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Total Synthesis of (+)-Boronolide, (+)-Deacetylboronolide, and (+)-Dideacetylboronolide†

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Total synthesis of (+)-boronolide, (+)-deacetylboronolide, and (+)-dideacetylboronolide has been achieved from a single intermediate **26**, which was synthesized in 11 steps from a D-mannitol-derived intermediate **8** in an overall yield of 10%. The key steps in the synthesis are inversion of a chiral center by taking an advantage of the inherent mechanism involved in the ring closing to an epoxide via intramolecular S_N2 reaction and lactonization of a diol using Fetizons reagent. The strategy is amenable to preparation of analogues of (+)-boronolide in sufficient amount for further screening of biological activity.

Introduction

6-Substituted 5,6-dihydro-2*H*-pyran-2-ones (α,*β*-unsaturated *δ*-lactones) **1** are important structural subunits in many biologically important natural products.[1] These units are important for a wide variety of biological activities, such as insect growth inhibition and insect antifeedal, antifungal, and antitumor properties. The pyrone units are widely distributed in all parts of plants (Lamiaceae, Piperaceae, Lauraceae, and Annonaceae families) including leaves, stems, flowers, and fruits. Various kinds of substitutions have been found at the C-6 position of the ring such as polyacetoxy alkane, polyhydroxy alkane, a combination of both, or even a simple alkane. Biological activity of these types of molecules, their structural complexities, and the challenge to synthesize them optically pure form made them an attractive target for many total syntheses. (+)-Boronolide **2**, (+)-deacetylboronolide **3**, and (+)-dideacetylboronolide **4** are such natural products, which have attracted attention from several synthetic organic chemists (Figure 1). These are α,*β*-unsaturated *δ*-lactones with a highly oxygenated side chain at the C-6 position. The (+)-boronolide **2** was isolated from the bark and branches of *Tetradenia fruticosa*[2] and from the leaves of *Tetradenia barbera*,[3] which have been used as local folk medicine in Madagascar and southern Africa.[4] (+)-Deacetylboronolide **3** and (+)-dideacetylboronolide **4** were obtained from

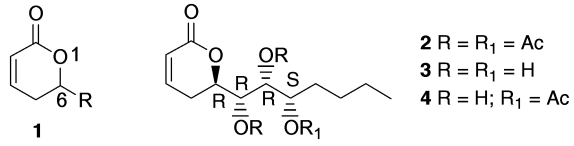

FIGURE 1.

Tetradenia riparia,[5] a central African species widely used as a tribal medicine. Medicinal properties of boronolides have been exploited for a long time in crude form. Zulu used roots of these plants as an emetic, and an infusion of leaves has been reported to be effective against malaria.[4,5]

Relative stereochemistry of **2** has been determined by X-ray analysis,[6] and the *R*-configuration at the C-6 position has been proposed by application of Hudson's lactone rule to the molecular rotation. Later, the stereochemistry at the C-6 position was confirmed by chemical degradation,[3] thus confirming the structure and absolute stereochemistry of boronolide as **2**. Although several syntheses of **2** have been reported[7,8] in the literature, there is no report on total syntheses of other boronolides such as **3** and **4**. In this paper, we delineate our efforts on total synthesis of all the three naturally occurring (+)-boronolides from D-mannitol.

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† Dedicated to Professor G. Mehta on the occasion of his 60th birthday.

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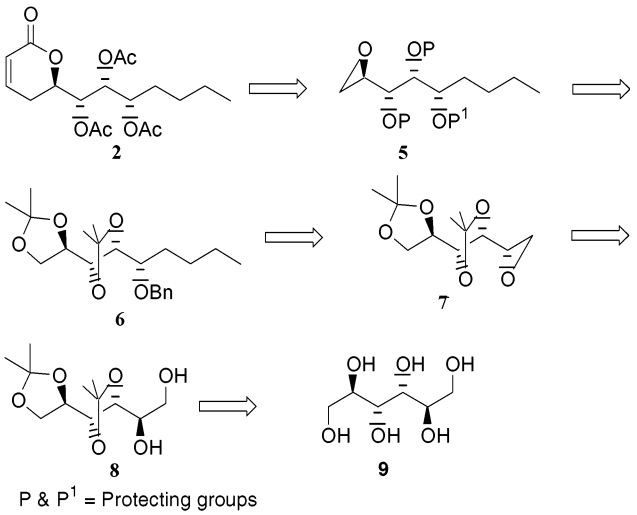


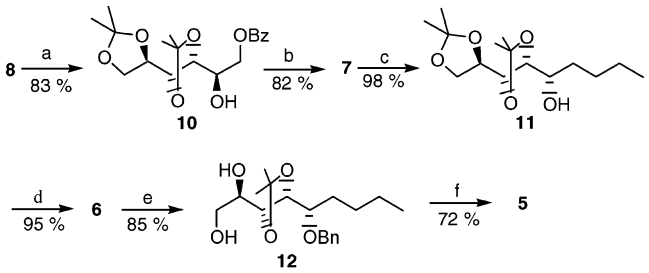
FIGURE 2. Retrosynthetic analysis of **2**.

Results and Discussion

Retrosynthetic analysis of (+)-boronolide **2** is shown in Figure 2. Inspection of the target **2** reveals that lactonic moiety can be obtained from an epoxide **5** and a functionalized three-carbon unit. The subtarget **5** can be obtained from **6** by simple functional group transformations. Structural mapping of the new target **6** was done with an epoxide **7** that can be directly correlated to **8**,[9] which can be obtained on a multigram scale in two simple steps from D-mannitol **9**. Since three of the four chiral centers of boronolide **2** can directly be mapped onto D-mannitol and its C_2 symmetry makes it possible to invert one of the chiral centers selectively, it was chosen as an ideal starting material.[10]

1,2:3,4-Di-*O*-isopropylidene-D-mannitol **8** was prepared according to the literature procedure.[9] Inversion in the stereochemistry of the secondary hydroxyl group in **8** was planned via intramolecular S_N2 displacement by the adjacent primary hydroxyl group. To achieve this, the primary hydroxyl group of the **8** was selectively protected as a benzoate ester **10**. It was essential to do the above protection reaction at very low temperature in order to avoid a problem of dibenzoylation and benzoyl migration. Initial activation of the secondary hyroxyl group as tosylate led to a partial migration. So it was activated as a mesylate at −80 °C. Treatment of the crude mesylated product with K_2CO_3 in methanol led to deprotection of the benzoate ester to hydroxyl group with concomitant ring closure via intramolecular S_N2 displacement of mesylate to provide the epoxide **7** with inverted stereochemistry in 90% yield. After successful inversion of configuration, the stage was set for introduction of the three-carbon aliphatic side chain (Scheme 1). Treatment of the epoxide **7** with *n*-propylmagnesium bromide or *n*-propyllithium gave products due to both internal and terminal attack along with some unidentified products. Lowering of the reaction temperature did not have any

SCHEME 1[a]



[a] Reaction conditions: (a) PhCOCl, Py, DMAP (cat.), DCM, −80 to −20 °C, 4 h; (b) (i) MsCl, Et_3N,DCM, −80 to −20 °C, 10 h, (ii) K_2CO_3, MeOH, rt, 2.5 h; (c) $Pr_2CuCNLi$, THF, −80 °C, 8 h; (d) NaH, BnBr, THF, rt, 12 h; (e) $CuCl_2{\cdot}2H_2O$, MeCN, 0 °C, 45 min; (f) (i) TsCl, Py, DCM, 0 °C, 24 h, (ii) K_2CO_3, MeOH, 0 °C, 1 h.

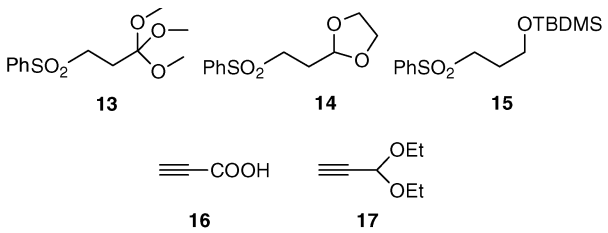


FIGURE 3.

effect on the outcome of the result. However, the ring opening of the epoxide **7** with propylmagnesium bromide in the presence of a stoichiometric amount of CuBr·DMS complex gave the desired product **11** in 85% yield. The yield of the **11** could further be improved (95%) on the use of higher order cuprate preapared in situ from *n*-propyllithium and CuCN. The hydroxyl group in **11** was converted to the benzyl ether **6** under standard conditions in quantitative yield. Selective hydrolysis of the terminal acetonide in **6** was achieved by treating it with $CuCl_2{\cdot}2H_2O$[11] in MeCN at 0 °C for 40 min. Thus, the desired product **12** was obtained in 85% yield. Conversion of the diol **12** to the epoxide **5** was done via usual selective tosylation of the primary alcohol, followed by its treatment with K_2CO_3 in methanol at 0 °C.

The **5** had basic stereochemical framework of the target **2** and only construction of α,β-unsaturated-δ-lactone ring was required. Initially we thought of constructing α,β-unsaturated-δ-lactone by using the Ghosez lactonization method.[12] Thus, the epoxide **5** was treated with an anion generated from **13** and *n*-BuLi. It was quite discouraging to note that the reaction did not give any ring-opened product. Use of similar stable sulfone reagents such as sulfone acetal **14**[12] and sulfone silyl ether **15**[13] were also unsuccessful. The presence of additives such as HMPA or $BF_3{\cdot}OEt_2$ failed to activate the epoxide. The epoxide ring opening was also unsuccessful with other nucleophiles derived from propiolic acid **16**[14] and propiolaldehyde diethylacetal **17**[15] (Figure 3).

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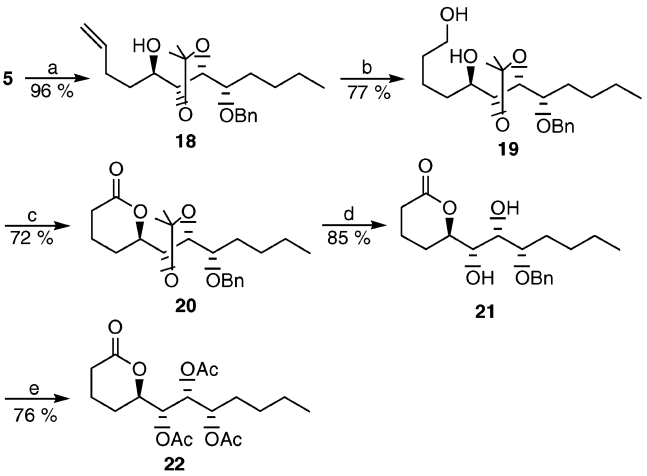
SCHEME 2[a]

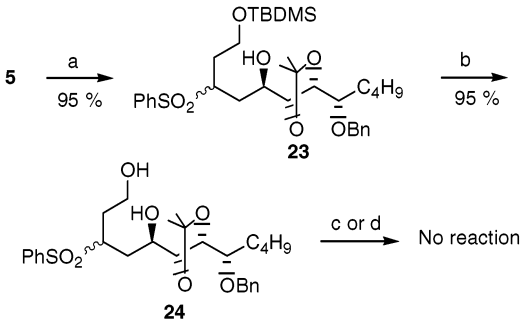


[a] Reaction conditions: (a) allylMgBr, CuCN, THF, −80 to −40 °C, 12 h; (b) (i) BH_3·DMS, $PhCH_3$, 0 °C to rt, 12 h, (ii) EtOH, 3 M NaOH, 30% H_2O_2, 2 h; (c) Ag_2CO_3−Celite, PhH, 85 °C, 12 h; (d) $CuCl_2$·$2H_2O$, MeCN, rt, 24 h; (e) (i) H_2, Pd−C, EtOH, rt, 12 h, (ii) Ac_2O, Py, rt, 76% (for two steps).

Because of the failure of the original strategy for constructing α,*β*-unsaturated-*δ*-lactone, a different approach was adopted. The epoxide **5** was treated with allylmagnesium bromide in the presence of stoichiometric amount of CuCN at −80 °C with a gradual warming to −40 °C.[16] It was heartening to note that the allylated product **18** was obtained in a quantitative yield. This was subjected to hydroboration under standard conditions, followed by oxidative workup to provide a diol **19** in 77% yield.[17] Oxidation of the diol **19** with Fetizons reagent[18] went smoothly without any problem. The diol **19**, when treated with large excess of Ag_2CO_3−Celite in benzene under reflux condition, gave a desired lactone **20** in good yield. Cleavage of the acetonide in the **20** with $CuCl_2$·$2H_2O$ gave a diol **21**, which was converted into **22** by hydrogenolysis of the benzyl ether followed by acetylation of the hydroxyl groups. Although the conversion of **22** to boronolide **2** was reported in the literature, we still wished to reach the target. When **22** was subjected to dehydrogenation with benzeneseleninic anhydride under the reported conditions,[6−8] only 25% of the desired product **2** was obtained along with unreacted starting material (Scheme 2). Repetition of this process improved the conversion to 50%. This could be due to impurities in technical grade of benzeneseleninic anhydride which was only 70% pure.

Failure to reach the target **2** from the triacetate **22** in an effective manner led us to think about usage of sulfonyl anion once again. Since higher order cuprates worked effectively in the ring opening of the epoxides **5** and **7**, we thought of using cuprate made from sulfonyl anion in this case also. We chose **15** as an ideal sulfone reagent as the silyl protecting group does not interfere with the protecting groups already present in the epoxide **5** and it is also more stable than the sulfone ortho ester

SCHEME 3[a]



[a] Reaction conditions: (a) **15**, *n*-BuLi, CuI, THF, −80 to −20 °C, 12 h; (b) TBAF, THF, rt, 8 h; (c) Ag_2CO_3−Celite, PhH, 85 °C, 24 h; (d) $RuCl_2(PPh_3)_3$, PhH, rt, 15 h.

13. Cuprate was made by treating the sulfone silyl ether anion with copper(I) salt (CuCN and CuBr·DMS) in THF at −80 °C, and then it was treated with a solution of epoxide **5**. Unfortunately, the ring-opening reaction did not proceed. However, by changing the copper salt to CuI gave the ring-opened product **23** in 95% yield. Deprotection of TBDMS group using TBAF in THF gave a diol **24** quantitatively. Conversion of the diol **24** into a lactone was expected to be smooth. However, it turned out to be quite problematic (Scheme 3). Refluxing the diol **24** in benzene with excess Ag_2CO_3 − celite did not yield any product and prolonged heating led to decomposition of the starting material. The attempted oxidation of the diol **24** with $RuCl_2(PPh_3)_3$[19] gave a complex mixture of products.

Failure to reach the target by the above two approaches prompted us to complete the total synthesis from the lactone **20** by usual phenylselenation and elimination reactions.[20] To accomplish this, the benzyl group in the **20** was removed by hydrogenation to give a hydroxy lactone **25** in quantitative yield. Then, the hydroxy lactone **25** was subjected to α-phenylselenation, by treatment with 2.5 equiv of LDA in a mixture of THF and HMPA and quenching the enolate by addition of a freshly prepared phenylselenyl bromide. The selenated product was subjected to oxidative syn-elimination with H_2O_2 and pyridine to give the desired α,*β*-unsaturated-*δ*-lactone **26**. Deprotection of acetonide in the **26** with Amberlite H^+ resin at 70 °C gave (+)-deacetylboronolide **3**. Acetylation of **26** under standard conditions gave **27** and removal of acetonide with $CuCl_2$·$2H_2O$ gave the (+)-dideacetylboronolide **4**. Acetylation of **4** under standard conditions gave the (+)-boronolide **2**. Thus, the total synthesis of all the naturally occurring boronolides was accomplished (Scheme 4).

In conclusion, we have completed the total synthesis boronolides from a single chiral intermediate obtained from D-mannitol. The synthesis is more flexible and can easily be adopted for preparation of its various analogues.

Experimental Section

^{1}H NMR spectra were recorded on 400 MHz NMR spectrophotometer using TMS as internal standard. Chemical shifts

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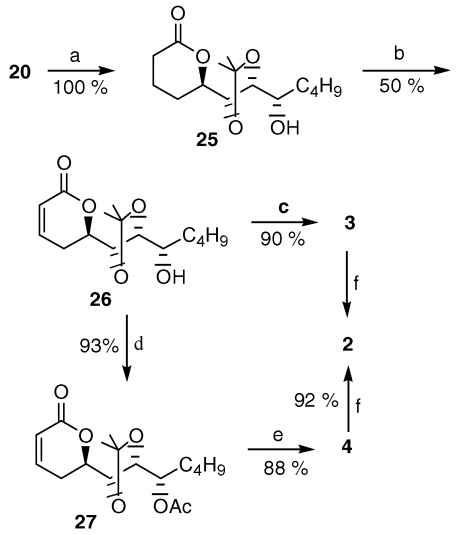
SCHEME 4[a]



[a] Reaction conditions: (a) H_2, Pd−C, EtOH, rt, 12 h; (b) (i) LDA, PhSeBr, THF, HMPA, −80 °C, (ii) 30% H_2O_2, Py, rt, 6 h; (c) Amberlite IR 120 H^+, 70 °C, H_2O, 7 h; (d) Ac_2O, Py, DCM, rt, 12 h; (e) $CuCl_2 \cdot 2H_2O$, MeCN, rt, 12 h; (f) Ac_2O, Py, rt, 12 h.

are reported in ppm, and coupling constants are reported in Hz. Routine monitoring of reactions was performed using silica gel-G obtained from Acme. Column chromatographic separations were done by using silica gel (Acme's 60−120 mesh). Petroleum ether used was of boiling range 60−80 °C. Reactions that needed anhydrous conditions were run under the atmosphere of nitrogen or argon using flame-dried glasswares. The organic extracts were dried over *anhydrous* sodium sulfate. Evaporation of solvents was performed at reduced pressure. Tetrahydrofuran (THF) was distilled from sodium benzophenone ketyl under nitrogen. Benzene, toluene, and CH_2Cl_2 were distilled from CaH_2.

1,2:3,4-Di-*O*-isopropylidene-D-mannitol 8. Compound **8** was prepared according to the literature procedure[9] with minor modifications. A solution of 1,2:3,4:5,6-tri-*O*-isopropylidene-D-mannitol (35.6 g) in 70% aqueous ethanol (810 mL) was treated with concentrated HCl (2.5 mL) at 45 °C for 1 h. The reaction was quenched by an addition of large excess of solid K_2CO_3. The ethanol layer was separated, and aqueous layer was extracted with EtOAc once. The combined organic layers were concentrated on rotary evaporator and residue was taken in cold water. The unreacted starting material (13.2 g) separated out as a solid and it was filtered. Aqueous layer was extracted with EtOAc to give the diol **8** in essentially pure form: yield 8.5 g (42% based on SM recovery) as a low melting solid; R_f 0.29 (40% EtOAc in petroleum ether); $[\alpha]^{25}_D$ +5.15 (*c* 1.8, $CHCl_3$); IR (thin film) 3451, 3054, 1423 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 1.377 (s, 6H), 1.38 (s, 3H), 1.47 (s, 3H), 2.53 (bs, 1H, −O*H*), 3.77 (m, 5H), 3.91 (t, J = 7.3 Hz, 1H), 4.05 (m, 1H), 4.22 (dd, J = 8.4, 6.0 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 25.0, 26.3, 26.78, 26.8, 63.8, 68, 72.2, 76.5, 80.7 (2 C), 109.6, 110.8; MS (FAB) 263 ($M^+ + 1$). Anal. Calcd for $C_{12}H_{22}O_6$: C, 54.96; H, 8.40. Found: C, 54.64; H, 8.30.

6-*O*-Benzoyl-1,2:3,4-di-*O*-isopropylidene-D-mannitol 10. To a solution of the diol **8** (6 g, 22.9 mmol) and DMAP (0.1 equiv) in dry DCM (60 mL) was added dry pyridine (3.7 mL, 45.8 mmol) at −80 °C under N_2 atmosphere. This was followed by a dropwise addition of benzoyl chloride (2.8 mL, 24.05 mmol) with vigorous stirring. The reaction was allowed to proceed for 4 h with gradual warming to −20 °C. The reaction mixture was diluted with DCM and washed with saturated $NaHCO_3$ solution, water, and brine. The organic layer was dried over anhydrous Na_2SO_4 and concentrated in vacuo. The crude product was chromatographed over silica gel to give 6.9 g (83%) of pure monobenzoate **10** as a colorless liquid: R_f 0.59 (20% EtOAc in petroleum ether); $[\alpha]^{25}_D$ +16.85 (*c* 3.22, $CHCl_3$); IR (thin film) 3451, 3055, 1720, 1451 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 1.36 (s, 3H), 1.38 (s, 3H), 1.40 (s, 3H), 1.47 (s, 3H), 3.76 (bs, 1H, −O*H*), 3.83 (t, J = 7.8 Hz, 1H), 3.95 (t, J = 7.6 Hz, 1H), 4.03 (m, 2H), 4.10 (m, 1H), 4.22 (dd, J = 8.5, 6.1 Hz, 1H), 4.39 (dd, J = 11.6, 6 Hz, 1H), 4.66 (dd, J = 11.6, 2.6 Hz, 1H), 7.44 (m, 2H), 7.56 (m, 1H), 8.08 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 25.1, 26.4, 26.8, 26.82, 66.4, 67.9, 71, 76.4, 80.3, 81, 109.8, 110.3, 128.3 (2C), 130.2, 132.9, 166.6; MS (FAB) 367 ($M^+ + 1$). Anal. Calcd for $C_{19}H_{27}O_7$: C, 62.29; H, 7.38. Found: C, 62.16; H, 7.26.

1,2:3,4-Di-*O*-isopropylidene-5-oxiranyl-D-mannitiol 7. To a cooled (−80 °C) solution of the benzoate **10** (6.9 g, 18.9 mmol) and triethylamine (4.2 mL, 29.9 mmol) in dry DCM (60 mL) was added methanesulfonyl chloride (1.76 mL, 22.6 mmol) dropwise. The reaction mixture was stirred for 15 min at the same temperature and kept in a freezer (−20 °C) overnight. The reaction mixture was diluted with more DCM and washed with water and brine. The DCM layer was dried over anhydrous Na_2SO_4 and concentrated on rotary evaporator. The crude yellow solid was dissolved in MeOH, 6.5 g (47.25 mmol, 2.5 equiv based on theoretical yield) of finely powdered K_2CO_3 was added, and the mixture was stirred vigorously at rt for 2 h. MeOH was evaporated on rotary evaporator. The residue was taken in water and extracted with diethyl ether, and the combined organic layers were washed with brine and dried over anhydrous Na_2SO_4 before concentration. The crude product was chromatographed over silica gel to give the epoxide **7** as a colorless liquid (3.8 g, 82%): R_f 0.54 (10% EtOAc in petroleum ether); $[\alpha]^{25}_D$ −16.50 (*c* 1.15, $CHCl_3$); IR (thin film) 3054, 1454, 1423 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 1.34 (s, 3H), 1.38 (s, 3H), 1.40 (s, 3H), 1.41 (s, 3H), 2.80 (d, J = 3.2 Hz, 2H), 3.10 (m, 1H), 3.83 (dd, J = 7.4, 4.8 Hz, 1H), 3.89 (t, J = 7.8 Hz, 1H), 3.99 (dd, J = 8.5, 4.1 Hz, 1H), 4.07 (m, 1H), 4.15 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 25.2, 26.6, 26.8, 27, 44.8, 52.1, 67.8, 77, 78.5, 80.3, 109.7, 110.2; MS (FAB) 245 ($M^+ + 1$). Anal. Calcd for $C_{12}H_{20}O_5$: C, 59.02; H, 8.20. Found: C, 58.92; H, 8.01.

5-Hydroxy 1,2:3,4-Di-*O*-isopropylidenenonane 11. To a suspension of CuCN (2.20 g, 24.59 mmol) in THF (50 mL) at −80 °C was added *n*-PrLi (15.7 mL, 49.1 mmol, 3.14 M) slowly under N_2 atmosphere. After the mixture was stirred for 30 min at the same temperature, the epoxide **7** (3 g, 12.3 mmol) in anhydrous THF (25 mL) was added dropwise. The reaction was allowed to proceed at the same temperature for 8 h and quenched by the addition of saturated NH_4Cl solution. The organic layer was separated, and the aqueous layer was extracted with ether. The combined organic layers were dried over Na_2SO_4, concentrated, and chromatographed over silica gel to give the product **11** as a colorless viscous liquid (3.47 g, 98%): R_f 0.42 (10% EtOAc in petroleum ether); $[\alpha]^{25}_D$ +1.11 (*c* 1.35, $CHCl_3$); IR (thin film) 3487, 3054, 1456 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) 0.92 (t, J = 6.8 Hz, 3H), 1.35 (s, 3H), 1.38 (s, 3H), 1.41 (s, 3H), 1.42 (s, 3H), 1.34−1.57 (m, 6H), 2.12 (d, J = 9.3 Hz, −OH), 3.66 (m, 1H), 3.91 (m, 2H), 3.96 (m, 1H), 4.05 (m, 1H), 4.14 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) 14.0, 22.7, 25.30, 26.6, 27.1, 27.2, 28.1, 34.5, 67.8, 70.3, 77.3, 77.6, 82.9, 109.3, 109.8; MS (FAB) 289 ($M^+ + 1$). Anal. Calcd for $C_{15}H_{28}O_5$: C, 62.47; H, 9.79. Found: C, 62.50; H, 9.69.

5-Benzyloxy-1,2:3,4-di-*O*-isopropylidenenonane 6. To a suspension of sodium hydride (50% suspension in mineral oil, 1.4 g, 2.5 equiv) in THF (30 mL) was slowly added a solution of the alcohol **11** (3.3 g, 11.4 mmol) in THF (20 mL). After 10 min, benzyl bromide (1.8 mL, 14.8 mmol) was added, and the reaction was allowed to proceed at rt for 12 h. THF was removed in vacuo, and the reaction was quenched by careful addition of water. The aqueous phase was extracted with ether. The combined organic layers were dried over Na_2SO_4, concentrated, and chromatographed over silica gel to give the product **6** as yellow oil (4.11 g, 95%): R_f 0.83 (10% EtOAc in petroleum

ether); $[\alpha]^{25}_D$ +16.93 (*c* 0.95, $CHCl_3$); IR (thin film) 3053, 1454, 1423 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 0.9 (t, J = 6.8 Hz, 3H), 1.34 (s, 3H), 1.36 (m, 3H), 1.38 (s, 6H), 1.44 (s, 3H), 1.67 (m, 3H), 3.53 (m, 1H), 3.90 (m, 1H), 4.01 (m, 2H), 4.09 (m, 2H), 4.63 (ABq, J = 11.5 Hz, 2H), 7.31 (m, 5H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 14.0, 22.8, 25.2, 26.5, 27.0, 27.3, 28.0, 30.9, 67.5, 72.5, 77.2, 77.4, 78.2, 82.0, 109.4, 109.6, 127.5, 127.7, 128.2, 138.7; MS (FAB) 379 (M^+ + 1). Anal. Calcd for $C_{22}H_{34}O_5$: C, 69.84; H, 8.99. Found: C, 69.73; H, 8.68.

1-[5-(1-Benzyloxypentyl)-2,2-dimethyl[1,3]dioxolan-4-yl]ethane-1,2-diol 12. To a solution of the benzyl ether **6** (3.5 g, 9.26 mmol) in MeCN (20 mL) was added $CuCl_2 \cdot 2H_2O$ (1.57 g, 9.26 mmol) at 0 °C. After 40 min, the reaction was quenched by addition of saturated $NaHCO_3$ at the same temperature. The reaction mixture was filtered through Celite and washed with EtOAc, the organic layer was separated, and the aqueous layer was extracted with EtOAc. The combined organic layers were dried over anhydrous Na_2SO_4, concentrated, and chromatographed over silica gel to give 1.0 g of unreacted starting material and 2.01 g (yield after SM recovery 85%) of the diol **12** as a white solid: mp 47 °C; R_f 0.17 (20% EtOAc in petroleum ether); $[\alpha]^{25}_D$ −12.52 (*c* 0.70, $CHCl_3$); IR (CCl_4 soln) 3578, 3405, 1456 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 0.89 (t, J = 6.8 Hz, 3H), 1.31 (m, 3H), 1.36 (s, 3H), 1.39 (s, 3H), 1.51 (m, 1H), 1.60 (m, 1H), 1.70 (m, 1H), 2.2 (bs, 1H, −OH), 3.60−3.79 (m, 5H), 3.91 (t, J = 8.0 Hz, 1H), 4.00 (dd, J = 8.3, 3.4 Hz, 1H), 4.65 (s, 1H), 4.66 (s, 1H), 7.35 (m, 5H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 14.0, 22.7, 26.89, 26.9, 28.6, 29.7, 64.0, 72.5, 73.6, 76.6, 78.1, 80.4, 108.9, 128.2, 128.3, 128.6, 137.1; MS (FAB) 339 (M^+ + 1). Anal. Calcd for $C_{19}H_{30}O_5$: C, 67.45; H, 8.87. Found: C, 67.50; H, 8.8.

4-(1-Benzyloxypentyl)-2,2-dimethyl-5-oxiranyl[1,3]dioxolane 5. To the diol **12** (1.5 g, 4.44 mmol) in a mixture of dry DCM (4 mL) and dry pyridine (4 mL) was added tosyl chloride (889 mg, 4.6 mmol) in portions at 0 °C. The reaction was allowed to proceed at 0 °C for 24 h. The reaction mixture was poured into a mixture of ice-cold ether and 6 N HCl (10 mL). The ether layer was separated, and the aqueous layer was extracted with ether. The combined organic layers were washed with water and brine. Finally, it was dried over anhydrous Na_2SO_4 and concentrated in vacuo. The crude tosylate was taken in MeOH (20 mL), and finely powdered K_2CO_3 (0.62 g) was added at 0 °C. The reaction was allowed to proceed at 0 °C for 1 h. MeOH was removed on rotary evaporator. The residue was taken in water and extracted with ether. The combined organic layers were dried over Na_2SO_4 and concentrated on rotary evaporator, and the crude product was chromatographed over silica gel to give 1.0 g (72% for two steps) of the epoxide **5** as a colorless oil: R_f 0.45 (10% EtOAc in petroleum ether); $[\alpha]^{25}_D$ − 8.60 (*c* 1.29, $CHCl_3$); IR (thin film) 3060, 3029, 1456 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 0.89 (t, J = 6.8 Hz, 3H), 1.32 (m, 3H), 1.42 (s, 3H), 1.43 (s, 3H), 1.62 (m, 3H), 2.66 (dd, J = 4.9, 2.4 Hz, 1H), 2.79 (dd, J = 4.9, 4.1 Hz, 1H), 3.03 (m, 1H), 3.49 (m, 1H), 3.75 (dd, J = 7.6, 5.6 Hz, 1H), 4.08 (dd, J = 7.8, 4.4 Hz, 1H), 4.63 (s, 2H), 7.31 (m, 5H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 14.0, 22.7, 26.7, 26.9, 28.0, 30.5, 45.0, 52.1, 72.9, 77.0, 78.3, 81.0, 109.5, 127.6, 127.9, 128.3, 138.5; MS (FAB) 321 (M^+ + 1). Anal. Calcd for $C_{19}H_{28}O_4$: C, 71.25; H, 8.75. Found: C, 71.12; H, 8.60.

1-[5-(1-Benzyloxypentyl)-2,2-dimethyl[1,3]dioxolan-4-yl]pent-4-en-1-ol 18. To a suspension of CuCN (196 mg, 2.18 mmol) in dry ether (4 mL) at −80 °C was slowly added allylmagnesium bromide (4.4 mmol, 1.11 M in ether) under N_2 atmosphere. After the mixture was stirred for 30 min at the same temperature, the epoxide **5** (350 mg, 1.09 mmol) in 2 mL of ether was added dropwise. The reaction was allowed to proceed at the same temperature for 8 h with gradual warming to −20 °C. The reaction was quenched by addition of saturated NH_4Cl, the organic layer was separated, and the aqueous layer extracted with ether. The combined organic layers were dried over Na_2SO_4, concentrated, and chromatographed over silica gel to give 378 mg (96%) of the alcohol **18** as colorless oil: R_f 0.45 (10% EtOAc in petroleum ether); $[\alpha]^{25}_D$ +2.70 (*c* 1.41, $CHCl_3$); IR (thin film) 3442, 3067, 3030, 1454 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 0.89 (t, J = 5.8 Hz, 3H), 1.34 (m, 3H), 1.40 (s, 3H), 1.42 (s, 3H), 1.45−1.73 (m, 5H), 2.12 (m, 1H), 2.27 (m, 1H), 3.12 (bs, 1H, −OH), 3.58 (m, 2H), 3.80 (t, J = 6.8 Hz, 1H), 3.96 (dd, J = 8.0, 3.2 Hz, 1H), 4.63 (ABq, J = 11.4 Hz, 2H), 5.01 (dd, J = 17.6, 10.2 Hz, 2H), 5.82 (m, 1H), 7.32 (m, 5H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 13.9, 22.7, 26.8, 27.0, 28.4, 29.5, 29.9, 32.5, 71.5, 72.9, 78.0, 79.0, 79.8, 108.3, 114.6, 127.9, 128.1, 128.4, 137.6, 138.5; MS (FAB) 363 (M^+ + 1). Anal. Calcd for $C_{22}H_{34}O_4$: C, 72.93; H: 9.39. Found: C, 72.89; H, 9.28.

1-[5-(1-Benzyloxypentyl)-2,2-dimethyl[1,3]dioxolan-4-yl]pentane-1,5-diol 19. To a cooled solution of the alcohol **18** (343 mg, 0.948 mmol) in dry hexane (1 mL) was added BH_3·DMS (100 μL, 0.948 mmol, 1 equiv) at 0 °C under N_2 atmosphere. The reaction was allowed to proceed for 12 h with gradual warming to rt. Excess borane was destroyed by addition of EtOH (1 mL). To this was added 3 M NaOH (350 μL) in one portion followed by dropwise addition of 30% H_2O_2 (350 μL), and the mixture was stirred for another 2 h at rt. Solvent was evaporated in vacuo, and the residue was taken in water and extracted with EtOAc. The combined organic layers were dried over Na_2SO_4, concentrated, and chromatographed over silica gel to give the diol **19** (277 mg, 77%) as colorless oil: R_f 0.39 (40% EtOAc in petroleum ether); $[\alpha]^{25}_D$ +2.54 (*c* 0.59, $CHCl_3$); IR (thin film) 3413, 3051, 2932, 1456 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 0.89 (t, J = 6.8 Hz, 3H), 1.25−1.48 (m, 6H), 1.37 (s, 3H), 1.39 (s, 3H), 1.52−1.73 (m, 6H), 2.29 (bs, 1H, −O*H*), 3.43 (bs, 1H, −O*H*), 3.59 (m, 4H), 3.79 (t, J = 7.6 Hz, 1H), 3.97 (dd, J = 8.0, 3.2 Hz, 1H), 4.63 (ABq, J = 11.5 Hz, 2H), 7.32 (m, 5H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 14.0, 21.4, 22.7, 26.9, 27.1, 28.5, 29.9, 32.5, 32.9, 62.4, 72.2, 73.0, 78.1, 79.1, 80.0, 108.4, 128.0, 128.2, 128.5, 137.6; MS (FAB) 381 (M^+ + 1). Anal. Calcd for $C_{22}H_{36}O_5$: C, 69.47; H, 9.47. Found: C, 69.50; H, 9.30.

6-[5-(1-Benzyloxypentyl)-2,2-dimethyl[1,3]dioxolan-4-yl]tetrahydropyran-2-one 20. To a solution of the diol **19** (270 mg,0.71 mmol) in dry benzene (10 mL) was added freshly prepared Ag_2CO_3−Celite (6.07 g, 15 equiv), and the mixture was refluxed under N_2 atmosphere for 12 h. The reaction mixture was filtered, concentrated, and chromatographed over silica gel to give 192 mg (72%) of the lactone **20** as a colorless oil: R_f 0.42 (20% EtOAc in petroleum ether); $[\alpha]^{25}_D$ +11.61 (*c* 1.55, $CHCl_3$); IR (thin film) 2931, 1741, 1455, 1372 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 0.89 (t, J = 6.85 Hz, 3H), 1.26−1.64 (m, 5H), 1.39 (s, 3H), 1.44 (s, 3H), 1.64−2.01 (m, 4H), 2.40 (m, 1H), 2.52 (m, 2H), 3.58 (m, 1H), 4.02 (m, 2H), 4.26 (ddd, J = 10.2, 6.6, 3.4 Hz, 1H), 4.51 (d, J = 11.7 Hz, 1H), 4.69 (d, J = 11.7 Hz, 1H), 7.30 (m, 5H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 14.1, 18.1, 22.9, 24.5, 27.0, 27.2, 28.2, 29.9, 30.9, 72.8, 78.1, 80.7, 81.3, 109.6, 127.5, 128.1, 128.3, 138.6, 170.3; MS (FAB) 377 (M^+ + 1). Anal. Calcd for $C_{22}H_{32}O_5$: C, 70.21; H, 8.51. Found: C, 70.10; H, 8.42.

6-(3-Benzyloxy-1,2-dihydroxyheptyl)tetrahydropyran-2-one 21. A solution of the lactone **20** (150 mg, 0.4 mmol) in MeCN (2 mL) was treated with $CuCl_2 \cdot 2H_2O$ (204 mg, 1.20 mmol). The reaction mixture was stirred at rt for 36 h and then quenched by addition of saturated $NaHCO_3$ solution and extracted with EtOAc. The combined organic layers were dried over Na_2SO_4, concentrated, and chromatographed over silica gel to give **21** 107 mg (85%) as a white solid: R_f 0.42 (50% EtOAc in petroleum ether); $[\alpha]^{25}_D$ +19.8 (*c* 0.61, $CHCl_3$); ^1H NMR (400 MHz, $CDCl_3$) δ 0.84 (t, J = 6.8 Hz, 3H), 1.17−1.34 (m, 5H), 1.51−1.84 (m, 4H), 2.06 (m, 1H), 2.39 (m, 1H), 2.51 (m, 1H), 3.16 (bs, 1H, −O*H*), 3.50 (m, 2H), 3.79 (bs, 1H), 4.25 (ddd, J = 10.7, 8.1, 3.4 Hz, 1H), 4.35 (d, J = 11.2 Hz, 1H), 4.62 (d, J = 11.2 Hz, 1H), 7.24 (m, 5H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 13.9, 18.0, 22.9, 24.2, 27.4, 29.4, 29.7, 68.9, 71.5, 74.2, 79.2, 81.7, 128.0, 128.1, 128.7, 137.5, 171.3. Anal. Calcd for $C_{19}H_{28}O_5$: C, 67.86; H, 8.33. Found: C, 67.46; H, 8.21.

Acetic Acid 2,3-Diacetoxy-1-(6-oxotetrahydropyran-2-yl)heptyl Ester 22. A solution of the **21** (75 mg, 0.223 mmol) in dry EtOH (2 mL) was treated with a catalytic amount of Pd−C. The suspension was evacuated and purged with H_2 gas; this process was repeated two times, and the reaction was allowed to proceed under H_2 balloon for 24 h at rt. The reaction mixture was filtered through Celite, washed with some EtOH, and concentrated in vacuo. The crude product in pyridine (2 mL) was treated with DMAP (10 mg) and Ac_2O (100 μL, 10 equiv based on theoretical yield) under N_2 atmosphere. The reaction mixture was stirred at rt for 16 h. The reaction mixture was poured into ice-cold 6 N HCl and extracted with EtOAc. The combined organic layers were washed with saturated aqueous $NaHCO_3$ solution, water, and brine. Finally, the combined organic layers were dried over Na_2SO_4, concentrated, and chromatographed over silica gel to give the lactone **22** (63 mg, 76% for two steps) as a colorless oil: R_f 0.57 (50% EtOAc in petroleum ether); $[\alpha]^{25}_D$ −20.0 (*c* 0.13, EtOH) [lit.[7,8] $[\alpha]^{25}_D$ −19.3 (*c* 0.36, EtOH)]; ^{1}H NMR (400 MHz,$CDCl_3$)[8] δ 0.87 (t, J = 6.6 Hz, 3H), 1.27−1.97 (m, 10H), 2.07 (s, 3H), 2.10 (s, 3H), 2.13 (s, 3H), 2.4−2.6 (m, 2H), 4.42 (ddd, J = 10.7, 5.8, 3.4 Hz, 1H), 5.02 (q, J = 6.4 Hz, 1H), 5.20 (dd, J = 5.8, 4.4 Hz, 1H), 5.35 (dd, J = 5.8, 4.2 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$)[7] δ 13.8, 18.1, 20.6, 20.7, 20.9, 22.3, 23.4, 26.9, 29.5, 30.2, 70.6, 71.3, 71.7, 77.8, 169.7, 169.8, 170.0, 170.4. Anal. Calcd for $C_{18}H_{28}O_8$: C, 58.05; H, 7.58. Found: C, 58.00; H, 7.56.

Benzeneseleninic Anhydride Dehydrogenation of 22. The lactone **22** (20 mg, 0.054 mmol) in anhydrous chlorobenzene (3 mL) was treated with benzeneseleninic anhydride (31 mg, 0.086 mmol) under N_2 atmosphere. The reaction mixture was refluxed for 72 h. The cholorobenzene was removed in vacuo, and the residue was chromatographed over silica gel to give a 1:3 mixture of **2** and **22** (ratio determined by NMR).

3-Benzenesulfonyl-1-[5-(1-benzyloxypentyl)-2,2-dimethyl[1,3]dioxolan-4-yl]-5-(*tert*-butyldimethylsilanyloxy)-pentan-1-ol 23. To the sulfone silyl ether **15** (926 mg, 2.95 mmol) in anhydrous THF (9 mL) was added *n*-BuLi (2 mL 1.46 M in hexanes) dropwise at 0 °C under N_2 atmosphere. The yellow reaction mixture was stirred at the same temperature for 30 min. A suspension of CuI (280 mg, 1.47 mmol) in dry THF (5 mL) was prepared separately. The suspension was cooled to −80 °C. The sulfone silyl ether anion formed previously was added and stirred at the same temperature for 1 h. The epoxide **5** (235 mg. 0.74 mmol) in THF (1.5 mL) was added to the cuprate and stirred for 12 h with gradual warming to −20 °C. The reaction was quenched by addition of saturated aqueous NH_4Cl solution. The organic layer was separated, and the aqueous layer was extracted with ether. The combined organic layers were dried over Na_2SO_4 and concentrated in vacuo. The crude product was chromatographed over silica gel to give **23** in 95% yield: R_f 0.24 (10% EtOAc in petroleum ether); $[\alpha]^{25}_D$ + 10.6 (*c* 0.96, $CHCl_3$); IR (thin film) 3054, 2931, 1449 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 0.00 (m, 6H), 0.85 (m, 9H), 0.89 (t, J = 6.8 Hz, 3H), 1.26−1.38 (m, 9H), 1.63−1.94 (m, 5 H), 2.10−2.39 (m, 1H), 3.48−3.74 (m, 6H), 3.94 (dt, J = 7.3, 3.2 Hz, 1H), 4.62 (m, 2H), 7.34 (m, 5H), 7.55 (m, 2H), 7.65 (m, 1H), 7.90 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ −5.4, 14.0, 18.1, 22.7, 25.8, 25.86, 26.9, 27.1, 28.4, 30.2, 30.9, 32.3, 32.5, 32.9, 58.2, 58.4, 59.9, 60.5, 69.8, 70.9, 73.1, 78.1, 78.3, 79.1, 79.3, 80.8, 81.0, 108.8, 127.8, 127.9, 128.0, 128.2, 128.4, 128.44, 128.9, 128.98, 129.06, 129.12, 133.6, 137.7; MS (FAB) 635 (M^+ + 1). Anal. Calcd for $C_{34}H_{54}O_7SSi$: C, 64.32; H, 8.57. Found: C, 64.29; H, 8.52.

Attempted Oxidation of 24 with $RuCl_2(PPh_3)_3$. The solution of **24** (177 mg, 0.466 mmol) in dry benzene (3 mL) was treated with $RuCl_2(PPh_3)_3$ (223 mg, 0.233 mmol) at 50 °C for 15 h. The reaction mixture was filtered through Celite, and the organic layer was concentrated in vacuo.

6-[5-(1-Hydroxypentyl)-2,2-dimethyl[1,3]dioxolan-4-yl]-tetrahydropyran-2-one 25. The lactone **20** in dry ethanol (2 mL) was treated with a catalytic amount of 10% Pd on activated charcoal. The reaction vessel was evacuated and purged with hydrogen gas; this process was repeated three times, and finally reaction was allowed to proceed for 12 h under hydrogen balloon. The reaction mixture was filtered through a Celite pad and washed with EtOAc. On concentration, hydroxy lactone **25** was obtained in quantitative yield, which was used as such in the next step: R_f 0.26 (25% EtOAc in petroleum ether); $[\alpha]^{25}_D$ −12.6 (*c* 1.98, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 0.91 (t, J = 7.1 Hz, 3H), 1.25−1.50 (m, 4H), 1.40 (s, 3H), 1.44(s, 3H), 1.54 (m, 2H), 1.72 (m, 1H), 1.86 (m, 1H), 1.97 (m, 1H), 2.13 (m, 1H), 2.47 (m, 1H), 2.58 (m, 1H), 3.67 (m, 1H), 3.96 (dd, J = 7.4, 2.4 Hz, 1H), 4.05 (t, J = 7.3 Hz, 1H), 4.31 (ddd, J = 13.7, 7.6, 3.6 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 13.8, 17.9, 22.5, 24.8, 26.9, 27.0, 27.8, 29.6, 34.4, 70.2, 77.6, 81.2, 82.1, 109.6, 170.2. Anal. Calcd for $C_{15}H_{26}O_5$: C, 62.91; H, 9.15. Found: C, 62.86; H, 9.10.

6-[5-(1-Hydroxypentyl)-2,2-dimethyl[1,3]dioxolan-4-yl]-5,6-dihydropyran-2-one 26. A mixture of diisopropylamine (245 μL, 2.44 mmol) and HMPA (1 mL) in anhydrous THF (2 mL) was cooled to −80 °C under N_2 atmosphere. *n*-BuLi (1.7 mL, 2.39 mmol, 1.4 M in hexanes) was added dropwise, and the mixture was stirred for 10 min at the same temperature. A solution of hydroxy lactone **25** in anhydrous THF (1 mL) was added dropwise over a period of 15 min and stirred for 45 min at the same temperature. The enolate was quenched by addition of a freshly prepared solution of phenylselenyl bromide in THF [prepared by addition of bromine (150 μL, 2.37 mmol) to diphenyldiselenide (915 mg, 2.43 mmol) in THF (1 mL) at 0 °C]. After being stirred for 1 h at −80 °C, the reaction was quenched by addition of saturated NH_4Cl at the same temperature. The organic layer was separated, and the aqueous layer was extracted with ether. The combined organic layers were dried over Na_2SO_4 and concentrated in vacuo. The crude product was chromatographed over silica gel and subjected to oxidative elimination. To the product in DCM (1 mL) were added pyridine (725 μL, 8.82 mmol) and 30% H_2O_2 (300 μL, 2.64 mmol) at 0 °C. The reaction mixture was stirred for 6 h with gradual warming to rt. The reaction mixture was diluted with more DCM and washed with water and brine. Finally, the organic layer was dried over Na_2SO_4, concentrated, and chromatographed over silica gel to give **26** as a colorless oil: yield 140 mg (50%); R_f 0.30 (30% EtOAc in petroleum ether). This compound was characterized after conversion of the hydroxy group to acetate.

Acetic Acid 1-[2,2-Dimethyl-5-(6-oxo-3,6-dihydro-2*H*-pyran-2-yl)[1,3]dioxolan-4-yl]pentyl Ester 27. A solution of hydroxy lactone **26** (140 mg) in dry pyridine (500 μL)was treated with few crystals of DMAP and cooled to 0 °C. This was treated with Ac_2O (50 μL) and stirred overnight at rt. The reaction mixture was concentrated under vacuum, and the residue was chromatographed over silica gel to give **27** as a colorless liquid yield 93%: R_f 0.41 (25% EtOAc in petroloeum ether); $[\alpha]^{25}_D$ +40.65 (*c* 1.39, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 0.90 (t, J = 6.8 Hz, 3H), 1.26−1.38 (m, 4H), 1.40 (s, 3H), 1.45 (s, 3H), 1.69 (m, 2H), 2.12 (s, 3H), 2.53 (m, 2H), 3.98 (m, 1H), 4.17 (dd, J = 6.6, 3.4 Hz, 1 H), 4.42 (q, J = 7.1 Hz, 1H), 5.06 (ddd, J = 12.2, 5.1, 3.4 Hz, 1H), 6.04 (td, J = 10, 1.7 Hz, 1H), 6.91 (td, J = 9.8, 4.4 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 13.9, 21.0, 22.5, 25.9, 26.9, 27.6, 29.7, 30.8, 72.5, 77.3, 78.1, 79.9, 11.6, 121.5, 144.5, 162.7, 170.6. Anal. Calcd for $C_{17}H_{26}O_6$: C, 62.56; H, 8.03. Found: C, 62.47; H, 7.98.

Deacetylboronolide 3. To **26** (75 mg, 0.307 mmol) in distilled water (1 mL) was added Amberlite H^+ (100 mg), and the reaction mixture was kept at 70 °C for 7 h. All the solids were removed by filtration, and the aqueous layer was concentrated in vacuo. The residue was crystallized from a 2:1 mixture of hexane and benzene to give **3** as a white solid: yield 60 mg (90%); mp 101 °C (lit.[3] mp 99−100 °C); R_f 0.43 (100% EtOAc); $[\alpha]^{25}_D$ + 54.0 (*c* 0.55, EtOH) [lit.[3] $[\alpha]^{25}_D$ +56.0 (*c* 0.07, EtOH)]: ^{1}H NMR (400 MHz, $CDCl_3$) 0.90 (t, J = 6.8 Hz, 3H), 1.34 (m, 3H), 1.58 (m, 3H), 2.51 (m, 1H), 2.62 (m, 1H), 3.75 (m, 2H), 3.84 (d, J = 7.6 Hz, 1H), 4.52 (ddd, J = 11.6, 7.2, 4.4 Hz, 1H), 6.02 (dd, J = 10.0, 2.4 Hz, 1H), 6.94 (ddd, J = 9.6,

6.0, 2.4 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 13.9, 22.6, 25.8, 27.6, 35.6, 70.0, 74.5, 74.6, 76.7 (along with $CDCl_3$ peaks), 121.1, 145.8, 163.7.

Dideacetylboronolide 4. A solution of **27** (100 mg, 0.306 mmol) in distilled MeCN (1 mL) was treated with $CuCl_2 \cdot 2H_2O$ (156 mg, 0.917 mmol). The reaction mixture was stirred at rt for 24 h and quenched by addition of saturated $NaHCO_3$. The solids were removed by filtration, and aqueous layer was extracted with EtOAc. The combined organic layers were dried over Na_2SO_4, concentrated, and chromatographed over silica gel to give **4**[5b] as a viscous liquid: yield 80 mg (88%); R_f 0.19 (50% EtOAc in petroleum ether); $[\alpha]^{25}_D$ +35.0 (*c* 0.72, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 0.83 (t, J = 6.8 Hz, 3H), 1.26 (m, 4H), 1.59 (m, 2H), 2.04 (s, 3H), 2.46 (m, 2H), 2.82 (bs, 2H), 3.74 (d, J = 6.4, 1H), 3.84 (d, J = 5.4 Hz, 1H), 4.43 (ddd, J = 10.7, 6.8, 4.9 Hz, 1H), 4.95 (q, J = 6.6 Hz, 1H), 5.95 (d. J = 9.8 Hz, 1H), 6.88 (ddd, J = 9.8, 5.6, 3.0 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 13.9, 21.1, 22.5, 25.6, 27.3, 30.4, 70.2, 72.0, 75.5, 77.3, 121.0, 145.7, 163.7, 171.7. Anal. Calcd for $C_{14}H_{22}O_6$: C, 58.73; H, 7.74. Found: C, 58.84; H, 7.80.

Boronolide 2. To **4** (46 mg, 0.16 mmol) in pyridine (1 mL) were added few crystals of DMAP. The reaction mixture was cooled to 0 °C, and Ac_2O (250 μL) was added. The reaction mixture was stirred at rt for 18 h. The reaction mixture was poured into ice-cold dilute HCl and extracted with EtOAc. The organic layer was dried over Na_2SO_4, concentrated, and chromatographed over silica gel to give 50 mg (92%) of **2** as white solid: mp 88 °C (lit.[3] mp 89−90 °C); R_f 0.57 (50% EtOAc in petroleum ether); $[\alpha]^{25}_D$ +25.44 (*c* 0.63, $CHCl_3$) [lit.[2] $[\alpha]^{25}_D$ +25 (EtOH); $[\alpha]^{25}_D$ +28 (*c* 0.08, EtOH)]; ^{1}H NMR (400 MHz, $CDCl_3$) δ 0.83 (t, J = 7.1 Hz, 3H), 1.23 (m, 4H), 1.52 (m, 2H), 2.02 (s, 3H), 2.05 (s, 3H), 2.09 (s, 3H), 2.16−2.30 (m, 1H), 2.43−2.52 (m, 1H), 4.48 (m, 1H), 4.98 (q, J = 6.1 Hz, 1H), 5.29 (m, 2H), 5.97 (dd, J = 9.8, 1.9 Hz, 1H), 6.83 (ddd, J = 2.4, 6.1, 9.8 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 13.7, 20.5, 20.6, 20.8, 22.3, 25.1, 26.9, 30.2, 70.5, 70.6, 71.6, 75.1, 121.3, 144.1, 162.3, 169.5, 169.8, 170.3.

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