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Stereoconvergent preparation of chiral vinylsilanes by cuprate substitution of α-acetoxyallylsilanes. Application to the synthesis of (*S*)-(+)-bishomomanicone

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Abstract—Enantiomerically enriched (*E*)- and (*Z*)-configured α-acetoxyallylsilanes have been prepared starting from a chiral acylsilane bearing an asymmetric unit at the silicon portion. Treatment of these compounds with organocuprates afforded the respective vinylogous substitution products in high yields and high stereoselectivities. The transformations proceed essentially by complete *anti* attack of the nucleophiles to the allylic acetates and predominantly via transition states leading to the (*E*)-configured vinylsilane products. By the proper choice of the double bond geometry in the starting material, the configuration of the newly formed stereogenic center can be controlled. The method represents a new and flexible entry into chiral vinylsilanes that can be used for subsequent transformations. As an example, the α,β-unsaturated γ-chiral, naturally occurring ketone (*S*)-(+)-bishomomanicone was synthesized with this method, which represents the first synthetic access to this compound.

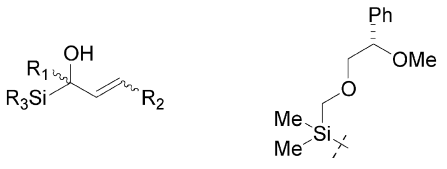
1. Introduction

α-Hydroxyallylsilanes **1** combine the structural and chemical features of α-hydroxysilanes, allylic silanes, and allylic alcohols, and the combination of the three functionalities result in new reactivities. Compounds of type **1** (Fig. 1) have been used as polyfunctional and versatile starting materials for a variety of stereoselective transformations, affording β,γ-substituted, δ,ε-unsaturated acylsilanes,[1] α,β-substituted, δ-silylated, γ,δ-unsaturated carboxylic acids,[2] aldol-type products,[3] 2-silylated 1,3-diols,[4] and more.[5] Simple substitutions of α-acetoxyallylsilanes, however, have not been investigated yet. Such substitutions, depending on the site of attack of the nucleophiles, should give rise to allylic or vinylic silanes; compounds that could be used for specific subsequent transformations.

Recently, we have introduced the new silicon-based chiral auxiliary **A** for the stereoselective synthesis of α-hydroxysilanes,[6] and in the present article we report on the stereospecific preparation of α-acetoxysilanes based on this auxiliary, the vinylogous substitution of the acetoxy group, and the application of this reaction for the synthesis of (*S*)-(+)-bishomomanicone, a constituent of the mandibular gland secretion of the ant *Manica rubida*[7] and of the oak moss oil of *Evernia prunastri* (L.) Ach.[8]

2. Results and discussion

The enantiomerically enriched α-acetoxyallylsilanes **5** (dr 98:2) and **6** (dr 98:2) that were used for our study were prepared from acetylsilane **2** by $MgBr_2$-promoted chelate-controlled addition of (*E*)- and (*Z*)-propenyl lithium—applied as a mixture, as described earlier[6]—followed by acetylation of the respective separated alcoholic products **3** and **4** (Scheme 1). For the acetylation reaction, MeMgBr was employed as a rather unusual base, which was necessary to avoid Brook rearrangement of the deprotonated α-hydroxysilanes.[2] The (*Z*)-configured alcohol precursor **3** was also accessible by the addition of propynyl lithium to acetylsilane **2** and partial hydrogenation of the triple bond of propiolic alcohol **7** in the presence of the Lindlar catalyst. The preparation of **5** via propargylic alcohol **7** not only



1 **A**

Figure 1.

Keywords: stereoconvergent; chiral vinylsilanes; α-acetoxyallylsilanes; (*S*)-(+)-bishomomanicone.
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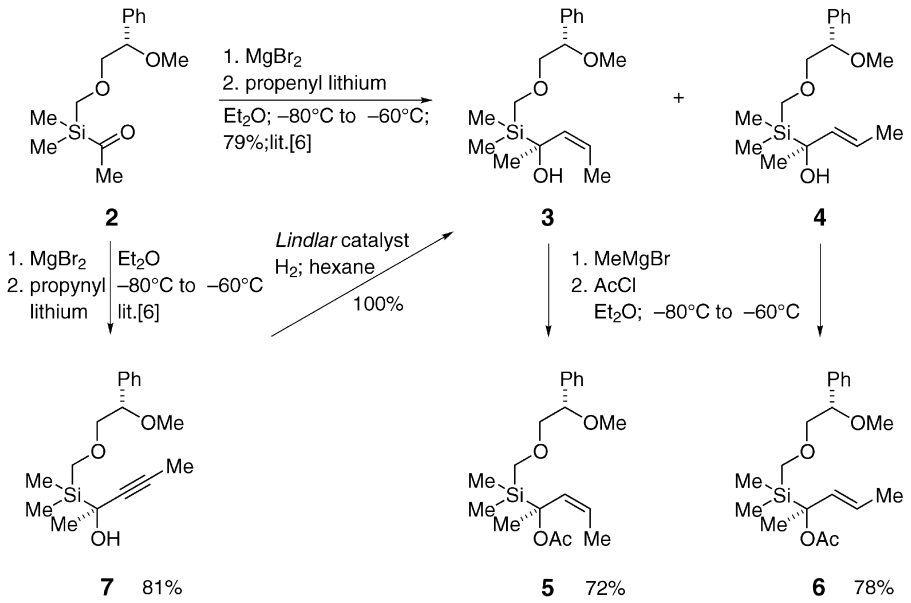
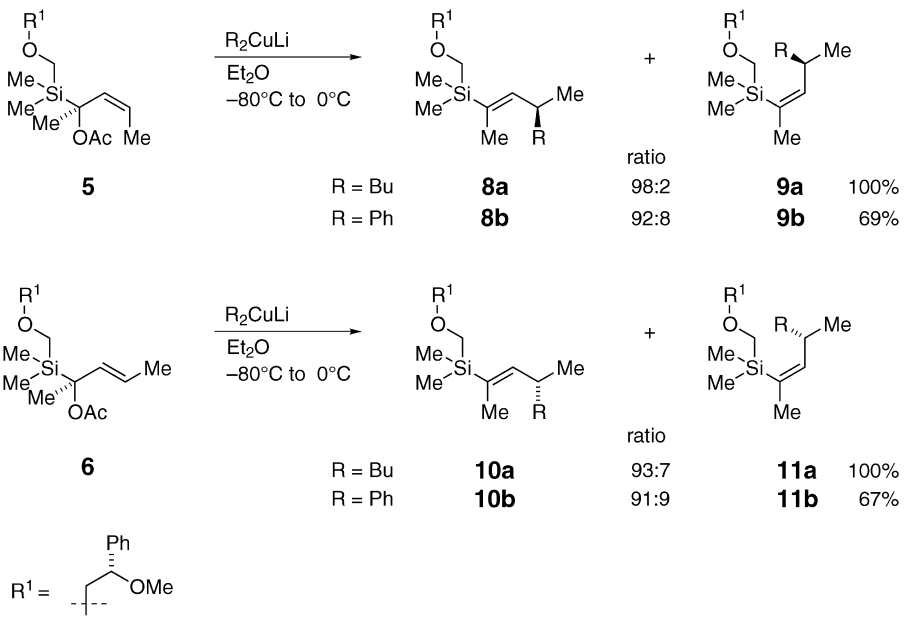


Scheme 1.

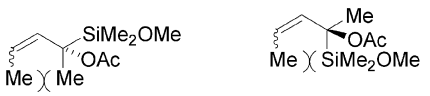
provided the (*Z*)-configured material in a stereoselective way but concurrently confirmed the proposed preference for *Si*-facial nucleophilic attack at the carbonyl function of ketone **2** to be independent of the nature of the organomagnesium reagent.

To study the suggested substitution reaction, the allylic acetates **5** and **6** were treated with two cuprates[9–11] (Scheme 2). The transformations, performed with Ph_2CuLi and Bu_2CuLi at −80 to 0°C in Et_2O,[9] delivered the vinylogous substitution products of type **8**–**11** in good yields and with high stereoselectivities. In this manner, the (*E*)-configured vinyl silanes of type **8** and **10** arose as the major products along with minor amounts of the (*Z*)-configured counterparts of type **9** and **11**, carrying in addition to the inverted double bond geometries also the opposite configurations at the newly formed stereogenic centers. The two major products **8** and **10** are of opposite absolute configuration at the allylic stereogenic centers. Thus, starting with homochiral substrates, the two enantiomeric series of products (with respect to the silicon-free carbon frameworks) can be attained likewise in a stereoconvergent manner by the proper choice of the double bond geometries in the allylic acetates.

The stereochemical course of the reactions as well as the degrees of the observed stereoselectivities can be explained by scrutinizing the ground-state stabilities of the conformations relevant for the transformations (Fig. 2). Comparing structures **B** and **C**, with the C–OAc-bond arranged parallel to the π-system as required for the substitution reaction, conformations of type **B** with the large silyl groups located at the 'outside' positions can be regarded as favored over structures of type **C** due to lesser $A^{1,3}$-strain.



Scheme 2.



B **C**

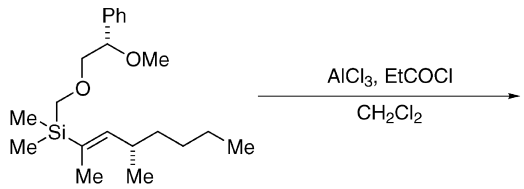
Figure 2.

Semi-empirical calculations (AM1 on MOPAC) for the shown pair of model compounds favor conformations **B** by approximately 7 and 3.5 kcal mol^{-1} for the (*Z*)- and (*E*)-configured α-acetoxyallylic silanes, respectively. Accordingly, the (*E*)-configured products of type **8** and **10**, arising via transition states related to conformations of type **B**, are predicted to be formed predominantly, and the selectivities of the transformations should be more pronounced for the (*Z*)-configured starting material **5**. Both these effects are observed experimentally as can be recognized from the data given in Scheme 2.

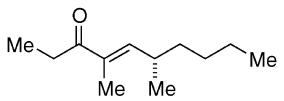
The configurations of the newly formed stereogenic centers of compounds **8**–**11** were deduced from the conformations of type **B** and **C**, assuming an attack of the cuprates *anti* to the leaving group. However, since a *syn* course of the reaction cannot be excluded with certainty—to be operative only partially or even completely[12]—independent proof of the absolute configurations of these centers was necessary as well as the determination of the isomeric excesses of the products. The latter was not directly possible by simple NMR measurements because the related epimeric compounds of type **8** and **10** (or **9** and **11**) cannot be distinguished spectroscopically. Thus, the mixtures of products of type **8/9** and **10/11** were each oxidized to the respective *dextro*- and *levo*-rotary forms of the acids **12** and **13** by treatment with $NaIO_4$ in presence of $RuCl_3$ (Scheme 3). The acids were subsequently correlated by the sign of their optical rotation to the known (*R*)- and (*S*)-configured compounds. The enantiomeric ratios of the acids were finally established via the Mosher esters **14**–**17** of their derived alcohols, obtained by reduction of the acids with $LiAlH_4$ and acylation of the products with (*R*)-Mosher acid chloride. Within the range of error, the enantiomeric ratios of the acids corresponded to the values that would be expected for substitution reactions proceeding with complete *anti* stereoselectivities.

Chiral compounds of type **8**–**11** that now can easily and flexibly be accessed by the new procedure should be amenable to classical vinylsilane chemistry such as, e.g. stereoselective substitution reactions with electrophiles.[13]

In this sense, treatment of **8a** with propionyl chloride in presence of $AlCl_3$ afforded the α,β-unsaturated ketone **18**, which is (*S*)-(+)-bishomomanicone, a constituent of the mandibular gland secretion of the ant *M. rubida*[7] and of the oak moss oil of *E. prunastri* (L.) Ach.[8] (Scheme 4). The reaction proceeded, as expected,[14] with complete retention of the double bond geometry, which was secured by means of NOE-experiments.



8a



(*S*)-(+)-Bishomomanicone 82%

18

Scheme 4.

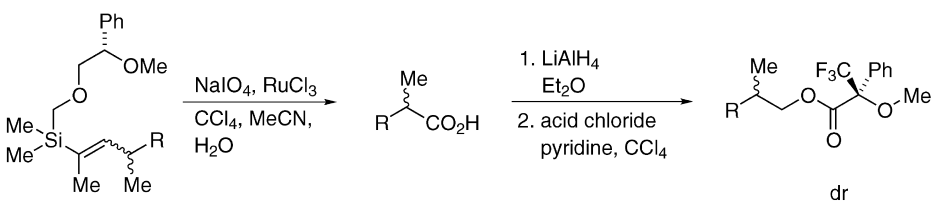
3. Conclusion

The vinylogous substituition of α-acetoxyallylsilanes proceeds with high stereoselectivity and gives a new, flexible, and stereoconvergent entry into chiral vinylsilanes that can be used for subsequent vinylsilane-specific reactions. As an example, the α,β-unsaturated γ-chiral, naturally occurring ketone (*S*)-(+)-bishomomanicone was synthesized with this method, which represents the first synthetic access to this compound.

4. Experimental

4.1. General methods

Unless otherwise stated, manipulations were carried out under Ar in oven-dried glass equipment. For reactions, Et_2O and THF were freshly distilled from Na with benzophenone ketyl as indicator. Extracts were washed with sat. aq. NH_4Cl solution and brine and were dried over $MgSO_4$. Solutions



				dr
R = Bu	**8a/9a**	(*S*)-(+)-**12**	89%	(*S*, *S*)-**14** 96:4
R = Bu	**10a/11a**	(*R*)-(−)-**12**	92%	(*R*, *S*)-**15** 92:8
R = Ph	**8b/9b**	(*S*)-(+)-**13**	90%	(*S*, *S*)-**16** 91:9
R = Ph	**10b/11b**	(*R*)-(−)-**13**	85%	(*R*, *S*)-**17** 89:11

Scheme 3.

for workup procedures were prepared in deionised H_2O. Chromatography: Merck silica gel 60 (40–63 μm). IR spectra: neat liquid films between NaCl plates; Perkin–Elmer IR 'Spectrum One' and Perkin–Elmer 781; in cm^{-1}. ^1H NMR spectra in $CDCl_3$; Bruker AC-300 (300 MHz); δ in ppm rel. to $CHCl_3$ (δ 7.26), J in Hz. ^{13}C NMR spectra in $CDCl_3$; Bruker AC-300 (75.5 MHz); δ in ppm rel. to $CDCl_3$ (δ 77.0); multiplicities from DEPT-135 and DEPT-90 experiments. Mass spectrometry (MS): Finnigan MAT 90 or Finnigan SSQ 700. Chemical ionization mass spectrometry (CI-MS): NH_3 as the reactant gas; quasi-molecular ions and characteristic fragments; in m/z (rel. %).

4.2. Preparation of α-acetoxyallylsilanes

4.2.1. (1*S*,2*Z*)-1-({[(2*S*)-2-Methoxy-2-phenylethoxy]-methyl}(dimethyl)silyl)-1-methylbut-2-enyl acetate (5). To a solution of (2*S*,3*Z*)-2-({[(2*S*)-2-methoxy-2-phenylethoxy]methyl}(dimethyl)silyl)pent-3-en-2-ol (**3**, 97 mg, 0.31 mmol, dr. with respect to C(2): 98:2,[6]) in Et_2O (2.5 ml), MeMgBr (3 m in Et_2O, 0.15 ml, 0.45 mmol) were added at −80°C. After 10 min, AcCl (50 μl, 0.70 mmol) was added, and the previously formed precipitate dissolved almost completely. The mixture was slowly allowed to warm to 23°C (ca. 2 h), and the stirring was continued for another 30 min. Quenching with sat. aq. $NaHCO_3$ solution, extraction with Et_2O, and chromatography (hexane/Et_2O 15:2) gave **5** (79 mg, 0.23 mmol, 72%) as a yellowish oil. $[\alpha]_D$=+60.0±0.2 (c=1.0, $CHCl_3$). IR: 3020w, 2930m, 1730s, 1450m, 1370m, 1265s, 1250m, 1230m, 1150w, 1120s, 1100s, 1025m, 940w, 845s, 760m, 700s. ^1H NMR: 7.36–7.29 (m, 5 arom. H); 5.35 (dq, J=12.1, 6.9 Hz, MeC*H*); 5.25 (dq, J=12.1, 1.3 Hz, C*H*CSi); 4.32 (dd, J=7.2, 4.5 Hz, PhC*H*); 3.63, 3.43 (AB of ABX, J_{AB}=10.3 Hz, J_{AX}=7.2 Hz, J_{BX}=4.5 Hz, PhCHCH_2-O); 3.30 (s, *Me*O); 3.28, 3.22 (AB, J=12.8 Hz, SiCH_2O); 2.01 (s, *Me*CO_2); 1.67 (dd, J=6.9, 1.3 Hz, *Me*CH); 1.54 (s, *Me*CSi); 0.14, 0.08 (2s, Me_2Si). ^{13}C NMR: 170.5 (s, CO); 136.6 (s, arom. C); 132.2 (d, arom. C); 128.2 (d, 2 arom. C); 127.7 (d, arom. C); 127.0 (d, 2 arom C); 121.9 (d, arom. C); 82.8 (d, MeO*C*); 79.7 (t, C*H*CH_2); 78.2 (s, Si*C*); 63.7 (t, SiCH_2); 57.1 (q, *Me*O); 22.8, 21.4 (2q); 14.1 (q, CH*Me*); −5.6, −5.7 (2q, Me_2Si). CI-MS: 368 (38, $[M+NH_4]^+$), 308 (63), 291 (28), 259 (84), 223 (100), 120 (73). Anal. calcd for $C_{19}H_{30}O_4Si$ (350.52): C 65.10, H 8.63, found C 64.91, H 8.65.

4.2.2. (1*S*,*E*)-1-({[(2*S*)-2-Methoxy-2-phenylethoxy]-methyl}(dimethyl)silyl)-1-methylbut-2-enyl acetate (6). Analogously to Section 4.2.1, the reaction of (2*S*,3*E*)-2-({[(2*S*)-2-methoxy-2-phenylethoxy]methyl}(dimethyl)silyl)-pent-3-en-2-ol (**4**, 150 mg, 0.486 mmol, dr. with respect to C(2): 98:2,[6]) with MeMgBr (3 M soln. in Et_2O, 0.23 ml, 0.69 mmol) and AcCl (70 μl, 0.95 mmol) in Et_2O (3.8 ml) gave, after chromatography (hexane/Et_2O 15:2), **6** (133 mg, 0.38 mmol, 78%) as a yellowish oil. $[\alpha]_D$=+49.8±0.2 (c=1.5, $CHCl_3$). IR: 3020w, 2930m, 1720s, 1450m, 1370m, 1270s, 1250m, 1230m, 1115s, 1100s, 1030m, 970m, 959w, 840s, 760m, 700s. ^1H NMR: 7.37–7.24 (m, 5 arom. H); 5.56 (dq, J=15.9, 1.6 Hz, C*H*CSi); 5.32 (dq, J=15.6, 6.4 Hz, MeC*H*); 4.32 (dd, J=7.2, 4.5, PhC*H*); 3.63, 3.41 (AB of ABX, J_{AB}=10.3 Hz, J_{AX}=7.2 Hz, J_{BX}=4.5 Hz, PhCHCH_2O); 3.30 (s, *Me*O); 3.24, 3.18 (AB, J=12.9 Hz, SiCH_2O); 1.99 (s, *Me*CO_2); 1.69 (dd, J=6.4, 1.6 Hz, *Me*CH); 1.45 (s, *Me*CSi); 0.09, 0.03 (2s, Me_2Si). ^{13}C NMR: 170.8 (s, CO); 139.7 (s, arom. C); 133.5 (d, arom. C); 128.3 (d, 2 arom. C); 127.7 (d, arom. C); 127.0 (d, 2 arom. C); 121.4 (d, arom. C); 82.9 (d, MeO*C*); 79.7 (t, C*H*CH_2); 77.7 (s, Si*C*); 63.8 (t, SiCH_2); 57.1 (q, *Me*O); 21.5, 21.0 (2q); 18.0 (q, CH*Me*); −5.8, −6.1 (2q, Me_2Si). CI-MS: 368 (38, $[M+NH_4]^+$), 308 (67), 291 (41), 259 (52), 223 (92), 120 (100). Anal. calcd for $C_{19}H_{30}O_4Si$ (350.52): C 65.10, H 8.63, found C 65.10, H 8.75.

4.2.3. (2*S*,*Z*)-2-({[(2*S*)-2-Methoxy-2-phenylethoxy]-methyl}(dimethyl)silyl)pent-3-en-2-ol (3). A solution of (2*S*)-2-({[(2*S*)-2-methoxy-2-phenylethoxy]methyl}(dimethyl)-silyl)pent-3-yn-2-ol (**7**, 50 mg, 0.16 mmol, dr. with respect to C(2): 91:9,[6]) in hexane (10 ml) in the presence of Lindlar catalyst (14 mg) was stirred under H_2 (1 atm) at 23°C for 40 min. The catalyst was removed by filtration and the solvent was evaporated to give **3** (50 mg, 0.16 mmol, 100%). The spectra of the products were in complete agreement with those of **3** obtained directly from **2** and propenyl lithium.[6]

4.3. Cuprate substitution reactions

4.3.1. [(*E*,3*S*)-1,3-Dimethylhept-1-enyl]{[(2*S*)-2-methoxy-2-phenylethoxy]methyl}dimethylsilane (8a) and [(*Z*,3*R*)-1,3-dimethylhept-1-enyl]{[(2*S*)-2-methoxy-2-phenylethoxy]methyl}dimethylsilane (9a). To a suspension of CuI (0.537 mg, 2.82 mmol) in Et_2O (14 ml), BuLi (1.6 M solution in Et_2O, 3.53 ml, 5.64 mmol) was added dropwise at −50°C. The temperature was slowly raised to 0°C (30 min), and the stirring was continued for an additional 2 h. The solution was cooled to −80°C and a solution of **5** (100 mg, 0.282 mmol) in Et_2O (2 ml) was added slowly. The temperature was raised to 0°C over a period of 30 min, and the mixture was stirred for 1 h. It was quenched with sat. aq. NH_4Cl solution at 0°C, extracted with Et_2O and chromatographed (hexane/Et_2O 20:1) to deliver a mixture of **8a** and **9a** (99 mg, 2.82 mmol, ratio 98:2, 100%) as a yellow oil. Following data from mixture. $[\alpha]_D$=+61.9±0.2 (c=1.1, $CHCl_3$). IR: 3030w, 2957s, 2925s, 2856s, 1618w, 1454m, 1376w, 1247m, 1120s, 971w, 837s, 756m, 700m. ^1H NMR of **8a**: 7.37–7.24 (m, 5 arom. H); 5.48 (dq, J=9.1, 1.7 Hz, C*H*CSi); 4.35 (dd, J=7.4, 4.2 Hz, PhC*H*); 3.64, 3.44 (AB of ABX, J_{AB}=10.5 Hz, J_{AX}=7.4 Hz, J_{BX}=4.2 Hz, PhCHCH_2O); 3.31 (s, *Me*O); 3.27, 3.20 (AB, J=12.9 Hz, SiCH_2O); 2.59–2.43 (m, C*H*CHCSi); 1.65 (d, J=1.7 Hz, *Me*CSi); 1.35–1.14 (m, MeCH_2CH_2CH_2, 6 H); 0.90 (d, J=6.6 Hz, *Me*C); 0.88 (t, J=7.2 Hz, *Me*CH_2); 0.07 (s, Me_2Si). ^3J (^1H, ^{29}Si)=8.2 Hz. ^{13}C NMR of **8a**: 147.6 (d, SiCCH); 139.7 (s, SiC); 131.3 (s, arom. C); 128.2 (d, 2 arom. C); 127.6 (d, arom. C); 126.9 (d, 2 arom. C); 83.0 (d, MeOCH); 79.7 (t, OCHCH_2); 64.6 (t, SiCH_2); 57.2 (q, MeO); 37.0 (t); 32.2 (d, MeCH); 29.7, 22.8 (2t); 20.5 (q, CHMe); 14.8, 14.1 (2q); −5.1 (q, Me_2Si). ^1H NMR signal of **9a**, which was shifted from the signal of **8a**: 5.74 (dq, C*H*CSi). EI-MS: 348 (<1, $M^{+\cdot}$), 135 (30); 121 (100), 99 (24), 89 (60), 77 (22), 75 (45), 73 (62), 59 (72). Anal. calcd for $C_{21}H_{36}O_2Si$ (348.59): C 72.35, H 10.41, found C 72.30, H 10.15.

4.3.2. [(*E*,3*R*)-1,3-Dimethylhept-1-enyl]{[(2*S*)-2-methoxy-2-phenylethoxy]methyl}dimethylsilane (10a) and [(*Z*,3*S*)-1,3-dimethylhept-1-enyl]{[(2*S*)-2-methoxy-2-phenylethoxy]methyl}dimethylsilane (11a). Analogously

to Section 4.3.1, **6** (92 mg, 0.26 mmol) gave a mixture of **10a** and **11a** (91 mg, 0.26 mmol, ratio 93:7, 100%) as a yellow oil. Following data from mixture. $[\alpha]_D$=+28.7±0.2 (*c*=1.1, $CHCl_3$). IR: 3030w, 2957s, 2925s, 2856s, 1618w, 1454m, 1376w, 1247m, 1120s, 971w, 837s, 756m, 700m. ^{1}H NMR of **10a**: 7.37–7.24 (m, 5 arom. H); 5.48 (dq, *J*=9.1, 1.7 Hz, C*H*CSi); 4.34 (dd, *J*=7.4, 4.2 Hz, PhC*H*); 3.64, 3.44 (AB of ABX, J_{AB}=10.5 Hz, J_{AX}=7.4 Hz, J_{BX}=4.2 Hz, PhCHCH_2O); 3.31 (s, *Me*O); 3.26, 3.20 (AB, *J*=12.9 Hz, SiCH_2O); 2.59–2.43 (m, C*H*CHCSi); 1.65 (d, *J*=1.7 Hz, *Me*CSi); 1.35–1.14 (m, MeCH_2CH_2CH_2, 6 H); 0.90 (d, *J*=6.6 Hz, *Me*C); 0.88 (t, *J*=7.2 Hz, *Me*CH_2); 0.07 (s, Me_2Si). ^3J (^{1}H, ^{29}Si)=8.3 Hz. ^{13}C NMR of **10a**: 147.6 (d, SiC*C*H); 139.7 (s, Si*C*); 131.3 (s, arom. C); 128.2 (d, 2 arom. C); 127.6 (d, arom. C); 126.9 (d, 2 arom. C); 83.0 (d, MeO*C*H); 79.7 (t, OCH*C*H_2); 64.6 (t, Si*C*H_2); 57.2 (q, *Me*O); 37.0 (t); 32.2 (d, Me*C*H); 29.7, 22.8 (2t); 20.5 (q, CH*Me*); 14.8, 14.1 (2q); −5.0, −5.1 (q, Me_2Si). ^{1}H NMR signal of **11a**, which was shifted from the signals of **10a**: 5.75 (dq, *J*=11.2, 1.6 Hz, C*H*CSi). ^3J (^{1}H, ^{29}Si)=13.1. EI-MS: 348 (22, $M^{+\cdot}$), 223 (13), 135 (38), 121 (100), 89 (44), 73 (28), 59 (21). Anal. calcd for $C_{21}H_{36}O_2Si$ (348.59): C 72.35, H 10.41, found C 72.60, H 10.59.

4.3.3. {[(2*S*)-2-Methoxy-2-phenylethoxy]methyl}(dimethyl)[(*E*,3*R*)-1-methyl-3-phenylbut-1-enyl]silane (8b) and {[(2*S*)-2-methoxy-2-phenylethoxy]methyl}(dimethyl)[(*Z*,3*S*)-1-methyl-3-phenylbut-1-enyl]silane (9b). Analogously to Section 4.3.1 Ph_2CuLi, obtained from CuI (1.30 mg, 6.84 mmol) and PhLi (1.8 M soln. in Et_2O, 7.60 ml, 13.68 mmol) in Et_2O (19 ml), reacted with **5** to deliver after chromatography (hexane/Et_2O 20:1) mixture of **8b** and **9b** (116 mg, 0.315 mmol, ratio 92:8, 69%) as a yellow oil. Following data from mixture. $[\alpha]_D$=+2.4±0.2 (*c*=1.25, $CHCl_3$). IR: 3084w, 3062w, 3028m, 2961s, 2927m, 2894m, 2823m, 1602w, 1493m, 1453m, 1247m, 1120s, 1101s, 838s, 812m, 758m, 699s. ^{1}H NMR of **8b**: 7.37–7.14 (m, 10 arom. H); 5.87 (dq, *J*=8.8, 1.7 Hz, C*H*CSi); 4.33 (dd, *J*=7.4, 4.2 Hz, PhC*H*OMe); 3.85 (dq, *J*=8.8, 7.0 Hz, PhC*H*Me); 3.63, 3.43 (AB of ABX, J_{AB}=10.5 Hz, J_{AX}=7.4 Hz, J_{BX}=4.2 Hz, PhCHCH_2O); 3.30 (s, *Me*O); 3.27, 3.20 (AB, *J*=12.9 Hz, SiCH_2O); 1.73 (d, *J*=1.7 Hz, *Me*CSi); 1.31 (d, *J*=7.0 Hz, *Me*CHPh); 0.09, 0.08 (2s, Me_2Si). ^3J (^{1}H, ^{29}Si)=8.0 Hz. ^{13}C NMR of **8b**: 146.5 (s, Si*C*); 145.3 (d, SiC*C*H); 139.7, 132.7 (2s, 2 arom. C); 128.4, 128.2 (2d, 2×2 arom. C); 127.7 (d, arom. C); 127.0, 126.9 (2d, 2×2 arom. C); 125.8 (d, arom. C); 82.9 (d, MeO*C*H); 79.7 (t, OCH*C*H_2); 64.5 (t, Si*C*H_2); 57.2 (q, *Me*O); 37.9 (d, Me*C*H); 21.9 (q, CH*Me*); 14.9 (q, C*Me*); −5.1 (q, Me_2Si). ^{1}H NMR signal of **9b**, which was shifted from the signals of **8b**: 5.87 (dq, *J*=15.6, 1.9 Hz, C*H*CSi). CI-MS: 386 (100, $[M+NH_4]^+$), 223 (86), 120 (97). Anal. calcd for $C_{23}H_{32}O_2Si$ (368.58): C 74.95, H 8.75, found C 74.92, H 8.70.

4.3.4. {[(2*S*)-2-Methoxy-2-phenylethoxy]methyl}(dimethyl)[(*E*,3*S*)-1-methyl-3-phenylbut-1-enyl]silane (10b) and {[(2*S*)-2-methoxy-2-phenylethoxy]methyl}(dimethyl)[(*Z*,3*R*)-1-methyl-3-phenylbut-1-enyl]silane (11b). After reaction of **6** (82 mg, 0.26 mmol) according to the procedure in Section 4.3.3, **10b** and **11b** (58 mg, 0.16 mmol, ratio 91:9, 67%) were obtained as a yellow oil. Following data from mixture. $[\alpha]_D$=+85.5±0.2 (*c*=1.0, $CHCl_3$). IR: 3084w, 3062w, 3028m, 2961s, 2927m, 2894m, 2823m, 1602w, 1493m, 1453m, 1247m, 1120s, 1101s, 838s, 812m, 758m, 699s. ^{1}H NMR of **10b**: 7.37–7.14 (m, 10 arom. H); 5.87 (dq, *J*=8.8, 1.7 Hz, C*H*CSi); 4.33 (dd, *J*=7.4, 4.2 Hz, PhC*H*OMe); 3.85 (dq, *J*=8.8, 7.0 Hz, PhC*H*Me); 3.63, 3.43 (AB of ABX, J_{AB}=10.5 Hz, J_{AX}=7.4 Hz, J_{BX}=4.2 Hz, PhCHCH_2O); 3.30 (s, *Me*O); 3.27, 3.20 (AB, *J*=12.9 Hz, SiCH_2O); 1.73 (d, *J*=1.7 Hz, *Me*CSi); 1.31 (d, *J*=7.0 Hz, *Me*CHPh); 0.09, 0.08 (2s, Me_2Si). ^3J (^{1}H, ^{29}Si)=8.1 Hz. ^{13}C NMR of **10b**: 146.5 (s, Si*C*); 145.3 (d, SiC*C*H); 139.7, 132.7 (2s, 2 arom. C); 128.4, 128.2 (2d, 2×2 arom. C); 127.7 (d, arom. C); 127.0, 126.9 (2d, 2×2 arom. C); 125.8 (d, arom. C); 82.9 (d, MeO*C*H); 79.7 (t, OCH*C*H_2); 64.5 (t, Si*C*H_2); 57.2 (q, *Me*O); 37.9 (d, Me*C*H); 21.9 (q, CH*Me*); 14.9 (q, C*Me*); −5.1 (q, Me_2Si). ^{1}H NMR of the signal of **11b** which was shifted from the signals of **10b**: 6.10 (dq, *J*=10.3, 1.6 Hz, C*H*CSi). EI-MS: 368 (<2, $M^{+\cdot}$), 135 (48), 121 (100), 117 (26), 105 (70), 91 (30), 89 (46), 77 (28), 75 (33), 73 (39), 59 (41). Anal. calcd for $C_{23}H_{32}O_2Si$ (368.58): C 74.95, H 8.75, found C 74.89, H 8.65.

4.4. Oxidation of vinylsilanes with $NaIO_4$ in the presence of $RuCl_3$

4.4.1. (*S*)-(+)-2-Methylhexanoic acid (12). To a stirred biphasic mixture of CCl_4 (0.7 ml), MeCN (0.7 ml), and H_2O (1.0 ml), **8a** and **9a** (0.114 mg, 0.337 mmol, ratio 98:2), $NaIO_4$ (0.293 mg, 1.37 mmol), and $RuCl_3{\cdot}H_2O$ (4.0 mg, 2.2 mol %) were added. It was stirred vigorously for 2 h at 23°C. Then CH_2Cl_2 (2 ml) was added and the phases were separated. The aq. phase was extracted with CH_2Cl_2. The solvent was removed i.v. and the residue chromatographed (hexane/Et_2O 3:1) to deliver **12** (38 mg, 0.29 mmol, 89%) as a colorless liquid. The ^{1}H NMR spectrum of the product was in agreement with the literature data.[15] $[\alpha]_D$=+15.2±0.2 (*c*=0.56, Et_2O) (lit: $[\alpha]_D$=+20 (*c*=6.36, Et_2O)[15], +19.7 (*c*=6, Et_2O).[16])

4.4.2. (*R*)-(−)-2-Methylhexanoic acid (12). After reaction of **10a** and **11a** (90 mg, 0.26 mmol, ratio 93:7) according to the procedure mentioned in Section 4.4.1, acid **12** (31 mg, 0.24 mmol, 92%) was obtained as a colorless liquid. The ^{1}H NMR spectrum of the product was in agreement with the literature data.[17] $[\alpha]_D$=−12.4±0.2 (*c*=0.9, Et_2O) (lit: $[\alpha]_D$=−15.3 (*c*=14, Et_2O).[18])

4.4.3. (*S*)-(+)-2-Phenylpropanoic acid (13). After reaction of **8b** and **9b** (79 mg, 0.21 mmol, ratio 92:8) according to the procedure mentioned in Section 4.4.1, the acid **13** (29 mg, 0.19 mmol, 90%) was obtained as a colorless liquid. The ^{1}H NMR spectrum of the product was in agreement with the literature data.[19] $[\alpha]_D$=+62.5±0.2 (*c*=1.0, $CHCl_3$) (lit: $[\alpha]_D$=+69.2 (*c*=1.4, $CHCl_3$),[20] +72.5 (*c*=1.0, $CHCl_3$),[21] +70.4 (*c*=3.02, $CHCl_3$),[22] +72.8 (*c*=1, $CHCl_3$).[23])

4.4.4. (*R*)-(−)-2-Phenylpropanoic acid (13). After reaction of **10b** and **11b** (58 mg, 0.16 mmol, ratio 91:9) according to the procedure mentioned in Section 4.4.1, the acid **13** (20 mg, 0.13 mmol, 85%) was obtained as a colorless liquid. The ^{1}H NMR spectrum of the product was in agreement with the literature data.[24] $[\alpha]_D$=−60.2±0.2 (*c*=0.7, $CHCl_3$) (lit: $[\alpha]_D$=−67.5 (*c*=0.4, $CHCl_3$),[24] −72.2 (*c*=1.0, $CHCl_3$).[25])

4.5. Mosher ester derivatives

4.5.1. (2*S*)-2-Methylhexyl (2*S*)-3,3,3-Trifluoro-2-methoxy-2-phenylpropanoate (14). A solution of (*S*)-(+)-**12** (39 mg, 0.30 mmol) in Et_2O (1.0 ml) was cooled to 0°C, and $LiAlH_4$ (14 mg, 37 mmol) was added. The mixture was stirred for 30 min, quenched with aq. HCl solution (10%), and extracted with Et_2O to deliver (2*S*)-2-methyl-1-hexanol (30 mg, 0.26 mmol, 86%). A portion of this alcohol (12 mg, 0.1 mmol) in CCl_4 (300 μl) was added to a solution of dry pyridine (300 μl) and (*R*)-(−)-α-methoxy-α-trifluoromethyl-phenylacetic acid chloride (26 μl, 0.14 mmol).[26] The mixture was stirred at 23° until the formation of crystalline pyridine hydrochloride ceased. Excess of 3-dimethylamino-1-propylamine (24 μl, 0.20 mmol) was added, and the mixture was allowed to stand for 5 min. It was diluted with Et_2O, washed with cold aq. HCl-(10%), Na_2CO_3-(sat.) and NaCl-(sat.) solutions, and the solvent was removed to deliver compound **14**. ^{1}H NMR (from mixture) of the major diastereoisomer: 7.57–7.35 (m, 5 arom. H); 4.24, 4.08 (AB of ABX, J_{AB}=10.7 Hz, J_{AX}=6.6 Hz, J_{BX}=5.7 Hz, OC*H*$_2$); 3.56 (q, *J*=1.1 Hz, *Me*O,); 1.93–1.76 (m, C*H*); 1.44–1.07 (m, MeC*H*$_2$C*H*$_2$-C*H*$_2$, 6 H); 0.91 (d, *J*=6.8 Hz, CH*Me*); 0.88 (t, CH_2*Me*). The diastereoisomeric ratio was determined with the signals for the OC*H*$_2$ groups (AB of ABX; 4.24, 4.08 for the major and 4.18, 4.14 for the minor isomer, dr 96:4).

4.5.2. (2*R*)-2-Methylhexyl (2*S*)-3,3,3-Trifluoro-2-methoxy-2-phenylpropanoate (15). According to the procedure mentioned in Section 4.5.1, (*R*)-(−)-**12** delivered **15**. ^{1}H NMR (of mixture) of the major diastereoisomer: 7.57–7.35 (m, 5 arom. H); 4.18, 4.14 (AB of ABX, J_{AB}=10.7 Hz, J_{AX}=6.3 Hz, J_{BX}=6.0 Hz, OC*H*$_2$); 3.55 (q, *J*=1.1 Hz, *Me*O,); 1.93–1.76 (m, C*H*); 1.44–1.07 (m, MeC*H*$_2$C*H*$_2$-C*H*$_2$, 6 H); 0.92 (d, *J*=6.8 Hz, CH*Me*); 0.88 (t, CH_2*Me*). The diastereoisomeric ratio was determined with the signals for the OC*H*$_2$ groups (AB of ABX; 4.18, 4.14 for the major and 4.24, 4.08 for the minor isomer, dr 92:8).

4.5.3. (2*S*)-2-Phenylpropyl (2*S*)-3,3,3-Trifluoro-2-methoxy-2-phenylpropanoate (16). According to the procedure mentioned in Section 4.5.1, (*S*)-(+)-**13** delivered **16**. ^{1}H NMR (of mixture) of the major diastereoisomer: 7.88–6.96 (m, 10 arom. H); 4.34, 4.11 (AB of ABX, J_{AB}=10.8 Hz, J_{AX}=7.1 Hz, J_{BX}=6.6 Hz, OC*H*$_2$); 3.41 (q, *J*=1.1 Hz, *Me*O,); 2.95–2.88 (m, C*H*); 1.08 (d, *J*=6.8 Hz, CH*Me*). The diastereoisomeric ratio was determined with the signals for the CH*Me* groups (d; 1.08 for the major and 1.03 for the minor isomer, dr 91:9).

4.5.4. (2*R*)-2-Phenylpropyl (2*S*)-3,3,3-Trifluoro-2-methoxy-2-phenylpropanoate (17). According to the procedure mentioned in Section 4.5.1, (*R*)-(−)-**13** delivered **17**. ^{1}H NMR (of mixture) of the major diastereoisomer: 7.88–6.96 (m, 10 arom. H); 4.34, 4.11 (AB of ABX, J_{AB}=10.8 Hz, J_{AX}=7.1 Hz, J_{BX}=6.6 Hz, OC*H*$_2$); 3.39 (q, *J*=1.1 Hz, *Me*O,); 2.89–2.81 (m, C*H*); 1.03 (d, *J*=6.8 Hz, CH*Me*). The diastereoisomeric ratio was determined with the signals for the CH*Me* groups (d; 1.03 for the major and 1.08 for the minor isomer, dr 89:11).

4.5.5. (*E*,6*S*)-4,6-Dimethyl-4-decen-3-one, [(*S*)-(+)-bishomomanicone(18)]. A mixture of $AlCl_3$ (81 mg, 0.61 mmol) and propionyl chloride (58 μl, 0.66 mmol) in CH_2Cl_2 (1.5 ml) was stirred at 0°C for 30 min. A solution of **8a** and **9a** (98 mg, 0.28 mmol, ratio 98:2) in CH_2Cl_2 (0.75 ml) was added. After 30 min it was neutralized with sat. aq. $NaCO_3$ solution, extracted tree times with Et_2O, and chromatographed (hexane/Et_2O 15:2) to deliver **18** (42 mg, 23 mmol, 82%, ee 96) as a colorless oil. $[\alpha]_D$=+22.1±0.2 (*c*=0.24, $CHCl_3$). IR: 2960s, 2930s, 2874s, 1717m, 1673s, 1641m, 1459m, 1378m, 1342w, 1242w, 1135w, 1054m, 801w. ^{1}H NMR: 6.37 (dq, *J*=9.5, 1.1 Hz, C*H*CCO); 2.68 (q, *J*=7.2 Hz, MeC*H*$_2$CO); 2.62–2.46 (m, CCHC*H*); 1.78 (d, *J*=1.1 Hz, *Me*CCO); 1.58–1.14 (m, MeC*H*$_2$C*H*$_2$C*H*$_2$, 6 H); 1.10 (t, *J*=7.2 Hz, *Me*CH$_2$CO); 1.01 (d, *J*=6.7 Hz, *Me*CH); 0.88 (t, *J*=7.0 Hz, *Me*CH$_2$CH$_2$). ^{1}H, ^{1}H-NOE: irradiation at 6.37, responsive signal at 2.68 (4%). ^{13}C NMR: 202.9 (s, CO); 148.0 (d, C*C*H); 135.4 (s, C); 36.7 (t); 33.5 (d, Me*C*H); 33.4, 29.7, 22.8 (3t); 20.1, 14.0, 11.6, 8.9 (4q). EI-MS: 182 (42, $M^{+\cdot}$), 153 (100), 125 (30), 83 (26), 69 (72), 57 (34), 41 (28), 29 (22). Anal. calcd for $C_{12}H_{22}O$ (182.30): C 79.06, H 12.16, found C 79.01, H 11.91. EI-MS of the synthetically obtained bishomomanicone is in full agreement with Bestmann et al.,[7] ^{1}H NMR and EI-MS in large agreement with Corbier et al.[8] The $[\alpha]_D$ of the natural product is not available.

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