JOC The Journal of Organic Chemistry

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Total Synthesis and Determination of the Absolute Configuration of 5,6-Dihydro-α-pyrone Natural Product Synargentolide B†

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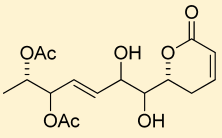
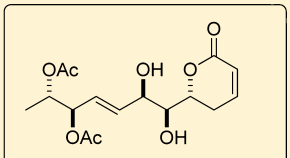
Supporting Information

ABSTRACT: Enantiospecific total synthesis and determination of the absolute stereochemistry of the α-pyrone-containing natural product synargentolide B were accomplished. The absolute stereochemistry of the natural product was established by synthesizing the possible diastereomers and comparison of the data with those reported for the natural product. During the process, total synthesis of the putative structure of related natural product 6*R*-[1*S*,2*R*,5*R*,6*S*-(tetraacetyloxy)-3*E*-heptenyl]-5,6-dihydro-2*H*-pyran-2-one was also accomplished and confirmed by X-ray crystal structure analysis. Wittig–Horner reaction of a chiral phosphonate derived from (*S*)-lactic acid and ring-closing metathesis were the key reactions during the course of the total synthesis.



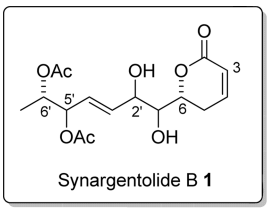
Synargentolide B
(reported structure)



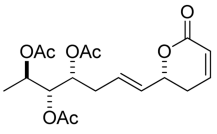
Synargentolide B
(Structure assigned
and confirmed by synthesis)

INTRODUCTION

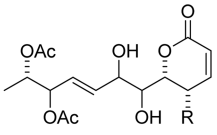
The 5,6-dihydro-α-pyrone unit is a common structural motif found in a number of natural products exhibiting interesting biological activities.[1] Synargentolide B (**1**) is such a pyrone isolated from *Syncolostemon argenteus* by Rivett's group in 1998 along with other synargentolides A (**2**), C (**3**), D (**4**), and E (**5**) (Figure 1).[2] While the absolute stereochemistry of synargentolide A (**2**)[3] was determined and revised by total synthesis, the absolute stereochemistry of the other synargentolides including synargentolide B (**1**) remained uncertain.



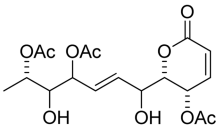
Synargentolide B **1**



Synargentolide A **2**
(revised structure)



R = OAc; Synargentolide C **3**
R = OH; Synargentolide D **4**



Synargentolide E **5**

Figure 1. Synargentolides A–E.

Rivett's group assigned the relative stereochemistry at the C-6, C-6′ positions in synargentolide B (**1**) to be *R*, *S*, respectively, on the basis of the positive Cotton effect in the CD spectrum and from biogenetic arguments proposed for structurally related α-pyrones derived from similar plant species. The absolute stereochemistry of the C-1′, C-2′ diol was proposed to be *threo* by Rivett's group based on the ^{1}H spin-decoupling and NOE difference experiments of the five-membered acetonide derivative **6**.[2] The stereochemistry at C-5′ was not assigned, and the structure of synargentolide B (**1**) was tentatively proposed as 6*R*-[5,6*S*-(diacetyloxy)-1,2-dihydroxy-3*E*-heptenyl]-5,6-dihydro-2*H*-pyran-2-one. Taking this into consideration, the tentative stereochemistry proposed by Rivett's group at the C-6, C-6′ positions and the *threo* relationship at the C-1′ and C-2′ positions of the natural product, it is expected that the structure of synargentolide B (**1**) would be one of the four possible diastereomers **1a–d** possessing the *threo* stereochemistry at the C-1′ and C-2′ of the diol unit (Figure 2).

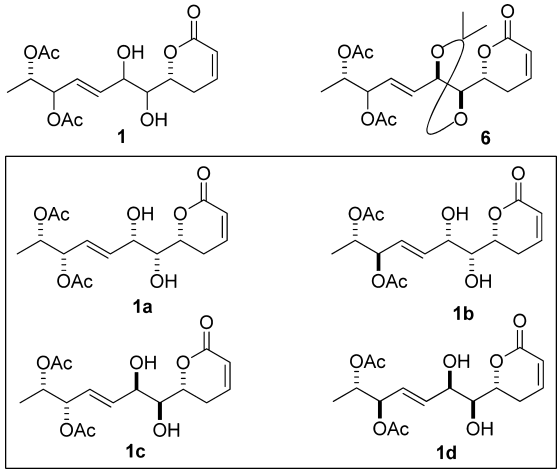


Figure 2. Possible diastereomers of synargentolide B.

Received: January 31, 2013
Published: March 11, 2013

   dx.doi.org/10.1021/jo400083v | *J. Org. Chem.* 2013, 78, 3313–3322

Incidentally, one of the diastereomers 6*R*-[5*R*,6*S*-(diacetyloxy)-1*S*,2*R*-dihydroxy-3*E*-heptenyl]-5,6-dihydro-2H-pyran-2-one (**1d**) was a reported natural product isolated in 1990, nine years prior to the isolation of synargentolide B (**1**) from *Hyptis oblangifolia*[4a] by Pereda-Miranda et al. along with its corresponding diacetylated product **7** (Figure 3). The relative

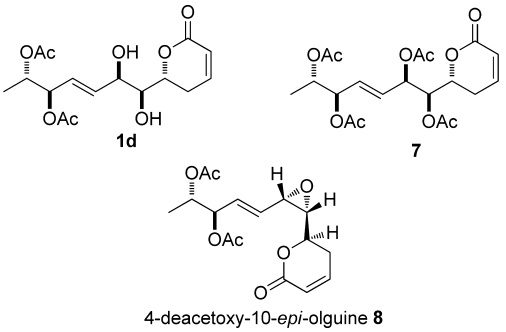


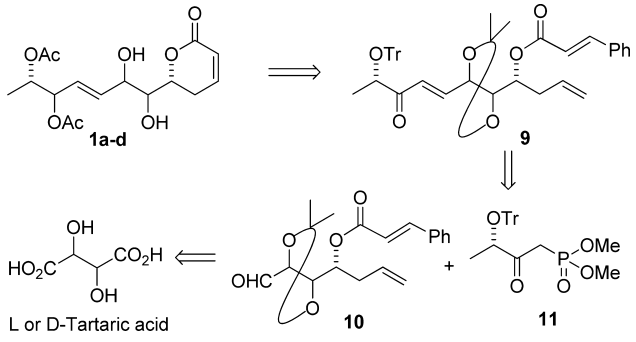
Figure 3. Natural products isolated from *Hyptis oblangifolia*.

stereochemistry of **1d** and **7** was proposed on the basis of the natural product 4-deacetoxy-10-*epi*-olguine **8**, the stereochemistry of which was previously determined by X-ray analysis.[4b] It was proposed that acidic hydrolysis of the epoxide **8** produced the diol **1d**, which on acetylation led to the tetraacetate **7**. Rivett's group observed that synargentolide B (**1**) isolated does not have considerable solubility in $CDCl_3$ and is soluble only in CD_3OD. Since one of the diastereomers, **1d**, isolated earlier by Pereda-Miranda et al. was soluble in $CDCl_3$, Rivett's group inferred that synargentolide B (**1**) may not be the diastereomer **1d** isolated by Pereda-Miranda et al. Considering the above argument, at the outset we undertook the synthesis of diastereomers **1a**–**c** in a quest to ascertain the absolute stereochemistry of synargentolide B (**1**).

RESULTS AND DISCUSSION

In a generalized approach for the diasteromers **1a**–**d**, we envisaged the installation of the C1′-C-2′ *threo* diol unit from abundant L-or D-tartaric acid, while formation of the C3′–C4′ olefin was planned via the Wittig–Horner reaction of the *β*-ketophosphonate **11**[5] derived from lactic acid. Stereoselective reduction of the ketone in **9** was envisioned to install the required stereochemistry at the C-5′ position, while ring-closing metathesis was anticipated for the formation of the *α*-pyrone unit (Scheme 1).

Scheme 1. Retrosynthesis for the Synthesis of Diastereomers 1a–d



Accordingly, the synthetic sequence commenced with the addition of allylmagnesium bromide to the known aldehyde **12**[6] derived from L-tartaric acid to furnish a separable mixture of **13** and known **14**[7] in 40% and 31% yield, respectively, which were separated by column chromatography. Cinnamoylation of **13** yielded the cinnamoyl ester **15** in 87% yield. Deprotection of TBS ether in **15** furnished the primary alcohol **16** in 89% yield. Oxidation of the alcohol in **16** with IBX afforded the aldehyde **10a**, which on reaction with the known phosphonate **11** derived from (*S*)-lactic acid afforded the unsaturated ketone **9a** in 71% yield for two steps. Reduction of ketone in **9a** with $NaBH_4$ in presence of $CeCl_3$ yielded a separable mixture of alcohols **17**[8] and **18** in 76% and 18% yield, respectively. Selective deprotection of the trityl ether in **17** was carried out with PPTS in MeOH to afford the free diol **19** in 90% yield. Acetylation of **19** produced the bis-acetylated product **20** in 89% yield, which on ring-closing metathesis with Grubbs' second-generation catalyst afforded the *α*-pyrone **21a** in 65% yield. Deprotection of the acetonide in **21a** with PPTS in MeOH furnished **1a** in 67% yield (Scheme 2).

It was found that the NMR spectral data of the acetal **21a** and the diastereomer **1a** were not in agreement with the data reported for the acetal **6** and synargentolide B (**1**). Rivett et al.[2] reported that synargentolide B (**1**) does not have considerable solubility in $CDCl_3$ and hence recorded the spectrum in CD_3OD. The diastereomer **1a** was soluble in $CDCl_3$ as well as in CD_3OD and the NMR data of **1a** in either solvent was not in agreement with those reported for the natural synargentolide B (**1**).

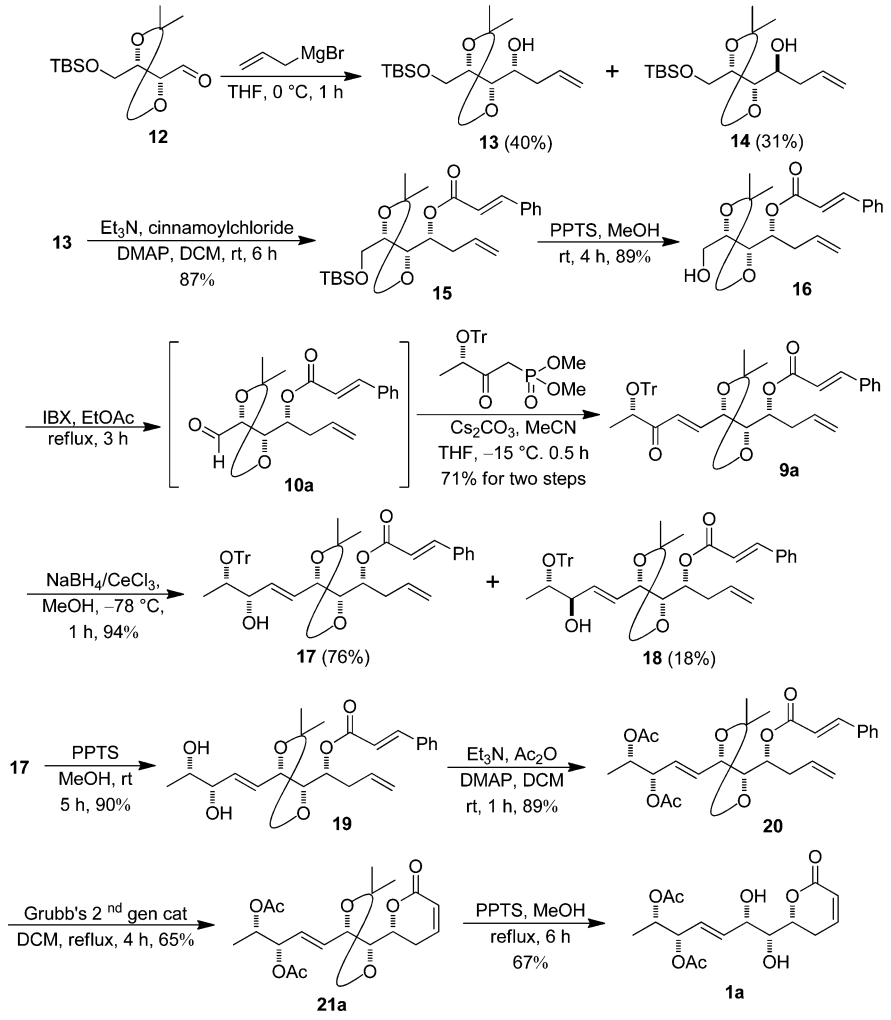
In a similar way, homoallylic alcohol **18** (which was also obtained by Mitsunobu inversion[9] of the alcohol **17**) was elaborated to the diastereomer **1b** following the same synthetic sequence (Scheme 3). NMR spectral data of **1b** in CD_3OD were not in agreement with those reported for synargentolide B (**1**). NMR spectral data of the dimethyl acetal **21b** also did not match those reported for the acetal **6**.

Since data of the diastereomers **1a** and **1b** were not in agreement with those reported for the natural product, we undertook the synthesis of the other two diastereomers **1c** and **1d** employing the homoallylic alcohol *ent*-**14** derived from D-tartaric acid. Thus, reaction of *ent*-**12** with allyl bromide in the presence of zinc[10] furnished a separable mixture of *ent*-**13** and the known *ent*-**14**[10c,d] in 9% and 81% yield, respectively. Applying the same aforementioned sequence for the synthesis of **1a** and **1b**, homoallylic alcohol *ent*-**14** was elaborated to the acetals **21c** and **21d** and subsequently to the diastereomers **1c** and **1d** (Scheme 4).

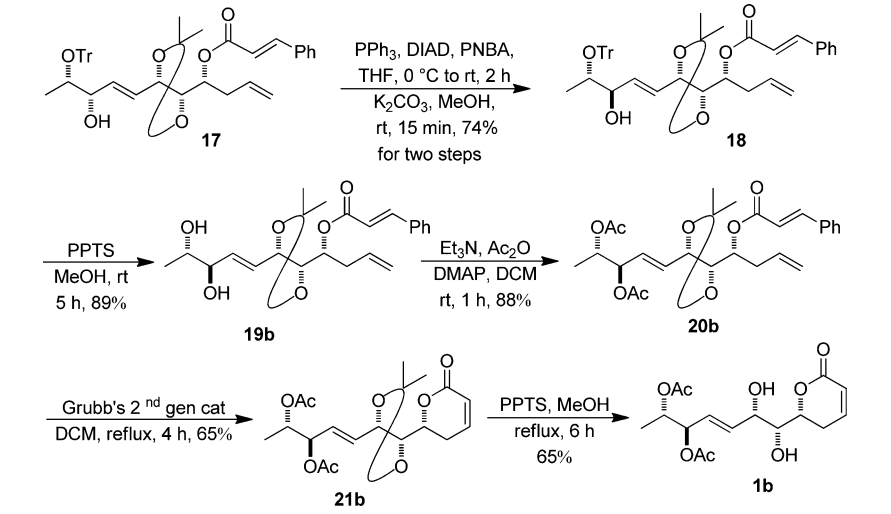
NMR data of **1c** recorded in CD_3OD were not in agreement with those reported for synargentolide B (**1**), while the NMR data of acetal **21c** also were not in agreement with those reported for **6**. However, we were pleased to find that the NMR spectral data of the diastereomeric acetal **21d** in $CDCl_3$ were in complete agreement with those reported for the acetal **6**, while the spectral data of diastereomer **1d** in CD_3OD were also in complete agreement with those reported for synargentolide B (**1**). From the comparison of the spectral data of the four diastereomers of the acetals **21a**–**d** and the diols **1a**–**d** (see Tables 1 and 2, Supporting Information) it was safe to corroborate that the structure of synargentolide B (**1**) isolated by Rivett et al. was indeed identical to the natural product 6*R*-[5*R*,6*S*-(diacetyloxy)-1*S*,2*R*-dihydroxy-3*E*-heptenyl]-5,6-dihydro-2*H*-pyran-2-one (**1d**) isolated by Pereda-Miranda et al. Contrary to the observation of Rivett et al. that synargentolide

dx.doi.org/10.1021/jo400083v | *J. Org. Chem.* 2013, 78, 3313–3322

Scheme 2. Synthesis of the Diastereomer 1a



Scheme 3. Synthesis of the Diastereomer 1b



B (**1**) was insoluble in $CDCl_3$, we found that the synthesized compound was soluble in $CDCl_3$. Specific rotation of the synthesized sample **1d** [+23.3 (*c* 1.2, MeOH)] was different from that reported for synargentolide B (**1**) by Rivett's group [+45.6 (*c* 1.2, MeOH)]. However, the specific rotation $[\alpha]_D$ +26.3 (*c* 0.2, $CHCl_3$) was in agreement with that reported for the same compound $[\alpha]_D$ +28.8 (*c* 0.18, $CHCl_3$) by Pereda-Miranda et al.[4a] The discrepancy in the solubility and the difference in the optical rotation with those reported by Rivett's group might be because of the impurities normally observed in isolation.[11] To confirm the integrity of the diol **1d**, we synthesized the corresponding acetate **7** which was also a

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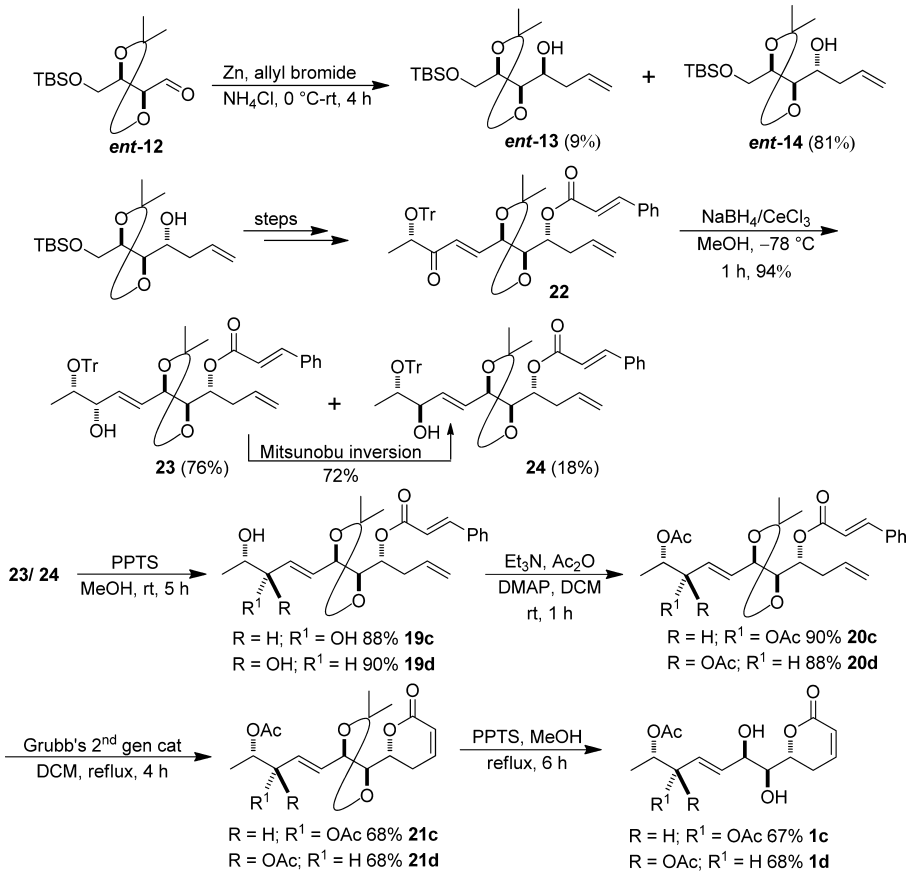
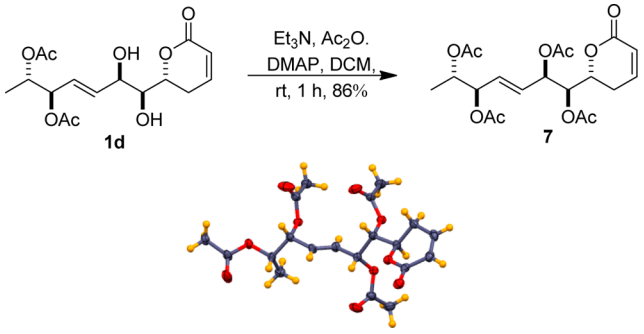
Scheme 4. Synthesis of the Acetals 21c and 21d and the Diastereomers 1c and 1d



natural product isolated by Pereda-Miranda et al. Thus, acylation of **1d** afforded the tetraacetate **7** in 86% yield (Scheme 5). While the ^{1}H NMR data of the synthesized

Scheme 5. Synthesis of the Tetraacetate 7

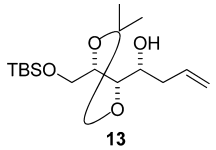


tetraacetate were in reasonable agreement with those reported for the isolated tetraacetate, to our surprise some of the ^{13}C NMR signals differed (see Table 4, Supporting Information). To clear the ambiguity, we determined the crystal structure of the tetraacetate **7**.[12] X-ray crystal structure determination comprehensively proved that the structure of synthesized tetraacetate **7** was indeed the same as the putative structure proposed for the compound by Pereda-Miranda et al. The crystal structure analysis also confirmed the absolute stereochemistry of the tetraacetate **7** and the diol **1d**.

In conclusion, total synthesis and absolute stereochemistry determination of the natural product synargentolide B (**1**) were presented. Out of the possible diastereomers, one of the diastereomers whose NMR spectral data were in agreement with those reported for the natural product was also found to be the same compound isolated earlier from another similar plant species. The absolute stereochemistry of the natural product was further corroborated by X-ray crystal structure of the corresponding acetate.

EXPERIMENTAL SECTION

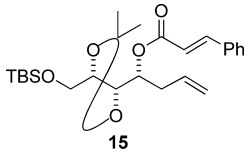
General Procedures. Column chromatography was performed on silica gel, Acme grade 100−200 mesh. TLC plates were visualized either with UV, in an iodine chamber, or with phosphomolybdic acid spray. All reagents were purchased from commercial sources and were used without additional purification. THF was freshly distilled over Na-benzophenone ketyl. Melting points were uncorrected. ^{1}H NMR and ^{13}C NMR spectra were recorded on a 400 MHz machine in $CDCl_3$ or CD_3OD as solvent with TMS as reference unless otherwise indicated. Unless stated otherwise, all reactions were performed under inert atmosphere. All specific rotations were determined at 24 °C. HRMS was obtained using a micromass-QTOF spectrometer using electrospray ionization (ESI).



*(R)-1-((4S,5S)-5-(((tert-Butyldimethylsilyl)oxy)methyl)-2,2-dimethyl-1,3-dioxolan-4-yl)but-3-en-1-ol (**13**).* To a precooled (0 °C), stirred solution of **12** (1.0 g, 3.62 mmol) in THF (15 mL) was added allylmagnesium chloride (7.5 mL, 7.5 mmol) dropwise over 15 min, and the resulting solution was stirred at the same temperature for 1 h. After completion of the reaction (monitored by TLC), it was cautiously quenched by addition of saturated NH_4Cl (10 mL), poured

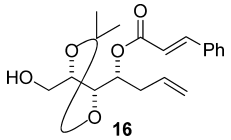
dx.doi.org/10.1021/jo400083v | J. Org. Chem. 2013, 78, 3313−3322

into water (10 mL), and extracted with diethyl ether (3 × 15 mL). The combined organic solution was washed with brine (2 × 10 mL) and dried over Na_2SO_4. Evaporation of the solvent gave the crude residue which was purified by silica gel column chromatography using petroleum ether/EtOAc (9:1) as eluent to furnish **13** (0.46 g, 40%) as a colorless oil and **14** (0.36 g, 31%) as a colorless oil. Data for **13**: $[\alpha]^{24}_D$ +10.2 (*c* 1.1, $CHCl_3$); IR (neat) 3457, 2860, 1641, 1254 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 5.86 (ddt, 1H, *J* = 14.0, 7.0, 4.0 Hz), 5.14 (d, 1H, *J* = 15.6 Hz), 5.11 (d, 1H, *J* = 9.1 Hz), 4.10−3.96 (m, 1H), 3.93 (dd, 1H, *J* = 7.7, 3.2 Hz), 3.80 (dd, 1H, *J* = 10.6, 4.0 Hz), 3.75−3.59 (m, 2H), 2.40−2.23 (m, 3H), 1.42 (s, 3H), 1.40 (s, 3H), 0.89 (s, 9H), 0.07 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 134.5, 117.6, 109.2, 80.8, 77.3, 70.0, 63.6, 39.0, 27.1 (2C), 25.8 (3C), 18.3, −5.5 (2C); HRMS for $C_{16}H_{32}O_4Si$ + Na calcd 339.1968, found 339.1970.



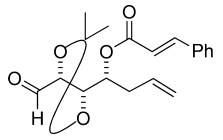
15

*(R)-1-((4S,5S)-5-(((tert-Butyldimethylsilyl)oxy)methyl)-2,2-dimethyl-1,3-dioxolan-4-yl)but-3-en-1-yl Cinnamate (**15**).* To a precooled (0 °C) stirred solution of **13** (0.32 g, 1.0 mmol) in dichloromethane (5 mL) were added Et_3N (0.4 mL, 3.0 mmol), DMAP (0.025 g, 0.20 mmol), and cinnamoylchloride (0.25 g, 1.5 mmol). The reaction mixture was allowed to warm to room temperature and stirred at the same temperature for 6 h. After completion of the reaction (TLC), the reaction mixture was poured into water (10 mL) and extracted with diethyl ether (3 × 15 mL). The combined organic solution was washed with brine (2 × 5 mL) and dried over Na_2SO_4. Evaporation of the solvent gave crude residue which was purified by silica gel column chromatography using petroleum ether/Et_2O (9:1) to give **15** (0.39 g, 87%) as a colorless oil: $[\alpha]^{24}_D$ +3.3 (*c* 1.1, $CHCl_3$); IR (neat) 2931, 1716, 1638, 1166 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.72 (d, 1H, *J* = 16.0 Hz), 7.58−7.46 (m, 2H), 7.44−7.33 (m, 3H), 6.47 (d, 1H, *J* = 16.0 Hz), 5.80 (ddt, 1H, *J* = 14.2, 10.2, 7.1 Hz), 5.24−5.09 (m, 2H), 5.09 (d, 1H, *J* = 10.2 Hz), 4.16 (dd, 1H, *J* = 7.7, 3.1 Hz), 3.90 (dt, 1H, *J* = 8.4, 4.4 Hz), 3.84−3.64 (m, 2H), 2.60−2.43 (m, 2H), 1.47 (s, 3H), 1.42 (s, 3H), 0.91 (s, 9H), 0.07 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.4, 145.3, 134.3, 133.3, 130.3, 128.9 (2C), 128.1 (2C), 118.2, 117.8, 109.3, 78.1, 77.2, 71.2, 63.1, 36.0, 27.2, 27.0, 25.9 (3C), 18.3, −5.4, −5.5; HRMS for $C_{25}H_{38}O_5Si$ + Na calcd 469.2386, found 469.2389.



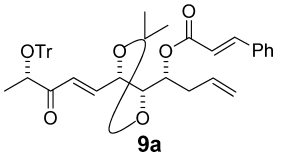
16

*(R)-1-((4S,5S)-5-(Hydroxymethyl)-2,2-dimethyl-1,3-dioxolan-4-yl)but-3-en-1-yl Cinnamate (**16**).* To a stirred solution of **15** (0.38 g, 0.85 mmol) in MeOH (10 mL) was added PPTS (0.43 g, 1.7 mmol) at room temperature, and the resulting solution was stirred at the same temperature for 4 h. After completion of the reaction (indicated by TLC), MeOH was evaporated under vacuum and the reaction mixture was diluted with DCM (10 mL). Solid $NaHCO_3$ (0.29 g, 3.4 mmol) was added to the reaction mixture, which was stirred for an additional 15 min. The reaction mixture was then filtered through a short pad of Celite, and the Celite pad was washed with DCM (3 × 10 mL). Evaporation of the solvent followed by silica gel column chromatography of the resulting residue using petroleum ether/EtOAc (4:1) as eluent yielded **16** (0.25 g, 89%) as a colorless oil: $[\alpha]^{24}_D$ +16.1 (*c* 1.7, $CHCl_3$); IR (neat) 3471, 1711, 1637, 1168 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.73 (d, 1H, *J* = 16.1 Hz), 7.58−7.47 (m, 2H), 7.45−7.33 (m, 3H), 6.46 (d, 1H, *J* = 16.0 Hz), 5.81 (ddt, 1H, *J* = 14.2, 10.1, 7.1 Hz), 5.26−5.12 (m, 1H), 5.13 (d, 1H, *J* = 14.5 Hz), 5.09 (d, 1H, *J* = 10.1 Hz), 4.11 (dd, 1H, *J* = 8.3, 2.9 Hz), 3.93 (dt, 1H, *J* = 7.8, 3.8 Hz), 3.84 (dd, 1H, *J* = 12.1, 3.4 Hz), 3.69 (dd, 1H, *J* = 12.0, 4.1 Hz), 2.65−2.41 (m, 2H), 1.46 (s, 3H), 1.44 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.6, 145.8, 134.2, 133.1, 130.5, 128.9 (2C), 128.2 (2C), 118.4, 117.4, 109.4, 77.4, 77.0, 70.7, 61.7, 35.9, 27.1, 26.8; HRMS for $C_{19}H_{24}O_5$ + Na calcd 355.1521, found 355.1524.



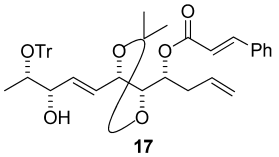
10a

*(R)-1-((4S,5R)-5-Formyl-2,2-dimethyl-1,3-dioxolan-4-yl)but-3-en-1-yl Cinnamate (**10a**).* To a stirred solution of **16** (0.23 g, 0.7 mmol) in EtOAc (5 mL) was added IBX (0.59 g, 2.1 mmol) at room temperature, and the resulting solution was refluxed for 3 h. After completion of the reaction (monitored by TLC), the solution was filtered through a short pad of Celite and the Celite pad was washed with diethyl ether (3 × 10 mL). The combined organic solution was washed with saturated $NaHCO_3$ solution (10 mL) and brine (10 mL), dried over Na_2SO_4, and concentrated. The crude aldehyde thus obtained was used in the next step without purification.

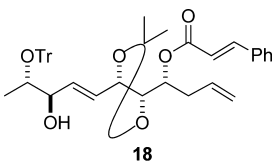


9a

*(R)-1-((4S,5S)-2,2-Dimethyl-5-((S,E)-3-oxo-4-(trityloxy)pent-1-en-1-yl)-1,3-dioxolan-4-yl)but-3-en-1-yl Cinnamate (**9a**).* Cs_2CO_3 (0.68 g, 2.1 mmol) was added to a solution of the phosphonate **11** (0.31 g, 0.7 mmol) in MeCN (5 mL), and the resulting solution was stirred for 45 min at room temperature. The reaction mixture was cooled to −15 °C, and the solution of the aldehyde **10a** obtained above in THF (5 mL) was added dropwise and stirred for 30 min at the same temperature. After completion of the reaction (monitored by TLC), the solution was cautiously quenched by addition of saturated citric acid (5 mL), poured into water (10 mL), and extracted with diethyl ether (3 × 10 mL). The combined organic solution was washed with brine (2 × 5 mL) and dried over Na_2SO_4. Evaporation of solvent gave the crude residue which was purified by silica gel column chromatography using petroleum ether:EtOAc (5:1) as eluent to furnish **9a** (0.32 g, 71% for two steps from **16**) as a colorless oil: $[\alpha]^{24}_D$ −66.5 (*c* 0.9, $CHCl_3$); IR (neat) 1713, 1636, 1166 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.73 (d, 1H, *J* = 16.0 Hz), 7.60−7.35 (m, 11H), 7.35−7.16 (m, 9H), 6.61−6.37 (m, 3H), 5.71 (ddt, 1H, *J* = 17.2, 11.0, 7.2 Hz), 5.14 (d, 2H, *J* = 17.1 Hz), 5.08 (d, 1H, *J* = 9.9 Hz), 4.26 (d, 1H, *J* = 8.4 Hz), 4.25 (d, 1H, *J* = 7.2 Hz), 3.79 (dd, 1H, *J* = 8.2, 2.5 Hz), 2.60−2.38 (m, 2H), 1.47 (s, 3H), 1.41 (s, 3H), 1.29 (d, 3H, *J* = 6.9 Hz); ^{13}C NMR (100 MHz, $CDCl_3$) δ 200.7, 166.2, 145.7, 143.9 (3C), 141.2, 134.2, 132.8, 130.5, 129.0 (6C), 128.9 (2C), 128.2 (2C), 127.9 (6C), 127.3 (3C), 125.3, 118.6, 117.4, 110.1, 88.0, 80.6, 76.2, 75.8, 69.8, 36.0, 26.8, 26.7, 19.7; HRMS for $C_{42}H_{42}O_6$ + Na calcd 665.2879, found 665.2874.



17



18

*(R)-1-((4S,5S)-5-((3S,4S,E)-3-Hydroxy-4-(trityloxy)pent-1-en-1-yl)-2,2-dimethyl-1,3-dioxolan-4-yl)but-3-en-1-yl Cinnamate (**17**).* $CeCl_3 \cdot 7H_2O$ (0.23 g, 0.62 mmol) was added to a stirred solution of **9a** (0.2 g, 0.31 mmol) in MeOH (5 mL), and the resulting solution was allowed to stir for 45 min at room temperature. The reaction mixture was cooled to −78 °C, and $NaBH_4$ (0.024 g, 0.62 mmol) was added portionwise over 10 min and stirred for 1 h at the same temperature. After completion of the reaction (monitored by TLC), the solution was quenched by the addition of water (1 mL) at −78 °C, slowly allowed to warm to room temperature, and stirred for additional 30 min at room temperature. The reaction mixture was then poured into water (10 mL) and extracted with diethyl ether (3 ×

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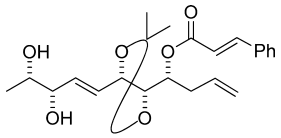
10 mL). The combined organic solution was washed with brine (2 × 5 mL) and dried over Na_2SO_4. Evaporation of solvent followed by silica gel column chromatography of the resulting residue using petroleum ether/Et_2O (5:1) as eluent furnished **17** (0.153 g, 76%) as a colorless oil and **18** (0.035 g, 18%) as a colorless oil. Data for **17**: $[\alpha]^{24}_D$ −31.6 (*c* 2.1, $CHCl_3$); IR (neat) 3441, 1712, 1637 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.72 (d, 1H, *J* = 16.0 Hz), 7.58−7.35 (m, 11H), 7.37−7.19 (m, 9H), 6.48 (d, 1H, *J* = 15.9 Hz), 5.84 (dd, 1H, *J* = 15.7, 5.3 Hz), 5.85−5.62 (m, 2H), 5.22−5.02 (m, 3H), 4.25 (t, 1H, *J* = 7.4 Hz), 3.84 (dd, 1H, *J* = 8.3, 2.4 Hz), 3.84−3.73 (m, 1H), 3.48 (dq, 1H, *J* = 11.7, 5.7 Hz), 2.63−2.43 (m, 2H), 2.05 (d, 1H, *J* = 3.8 Hz), 1.47 (s, 3H), 1.45 (s, 3H), 0.92 (d, 3H, *J* = 6.1 Hz); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.3, 145.4, 144.8 (3C), 134.3, 133.8, 133.1, 130.4, 128.9 (2C), 128.9 (6C), 128.3, 128.1 (2C), 127.8 (6C), 127.1 (3C), 118.4, 117.7, 109.3, 86.9, 81.3, 77.5, 74.3, 73.0, 69.9, 36.2, 27.1, 26.7, 16.8; HRMS for $C_{42}H_{44}O_6$ + Na calcd 667.3036, found 667.3038.

Data for ***18****:* $[\alpha]^{24}_D$ −6.3 (*c* 1.0, $CHCl_3$); IR (neat) 3413, 1715, 1636 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.72 (d, 1H, *J* = 16.0 Hz), 7.58−7.46 (m, 8H), 7.45−7.20 (m, 12H), 6.46 (d, 1H, *J* = 16.0 Hz), 5.74 (ddt, 1H, *J* = 17.0, 9.9, 7.0 Hz), 5.54 (ddd, 2H, *J* = 19.6, 15.6, 4.1 Hz), 5.20−5.00 (m, 3H), 4.23−4.06 (m,1H), 3.82 (dd, 1H, *J* = 8.2, 2.7 Hz), 3.74 (dq, 1H, *J* = 8.9, 2.6 Hz), 3.34−3.24 (m, 1H), 2.60−2.35 (m, 2H), 2.25 (bd, 1H, *J* = 2.2 Hz), 1.44 (s, 3H), 1.43 (s, 3H), 1.03 (d, 3H, *J* = 6.3 Hz); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.2, 145.4, 144.7 (3C), 134.3, 134.1, 133.1, 130.4, 128.9 (2C), 128.8 (6C), 128.1 (2C), 127.9 (6C), 127.2 (3C), 127.2, 118.4, 117.7, 109.3, 87.3, 81.1, 77.7, 73.1, 72.5, 70.0, 36.1, 27.1, 26.7, 15.1; HRMS for $C_{42}H_{44}O_6$ + Na calcd 667.3036, found 667.3038.

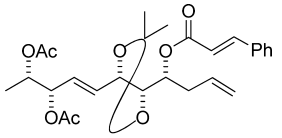
Synthesis of ***18*** *from* ***17*** *by Mitsunobu Inversion.* To a precooled (0 °C) solution of **17** (0.1 g, 0.15 mmol), in toluene (0.5 mL) were added triphenylphosphine (0.118 g, 0.45 mmol), *p*-nitrobenzoic acid (0.075 g, 0.45 mmol), and DIAD (0.1 mL, 0.5 mmol). The reaction mixture was then slowly allowed to warm to room temperature and stirred for 2 h. After completion of the reaction (monitored by TLC), most of the solvent was evaporated under vacuum, and the residue obtained was purified by silica gel column chromatography using petroleum ether/Et_2O (9:1) as eluent to give *p*-nitrobenzoate as a colorless oil which was used in the next step without any further characterization.

To a solution of the *p*-nitrobenzoate obtained above in MeOH (3 mL) was added K_2CO_3 (0.062 g, 0.45 mmol), and the resulting solution was stirred for 15 min at room temperature. After completion of the reaction (monitored by TLC), the mixture was poured into water (5 mL) and extracted with diethyl ether (3 × 5 mL). The combined organic solution was washed with brine (2 × 5 mL) and dried over Na_2SO_4. Evaporation of solvent gave the crude residue which was purified by silica gel column chromatography using petroleum ether/Et_2O (5:1) as eluent to furnish **18** (0.072 g, 74% for two steps) as a colorless oil. Spectral and physical data are same as those described previously obtained from the reduction of **9a**.



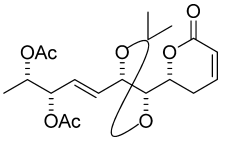
19

*(R)-1-((4S,5S)-5-((3S,4S,E)-3,4-Dihydroxypent-1-en-1-yl)-2,2-dimethyl-1,3-dioxolan-4-yl)but-3-en-1-yl Cinnamate (****19****).* To a stirred solution of **17** (0.051 g, 0.08 mmol) in MeOH (3 mL) was added PPTS (0.060 g, 0.24 mmol) at room temperature, and the resulting solution was stirred for 5 h. After completion of the reaction (indicated by TLC), MeOH was evaporated under vacuum and the reaction mixture was diluted with DCM (5 mL). Solid $NaHCO_3$ (0.04 g, 0.48 mmol) was added to the reaction mixture, which was stirred for an additional 15 min. The reaction mixture was then filtered through a short pad of Celite, and the Celite pad was washed with DCM (3 × 10 mL). Evaporation of solvent followed by silica gel column chromatography of the resulting residue using petroleum ether/EtOAc (1:1) as eluent yielded **19** (0.029 g, 90%) as a colorless oil: $[\alpha]^{24}_D$ −16.5 (*c* 1.0, $CHCl_3$); IR (neat) 3412, 1710, 1637 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.74 (d, 1H, *J* = 16.0 Hz), 7.66−7.48 (m, 2H), 7.46−7.30 (m, 3H), 6.48 (d, 1H, *J* = 16.0 Hz), 6.03−5.67 (m, 3H), 5.23−5.03 (m, 3H), 4.23 (t, 1H, *J* = 8.2 Hz), 3.91 (t, 1H, *J* = 6.0 Hz), 3.86 (dd, 1H, *J* = 8.4, 2.3 Hz), 3.68 (dq, 1H, *J* = 12.5, 6.2 Hz), 2.72 (bs, 2H), 2.68−2.41 (m, 2H), 1.47 (s, 3H), 1.45 (s, 3H), 1.20 (d, 3H, *J* = 6.3 Hz); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.4, 145.7, 134.9, 134.2, 133.0, 130.5, 128.9 (2C), 128.8, 128.2 (2C), 118.5, 117.5, 109.4, 81.1, 77.4, 76.4, 70.5, 69.6, 36.1, 27.0, 26.7, 18.9; HRMS for $C_{23}H_{30}O_6$ + Na calcd 425.1940, found 425.1941.



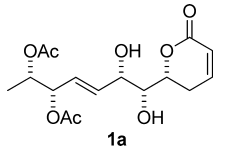
20

*(2S,3S,E)-5-((4S,5S)-5-((R)-1-(Cinnamoyloxy)but-3-en-1-yl)-2,2-dimethyl-1,3-dioxolan-4-yl)pent-4-ene-2,3-diyl Diacetate (****20****).* To a precooled (0 °C) stirred solution of **19** (0.025 g, 0.062 mmol) in dichloromethane (2 mL) were added Et_3N (0.05 mL, 0.37 mmol), DMAP (0.003 g, 0.025 mmol), and acetic anhydride (0.04 mL, 0.37 mmol). The reaction mixture was allowed to warm to room temperature and stirred at the same temperature for 1 h. After completion of the reaction, the reaction mixture was poured into water (5 mL) and extracted with diethyl ether (3 × 5 mL). The combined organic solution was washed with brine (2 × 5 mL) and dried over Na_2SO_4. Evaporation of solvent gave the crude residue which was purified by silica gel column chromatography using petroleum ether/EtOAc (5:1) to give **20** (0.027 g, 89%) as a colorless oil: $[\alpha]^{24}_D$ −16.6 (*c* 1.0, $CHCl_3$); IR (neat) 1741, 1714, 1637 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.74 (d, 1H, *J* = 16.0 Hz), 7.67−7.49 (m, 2H), 7.46−7.30 (m, 3H), 6.47 (d, 1H, *J* = 16.0 Hz), 5.88−5.68 (m, 3H), 5.42−5.29 (m, 1H), 5.23−4.96 (m, 4H), 4.22 (dd, 1H, *J* = 6.5, 1.8 Hz), 3.81 (dd, 1H, *J* = 8.4, 2.1 Hz), 2.63−2.38 (m, 2H), 2.08 (s, 3H), 2.07 (s, 3H), 1.46 (s, 3H), 1.44 (s, 3H), 1.22 (d, 3H, *J* = 6.4 Hz); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.2, 169.8, 166.3, 145.6, 134.2, 133.0, 131.4, 130.5, 128.9 (2C), 128.8, 128.1 (2C), 118.4, 117.5, 109.6, 81.1, 77.0, 74.4, 70.4, 69.6, 36.1, 27.0, 26.7, 21.1, 20.9, 16.1; HRMS for $C_{27}H_{34}O_8$ + Na calcd 509.2151, found 509.2152.



21a

*(2S,3S,E)-5-((4S,5S)-2,2-Dimethyl-5-((R)-6-oxo-3,6-dihydro-2H-pyran-2-yl)-1,3-dioxolan-4-yl)pent-4-ene-2,3-diyl Diacetate (****21a****).* To a stirred solution of **20** (0.02 g, 0.04 mmol) in DCM (6 mL) was added Grubbs' second-generation catalyst (0.004 g, 0.004 mmol) at room temperature, and the resulting solution was refluxed for 4 h. After completion of the reaction (indicated by TLC), DCM was evaporated under vacuum, and the resulting crude reaction mixture was purified by silica gel column chromatography using petroleum ether:EtOAc (3:7) as eluent to yield **21a** (0.01 g, 65%) as a colorless oil: $[\alpha]^{24}_D$ −9.4 (*c* 0.45, $CHCl_3$); IR (neat) 2855, 1738, 1062 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 6.99−6.85 (m, 1H), 6.04 (dd, 1H, *J* = 9.7, 1.8 Hz), 5.84 (dd, 1H, *J* = 16.0, 6.1 Hz), 5.75 (dd, 1H, *J* = 15.7, 7.0 Hz), 5.34 (t, 1H, *J* = 5.5 Hz), 5.05 (dq, 1H, *J* = 12.6, 6.4 Hz), 4.68 (t, 1H, *J* = 7.8 Hz), 4.48−4.35 (m, 1H), 3.71 (dd, 1H, *J* = 8.4, 2.1 Hz), 2.78−2.60 (m, 1H), 2.42−2.25 (m, 1H), 2.11 (s, 3H), 2.05 (s, 3H), 1.45 (s, 3H), 1.44 (s, 3H), 1.21 (d, 3H, *J* = 6.4 Hz); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.2, 169.8, 163.5, 144.8, 130.6, 129.5, 121.2, 110.1, 81.1, 75.9, 74.1, 73.9, 70.3, 27.1, 26.5 (2C), 21.0, 20.9, 16.0; HRMS for $C_{19}H_{26}O_8$ + Na calcd 405.1525, found 405.1529.



1a

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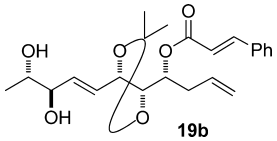
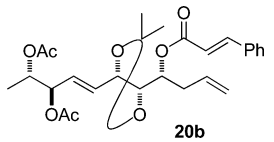
*(2S,3S,6S,7R,E)-6,7-Dihydroxy-7-((R)-6-oxo-3,6-dihydro-2H-pyran-2-yl)hept-4-ene-2,3-diyl Diacetate (**1a**).* To a stirred solution of **21a** (0.01 g, 0.026 mmol) in MeOH (3 mL) was added PPTS (0.02 g, 0.08 mmol) at room temperature, and the resulting solution was refluxed for 6 h. After completion of the reaction (indicated by TLC), MeOH was evaporated under vacuum and the reaction mixture was diluted with DCM (5 mL). Solid $NaHCO_3$ (0.014 g, 0.16 mmol) was added to the reaction mixture which was stirred for additional 15 min. The reaction mixture was then filtered through a short pad of Celite, and the Celite pad was washed with DCM (3 × 5 mL). Evaporation of solvent followed by silica gel column chromatography of the resulting residue using EtOAc as eluent yielded **1a** (0.006 g, 67%) as a colorless oil: $[\alpha]^{24}_D$ +5.6 (*c* 0.2, $CHCl_3$); IR (neat) 3449, 1735, 1234 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.03–6.89 (m, 1H), 6.03 (dd, 1H, *J* = 9.8, 2.5 Hz), 5.95–5.69 (m, 2H), 5.37–5.23 (m, 1H), 5.07 (qd, 1H, *J* = 12.4, 6.2 Hz), 4.53 (dt, 1H, *J* = 12.8, 3.4 Hz), 4.45–4.35 (m, 1H), 3.57–3.47 (m, 1H), 2.92–2.70 (m, 3H), 2.41–2.22 (m, 1H), 2.10 (s, 3H), 2.05 (s, 3H), 1.20 (d, 3H, *J* = 6.5 Hz); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.4, 170.1, 163.6, 145.7, 132.9, 128.0, 120.7, 77.8, 74.8, 74.6, 71.7, 70.4, 25.8, 21.0 (2C), 16.1; HRMS for $C_{16}H_{22}O_8$ + Na calcd 365.1212, found 365.1211.

$[\alpha]^{24}_D$ −11.0 (*c* 0.3, MeOH); ^1H NMR (400 MHz, CD_3OD) δ 7.15–7.02 (m, 1H), 5.96 (dd, 1H, *J* = 9.7, 2.1 Hz), 5.88 (dd, 1H, *J* = 15.6, 6.8 Hz), 5.78 (dd, 1H, *J* = 15.6, 6.8 Hz), 5.32 (t, 1H, *J* = 5.9 Hz), 5.03 (dq, 1H, *J* = 12.5, 6.4 Hz), 4.51 (dt, 1H, *J* = 12.6, 3.4 Hz), 4.30 (t, 1H, *J* = 6.8 Hz), 3.48 (qd, 1H, *J* = 6.9, 3.2 Hz), 2.89–2.65 (m, 1H), 2.44–2.27 (m, 1H), 2.07 (s, 3H), 2.02 (s, 3H), 1.19 (d, 3H, *J* = 6.5 Hz); ^{13}C NMR (100 MHz, CD_3OD) δ 172.3, 172.1, 166.8, 149.0, 135.6, 128.5, 120.8, 79.6, 76.6, 75.9, 73.5, 72.1, 26.8, 21.0, 20.9, 16.3.



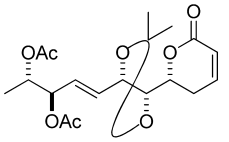
19b

*(R)-1-((4S,5S)-5-((3R,4S,E)-3,4-Dihydroxypent-1-en-1-yl)-2,2-dimethyl-1,3-dioxolan-4-yl)but-3-en-1-yl Cinnamate (**19b**).* The above diol **19b** was synthesized from **18** (0.045 g, 0.07 mmol) following the same procedure described for the synthesis of **19**. (0.025 g, 89%, colorless oil): $[\alpha]^{24}_D$ −5.8 (*c* 1.8, $CHCl_3$); IR (neat) 3418, 1710, 1639 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.74 (d, 1H, *J* = 16.0 Hz), 7.60–7.48 (m, 2H), 7.46–7.30 (m, 3H), 6.48 (d, 1H, *J* = 16.0 Hz), 5.91 (dd, 1H, *J* = 15.5, 5.4 Hz), 5.88–5.62 (m, 2H), 5.24–5.10 (m, 2H), 5.09 (d, 1H, *J* = 10.2 Hz), 4.23 (t, 1H, *J* = 8.0 Hz), 4.15 (dq, 1H, *J* = 15.3, 7.6 Hz), 3.95–3.80 (m, 2H), 2.66–2.42 (m, 4H), 1.47 (s, 3H), 1.46 (s, 3H), 1.17 (d, 3H, *J* = 6.4 Hz); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.5, 145.8, 134.1, 134.0, 133.0, 130.5, 128.9 (2C), 128.6, 128.2 (2C), 118.5, 117.4, 109.3, 81.2, 77.6, 75.2, 70.2, 69.6, 36.1, 27.0, 26.7, 17.7; HRMS for $C_{23}H_{30}O_6$ + Na calcd 425.1940, found 425.1941.



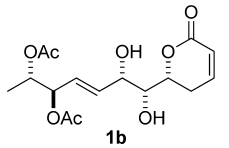
20b

*(2S,3R,E)-5-((4S,5S)-5-((R)-1-(Cinnamoyloxy)but-3-en-1-yl)-2,2-dimethyl-1,3-dioxolan-4-yl)pent-4-ene-2,3-diyl Diacetate (**20b**).* The above diacetate was synthesized from **19b** (0.021 g, 0.05 mmol) following the same procedure described for the synthesis of **20** (0.022 g, 88%, colorless oil): $[\alpha]^{24}_D$ −50.7 (*c* 1.3, $CHCl_3$); IR (neat) 1741, 1714, 1638 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.74 (d, 1H, *J* = 16.0 Hz), 7.59–7.30 (m, 5H), 6.48 (d, 1H, *J* = 16.0 Hz), 5.86–5.68 (m, 3H), 5.46–5.35 (m, 1H), 5.23–5.03 (m, 4H), 4.32–4.19 (m, 1H), 3.85 (dd, 1H, *J* = 8.3, 2.6 Hz), 2.59–2.46 (m, 2H), 2.08 (s, 3H), 2.06 (s, 3H), 1.47 (s, 3H), 1.45 (s, 3H), 1.21 (d, 3H, *J* = 6.6 Hz); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.3, 169.9, 166.3, 145.6, 134.2, 133.0, 131.4, 130.4, 128.9 (2C), 128.3, 128.1 (2C), 118.4, 117.5, 109.6, 81.1, 77.1, 74.2, 70.4, 69.8, 36.0, 27.0, 26.7, 21.1, 21.0, 15.0; HRMS for $C_{27}H_{34}O_8$ + Na calcd 509.2151, found 509.2152.



21b

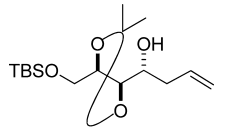
*(2S,3R,E)-5-((4S,5S)-2,2-Dimethyl-5-((R)-6-oxo-3,6-dihydro-2H-pyran-2-yl)-1,3-dioxolan-4-yl)pent-4-ene-2,3-diyl Diacetate (**21b**).* Compound **21b** was synthesized from **20b** (0.02 g, 0.04 mmol) following the same procedure described for the synthesis of **21a** (0.01 g, 65%, colorless oil): $[\alpha]^{24}_D$ −22.5 (*c* 1.1, $CHCl_3$); IR (neat) 1742, 1159 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 6.99–6.86 (m, 1H), 6.04 (dd, 1H, *J* = 9.8, 2.0 Hz), 5.87 (dd, 1H, *J* = 15.6, 6.6 Hz), 5.79 (dd, 1H, *J* = 15.7, 7.2 Hz), 5.36 (dd, 1H, *J* = 6.3, 3.4 Hz), 5.08 (dq, 1H, *J* = 9.9, 6.4 Hz), 4.69 (t, 1H, *J* = 7.9 Hz), 4.42 (dd, 1H, *J* = 11.6, 3.4 Hz), 3.75 (dd, 1H, *J* = 8.6, 2.1 Hz), 2.80–2.63 (m, 1H), 2.50–2.23 (m, 1H), 2.09 (s, 3H), 2.05 (s, 3H), 1.46 (s, 3H), 1.45 (s, 3H), 1.22 (d, 3H, *J* = 6.6 Hz); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.3, 169.9, 163.4, 144.8, 131.6, 129.3, 121.2, 110.1, 81.1, 76.0, 74.5, 73.9, 70.4, 27.1, 26.5 (2C), 21.1, 21.0, 15.1; HRMS for $C_{19}H_{26}O_8$ + Na calcd 405.1525, found 405.1527.



1b

*(2S,3R,6S,7R,E)-6,7-Dihydroxy-7-((R)-6-oxo-3,6-dihydro-2H-pyran-2-yl)hept-4-ene-2,3-diyl Diacetate (**1b**).* Compound **1b** was synthesized from **21b** (0.007 g, 0.018 mmol) following the same procedure described for the synthesis of **1a** (0.004 g, 65%, colorless oil): $[\alpha]^{24}_D$ −18.2 (*c* 0.2, $CHCl_3$); IR (neat) 3439, 1737, 1732 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.03–6.90 (m, 1H), 6.03 (dd, 1H, *J* = 9.9, 2.5 Hz), 5.92–5.74 (m, 2H), 5.37–5.26 (m, 1H), 5.08 (dq, 1H, *J* = 10.4, 6.5 Hz), 4.54 (dt, 1H, *J* = 12.7, 3.7 Hz), 4.47–4.37 (m, 1H), 3.60–3.50 (m, 1H), 3.02 (bs, 1H), 2.93 (bs, 1H), 2.91–2.70 (m, 1H), 2.41–2.25 (m, 1H), 2.08 (s, 3H), 2.05 (s, 3H), 1.22 (d, 3H, *J* = 6.5 Hz); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.4, 170.1, 163.4, 145.8, 133.4, 127.7, 120.7, 78.1, 74.9, 74.6, 71.8, 70.4, 25.9, 21.2, 21.1, 15.3; HRMS for $C_{16}H_{22}O_8$ + Na calcd 365.1212, found 365.1211.

$[\alpha]^{24}_D$ −45.0 (*c* 0.3, MeOH); ^1H NMR (400 MHz, CD_3OD) δ 7.09 (ddd, 1H, *J* = 9.5, 6.3, 2.1 Hz), 5.96 (dd, 1H, *J* = 9.8, 2.3 Hz), 5.97–5.75 (m, 2H), 5.34 (dd, 1H, *J* = 5.5, 3.6 Hz), 5.07 (qd, 1H, *J* = 10.1, 3.6 Hz), 4.53 (dt, 1H, *J* = 12.6, 3.6 Hz), 4.32 (t, 1H, *J* = 6.5 Hz), 3.51 (dd, 1H, *J* = 6.6, 3.3 Hz), 2.84–2.65 (m, 1H), 2.37 (ddd, 1H, *J* = 10.2, 6.3, 3.9 Hz), 2.04 (s, 3H), 2.02 (s, 3H), 1.20 (d, 3H, *J* = 6.2 Hz); ^{13}C NMR (100 MHz, CD_3OD) δ 172.1, 171.8, 166.6, 148.9, 135.5, 127.9, 120.9, 79.8, 76.4, 76.0, 73.7, 72.0, 26.9, 21.0, 20.9, 15.4.



***ent*-14**

*(R)-1-((4R,5R)-5-(((tert-Butyldimethylsilyl)oxy)methyl)-2,2-dimethyl-1,3-dioxolan-4-yl)but-3-en-1-ol (**ent-14**).* To a precooled (0 °C) stirred solution of ***ent*-12** (1.0 g, 3.62 mmol) in THF (10 mL) were added allyl bromide (0.94 mL, 10.9 mmol) and zinc (0.95 g, 14.5 mmol). Saturated NH_4Cl (4 mL) was then added dropwise to the reaction mixture over 15 min and stirred at the same temperature for 30 min. The reaction mixture was allowed to warm to room temperature and stirred at the same temperature for 4 h. After completion of the reaction (monitored by TLC), it was diluted by the addition of satd NH_4Cl (20 mL), poured into water (20 mL), and extracted with diethyl ether (3 × 30 mL). The combined organic solution was washed with brine (2 × 10 mL) and dried over Na_2SO_4. Evaporation of solvent gave the crude residue, which was purified by silica gel column chromatography using petroleum ether/EtOAc (9:1) as eluent to furnish ***ent*-14** (0.93 g, 81%) as a colorless oil and ***ent*-13** (0.11 g, 9%) as a colorless oil. Data for ***ent*-14**: $[\alpha]^{24}_D$ −7.2 (*c* 1.5,

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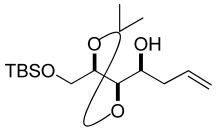
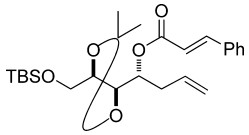
$CHCl_3$) [lit.[10c,d] $[\alpha]^{25}_D$ +8.0 (*c* 1.0, $CHCl_3$)]; IR (neat) 3448, 2860, 1254 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 5.90 (ddt, 1H, *J* = 17.1, 10.1, 7.1 Hz), 5.15 (d, 1H, *J* = 19.6 Hz), 5.11 (d, 1H, *J* = 11.2 Hz), 4.00−3.86 (m, 1H), 3.86 (dd, 1H, *J* = 10.2, 3.9 Hz), 3.79−3.61 (m, 3H), 3.04 (s, 1H), 2.52−2.38 (m, 1H), 2.32−2.14 (m, 1H), 1.39 (s, 3H), 1.37 (s, 3H), 0.89 (s, 9H), 0.09 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 134.5, 117.6, 108.8, 81.7, 79.5, 71.5, 64.2, 37.9, 26.9, 26.8, 25.8 (3C), 18.3, −5.48, −5.53; HRMS for $C_{16}H_{32}O_4Si$ + Na calcd 339.1968, found 339.1968.

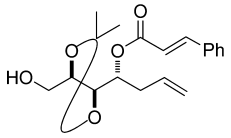


***ent*-13**

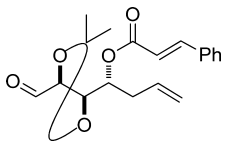
(S)-1-((4R,5R)-5-(((tert-Butyldimethylsilyl)oxy)methyl)-2,2-dimethyl-1,3-dioxolan-4-yl)but-3-en-1-ol (***ent*-13**): $[\alpha]^{24}_D$ −9.5 (*c* 1.8, $CHCl_3$); IR (neat) 3463, 1254 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 5.87 (ddt, 1H, *J* = 14.5, 10.0, 7.1 Hz), 5.14 (d, 1H, *J* = 9.4 Hz), 5.12 (d, 1H, *J* = 6.6 Hz), 4.09−3.94 (m, 1H), 3.92 (dd, 1H, *J* = 7.6, 3.1 Hz), 3.79 (dd, 1H, *J* = 7.5, 3.7 Hz), 3.76−3.59 (m, 2H), 2.43−2.16 (m, 2H), 1.42 (s, 3H), 1.39 (s, 3H), 0.89 (s, 9H), 0.07 (s, 3H), 0.065 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 134.6, 117.6, 109.2, 80.9, 77.3, 70.0, 63.7, 39.1, 27.2 (2C), 25.9 (3C), 18.3, −5.4, −5.5; HRMS for $C_{16}H_{32}O_4Si$ + Na calcd 339.1968, found 339.1980.



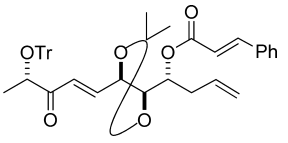
(R)-1-((4R,5R)-5-(((tert-Butyldimethylsilyl)oxy)methyl)-2,2-dimethyl-1,3-dioxolan-4-yl)but-3-en-1-yl Cinnamate. The above cinnamate was synthesized from ***ent*-14** (0.9 g, 2.85 mmol) following the same procedure described for the synthesis of **15** (1.10 g, 86%, colorless oil): $[\alpha]^{24}_D$ +4.6 (*c* 1.4, $CHCl_3$); IR (neat) 1718, 1638 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.69 (d, 1H, *J* = 16.0 Hz), 7.57−7.46 (m, 2H), 7.44−7.33 (m, 3H), 6.44 (d, 1H, *J* = 16.0 Hz), 5.81 (ddt, 1H, *J* = 16.9, 6.8, 6.8 Hz), 5.26 (dt, 1H, *J* = 8.2, 4.4 Hz), 5.13 (d, 1H, *J* = 17.0 Hz), 5.07 (d, 1H, *J* = 10.2 Hz), 4.18−4.05 (m, 1H), 4.10−3.96 (m, 1H), 3.80 (dd, 1H, *J* = 11.0, 4.0 Hz), 3.70 (dd, 1H, *J* = 11.0, 4.0 Hz), 2.63−2.38 (m, 2H), 1.41 (s, 6H), 0.90 (s, 9H), 0.08 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.1, 145.3, 134.3, 133.2, 130.4, 128.9 (2C), 128.1 (2C), 118.1, 117.7, 109.6, 79.2, 78.0, 73.0, 63.8, 35.2, 27.2, 27.1, 25.9 (3C), 18.4, −5.3, −5.4; HRMS for $C_{25}H_{38}O_5Si$ + Na calcd 469.2386, found 469.2390.



(R)-1-((4R,5R)-5-(Hydroxymethyl)-2,2-dimethyl-1,3-dioxolan-4-yl)but-3-en-1-yl Cinnamate. The above alcohol was synthesized from the TBS ether (0.3 g, 0.67 mmol) following the same procedure described for the synthesis of **16** (0.19 g, 85%, colorless oil): $[\alpha]^{24}_D$ −3.2 (*c* 1.2, $CHCl_3$); IR (neat) 3479, 1717, 1638 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.70 (d, 1H, *J* = 16.0 Hz), 7.58−7.46 (m, 2H), 7.44−7.33 (m, 3H), 6.42 (d, 1H, *J* = 16.0 Hz), 5.80 (ddt, 1H, *J* = 17.2, 10.1, 7.4 Hz), 5.20 (dt, 1H, *J* = 9.9, 6.0 Hz), 5.14 (d, 1H, *J* = 17.1 Hz), 5.09 (d, 1H, *J* = 10.4 Hz), 4.15−3.98 (m, 2H), 3.91−3.76 (m, 1H), 3.71−3.55 (m, 1H), 2.67−2.51 (m, 1H), 2.55−2.37 (m, 1H), 2.11 (t, 1H, *J* = 5.8 Hz), 1.43 (s, 3H), 1.42 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.2, 145.7, 134.1, 132.9, 130.5, 128.9 (2C), 128.2 (2C), 118.4, 117.4, 109.7, 79.3, 77.1, 73.3, 62.8, 35.6, 27.1, 27.0; HRMS for $C_{19}H_{24}O_5$ + Na calcd 355.1521, found 355.1521.

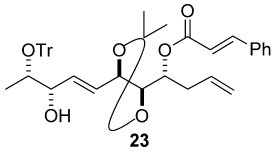


(R)-1-((4R,5S)-5-Formyl-2,2-dimethyl-1,3-dioxolan-4-yl)but-3-en-1-yl Cinnamate. The above aldehyde was synthesized from the alcohol (0.18 g, 0.54 mmol) following the same procedure described for the synthesis of **10a**.

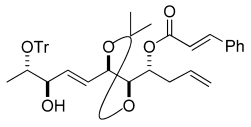


22

(R)-1-((4R,5R)-2,2-Dimethyl-5-((S,E)-3-oxo-4-(trityloxy)pent-1-en-1-yl)-1,3-dioxolan-4-yl)but-3-en-1-yl cinnamate ***22***. **22** was synthesized from **11** (0.24 g, 0.54 mmol) and aldehyde obtained above following the same procedure described for the synthesis of **9a** (0.24 g, 69%, colorless oil): $[\alpha]^{24}_D$ −31.5 (*c* 0.9, $CHCl_3$); IR (neat) 1718, 1637 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.68 (d, 1H, *J* = 16.0 Hz), 7.56−7.44 (m, 2H), 7.45−7.32 (m, 9H), 7.32−7.16 (m, 9H), 6.64 (d, 1H, *J* = 15.6 Hz), 6.47 (dd, 1H, *J* = 15.6, 5.0 Hz), 6.40 (d, 1H, *J* = 16.0 Hz), 5.77 (ddt, 1H, *J* = 17.0, 10.1, 6.9 Hz), 5.19 (td, 1H, *J* = 11.3, 7.0 Hz), 5.20−5.04 (m, 2H), 4.41 (t, 1H, *J* = 6.3 Hz), 4.19 (q, 1H, *J* = 6.9 Hz), 3.74 (t, 1H, *J* = 7.1 Hz), 2.63−2.47 (m, 1H), 2.49−2.31 (m, 1H), 1.43 (s, 3H), 1.37 (s, 3H) 1.19 (d, 3H, *J* = 6.8 Hz); ^{13}C NMR (100 MHz, $CDCl_3$) δ 200.9, 166.0, 145.9, 143.9 (3C), 141.9, 134.2, 132.6, 130.5, 129.0 (6C), 128.9 (2C), 128.3 (2C), 127.9 (6C), 127.4 (3C), 123.5, 118.6, 117.3, 110.3, 88.0, 80.6, 78.1, 75.9, 72.8, 35.8, 27.0, 26.8, 19.6; HRMS for $C_{42}H_{42}O_6$ + Na calcd 665.2879, found 665.2877.



23



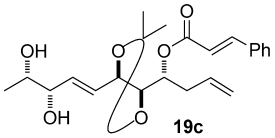
24

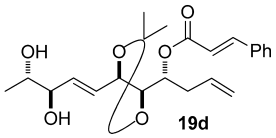
Preparation of ***23*** *and* ***24***. Reduction of **22** (0.22 g, 0.34 mmol) was carried out similar to the procedure described for the reduction of **9a**. The diastereomers **23** and **24** were separated by chromatography. Data for **23** (0.166 g, 76%, colorless oil): $[\alpha]^{24}_D$ −4.5 (*c* 2.2, $CHCl_3$); IR (neat) 3398, 1707, 1654 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.70 (d, 1H, *J* = 15.9 Hz), 7.53−7.15 (m, 20H), 6.43 (d, 1H, *J* = 16.0 Hz), 5.83 (td, 2H, *J* = 15.4, 5.4 Hz), 5.72 (dd, 1H, *J* = 15.6, 7.0 Hz), 5.34−5.20 (m, 1H), 5.10 (d, 1H, *J* = 17.6 Hz), 5.09 (d, 1H, *J* = 10.2 Hz), 4.45 (t, 1H, *J* = 7.4 Hz), 3.90 (t, 1H, *J* = 7.5 Hz), 3.71 (bs, 1H), 3.47 (dq, 1H, *J* = 12.1, 6.0 Hz), 2.60−2.45 (m, 1H), 2.53−2.36 (m, 1H), 2.00 (bs, 1H), 1.42 (s, 6H) 0.88 (d, 3H, *J* = 6.2 Hz); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.2, 145.4, 144.8 (3C), 134.2, 133.7, 133.0, 130.3, 129.6, 128.8 (2C), 128.8 (6C), 128.1 (2C), 127.7 (6C), 127.1 (3C), 118.2, 117.7, 109.4, 86.9, 81.0, 78.8, 73.9, 72.7, 72.4, 35.5, 27.0, 26.8, 16.5; HRMS for $C_{42}H_{44}O_6$ + Na calcd 667.3036, found 667.3049.

Data for **24** (minor isomer, 0.04 g, 18%, colorless oil): $[\alpha]^{24}_D$ +18.6 (*c* 1.3, $CHCl_3$); IR (neat) 3471, 1718, 1637 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.66 (d, 1H, *J* = 16.0 Hz), 7.58−7.17 (m, 20H), 6.41 (d, 1H, *J* = 16.0 Hz), 5.80 (ddt, 1H, *J* = 16.7, 9.8, 6.7 Hz), 5.67−5.44 (m, 2H), 5.30−5.16 (m, 1H), 5.11 (d, 1H, *J* = 16.0 Hz), 5.08 (d, 1H, *J* = 9.0 Hz), 4.43−4.30 (m, 1H), 3.84 (t, 1H, *J* = 7.0 Hz), 3.72−3.62 (m, 1H), 3.40 (bs, 1H), 2.59−2.41 (m, 1H), 2.49−2.33 (m, 1H), 2.21 (d, 1H, *J* = 2.7 Hz), 1.42 (s, 3H), 1.41 (s, 3H) 0.98 (d, 3H, *J* = 6.2 Hz);^{13}C NMR (100 MHz, $CDCl_3$) δ 166.1, 145.4, 144.6 (3C), 134.2, 133.0, 132.4, 130.4, 128.9 (2C), 128.7 (6C), 128.4, 128.1 (2C), 127.8 (6C), 127.2 (3C), 118.2, 117.6, 109.4, 87.2, 81.0, 78.7, 73.4, 72.6, 72.3, 35.5, 27.0, 26.8, 15.0; HRMS for $C_{42}H_{44}O_6$ + Na calcd 667.3036, found 667.3032.

Synthesis of ***24*** *from* ***23*** *by Mitsunobu Inversion.* Compound **24** was synthesized from **23** (0.06 g, 0.09 mmol) following the same procedure described for the synthesis of **18** from **17** (0.042 g, 72%, colorless oil).

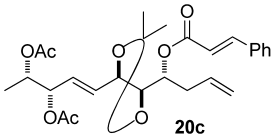
dx.doi.org/10.1021/jo400083v | J. Org. Chem. 2013, 78, 3313−3322

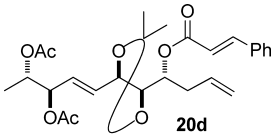

19c


19d

*Preparation of **19c** and **19d**.* The above diols **19c** and **19d** were synthesized from **23** (0.1 g, 0.155 mmol) and from **24** (0.08 g, 0.124 mmol), respectively, following the same procedure described for the synthesis of **19**. Data for **19c** (0.055 g, 88%, colorless oil): $[\alpha]^{24}_{D}$ −1.5 (*c* 1.0, $CHCl_3$); IR (neat) 3426, 1709, 1638 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.69 (d, 1H, *J* = 16.0 Hz), 7.57−7.46 (m, 2H), 7.44−7.32 (m, 3H), 6.42 (d, 1H, *J* = 16.0 Hz), 5.91−5.68 (m, 3H), 5.20 (dt, 1H, *J* = 8.6, 4.7 Hz), 5.13 (d, 1H, *J* = 17.2 Hz), 5.09 (d, 1H, *J* = 10.3 Hz), 4.45−4.32 (m, 1H), 3.93−3.80 (m, 2H), 3.59 (dq, 1H, *J* = 12.3, 6.0 Hz), 2.59−2.39 (m, 4H), 1.42 (s, 6H), 1.14 (d, 3H, *J* = 6.3 Hz); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.3, 145.7, 134.1, 134.0, 133.0, 130.5, 130.0, 128.9 (2C), 128.1 (2C), 118.3, 117.5, 109.7, 81.1, 79.1, 76.2, 72.5, 70.3, 35.2, 27.0, 26.8, 18.9; HRMS for $C_{23}H_{30}O_6$ + Na calcd 425.1940, found 425.1940.

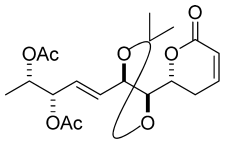
Data for **19d** (0.045 g, 90%, colorless oil): $[\alpha]^{24}_{D}$ +16.3 (*c* 1.5, $CHCl_3$); IR (neat) 3435, 1713, 1636 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.68 (d, 1H, *J* = 16.0 Hz), 7.57−7.46 (m, 2H), 7.44−7.32 (m, 3H), 6.42 (d, 1H, *J* = 16.0 Hz), 5.94−5.68 (m, 3H), 5.23 (dt, 1H, *J* = 9.6, 5.2 Hz), 5.10 (dd, 2H, *J* = 13.2, 10.4 Hz), 4.42 (t, 1H, *J* = 7.6 Hz), 4.03 (t, 1H, *J* = 4.8 Hz), 3.89 (dd, 1H, *J* = 8.0, 5.6 Hz), 3.79 (qd, 1H, *J* = 10.0, 4.0 Hz), 2.60−2.38 (m, 4H), 1.42 (s, 3H), 1.41 (s, 3H), 1.10 (d, 3H, *J* = 6.4 Hz); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.3, 145.6, 134.1, 132.9 (2C), 130.5 (2C), 128.9 (2C), 128.1 (2C), 118.3, 117.5, 109.6, 81.0, 79.0, 75.4, 72.4, 69.9, 35.3, 27.0, 26.8, 17.6; HRMS for $C_{23}H_{30}O_6$ + Na calcd 425.1940, found 425.1942.

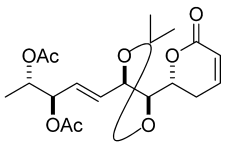

20c


20d

*Preparation of **20c** and **20d**.* The above diacetates were synthesized from **19c** (0.052 g, 0.13 mmol) and **19d** (0.044 g, 0.11 mmol) following the same procedure described for the synthesis of **20**. Data for **20c** (0.057 g, 90%, colorless oil): $[\alpha]^{24}_{D}$ +19.4 (*c* 3.0, $CHCl_3$); IR (neat) 1735, 1228 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.69 (d, 1H, *J* = 16.0 Hz), 7.58−7.47 (m, 2H), 7.43−7.32 (m, 3H), 6.41 (d, 1H, *J* = 16.0 Hz), 5.90−5.67 (m, 3H), 5.33 (t, 1H, *J* = 6.1 Hz), 5.23 (dt, 1H, *J* = 10.2, 5.1 Hz), 5.11 (d, 1H, *J* = 18.9 Hz), 5.08 (d, 1H, *J* = 11.2 Hz), 4.99 (dq, 1H, *J* = 12.6, 6.4 Hz), 4.43 (t, 1H, *J* = 7.0 Hz), 3.92−3.78 (m, 1H), 2.58−2.42 (m, 1H), 2.52−2.34 (m, 1H), 1.99 (s, 3H), 1.95 (s, 3H), 1.40 (s, 6H), 1.17 (d, 3H, *J* = 6.5 Hz); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.1, 169.7, 166.1, 145.6, 134.1, 132.9, 132.8, 130.4, 128.9 (2C), 128.1 (2C), 127.8, 118.3, 117.4, 109.7, 80.9, 78.2, 74.4, 72.3, 70.3, 35.5, 26.8 (2C), 21.0, 20.8, 16.1; HRMS for $C_{27}H_{34}O_8$ + Na calcd 509.2151, found 509.2150.

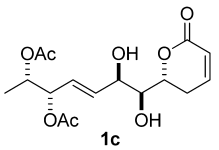
Data for **20d** (0.047 g, 88%, colorless oil): $[\alpha]^{24}_{D}$ −2.6 (*c* 1.8, $CHCl_3$); IR (neat) 1738, 1638, 1167 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.69 (d, 1H, *J* = 16.0 Hz), 7.58−7.33 (m, 5H), 6.42 (d, 1H, *J* = 16.0 Hz), 5.86−5.69 (m, 3H), 5.46−5.32 (m, 1H), 5.30−5.16 (m, 1H), 5.11 (d, 1H, *J* = 18.8 Hz), 5.08 (d, 1H, *J* = 11.2 Hz), 5.04−4.92 (m, 1H), 4.48−4.35 (m, 1H), 3.85 (t, 1H, *J* = 6.4 Hz), 2.62−2.46 (m, 1H), 2.51−2.33 (m, 1H), 2.02 (s, 3H), 1.95 (s, 3H), 1.41 (s, 6H), 1.13 (d, 3H, *J* = 6.4 Hz); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.3, 169.8, 166.1, 145.7, 134.1, 132.9, 132.5, 130.5, 128.9 (2C), 128.2 (2C), 127.7, 118.4, 117.4, 109.7, 80.8, 78.7, 74.2, 72.6, 70.4, 35.7, 26.9, 26.8, 21.0, 20.9, 14.8; HRMS for $C_{27}H_{34}O_8$ + Na calcd 509.2151, found 509.2151.

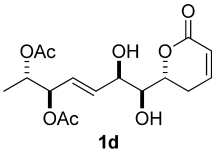

21c


21d

*Preparation of **21c** and **21d**.* Compounds **21c** and **21d** were synthesized from **20c** (0.054 g, 0.111 mmol) and **20d** (0.046 g, 0.095 mmol), respectively, following the same procedure described or the synthesis of **21a**. Data for **21c** (0.029 g, 68%, colorless oil): $[\alpha]^{24}_{D}$ +52.4 (*c* 1.6, $CHCl_3$); IR (neat) 2924, 1743, 1250 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 6.88 (dt, 1H, *J* = 9.6, 5.5 Hz), 6.0 (d, 1H, *J* = 9.8 Hz), 5.94−5.72 (m, 2H), 5.33 (t, 1H, *J* = 6.0 Hz), 5.01 (dq, 1H, *J* = 12.6, 6.4 Hz), 4.52−4.36 (m, 2H), 3.83 (t, 1H, *J* = 7.4 Hz), 2.59−2.44 (m, 2H), 2.09 (s, 3H), 2.03 (s, 3H), 1.41 (s, 6H), 1.20 (d, 3H, *J* = 6.4 Hz); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.2, 169.9, 162.5, 144.5, 132.1, 127.3, 121.3, 110.2, 80.7, 79.2, 77.9, 74.4, 70.5, 26.9 (2C), 26.2, 21.0, 20.9, 16.1; HRMS for $C_{19}H_{26}O_8$ + Na calcd 405.1525, found 405.1523.

Data for **21d** (0.025 g, 68%, colorless oil): $[\alpha]^{24}_{D}$ +46.8 (*c* 1.5, $CHCl_3$); IR (neat) 2935, 1735, 1064 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 6.89 (dt, 1H, *J* = 9.1, 4.3 Hz), 6.06 (d, 1H, *J* = 9.9 Hz), 5.94−5.74 (m, 2H), 5.43−5.31 (m, 1H), 5.04 (dq, 1H, *J* = 9.9, 6.5 Hz), 4.52−4.34 (m, 2H), 3.86 (t, 1H, *J* = 7.1 Hz), 2.57−2.45 (m, 2H), 2.05 (s, 3H), 2.01 (s, 3H), 1.40 (s, 6H), 1.18 (d, 3H, *J* = 6.6 Hz); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.3, 169.8, 162.6, 144.6, 132.3, 127.2, 121.3, 110.3, 80.7, 79.0, 77.9, 74.4, 70.5, 26.8 (2C), 26.1, 21.1, 21.0, 14.9; HRMS for $C_{19}H_{26}O_8$ + Na calcd 405.1525, found 405.1526.


1c

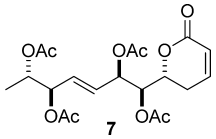

1d

*Preparation of **1c** and **1d**.* Compounds **1c** and **1d** were synthesized from **21c** (0.028 g, 0.073 mmol) and **21d** (0.023 g, 0.06 mmol) following the procedure described for the synthesis of **1a** and **1b**. Data for **1c**: (0.017 g, 67%, colorless oil); $[\alpha]^{24}_{D}$ +47.3 (*c* 0.7, $CHCl_3$); IR (neat) 3440, 1738, 1732 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 6.94 (dt, 1H, *J* = 9.1, 4.2 Hz), 6.01 (d, 1H, *J* = 9.8 Hz), 5.86 (dd, 1H, *J* = 15.6, 5.4 Hz), 5.75 (dd, 1H, *J* = 15.6, 6.4 Hz), 5.31 (dd, 1H, *J* = 11.6, 5.7 Hz), 5.06 (dq, 1H, *J* = 12.2, 6.2 Hz), 4.57−4.40 (m, 2H), 3.77−3.64 (m, 1H), 2.96 (bs, 1H), 2.86 (bs, 1H), 2.64−2.44 (m, 2H), 2.09 (s, 3H), 2.04 (s, 3H), 1.20 (d, 3H, *J* = 6.5 Hz); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.6, 170.2, 163.7, 145.8, 133.7, 127.2, 120.9, 76.9, 74.8, 74.2, 70.6, 69.4, 25.5, 21.1, 21.0, 16.2; HRMS for $C_{16}H_{22}O_8$ + Na calcd 365.1212, found 365.1214.

$[\alpha]^{24}_{D}$ +53.6 (*c* 0.7, MeOH); ^1H NMR (400 MHz, CD_3OD) δ 7.04 (ddd, 1H, *J* = 8.6, 5.0, 4.0 Hz), 6.01−5.83 (m, 2H), 5.80−5.64 (m, 1H), 5.30 (t, 1H, *J* = 6.3 Hz), 4.99 (dq, 1H, *J* = 12.6, 6.3 Hz), 4.57−4.42 (m, 1H), 4.33−4.21 (m, 1H), 3.61 (dd, 1H, *J* = 6.3, 3.5 Hz), 2.58−2.44 (m, 2H), 2.03 (s, 3H), 1.99 (s, 3H), 1.17 (d, 3H, *J* = 6.5 Hz); ^{13}C NMR (100 MHz, CD_3OD) δ 172.1, 171.8, 166.4, 148.6, 136.6, 127.2, 121.1, 78.9, 76.6, 75.6, 72.0, 71.4, 26.3, 21.0, 20.9, 16.4. Data for **1d** (0.014 g, 68%, colorless oil): $[\alpha]_{D}^{24}$ +26.3 (*c* 0.2, $CHCl_3$) [lit.[4a] $[\alpha]^{25}_{D}$ +28.8 (*c* 0.18, $CHCl_3$)]; IR (neat) 3394, 1733, 1717 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 6.95 (dt, 1H, *J* = 9.4, 4.9 Hz), 6.01 (d, 1H, *J* = 9.6 Hz), 5.88 (dd, 1H, *J* = 15.7, 5.2 Hz), 5.79 (dd, 1H, *J* = 15.6, 6.6 Hz), 5.31 (dt, 1H, *J* = 9.9, 3.6 Hz), 5.05 (dq, 1H, *J* = 10.2, 3.7 Hz), 4.57−4.41 (m, 2H), 3.76−3.64 (m, 1H), 3.05 (bs, 1H), 2.95 (bs, 1H), 2.62−2.49 (m, 2H), 2.07 (s, 3H), 2.03 (s, 3H), 1.19 (d, 3H, *J* = 6.5 Hz); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.5, 170.3, 163.8, 145.8, 134.2, 126.6, 120.9, 76.9, 75.0, 74.3, 70.5, 69.5, 25.5, 21.11, 21.07, 15.1; HRMS for $C_{16}H_{22}O_8$ + Na calcd 365.1212, found 365.1212.

$[\alpha]^{24}_{D}$ +23.3 (*c* 1.2, MeOH) [lit.[2] $[\alpha]^{25}_{D}$ +45.6 (*c* 1.2, MeOH)]; ^1H NMR (400 MHz, CD_3OD) δ 7.17−7.02 (m, 1H), 6.00 (d, 1H, *J* = 5.4 Hz), 5.96 (dd, 1H, *J* = 15.5, 5.0 Hz), 5.81 (dd, 1H, *J* = 15.8, 6.8 Hz), 5.42 (dd, 1H, *J* = 6.6, 3.3 Hz), 5.07 (qd, 1H, *J* = 9.9, 3.5 Hz), 4.55 (dt, 1H, *J* = 11.2, 6.0 Hz), 4.39−4.27 (m, 1H), 3.67 (dd, 1H, *J* = 6.4, 3.4 Hz), 2.68−2.46 (m, 2H), 2.07 (s, 3H), 2.03 (s, 3H), 1.22 (d, 3H, *J* = 6.6 Hz); ^{13}C NMR (100 MHz, CD_3OD) δ 172.2, 171.9, 166.4, 148.6, 136.5, 126.6, 121.1, 78.9, 76.2, 75.7, 72.1, 71.4, 26.4, 21.0, 20.9, 15.1.

dx.doi.org/10.1021/jo400083v | J. Org. Chem. 2013, 78, 3313−3322



7

(1R,2R,5R,6S,E)-1-((R)-6-Oxo-3,6-dihydro-2H-pyran-2-yl)hept-3-ene-1,2,5,6-tetryl Tetraacetate **7**. To a stirred solution of **1d** (0.01 g, 0.03 mmol) in dichloromethane (2 mL) were added Et_3N (0.05 mL, 0.35 mmol), DMAP (0.002 g, 0.012 mmol), and acetic anhydride (0.04 mL, 0.35 mmol). The reaction mixture was then allowed to warm up to room temperature and stirred at same temperature for 1 h. After completion of the reaction, the reaction mixture was poured into water (5 mL) and extracted with diethyl ether (3 × 5 mL). Combined organic solution was washed with brine (2 × 5 mL) and dried over Na_2SO_4. Evaporation of solvent gave the crude residue which was purified by silica gel column chromatography using petroleum ether:EtOAc (1:1) to give **7** (0.011 g, 86%) as a colorless oil. Recrystallization from pentane−benzene solvent system (1:1) afforded small white needles: $[\alpha]^{24}_D$ +12.5 (*c* 0.1, $CHCl_3$) [lit.[4a] $[\alpha]^{25}_D$ +16.0 (*c* 0.1, $CHCl_3$)]; mp 106−108 °C (lit.[4a] mp 106−107 °C); IR (neat) 2926, 1745 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 6.89 (ddd, 1H, *J* = 12.3, 5.8, 2.5 Hz), 6.05 (dt, 1H, *J* = 9.8, 1.6 Hz), 5.77 (dd, 1H, *J* = 15.4, 6.3 Hz), 5.69 (dd, 1H, *J* = 15.5, 5.7 Hz), 5.63 (dd, 1H, *J* = 5.4, 4.2 Hz), 5.37−5.23 (m, 2H), 5.05 (qd, 1H, *J* = 6.6, 4.0 Hz), 4.64−4.48 (m, 1H), 2.55−2.42 (m, 1H), 2.46−2.33 (m, 1H), 2.13 (s, 3H), 2.12 (s, 3H), 2.08 (s, 3H), 2.05 (s, 3H), 1.16 (d, 3H, *J* = 6.6 Hz); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.3, 169.8, 169.5, 169.3, 162.4, 144.2, 129.0, 128.9, 121.4, 74.6, 74.4, 72.7, 70.5, 70.1, 25.3, 21.0, 20.9, 20.8, 20.6, 15.2; HRMS for $C_{20}H_{26}O_{10}$ + Na calcd 449.1424, found 449.1422.

■ ASSOCIATED CONTENT

Supporting Information

Copies of ^1H and ^{13}C NMR spectra of all new compounds and crystallographic data for the compound **7**. This material is available free of charge via the Internet at http://pubs.acs.org

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Notes

The authors declare no competing financial interest.

■ ACKNOWLEDGMENTS

We thank the Department of Science and Technology (DST), New Delhi, for funding. K.R.P. is a Swarnajayanthi fellow of DST, New Delhi. P.G. thanks the Council of Scientific and Industrial Research (CSIR), New Delhi, for a senior research fellowship. We thank Prof. T. N. Guru Row and Mr. Amol G. Dikundwar of the Solid State and Structural Chemistry Unit (SSCU) of the Indian Institute of Science (IISc) for their kind help in determining the X-ray crystal structure of **7**.

■ DEDICATION

†In memory of Prof. A. Srikrishna (1955−2013), an outstanding organic chemist and a trusted friend.

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(11) We understand from colleagues at Rhodes University, South Africa, that Prof. Rivett sadly passed away in 2010. One of the coauthors of the paper, Prof. Michael T. Davies-Coleman, in a telephone conversation with the corresponding author (K.R.P.) has expressed his inability to locate the original spectra reported for synargentolide B (**1**). Prof. Coleman has recently moved to the University of Western Cape and was unable to locate spectra/papers concerning the work that was undertaken 15 years ago. (Personal communication from Prof. Michael T. Davies-Coleman. We sincerely thank Prof. Davies-Coleman for his efforts in locating the spectra.)

(12) Crystal data for the compound have been deposited at the Cambridge Crystallographic Data Centre (CCDC No. 919230). The data can be requested free of charge from CCDC www.ccdc.cam.ac.uk/data_request/cif.