,H = 1.2 Hz, CH₃), 1.33 (s, 3H, CH₃), 1.07–0.98 (m, 18H, 2 × SiC(CH₃)₃), 0.17–0.11 (m, 12H, 2 × Si(CH₃)₂).
\(^{13}\)C\(^{3}\)H NMR (75 MHz, C\(_6\)D\(_6\)): \(\delta = 155.1\) (R\(_2\)C\(=\)), 137.5 (R\(_2\)C\(=\)), 135.6 (C(H)\(\equiv\)CR\(_2\)), 131.5 (R\(_2\)C\(=\)), 126.9 (C(H)\(\equiv\)CR\(_2\)), 107.0 (\(\equiv\)CH\(_2\)), 73.9 (C(H)OSi), 66.9 (CH\(_2\)OSi), 54.7 (C(H)C\(\equiv\)CR\(_2\)), 42.5 (CH\(_2\)), 39.6 (CH\(_2\)), 32.9 (CH\(_2\)), 26.3 (Si(C(H)\(_3\))\(_3\)), 26.2 (Si(C(H)\(_3\))\(_3\)), 25.8 (CH\(_2\)), 18.6 (2 \times Si(C(H)\(_3\))\(_3\)), 17.1 (CH\(_3\)), 16.5 (CH\(_3\)), -3.4 (Si(C(H)\(_3\))(CH\(_3\))'), -4.6 (Si(CH\(_3\))(CH\(_3\))'), -5.1 (Si(CH\(_3\))(CH\(_3\))'), -5.2 (Si(CH\(_3\))(CH\(_3\))').

IR (ATR): \(\tilde{\nu} = 3854\) (w), 3735 (w), 3649 (w), 3567 (w), 2928 (m), 2855 (m), 2708 (w), 2361 (m), 2090 (w), 1920 (w), 1650 (m), 1458 (m), 1361 (m), 1250 (m), 1056 (m), 833 (s), 769 (s), 668 (m) cm\(^{-1}\).

MS (GC, EI): m/z 464.4 [M]\(^{+}\), 407.3 [M-\(\text{tBu}\)]\(^{+}\).

HRMS: No molecular ion peak detectable (collected HPLC fraction, ionization modes: ESI, APCI, EI).

(1S,2E,6E,10R)-10-(3-Hydroxyprop-1-en-2-yl)-3,7-dimethylcycloocta-2,6-dienol [(\(-\))-SI-32 and (\(\pm\))-SI-32]

To a stirred solution of TBS protected diol (\(\pm\))-23 (66.0 mg, 0.14 mmol, 1.0 equiv.) in anhydrous THF (1.5 mL) at rt was added a TBAF\(\times 3\)H\(_2\)O solution (0.28 mL, 0.28 mmol, 2.0 equiv., 1.0 M in THF). After 15 h at this temperature (TLC control, Et\(_2\)O/PE, 4:1) the solution was diluted with Et\(_2\)O (20 mL) and washed with pH 7 phosphate buffer (20 mL), followed by sat. NaHCO\(_3\) solution (20 mL) and brine (3 \times 10 mL). The organic layer was then dried with MgSO\(_4\), filtered and concentrated \textit{in vacuo}. Column chromatography of the residue (Et\(_2\)O/PE, 4:1 + 0.5% Et\(_2\)NMe, 2 \times 15 cm) provided the diol (\(\pm\))-SI-32 (31.0 mg, 0.13 mmol, 93%) as a colorless oil.

Under the same conditions TBS protected diol (\(-\))-23 (160 mg, 0.34 mmol) was converted to diol (\(-\))-SI-32, yielding 74.3 mg (0.31 mmol, 91%) of a colorless oil.

\textbf{TLC}: \(R_t = 0.23\) (Et\(_2\)O/PE, 4:1).
\[ \alpha_D^{23} = -68.0 \ (c = 1.0, \text{THF}, 92\% \text{ ee}). \]

\(^1\text{H NMR}\) (400 MHz, C\(_6\)D\(_6\)): \(\delta = 5.16 \ (s, 1H, \equiv \text{C(H)H'})\), 4.93 \((s, 1H, \equiv \text{C(H)H'})\), 4.67 \((d, 1H, \text{J}_{3JH,H} = 10.6\ Hz, \text{C(H)}=)\), 4.59 \((d, 1H, \text{J}_{3JH,H} = 9.4\ Hz, \text{C(H)}=)\), 4.19–4.02 \((m, 3H, \text{C(H)}OH + \text{CH}_2\text{OH})\), 3.32 \((br\ s, 1H, \text{OH})\), 2.51 \((br\ s, 1H, \text{OH})\), 2.27–2.13 \((m, 2H, \text{C(H)}\text{C(R)}=\text{CH}_2 + \text{C(H)H'})\), 2.10–1.92 \((m, 4H, \text{CH}_2 + \text{C(H)H'} + \text{C(H)H'})\), 1.90–1.76 \((m, 1H, \text{C(H)H'})\), 1.60–1.52 \((m, 2H, \text{CH}_2)\), 1.46 \((s, 3H, \text{CH}_3)\), 1.24 \((s, 3H, \text{CH}_3)\).

\(^{13}\text{C}\{^1\text{H}\}\text{NMR}\) (101 MHz, C\(_6\)D\(_6\)): \(\delta = 153.9 \ (\text{R}_2\text{C}=)\), 137.8 \((\text{R}_2\text{C}=)\), 134.1 \((\text{C(H)}=\text{CR}_2)\), 133.5 \((\text{R}_2\text{C}=)\), 127.0 \((\text{C(H)}=\text{CR}_2)\), 111.9 \((=\text{CH}_2)\), 71.6 \((\text{C(H)}\text{OH})\), 65.2 \((\text{CH}_2\text{OH})\), 55.6 \((\text{C(H)}\text{C(R)}=\text{CH}_2)\), 41.9 \((\text{CH}_2)\), 39.7 \((\text{CH}_2)\), 32.5 \((\text{CH}_2)\), 26.2 \((\text{CH}_2)\), 16.9 \((\text{CH}_3)\), 16.4 \((\text{CH}_3)\).  

\(\text{IR\ (ATR)}\): \(\nu = 3326 \ (m), 2923 \ (m), 2362 \ (m), 2171 \ (w), 2066 \ (w), 1985 \ (w), 1646 \ (m), 1439 \ (m), 1383 \ (m), 1275 \ (m), 1183 \ (m), 1000 \ (s), 898 \ (s), 750 \ (cm^{-1}).\)

\(\text{HRMS\ (ESI, TOF)}\): m/z calc’d for C\(_{15}\)H\(_{24}\)O\(_2\) [M+Na]\(^+\) 259.1669; observed 259.1670.

---

\((4S,5S,6R,7R)\)-Parthenolide [(\(+\))-1 and \((\pm\))-1]

\[ \text{(\(-\))-SI-32} \quad \text{cat. Ti(OiPr)}_4, \text{ L-DIPT,} \quad \text{\(^1\text{BuOOH, 4 Å MS, CH}_2\text{Cl}_2,} \quad \text{–40 to –20 °C, 18 h} \quad \rightarrow \quad \text{80\%, 4:1:1 dr} \quad \rightarrow \quad \text{24 \ (\pm)-24} \quad \text{separable} \quad \text{21 \ (\pm)-21} \]

\[ \text{cat. TEMPO,} \quad \text{Ph(OAc)}_2, \quad \text{CH}_2\text{Cl}_2, \text{ rt, 18 h} \quad \rightarrow \quad \text{67\%} \quad \rightarrow \quad \text{(\(+\))-1} \quad \text{\((\pm\))-1} \]

Freshly activated powdered 4 Å molecular sieves (10 mg) were suspended in anhydrous (MeOH-free) CH\(_2\text{Cl}_2\) (0.15 mL) with stirring. \(\text{L-(+)-DIPT} \ 1.29 \mu l, 1.44 \text{ mg, 5.08 \mu mol, 0.25 equiv.})\) was added and the mixture was stirred for 20 min after which it was cooled to –20 °C. Ti(OiPr)\(_4\) 1.50 \mu l, 1.44 mg, 5.08 \mu mol, 0.20 equiv.) was added and stirring was continued for 15 min. An anhydrous \(^1\text{BuOOH} \) solution (10.4 \mu l, 50.8 \mu mol, 2.0 equiv., 5.0 M)
in decane with 4 Å molecular sieves) was added and after additional 30 min the mixture was cooled to −40 °C. Then allyl alcohol (±)-SI-32 (6.0 mg, 25.4 μmol, 1.0 equiv.) was added as a solution in anhydrous CH₂Cl₂ (0.1 mL) and the temperature was allowed to reach −20 °C over 30 min. After 18 h at this temperature (TLC control, EtOAc/PE, 5:1) the cooling bath was removed and the mixture was filtered through a short plug of silica (d × h = 0.5 × 1 cm, MTBE/PE, 4:1). The filtrate was washed with a 1:2 mixture of sat. Na₂SO₃ solution and sat. NaHCO₃ solution (5 mL), followed by sat. NaHCO₃ solution (5 mL) and brine (5 mL). The solution was dried with MgSO₄, filtered and concentrated in vacuo. The following products were obtained after column chromatography of the residue (EtOAc/PE, 3:1→4:1, 2.5 × 40 cm), in order of elution: Epoxy alcohol (±)-21 (0.83 mg, 3.30 μmol, 13%) and epoxy alcohol (±)-24 (3.91 mg, 15.5 μmol, 61%), both as colorless glasses which readily decomposed at within several hours.

Under the same conditions allyl alcohol (−)-SI-32 (58.0 mg, 0.25 mmol) was converted to epoxy alcohol (+)-21 (9.66 mg, 38.3 μmol, 15%) and epoxy alcohol (+)-24 (39.6 mg, 0.16 mmol, 64%).

**TLC:** Rᵣ = 0.37 (EtOAc/PE, 5:1).

**HRMS** (ESI, TOF): m/z calc’d for C₁₅H₂₄O₃ [M+Na]⁺ 275.1618; observed 275.1619.

The epoxy diol (±)-24 (1.6 mg, 6.34 μmol) was dissolved in anhydrous CH₂Cl₂ (0.1 mL) and TEMPO (0.30 mg, 1.90 μmol, 0.3 equiv.) was added at rt under stirring, followed by PhI(OAc)₂ (6.13 mg, 19.0 μmol, 3.0 equiv.). After 18 h (TLC control, PE/EtOAc, 2:1) the solution was diluted with PE (0.5 mL) and directly subjected to column chromatography (PE/EtOAc, 3:1, 2 × 20 cm), obtaining racemic (4S*,5S*,6R*,7R*)-parthenolide (±)-1 (1.10 mg, 4.44 μmol, 70%) as a colorless solid. Milligram amounts of the pure enantiomers (4R,5R,6R,7R) and (4S,5S,6S,7S)-1 were obtained by multi-run separation on a HPLC system using an semi-preparative Daicel Chiralcel-OJ column, like described below.

Under the same conditions epoxy diol (+)-24 (13.7 mg, 54.3 μmol) was converted to (4S,5S,6R,7R)-(+)parthenolide (+)-1, yielding 9.0 mg (36.2 μmol, 67%) of a colorless solid.
TLC: \( R_f = 0.34 \) (PE/EtOAc, 2:1).

\([\alpha]_D^{22} = +80.0 \) (c = 1.0, THF, >99% ee), \(+73.6 \) (c = 1.0, THF, 92% ee) for (4S,5S,6R,7R)-1.

\([\alpha]_D^{22} = -77.7 \) (c = 1.0, THF, >99% ee) for (4R,5R,6S,7S)-1.

NMR:

**Table S3.** \(^1\)H NMR data of (−)-1 in comparison with commercial material (TCI).

<table>
<thead>
<tr>
<th>400 MHz, C(_6)D(_6) (reference)</th>
<th>Assignment</th>
<th>400 MHz, C(_6)D(_6) (this work)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.24 ((d, 1H, (^2)J(_{H,H} = 3.7) Hz))</td>
<td>=C(H)H’</td>
<td>6.23 ((d, 1H, (^2)J(_{H,H} = 3.7) Hz))</td>
</tr>
<tr>
<td>4.94 ((d, 1H, (^2)J(_{H,H} = 3.3) Hz, 1H))</td>
<td>=C(H)H’</td>
<td>4.94 ((d, 1H, (^2)J(_{H,H} = 3.3) Hz, 1H))</td>
</tr>
<tr>
<td>4.71 ((dd, 1H, (^3)J(_{H,H} = 12.0, 2.2) Hz))</td>
<td>=C(H)CH(_2)</td>
<td>4.66 ((dd, 1H, (^3)J(_{H,H} = 12.4, 2.3) Hz))</td>
</tr>
<tr>
<td>3.30 ((dd, 1H, (^3)J(_{H,H} = 8.8, 8.6) Hz))</td>
<td>C(H)OCO</td>
<td>3.25 ((dd, 1H, (^3)J(_{H,H} = 8.9, 8.6) Hz))</td>
</tr>
<tr>
<td>2.31 ((d, 1H, (^3)J(_{H,H} = 8.9) Hz))</td>
<td>C(O)CH, epoxide</td>
<td>2.23 ((d, 1H, (^3)J(_{H,H} = 8.9) Hz))</td>
</tr>
<tr>
<td>2.09–1.90 ((m, 2H))</td>
<td>C(H)C=CH(_2) + C(H)H’</td>
<td>2.07–1.86 ((m, 2H))</td>
</tr>
<tr>
<td>1.89–1.74 ((m, 3H))</td>
<td>2 × C(H)H’ + C(H)H’</td>
<td>1.86–1.69 ((m, 3H))</td>
</tr>
<tr>
<td>1.61 ((dd, 1H, (^3)J(_{H,H} = 18.4, 7.0) Hz))</td>
<td>C(H)H’</td>
<td>1.55 ((dd, 1H, (^3)J(_{H,H} = 18.4, 7.0) Hz))</td>
</tr>
<tr>
<td>1.43 ((dd, 1H, (^3)J(_{H,H} = 15.2, 6.2) Hz))</td>
<td>C(H)H’</td>
<td>1.38 ((dd, 1H, (^3)J(_{H,H} = 15.2, 6.2) Hz))</td>
</tr>
<tr>
<td>1.27 ((s, 3H))</td>
<td>CH(_3)</td>
<td>1.25 ((s, 3H))</td>
</tr>
<tr>
<td>1.04–0.91 ((m, 5H))</td>
<td>CH(_3) + 2 × C(H)H’</td>
<td>1.03–0.82 ((m, 5H))</td>
</tr>
</tbody>
</table>

The \(^1\)H NMR spectra of synthetic and reference material are almost identical, with a chemical shift average deviation of 1.9%, possibly due to impurities (see spectrum). All coupling constants are in good agreement.
Table S4. $^{13}$C{$^1$H} NMR data of (−)-1 in comparison with commercial material (TCI).

<table>
<thead>
<tr>
<th>101 MHz, C$_6$D$_6$ (reference)</th>
<th>Assignment</th>
<th>101 MHz, C$_6$D$_6$ (this work)</th>
</tr>
</thead>
<tbody>
<tr>
<td>169.1</td>
<td>CO$_2$</td>
<td>168.9</td>
</tr>
<tr>
<td>140.6</td>
<td>C=CH$_2$</td>
<td>140.6</td>
</tr>
<tr>
<td>134.3</td>
<td>C(CH$_2$)CH$_3$</td>
<td>134.2</td>
</tr>
<tr>
<td>125.3</td>
<td>C(H)CH$_2$</td>
<td>125.3</td>
</tr>
<tr>
<td>119.7</td>
<td>CH$_2$</td>
<td>119.5</td>
</tr>
<tr>
<td>82.1</td>
<td>C(H)OCO</td>
<td>82.0</td>
</tr>
<tr>
<td>66.2</td>
<td>C(O)CH$_3$, epoxide</td>
<td>66.1</td>
</tr>
<tr>
<td>60.8</td>
<td>C(O)CH$_3$, epoxide</td>
<td>60.6</td>
</tr>
<tr>
<td>47.3</td>
<td>C(H)C=CH$_2$</td>
<td>47.3</td>
</tr>
<tr>
<td>41.1</td>
<td>CH$_2$</td>
<td>41.1</td>
</tr>
<tr>
<td>36.7</td>
<td>CH$_2$</td>
<td>36.7</td>
</tr>
<tr>
<td>30.3</td>
<td>CH$_2$</td>
<td>30.3</td>
</tr>
<tr>
<td>24.3</td>
<td>CH$_2$</td>
<td>24.2</td>
</tr>
<tr>
<td>17.4</td>
<td>C(CH$_2$)CH$_3$</td>
<td>17.3</td>
</tr>
<tr>
<td>16.7</td>
<td>CH$_3$</td>
<td>16.7</td>
</tr>
</tbody>
</table>

Considering spectrometer accuracy, the $^{13}$C{$^1$H} NMR spectra of synthetic and commercial material were identical.
HRMS (ESI, TOF): m/z calc’d for C$_{15}$H$_{20}$O$_3$ [M+Na]$^+$ 271.1305; observed 271.1308.

RP-HPLC [Nucleodur C18 Gravity column (5.0µm, 125 × 10 mm ID) with guard cartridge, gradient (%MeCN in H$_2$O): 10%$_{1 \text{min}}$ → 95%$_{5 \text{min}}$ → 10%$_{4 \text{min}}$, 1 mL/min, 25 °C, 203 nm]:

a. (4$S$,5$S$,6$R$,7$R$)-(+) -1

b. co-injection of (4$S$,5$S$,6$R$,7$R$)-(+) -1 and commercial (−)-parthenolide (TCI)
Chiral HPLC [Daicel Chiralcel-OJ column (10.0 μm, 250 × 10.0 mm ID) with guard cartridge, n-Hexan/EtOH, 90:10, 3 mL/min, 25 °C, 203 nm]:

**a. (±)-1** (crude mixture)

<table>
<thead>
<tr>
<th>No.</th>
<th>Ret. time / min</th>
<th>Area / mAU×min</th>
<th>Height / mAU</th>
<th>Rel. area / %</th>
<th>Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>35.5</td>
<td>156.4</td>
<td>117.2</td>
<td>47.6</td>
<td>13.0</td>
</tr>
<tr>
<td>2</td>
<td>45.0</td>
<td>172.1</td>
<td>89.5</td>
<td>52.4*</td>
<td>–</td>
</tr>
</tbody>
</table>

* co-elutes with impurity

**b. (4S,5S,6R,7R)-(+)-1;** $t_R = 33.9$ (major), 45.3, $er = 96:4$, $ee = 93\%$.

<table>
<thead>
<tr>
<th>No.</th>
<th>Ret. time / min</th>
<th>Area / mAU×min</th>
<th>Height / mAU</th>
<th>Rel. area / %</th>
<th>Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>33.9</td>
<td>963.8</td>
<td>531.8</td>
<td>96.54</td>
<td>10.1</td>
</tr>
<tr>
<td>2</td>
<td>45.3</td>
<td>34.5</td>
<td>20.4</td>
<td>3.46</td>
<td>–</td>
</tr>
</tbody>
</table>

c. (4S,5S,6R,7R)-(+)-1, >99% ee after preparative chiral HPLC.

d. (4R,5R,6S,7S)-(−)-1 (natural isomer) >99% ee after preparative chiral HPLC.
3.5 Single-crystal X-ray structure analysis of bromide (±)-9

*Fig. S1.* Molecular structure of bromide (±)-9 obtained from single-crystal X-ray analysis. Only the (R,R,R,R)-enantiomer is depicted. Most of the H atoms are omitted for clarity reasons. C = grey, H = white, Br = orange, O = red, S = bright yellow, Si = pale yellow.

Crystal Structure Determination

The intensity data were collected on a Nonius KappaCCD diffractometer, using graphite-monochromated Mo-Kα radiation. Data were corrected for Lorentz and polarization effects; absorption was taken into account on a semi-empirical basis using multiple-scans.\textsuperscript{S27} The structure was solved by direct methods (SHELXS)\textsuperscript{S28} and refined by full-matrix least squares techniques against Fo\textsuperscript{2} (SHELXL-97).\textsuperscript{S29} The hydrogen atoms bound to the vinylidene-groups of (±)-9 were located by difference Fourier synthesis and refined isotropically. All other hydrogen atoms were included at calculated positions with fixed thermal parameters. All non-hydrogen atoms were refined anisotropically.\textsuperscript{S29} MERCURY\textsuperscript{S30} was used for structure representations.

*Crystal Data for* (±)-9: C\textsubscript{33}H\textsubscript{57}BrO\textsubscript{5}SSi\textsubscript{2}, Mr = 701.94 g mol\textsuperscript{-1}, colourless prism, size 0.122 × 0.112 × 0.108 mm\textsuperscript{3}, monoclinic, space group P 2\textsubscript{1}/n, a = 28.3329(4), b = 9.8848(2), c = 30.0449(4) Å, β = 118.103(1)°, V = 7422.5(2) Å\textsuperscript{3}, T = –140 °C, Z = 8, ρ\textsubscript{calc} = 1.256 g cm\textsuperscript{-3}},
\( \mu (\text{Mo-K}_\alpha) = 12.64 \text{ cm}^{-1}, \) multi-scan, \( \text{trans}_{\min} = 0.6697, \text{trans}_{\max} = 0.7456, \text{F}(000) = 2992, 70579 \) reflections in \( h(-36/35), \) \( k(-12/8), \) \( l(-39/38), \) measured in the range \( 1.36^\circ \leq \Theta \leq 27.48^\circ, \) completeness \( \Theta_{\max} = 99.9\%, \) 16971 independent reflections, \( R_{\text{int}} = 0.0433, \) 13131 reflections with \( F_o > 4\sigma(F_o), \) 797 parameters, 0 restraints, \( R1_{\text{obs}} = 0.0467, wR^2_{\text{obs}} = 0.1043, \) \( R1_{\text{all}} = 0.0685, wR^2_{\text{all}} = 0.1152, \text{GOOF} = 1.042, \) largest difference peak and hole: 2.293/–0.605 e \( \text{Å}^{-3}. \)

**Supporting Information Available:** Crystallographic data deposited at the Cambridge Crystallographic Data Centre under CCDC-1902988 for (±)-9 contain the supplementary crystallographic data excluding structure factors; these data can be obtained free of charge via www.ccdc.cam.ac.uk/conts/retrieving.html (or from the Cambridge Crystallographic Data Centre, 12, Union Road, Cambridge CB2 1EZ, UK; fax: (+44) 1223-336-033; or deposit@ccdc.cam.ac.uk).
4 References


5  NMR spectra of new compounds

\[ \text{SI-5 + SI-6} \]

\[^1\text{H}, \text{C}_6\text{D}_6, 400 \text{ MHz}\]

\[ \text{SI-5 + SI-6} \]

\[^{13}\text{C}(^1\text{H}), \text{C}_6\text{D}_6, 101 \text{ MHz}\]
SI-5 + SI-6

$^{119}\text{Sn}(^{1}H), \text{C}_6\text{D}_6, 149 \text{ MHz}$
$^{1}H$, $C_6D_6$, 300 MHz

$^{13}C\left(^{1}H\right)$, $C_6D_6$, 75 MHz
$^{1}H$, C$_{6}$D$_{6}$, 300 MHz

$^{13}$C($^{1}H$), C$_{6}$D$_{6}$, 75 MHz

S79
$^1$H, C$_6$D$_6$, 300 MHz

$^{13}$C($^1$H), C$_6$D$_6$, 75 MHz
SI-10
$^1$H, C$_6$D$_6$, 300 MHz

SI-10
$^{13}$C($^1$H), C$_6$D$_6$, 75 MHz
SI-11

$^1$H, C$_6$D$_6$, 300 MHz

$^{13}$C($^1$H), C$_6$D$_6$, 75 MHz
PhS\(\text{B(pin)}\)

(Z)-11a

\(^{11}\text{B}\)\(^{(1\text{H})}\), \(\text{C}_6\text{D}_6\), 128 MHz

---

PhS\(\text{B(pin)}\)

(Z)-11a

\(^1\text{H}\), \(\text{C}_6\text{D}_6\), 400 MHz

**up**: 1D-NOESY, irrad. at \(\text{CH}_2\text{O}\) signal

**down**: \(^1\text{H}\)
(Z)-11b
$^1$H, C$_6$D$_6$, 400 MHz

$^{13}$C($^1$H), C$_6$D$_6$, 101 MHz
(Z)-11b

$^{11}$B$^1$H, C$_6$D$_5$, 128 MHz
(Z)-11c

\[ ^1H, \text{C}_6\text{D}_6, 400 \text{ MHz} \]

\[ ^13C\{^1H\}, \text{C}_6\text{D}_6, 101 \text{ MHz} \]
(Z)-11c
$^{11}$B($^1$H), C$_6$D$_6$, 128 MHz
$^{1}H$, C$_6$D$_6$, 300 MHz

$^{13}C[^{1}H]$, C$_6$D$_6$, 75 MHz
$^1$H, C$_6$D$_6$, 300 MHz

$^{13}$C($^1$H), C$_6$D$_6$, 75 MHz
$^{1}$H, C$_6$D$_6$, 300 MHz

$^{13}$C($^{1}$H), C$_6$D$_6$, 75 MHz
$^{1}H$, C$_6$D$_6$, 300 MHz

$^{13}$C($^{1}H$), C$_6$D$_6$, 75 MHz
SI-20

$^1$H, C$_6$D$_6$, 300 MHz

SI-20

$^{13}$C($^1$H), C$_6$D$_6$, 75 MHz
OPMB

SI-21

$^1$H, C$_6$D$_6$, 300 MHz

$^{13}$C($^1$H), C$_6$D$_6$, 75 MHz

* = MTBE
SI-15

$^1$H, C$_6$D$_5$, 300 MHz

$^{13}$C($^1$H), C$_6$D$_5$, 75 MHz
$^1$H, C$_6$D$_5$, 300 MHz

$^{13}$C[$^1$H], C$_6$D$_5$, 75 MHz

* = MTBE
SI-16

$^1$H, C$_6$D$_5$, 300 MHz

SI-16

$^{13}$C($^1$H), C$_6$D$_5$, 75 MHz
$^{1}{H}$, C$_{6}$D$_{6}$, 300 MHz

$^{13}$C($^1$H), C$_{6}$D$_{6}$, 75 MHz
$^1$H, C$_6$D$_6$, 300 MHz

$^{13}$C($^1$H), C$_6$D$_6$, 75 MHz
$^1$H, C$_6$D$_6$, 300 MHz

$^{13}$C($^1$H), C$_6$D$_6$, 75 MHz
$^1$H, CDCl$_3$, 300 MHz

$^{13}$C($^1$H), CDCl$_3$, 75 MHz
$^{1}H$, C$_6$D$_6$, 300 MHz

$^{13}$C($^1$H), C$_6$D$_6$, 75 MHz
SI-25

$^1$H, C$_6$D$_6$, 400 MHz

SI-25

$^{13}$C($^1$H), C$_6$D$_6$, 101 MHz
SI-30
$^1$H, C$_6$D$_6$, 300 MHz

SI-30
$^{13}$C($^1$H), C$_6$D$_6$, 75 MHz
SI-27
$^1$H,$^1$H NOESY,
C$_6$D$_6$, 400 MHz

*formed*

![NOESY diagram](image1)

![HMBC diagram](image2)

(Felkin)

*not formed*

![NOESY diagram](image3)

(expected nOe correlations for anti-Felkin)

(anti-Felkin)
$^1$H, C$_6$D$_6$, 300 MHz

$^{13}$C($^1$H), C$_6$D$_6$, 75 MHz
1H, 13C HSQC/DEPT,
C6D6, 300/75 MHz
$^{1}H,^{13}C$ HSQC/DEPT,
C$_6$D$_6$, 300/75 MHz
$^1$H, C$_6$D$_6$, 300 MHz

$^{13}$C($^1$H), C$_6$D$_6$, 75 MHz

S120
$^1$H, C$_6$D$_6$, 300 MHz

$^{13}$C($^1$H), C$_6$D$_6$, 75 MHz
$^{1}H,^{13}C$ HSQC/DEPT,
C$_6$D$_6$, 300/75 MHz

$^{1}H,^{13}C$ HMBC,
C$_6$D$_6$, 300/75 MHz
$^1$H, CDCl$_3$, 400 MHz

$^{13}$C($^1$H), CDCl$_3$, 101 MHz

S124
$^1$H, CDCl$_3$, 400 MHz

up: this work

down: [ref. S22]
CDCl$_3$, 300 MHz

$^{13}$C($^1$H), CDCl$_3$, 101 MHz

up: this work

down: [ref. S22]
CDCl$_3$, 75 MHz
$^1$H, C$_6$D$_6$, 300 MHz

$^{13}$C($^1$H), C$_6$D$_6$, 75 MHz
$^{1}H, ^{13}C$ HSQC/DEPT.
C$_6$D$_6$, 400/101 MHz
SI-32

\(^1\)H,\(^{13}\)C HSQC/DEPT,
C\(_6\)D\(_6\), 400/101 MHz
$^1$H, C$_6$D$_6$, 400 MHz

$^{13}$C($^1$H), C$_6$D$_6$, 101 MHz

* = impurity from solvent
$^1$H,$^13$C HSQC/DEPT,
C$_6$D$_6$, 400/101 MHz

$^1$H,$^13$C HMBC
C$_6$D$_6$, 400/101 MHz
\[ \text{up: this work} \]

\[ \text{down: commercial (−)-1 (TCI)} \]

\[ \text{C}_6\text{D}_6, 400 \text{ MHz} \]

\[ \text{* = impurity from solvent} \]

\[ \text{up: this work} \]

\[ \text{down: commercial (−)-1 (TCI)} \]

\[ \text{C}_6\text{D}_6, 101 \text{ MHz} \]

\[ \text{* = impurity from solvent} \]