A β-Hydroxyethyl Carbanion Equivalent

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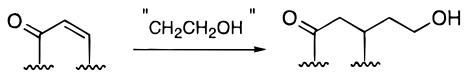
In the course of our ongoing work on a total synthesis of the marine hepatotoxin cylindrospermopsin, we required methodology for the formal conjugate addition of a β-hydroxyethyl moiety to an enone to produce an adduct such as **1** (eq 1).[1] Although we ultimately effected this

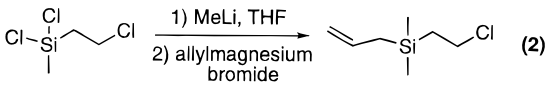


(1)

1

transformation *via* vinyl cuprate 1,4-addition, followed by hydroboration, we considered possible alternatives to this process, since the second step is incompatible with several common types of functional groups, and a more general sequence was desirable.

The seminal work of Tamao and Kumada[2] and of Fleming[3] has demonstrated that a silyl group is a useful masked hydroxyl function, and many applications of this chemistry have appeared in recent years.[3] We describe here an extension of this methodology in the context of a β-hydroxyethyl carbanion equivalent.[4] On the basis of the work of Tamao *et al.*,[2] it appeared that the best reagent for this purpose would be allyl(2-chloroethyl)dimethylsilane (**3**).[2,5] This compound has previously been synthesized by a multistep route from chloro(chloromethyl)dimethylsilane.[6] We have found, however, that silane **3** can be prepared in good yield in a one-pot operation from commercially available trichlorosilyl compound **2** *via* sequential treatment with methyllithium followed by allylmagnesium bromide (eq 2).

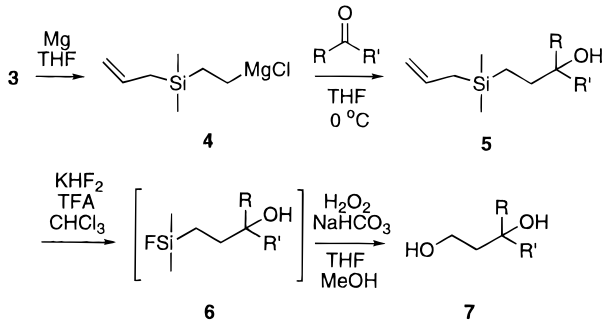


(2)

2 **3**

Chloroethyl compound **3** could be transformed into Grignard reagent **4** by standard means (Scheme 1). Addition of **4** to aldehydes and ketones gives adducts **5** that can be converted into silyl fluorides **6** using the procedure of Tamao.[2c] Without purification, compounds **6** are then oxidized with H_2O_2 to yield 1,3-diols **7**. The results of this sequence for hydroxyethylation of several aldehydes and ketones are compiled in Table 1.[7−12]

Scheme 1



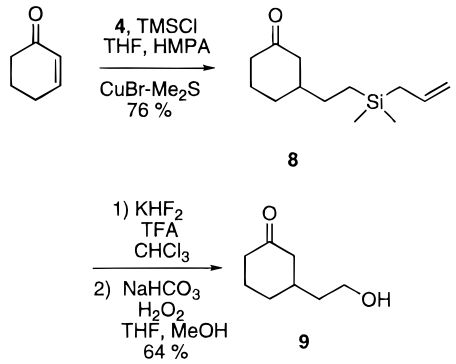
4 **5** **6** **7**

Table 1. Addition of β-Hydroxyethyl Carbanion Equivalent to Aldehydes and Ketones

entry	aldehyde or ketone	adduct **5** (% isolated yield)	diol **7**[a] (% isolated yield)
a	R = Ph, R′ = H	65	78
b	R = cyclohexyl, R = H	71	66
c	R = *n*-Pr, R′ = H	77	79
d	R = *i*-Pr, R′ = H	72	66
e	R = CH_2Ph, R′ = H	50	58
f	R,R′ = $(CH_2)_4$	79	70
g	R,R′ = $(CH_2)_5$	71	80
h	R = R′ = *n*-Pr	81	84

[a] All 1,3-diols are known compounds.[7−12]

Scheme 2



8 **9**

It is also possible to effect the type of enone conjugate addition of a β-hydroxyethyl carbanion outlined in eq 1. Thus, Grignard reagent **4** can be added *via* a cuprate[13] to 2-cyclohexen-1-one to afford 1,4-adduct **8** in good yield (Scheme 2). Silane **8** could then be converted to β-hydroxyethyl adduct **9** by the same two-step sequence shown in Scheme 1.[14]

An epoxide can also be used as the electrophile in reaction with a cuprate[15] derived from Grignard reagent

(1) Heintzelman, G. R.; Weinreb, S. M. *J. Org. Chem.* **1996**, *61*, 4594.
(2) For related hydroxymethyl carbanion equivalents, see: (a) Tamao, K.; Ishida, N.; Kumada, M. *J. Org. Chem.* **1983**, *48*, 2120. (b) Tamao, K.; Ishida, N. *Tetrahedron Lett.* **1984**, *25*, 4245. (c) Tamao, K.; Ishida, N. *J. Organomet. Chem.* **1984**, *269*, C37.
(3) For an excellent review of C−Si bond oxidation and lead references see: Jones, G. R.; Landais, Y. *Tetrahedron* **1996**, *52*, 7599.
(4) *Cf.* Trost, B. M.; Imi, K.; Davies, I. W. *J. Am. Chem. Soc.* **1995**, *117*, 5371.
(5) An attempt to form a Grignard reagent from commercially available (2-chloroethyl)triethoxysilane failed.
(6) Saigo, K.; Tateishi, K.; Adachi, H.; Saotome, Y. *J. Org. Chem.* **1988**, *53*, 1572.
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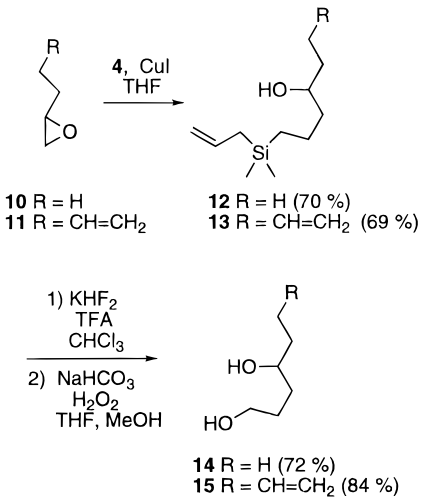
(9) Gajda, T. *Synthesis* **1987**, 1108.
(10) Vigneron, J. P.; Dhaenens, M.; Horeau, A. *Tetrahedron* **1977**, *33*, 507.
(11) Canonne, P.; Foscolos, G. B.; Belanger, D. *J. Org. Chem.* **1980**, *45*, 1828.
(12) Portnyagin, Y. M.; Pak, N. E. *J. Org. Chem. USSR (Engl. Transl.)* **1973**, *9*, 461.
(13) Piers, E.; Oballa, R. M. *J. Org. Chem.* **1996**, *61*, 8439.
(14) Fetizon, M.; Golfier, M.; Montaufier, M. T.; Rens, J. *Tetrahedron* **1975**, *31*, 987.
(15) Whitesell, J. K.; Lawrence, R. M.; Chen, H.-H. *J. Org. Chem.* **1986**, *51*, 4779.

S0022-3263(97)00226-0 CCC: $14.00

Scheme 3



4. Thus, epoxides **10** and **11** can be opened to afford hydroxysilanes **12** and **13**, respectively (Scheme 3). Subjection of these compounds to the usual oxidation conditions provided 1,4-diols **14**[16] and **15**.

In conclusion, readily available Grignard reagent **4** provides a convenient β-hydroxyethyl carbanion equivalent that reacts with a variety of electrophiles. The inital product silane can, in principle, be maintained as a masked hydroxyl group during other transformations within the molecule of interest and can then be subjected to oxidation when appropriate.

Experimental Section

Preparation of Allyl(2-chloroethyl)dimethylsilane (3). (2-Chloroethyl)dichloromethylsilane (**2**, United Chemical Technologies, 10.6 g, 59.6 mmol) and 50 mL of THF were added to an oven-dried 500 mL flask under argon. The flask was cooled to −78 °C, methyllithium (43 mL, 1.4 M in Et_2O, 60.2 mmol) was added, and the reaction mixture was stirred at −78 °C for 1 h. The mixture was warmed to −20 °C, allylmagnesium bromide (60 mL, 1.0 M in Et_2O, 60.0 mmol) was added, and the reaction mixture was stirred for an additional 1 h. The reaction mixture was diluted with 100 mL of 5% aqueous HCl. The aqueous layer was extracted with ether (3 × 75 mL). The combined organic extracts were washed (saturated NaCl), dried (Na_2SO_4), and concentrated. The residue was distilled (70 °C, 40 mmHg) to yield 7.94 g (81%) of the known[6] allylsilane **3** as a pale yellow liquid. ^{1}H NMR (200 MHz, $CDCl_3$) δ 5.88−5.61 (1 H, m), 4.97−4.80 (2 H, m), 3.76−3.58 (2 H, m), 1.61−1.49 (2 H, m), 1.31−1.12 (2 H, m), 0.01 (6 H, s). Anal. Calcd for $C_7H_{15}SiCl$: C, 51.66; H, 9.29. Found: C, 51.72; H, 9.22.

General Procedure for Formation of Grignard Reagent 4 and Addition to Aldehydes and Ketones. Preparation of 1-(Allyldimethylsilyl)-3-phenylpropan-3-ol (5a). A 25 mL two-necked flask was charged with Mg turnings (205 mg, 8.43 mmol) and fitted with a condenser. The apparatus was flame-dried under vacuum. THF (10 mL) was added, vigorous stirring was started, and the solution was warmed to a gentle reflux under argon. The magnesium was activated by addition of 10 μL of 1,2-dibromoethane, followed by approximately 0.4 mL of the allyl(2-chloroethyl)dimethylsilane (**3**, 1.3 mL total, 8.15 mmol). The reaction mixture was refluxed for 10−15 min, and the remaining 0.9 mL of the silane was added dropwise over 20 min. The reaction mixture was then refluxed for 15 h, resulting in a dark gray solution of the Grignard reagent **4**.[17] This solution was transferred to a flame-dried 50 mL flask under argon. The solution was diluted with 10 mL of THF and cooled to 0 °C. Freshly distilled benzaldehyde (407 mg, 3.83 mmol) was added, and the reaction mixture was stirred at 0 °C for 15 h. The reaction was diluted with 5% aqueous HCl (60 mL) and extracted with ether (3 × 50 mL). The combined organic extracts were dried (Na_2SO_4) and concentrated. The crude product was purified by silica gel chromatography (10% EtOAc/hexanes) to yield 584 mg (65%) of benzyl alcohol **5a**: R_f = 0.52 (20% EtOAc/hexanes); IR (film) 3441, 3078, 1629, 1493, 1453, 1044, 944 cm^{-1}; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.33 (5 H, s), 5.86−5.67 (1 H, m), 4.87−4.79 (2 H, m), 4.59 (1 H, t, J = 6.3 Hz), 2.53 (1H, bs), 1.79−1.60 (3 H, m), 1.53 (2 H, t, J = 9.1 Hz), 0.72−0.58 (1 H, m), 0.51−0.34 (1 H, m), −0.02 (6 H, s); ^{13}C NMR (75 MHz, $CDCl_3$) δ 144.5, 134.8, 128.3, 127.3, 125.9, 112.7, 76.7, 33.1, 22.9, 21.0, 10.4, −3.9; CIMS m/z (relative intensity) 217 (26, M^+ − OH), 191 (16), 115 (12), 101 (18), 99 (23), 75 (100).

Preparation of 1-(Allyldimethylsilyl)-3-cyclohexylpropan-3-ol (5b). The general procedure was followed using cyclohexanecarboxaldehyde (0.50 g, 4.46 mmol), 40 mL of THF, and 15 mL of Grignard reagent **4** (∼0.53 M, 8.0 mmol). The crude product was purified by silica gel chromatography (10% EtOAc/hexanes) to yield 768 mg (71%) of alcohol **5b**: R_f = 0.58 (20% EtOAc/hexanes); IR (film) 3467, 3077, 1629, 1042, 918 cm^{-1}; ^{1}H NMR (200 MHz, $CDCl_3$) δ 5.88−5.63 (1 H, m), 4.93−4.76 (2 H, m), 3.22 (1 H, bs), 1.81−1.46 (10 H, m), 1.40−0.91 (7 H, m), 0.78−0.32 (2 H, m), −0.03 (6 H, s); ^{13}C NMR (75 MHz, $CDCl_3$) δ 134.9, 113.2, 78.1, 43.3, 27.8, 26.0, 23.1, 21.1, 11.8, 10.0, −1.9; CIMS m/z (relative intensity) 241 (2), 223 (8), 197 (24), 181 (35), 127 (26), 101 (36), 75 (100).

Preparation of 1-(Allyldimethylsilyl)hexan-3-ol (5c). The general procedure was followed using butyraldehyde (0.36 g, 4.99 mmol), 20 mL of THF, and 8.0 mL of Grignard reagent **4** (∼0.83 M, 6.6 mmol). The crude product was purified by silica gel chromatography (10% EtOAc/hexanes) to yield 773 mg (77%) of alcohol **5c**: R_f = 0.43 (20% EtOAc/hexanes); IR (film) 3457, 3078, 1629, 992, 912 cm^{-1}; ^{1}H NMR (200 MHz, $CDCl_3$) δ 5.87−5.62 (1 H, m), 4.89−4.74 (2 H, m), 3.49 (1 H, bs), 1.54−1.21 (7 H, m), 0.95−0.82 (3 H, m), 0.69−0.32 (2 H, m) −0.02 (6 H, s); ^{13}C NMR (75 MHz, $CDCl_3$) δ 134.5, 113.1, 73.6, 38.8, 31.0, 21.1, 18.8, 14.0, 11.9, 10.1, −1.9; CIMS m/z (relative intensity) 199 (2, M^+ − H), 183 (14, M^+ − OH), 157 (17, M^+ − C_3H_7), 143 (18), 101 (39), 75 (100), 73 (36).

Preparation of 1-(Allyldimethylsilyl)-4-methylpentan-3-ol (5d). The general procedure was followed using isobutyraldehyde (175 mg, 2.42 mmol), 10 mL of THF, and 4.1 mL of Grignard reagent **4** (∼0.85 M, 3.5 mmol). The crude product was purified by silica gel chromatography (10% EtOAc/hexanes) to yield 351 mg (72%) of 1-(allyldimethylsilyl)-4-methylpentan-3-ol (**5d**): IR (film) 3469, 3078, 1629, 1053, 992, 890 cm^{-1}; ^{1}H NMR (200 MHz, $CDCl_3$) δ 5.90−5.68 (1 H, m), 4.93−4.77 (2 H, m), 3.31−3.18 (1 H, m), 1.52 (2 H, t, J = 7.2 Hz), 1.47−1.24 (3 H, m); 0.88 (6 H, dd, J = 2.4, 5.6 Hz), 0.73−0.36 (2 H, m), −0.02 (6 H, s); ^{13}C NMR (75 MHz, $CDCl_3$) δ 134.6, 113.2, 78.9, 32.6, 27.9, 21.2, 16.9, 8.6, −1.8. CIMS m/z (relative intensity) 199 (11), 183 (6, M^+ − OH), 167 (16), 157 (10, M^+ − i-Pr) 143 (78), 129 (35), 101 (100), 75 (71).

Preparation of 1-(Allyldimethylsilyl)-4-phenylbutan-3-ol (5e). The general procedure was followed using phenylacetaldehyde (359 mg, 2.99 mmol), Grignard reagent **4** (5.6 mL of approximately 0.79 M, 4.45 mmol), and THF (10 mL). The crude product was purified by silica gel chromatography (10% EtOAc/hexanes) to yield 368 mg (50%) of the alcohol **5e**: R_f = 0.41 (20% EtOAc/hexanes); IR (film) 3596, 3078, 2918, 1629, 1494, 1251, 1032, 994 cm^{-1}; ^{1}H NMR (200 MHz, $CDCl_3$) δ 7.38−7.19 (5 H, m), 5.88−5.65 (1 H, m), 4.90−4.73 (2 H, m), 3.70 (1 H, bs), 2.88−2.81 (1 H, m), 2.66−2.54 (1 H, m), 1.58−1.42 (5 H, m), 0.73−0.42 (2 H, m), −0.03 (6 H, s); ^{13}C NMR (75 MHz, $CDCl_3$) δ 138.9, 134.5, 129.3, 128.5, 126.3, 113.2, 74.8, 43.2, 30.7, 21.2, 8.4, −3.8; CIMS m/z (relative intensity) 231 (10, M^+ − OH), 205 (17), 189 (38), 141 (9), 115 (18), 101 (40), 99 (37), 75 (100).

Preparation of 1-[2′-(Allyldimethylsilyl)ethyl]cyclopentan-1-ol (5f). The general procedure was followed using cyclopentanone (342 mg, 4.07 mmol), 20 mL of THF, and 18 mL of Grignard reagent **4** (∼0.46 M, 8.2 mmol). The crude product was isolated by silica gel chromatography (10% EtOAc/hexanes)

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(17) The molarity of Grignard reagent **4** can be assayed by standard procedures: Crompton, T. R. In *The Chemistry of the Metal−Carbon Bond*; Hartley, F. R., Patai, S., Eds.; Wiley: Chichester, 1982; Vol. 1, p 664.

to yield 680 mg (79%) of alcohol **5f**: R_f = 0.47 (20% EtOAc/hexanes); IR (neat) 3380, 3076, 1630, 1032, 991 cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$) δ 5.90−5.68 (1 H, m), 4.91−4.74 (2 H, m), 1.94−1.42 (12 H, m), 0.61−0.50 (2 H, m), −0.04 (6 H, s); ^{13}C NMR (75 MHz, $CDCl_3$) δ 135.0, 112.8, 83.3, 39.2, 35.1, 24.0, 23.0, 8.9, −4.0; CIMS *m/z* (relative intensity) 195 (37, M^+ − OH), 171 (11, M^+ − allyl), 169 (18), 153 (14), 101 (16), 99 (21), 75 (100).

Preparation of 1-[2′-(Allyldimethylsilyl)ethyl]cyclohexan-1-ol (5g). The general procedure was followed using cyclohexanone (237 mg, 2.41 mmol), 9 mL of THF, and 9 mL of Grignard reagent **4** (∼0.53 M, 4.8 mmol). The crude product was purified by silica gel chromatography (10% EtOAc/hexanes) to yield 385 mg (71%) of alcohol **5g**: R_f = 0.51 (20% EtOAc/hexanes); IR (film) 3459, 3078, 2908, 1629, 1448, 1260, 1036, 993 cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$) δ 5.88−5.67 (1 H, m), 4.92−4.78 (2 H, m), 1.61−1.19 (14 H, m), 0.59−0.40 (2 H, m), −0.04 (6 H, s); ^{13}C NMR (75 MHz, $CDCl_3$) δ 134.8, 113.2, 72.1, 37.3, 27.9, 25.8, 23.7, 21.1, 6.0, −4.9. CIMS *m/z* (relative intensity) 209 (40, M^+ − OH), 183 (38), 167 (38), 141 (13), 101 (42), 75 (100).

Preparation of 1-(Allyldimethylsilyl)-3-propylhexan-3-ol (5h). The general procedure was followed using 4-heptanone (343 mg, 3.00 mmol), 16 mL of THF, and 12 mL of Grignard reagent **4** (∼0.50 M, 6.0 mmol). The crude product was purified by silica gel chromatography (10% EtOAc/hexanes) to yield 586 mg (81%) of compound **5h**: R_f = 0.52 (20% EtOAc/hexanes); IR (neat) 3412, 2957, 1631, 1456, 1249, 1158, 974 cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$) δ 5.89−5.65 (1 H, m), 4.90−4.76 (2 H, m), 1.52 (2 H, t, J = 8.4 Hz), 1.41−1.16 (10 H, m), 1.07 (1 H, bs), 0.88 (6 H, t, J = 6.8 Hz), 0.52−0.34 (2 H, m), −0.05 (6 H, s); ^{13}C NMR (75 MHz, $CDCl_3$) δ 134.8, 113.1, 74.9, 41.0, 32.8, 21.2, 16.7, 14.7, 7.8, −3.9; CIMS *m/z* (relative intensity) 225 (14, M^+ − OH), 201 (8, M^+ − allyl), 199 (48), 157 (22), 127 (6), 115 (52), 101 (30), 75 (90), 73 (100).

Preparation of 3-[2′-(Allyldimethylsilyl)ethyl]cyclohexan-1-one (8). A 250 mL flask was charged with $CuBr{\cdot}Me_2S$ (498 mg, 2.42 mmol), flame dried under vacuum, and returned to an argon atmosphere. THF (45 mL) was added, stirring was started, and the mixture was cooled to −78 °C. Grignard reagent **4** (18 mL, ∼0.54 M, 9.7 mmol) was added dropwise, resulting in a cloudy, dark green solution. After the mixture was stirred for 1 h, HMPA (1.7 mL, 9.7 mmol) was added, followed by the dropwise addition of a solution of 2-cyclohexen-1-one (467 mg, 4.85 mmol) and freshly distilled chlorotrimethylsilane (1.11 g, 10.2 mmol) in THF (7 mL). The mixture was stirred at −78 °C for 3 h, warmed to −50 °C, and stirred for an additional 3 h. Water (30 mL) was added, and the mixture was stirred at rt open to the atmosphere for 1 h. NH_4OH (10%) in saturated NH_4Cl solution (100 mL) was added, and the mixture was stirred for 1 h, resulting in a royal blue solution. The layers were separated, and the aqueous phase was extracted with ether (4 × 30 mL). The combined organic extracts were washed with water (4 × 25 mL), dried (Na_2SO_4), and concentrated. The crude residue was purified by silica gel chromatography (10% EtOAc/hexanes) to yield 832 mg (76%) of the cyclohexanone **8**: R_f = 0.49 (20% EtOAc/hexanes); IR (film) 3059, 1696, 1629, 1035, 914 cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$) δ 5.90−5.63 (1 H, m), 4.92−4.74 (2 H, m), 2.47−2.19 (2 H, m), 2.11−1.82 (3 H, m), 1.71−1.40 (5 H, m), 1.36−1.15 (3 H, m), 0.56−0.38 (2 H, m), −0.09 (6 H, s); ^{13}C NMR (75 MHz, $CDCl_3$) δ 211.8, 134.3, 113.1, 47.6, 41.8, 41.2, 31.6, 30.1, 25.0, 20.9, 11.4, 9.3, −2.0; CIMS *m/z* (relative intensity) 209 (36, M^+ − Me), 183 (100, M^+ − allyl), 169 (15), 155 (18), 109 (38), 75 (34), 73 (12).

General Procedure for CuI-Catalyzed Opening of an Epoxide with Grignard Reagent 4. Preparation of 1-(Allyldimethylsilyl)-7-octen-4-ol (13). A 250 mL flask was charged with CuI (184 mg, 0.97 mmol), flame-dried under vacuum, and returned to an argon atmosphere. THF (40 mL) was added, stirring was started, and the mixture was cooled to −78 °C. Grignard reagent **4** (17 mL, ∼0.54 M, 9.2 mmol) was added dropwise, resulting in a cloudy gray solution. After the mixture was stirred for 1 h, a solution of 1,2-epoxy-5-hexene (**11**, 601 mg, 6.1 mmol) in THF (7 mL) was added dropwise. The mixture was stirred at −78 °C for 3 h and then warmed to −30 °C and stirred for an additional 3 h, resulting in a dark green solution. NH_4OH (10%) in saturated NH_4Cl solution (100 mL) was added, and the mixture was stirred at rt for 1 h. The layers were separated, and the aqueous layer was extracted with ether (4 × 30 mL). The combined organic extracts were washed with brine (50 mL), dried (Na_2SO_4), and concentrated. The crude residue was purified by silica gel chromatography (10% EtOAc/hexanes) to yield 957 mg (69%) of alcohol **13**: R_f = 0.47 (20% EtOAc/hexanes); ^1H NMR (200 MHz, $CDCl_3$) δ 5.92−5.67 (2 H, m), 5.09−4.75 (4 H, m), 3.66−3.55 (1 H, m), 2.21−2.07 (2 H, m), 1.58−1.24 (9 H, m), 0.59−0.40 (2 H, m), −0.05 (6 H, s); ^{13}C NMR (90 MHz, $CDCl_3$) δ 138.6, 134.7, 114.6, 112.8, 71.1, 41.4, 36.5, 30.0, 23.2, 21.3, 14.9, −3.5; CIMS *m/z* (relative intensity) 209 (M^+ − OH), 185 (41), 169 (94), 167 (100), 141 (76), 129 (40), 127 (38), 101 (20), 75 (96).

Preparation of 1-(Allyldimethylsilyl)hexan-4-ol (12). The general procedure for epoxide opening was followed using CuI (188 mg, 0.99 mmol), 15 mL of Grignard reagent **4** (∼0.60 M, 9.0 mmol), 1,2-epoxybutane (**10**, 419 mg, 5.8 mmol), and 45 mL of THF. The crude residue was purified by silica gel chromatography (10% EtOAc/hexanes) to yield 815 mg (70%) of alcohol **12**: R_f = 0.42 (20% EtOAc/hexanes); IR (film) 2932, 1629, 1458, 1250, 929 cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$) δ 5.87−5.65 (1 H, m), 4.90−4.78 (2 H, m), 3.58−3.46 (1 H, m), 1.54−1.24 (8 H, m), 0.91 (3 H, t, J = 7.4 Hz), 0.57−0.43 (2 H, m), −0.05 (6 H, s). ^{13}C NMR (75 MHz, $CDCl_3$) δ 134.8, 112.6, 73.0, 40.9, 30.2, 23.2, 21.3, 19.9, 9.9, −3.6; CIMS *m/z* (relative intensity) 183 (12, M^+ − OH), 157 (18), 143 (82), 101 (38), 84 (100).

General Procedure for Conversion of Allylsilanes to Alcohols via Fluorosilanes. Preparation of 1-Phenyl-1,3-propanediol (7a). The benzyl alcohol **5a** (210 mg, 0.90 mmol) was dissolved in $CHCl_3$ (12 mL) and added to a 50 mL Teflon Erlenmeyer flask under argon. The solution was stirred for 15 min, KHF_2 (150 mg, 1.92 mmol) and TFA (0.3 mL, 3.89 mmol) were added, and the reaction mixture was stirred at rt for 18 h. The reaction mixture was transferred to a glass round-bottomed flask and concentrated by rotary evaporation to yield the crude fluorosilane. THF (7 mL), methanol (7 mL), and $NaHCO_3$ (350 mg, 4.17 mmol) were added, and stirring was resumed. After 15 min, H_2O_2 (1.5 mL, 16.3 mmol) was added dropwise, a condenser was fitted onto the flask, and the mixture was warmed at a gentle reflux for 18 h. The mixture was cooled to rt and concentrated to one-quarter volume by rotary evaporation. EtOAc (25 mL) and Na_2SO_4 were added, and the mixture was allowed to stand at rt for 30 min. The mixture was filtered through Celite and concentrated by rotary evaporation. The crude residue was purified by silica gel chromatography (50% EtOAc/hexanes) to yield 108 mg (78%) of known[7] 1-phenyl-1,3-propanediol (**7a**): ^1H NMR (200 MHz, $CDCl_3$) δ 7.36 (5 H, s), 4.81 (1 H, m), 3.41 (2 H, bs), 2.41−2.07 (5 H, m).

Preparation of 1-Cyclohexyl-1,3-propanediol (7b). The general procedure was followed using 1-(allyldimethylsilyl)-3-cyclohexylpropan-3-ol (**5b**, 140 mg, 0.58 mmol), KHF_2 (105 mg, 1.34 mmol), TFA (0.35 mL, 4.54 mmol), and $CHCl_3$ (10 mL). The crude fluorosilane (∼110 mg) was oxidized using THF (5 mL), methanol (5 mL), $NaHCO_3$ (210 mg, 2.50 mmol), and H_2O_2 (1.2 mL, 11.7 mmol). The crude residue was purified by silica gel chromatography (50% EtOAc/hexanes) to yield 60 mg (65%) of known[8] compound **7b**: ^1H NMR (200 MHz, $CDCl_3$) δ 3.92−3.80 (2 H, m), 3.63 (1 H, q, J = 9 Hz), 2.80 (2 H, bs), 1.88−1.61 (7 H, m), 1.39−0.94 (6 H, m).

Preparation of 1,3-Hexanediol (7c). The general procedure was followed using 1-(allyldimethylsilyl)hexan-3-ol (**5c**, 230 mg, 1.15 mmol), KHF_2 (190 mg, 2.43 mmol), TFA (0.5 mL, 6.49 mmol), and $CHCl_3$ (10 mL). The crude fluorosilane (∼200 mg) was oxidized using THF (6 mL), methanol (6 mL), $NaHCO_3$ (490 mg, 5.83 mmol), and H_2O_2 (2.4 mL, 22.9 mmol). The crude residue was purified by silica gel chromatography (50% EtOAc/hexanes) to yield 107 mg (79%) of known[9] compound **7c**: ^1H NMR (200 MHz, $CDCl_3$) δ 3.81 (3 H, m), 2.15 (2 H, bs), 1.74−1.58 (2 H, m), 1.49−1.14 (4 H, m), 0.90 (3 H, t, J = 8 Hz).

Preparation of 4-Methyl-1,3-pentanediol (7d). The general procedure was followed using 1-(allyldimethylsilyl)-4-methylpentan-3-ol (**5d**, 266 mg, 1.33 mmol), KHF_2 (215 mg, 2.75 mmol), TFA (0.45 mL, 5.84 mmol), and $CHCl_3$ (15 mL). The crude fluorosilane (∼230 mg) was oxidized using THF (9 mL), methanol (9 mL), $NaHCO_3$ (490 mg, 5.83 mmol), and 30% H_2O_2 (2.6 mL, 25.4 mmol). The crude product was purified by silica gel chromatography (50% EtOAc/hexanes) to yield 98 mg (66%) of known[10] compound **7d**: ^1H NMR (200 MHz, $CDCl_3$) δ 3.82 (2 H, t, J = 6.0 Hz), 3.60 (1 H, q, J = 5.6 Hz), 3.24 (2 H, br s), 1.69−1.56 (3 H, m), 0.87 (6 H, dd, J = 5.8, 2.4 Hz).

Preparation of 4-Phenyl-1,3-butanediol (7e). The general procedure was followed using 1-(allyldimethylsilyl)-4-phenylbutan-3-ol (**5e**, 368 mg, 1.48 mmol), KHF_2 (258 mg, 3.30 mmol), TFA (0.50 mL, 6.49 mmol), and $CHCl_3$ (15 mL). The crude fluorosilane (~315 mg) was oxidized using THF (8 mL), methanol (8 mL), $NaHCO_3$ (0.51 g, 6.1 mmol),and 30% H_2O_2 (2.8 mL, 27.4 mmol). The crude residue was purified by silica gel chromatography (50% EtOAc/hexanes) to yield 144 mg (58%) of known[9] compound **7e**: ^{1}H NMR (200 MHz, $CDCl_3$) δ 7.46−7.17 (5 H, m), 4.21−4.02 (1 H, m), 3.99−3.73 (2 H, m), 2.89−2.70 (2 H, m), 2.34 (2 H, bs), 1.83−1.60 (2 H, m).

Preparation of 1-(2′-Hydroxyethyl)-1-cyclopentanol (7f). The general procedure was followed using 1-[2′-(allyldimethylsilyl)ethyl]cyclopentan-1-ol (**5f**, 262 mg, 1.23 mmol), $CHCl_3$ (12 mL), KHF_2 (180 mg, 2.30 mmol), and TFA (0.7 mL, 9.1 mmol). The crude fluorosilane (~200 mg) was oxidized using THF (10 mL), methanol (10 mL), $NaHCO_3$ (540 mg, 6.43 mmol), and H_2O_2 (2.6 mL, 25.9 mmol). The crude residue was purified by silica gel chromatography (50% EtOAc/hexanes) to yield 112 mg (70%) of known[11] compound **7f**: ^{1}H NMR (200 MHz, $CDCl_3$) δ 3.91 (2 H, t, J = 6.2 Hz), 3.52 (2 H, bs), 2.12−1.91 (3 H, m), 1.87−1.40 (9 H, m).

Preparation of 1-(2′-Hydroxyethyl)-1-cyclohexanol (7g). The general procedure was followed using 1-[2′-(allyldimethylsilyl)ethyl]cyclohexan-1-ol (**5g**, 453 mg, 2.00 mmol), $CHCl_3$ (20 mL), KHF_2 (320 mg, 4.10 mmol), and TFA (0.64 mL, 8.3 mmol). The crude fluorosilane (~410 mg) was oxidized using THF (10 mL), methanol (10 mL), $NaHCO_3$ (495 mg, 5.89 mmol), and H_2O_2 (2.9 mL, 28.4 mmol). The crude residue was purified by silica gel chromatography (50% EtOAc/hexanes) to yield 232 mg (80%) of known[11] compound **7g**: ^{1}H NMR (200 MHz, $CDCl_3$) δ 3.86 (2 H, t, J = 5.9 Hz), 1.71 (2 H, t, J = 5.9 Hz), 1.62−1.47 (4 H, m), 1.46−1.18 (8 H, m).

Preparation of 3-Propyl-1,3-hexanediol (7h). The general procedure was followed using 1-(allyldimethylsilyl)-3-propylhexan-3-ol (**5h**, 265 mg, 1.09 mmol), KHF_2 (191 mg, 2.44 mmol), TFA (0.40 mL, 5.20 mmol), and $CHCl_3$ (15 mL). The crude fluorosilane (~230 mg) was oxidized using THF (10 mL), methanol (10 mL), $NaHCO_3$ (340 mg, 4.05 mmol), and H_2O_2 (2.1 mL, 20.5 mmol). The crude residue was purified by silica gel chromatography (50% EtOAc/hexanes) to yield 140 mg (84%) of known[12] compound **7h**: ^{1}H-NMR (200 MHz, $CDCl_3$) δ 3.83 (2 H, t, J = 5.6 Hz), 2.82 (1 H, bs), 2.24 (1 H, bs), 1.68 (2 H, t, J = 5.8 Hz), 1.51−1.40 (4 H, m), 1.39−1.17 (5 H, m), 0.89 (6 H, t, J = 7.2 Hz).

Preparation of 3-(2-Hydroxyethyl)-1-cyclohexanone (9). The general procedure was followed using 1-(allyldimethylsilyl)-4-methylhexan-3-ol (**8**, 125 mg, 0.56 mmol), KHF_2 (92 mg, 1.22 mmol), TFA (0.18 mL, 2.35 mmol), and $CHCl_3$ (8 mL). The crude fluorosilane (~125 mg) was oxidized using THF (7 mL), methanol (7 mL), $NaHCO_3$ (640 mg, 7.6 mmol), and 30% H_2O_2 (1.6 mL, 15.6 mmol). The crude product was purified by silica gel chromatography (50% EtOAc/hexanes) to yield 68 mg (64%) of known[14] cyclohexanone **9**: ^{1}H NMR (200 MHz, $CDCl_3$) δ 3.65 (1H, t, J = 8.0 Hz), 3.11 (2 H, d, J = 12 Hz), 2.05−1.92 (2 H, m), 1.74−1.12 (9 H, m), 1.07−0.81 (2 H, m).

Preparation of 1,4-Hexanediol (14). The general procedure was followed using 1-(allyldimethylsilyl)hexan-4-ol (**12**, 261 mg, 1.30 mmol), KHF_2 (240 mg, 3.07 mmol), TFA (0.45 mL, 5.84 mmol), and $CHCl_3$ (15 mL). The crude fluorosilane was oxidized using THF (8 mL), methanol (8 mL), $NaHCO_3$ (513 mg, 6.10 mmol), and 30% H_2O_2 (2.5 mL, 24.5 mmol). The crude residue was purified by silica gel chromatography (50% EtOAc/hexanes) to yield 111 mg (72%) of known[16] diol **14**: R_f = 0.12 (50% EtOAc/hexanes); ^{1}H NMR (200 MHz, $CDCl_3$) δ 3.72−3.50 (3 H, m), 2.23 (2 H, bs), 1.70−1.58 (3 H, m), 1.57−1.35 (3 H, m), 0.90 (3 H, t, J = 7.2 Hz).

Preparation of 7-Octene-1,4-diol (15). The general procedure was followed using 1-(allyldimethylsilyl)-7-octen-4-ol (**13**, 264 mg, 1.16 mmol), KHF_2 (195 mg, 2.50 mmol), TFA (0.4 mL, 5.19 mmol), and $CHCl_3$ (12 mL). The crude fluorosilane (~250 mg) was oxidized using THF (7 mL), methanol (7 mL), $NaHCO_3$ (420 mg, 4.99 mmol), and 30% H_2O_2 (2.1 mL, 20.5 mmol). The crude residue was purified by silica gel chromatography (50% EtOAc/hexanes) to yield 141 mg (84%) of 7-octene-1,4-diol (**15**): R_f = 0.10 (50% EtOAc/hexanes); IR (film) 3332, 3079, 2939, 1640, 1448, 1253, 991 cm^{-1}; ^{1}H NMR (200 MHz, $CDCl_3$) δ 5.88−5.67 (1 H, m), 5.09−4.87 (2 H, m), 3.95 (2 H, bs), 3.62−3.47 (3 H, m), 2.17−1.95 (2 H, m), 1.68−1.32 (6 H, m); ^{13}C NMR (50 MHz, $CDCl_3$) δ 139.0, 114.9, 70.9, 62.3, 36.0, 33.8, 29.6, 28.4; CIMS m/z (relative intensity) 145 (37, $M^+ + H$), 127 (100, $M^+ - OH$), 109 (80), 89 (22).

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Supporting Information Available: Copies of ^{1}H and ^{13}C NMR spectra of new compounds (20 pages). This material is contained in libraries on microfiche, immediately follows this article in the microfilm version of the journal, and can be ordered from the ACS; see any current masthead page for ordering information.

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