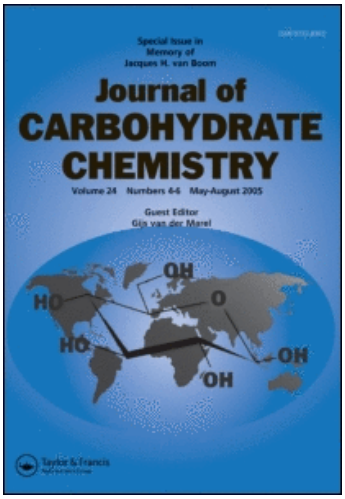

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5-*EXO*-DIG RADICAL CYCLISATION OF 1,2,6-TRIDEOXY-6-IODO-L-ARABINO-HEX-1-YNITOLS DERIVATIVES

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ABSTRACT

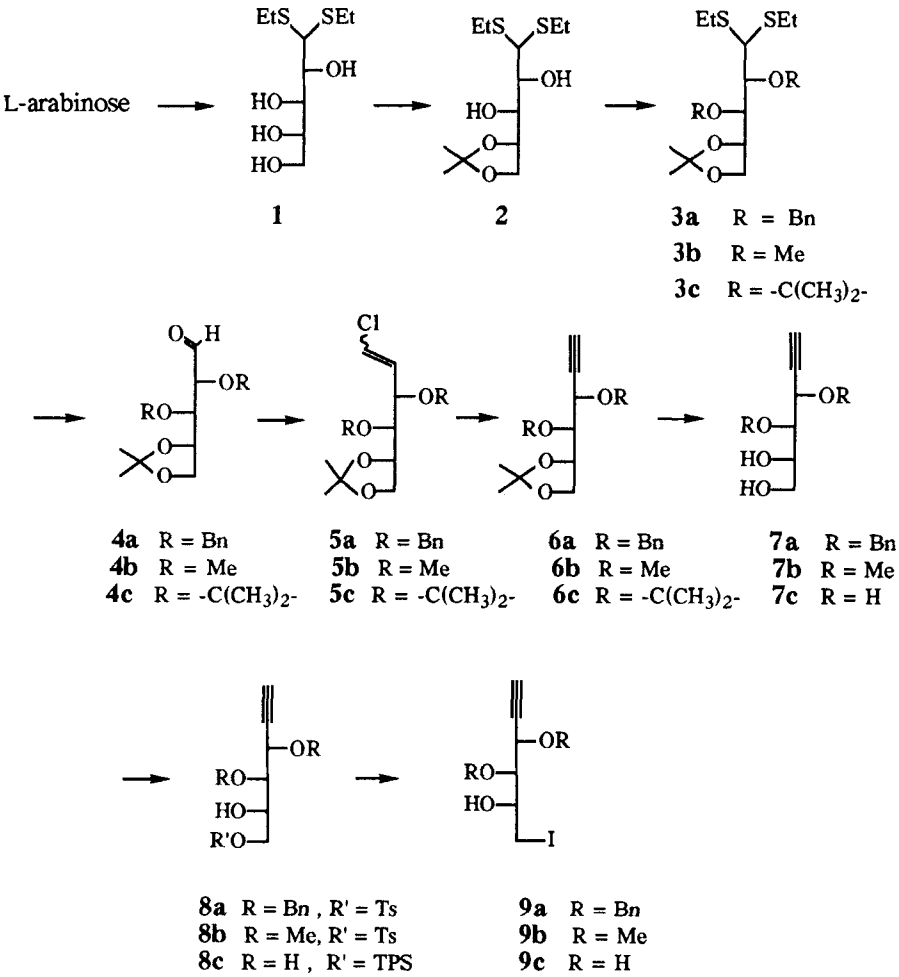
Free radical cyclisation of the title iodides led to five-membered carbocycles in good yield. With 3,4-di-*O*-benzyl-1,2,6-trideoxy-6-iodo-L-*arabino*-hex-1-ynitol **(9a)**, a three step process (5-*exo*-dig-cyclisation, [1,5] hydrogen atom transfer, fragmentation) resulted in extrusion of benzaldehyde giving mainly a mixture of (1*S*, 2*R*)-2-benzyloxy-4-methylene cyclopentan-1-ol **(11a)** and (1*S*, 2*R*)-2-benzyloxy-4-methylcyclopent-3-en-1-ol **(12a)**. With 1,2,6-trideoxy-3,4-di-*O*-methyl-6-iodo-L-*arabino*-hex-1-ynitol **(9b)** or 1,2,6-trideoxy-6-iodo-L-*arabino*-hex-1-ynitol **(9c)**, the expected (1*S*, 2*S*, 3*S*)-2,3-dimethoxy-4-methylene cyclopentan-1-ol **(10b)** or (1*S*, 2*S*, 3*S*)-4-methylenecyclopentan-1,2,3-triol **(10c)**, were respectively obtained.

INTRODUCTION

Over the past few years the free radical route has proven its usefulness for the conversion of carbohydrates to carbocycles. In this context pentoses are particularly suitable starting materials for performing highly regioselective 5-*exo* mode cyclisations since the aldehydic function can be transformed into a radicophilic unsaturation and the terminal primary alcohol converted into a radical precursor. Following this approach the preparation of densely functionalized cyclopentane derivatives has been reported from D-ribonic-γ-lactone,[1] D-ribose[2] or arabinose,[3] the radical trap being either a conjugated carbon-carbon double bond or an oxime ether. We recently became interested in carrying out similar transformations with a carbon-carbon triple bond as radical acceptor.

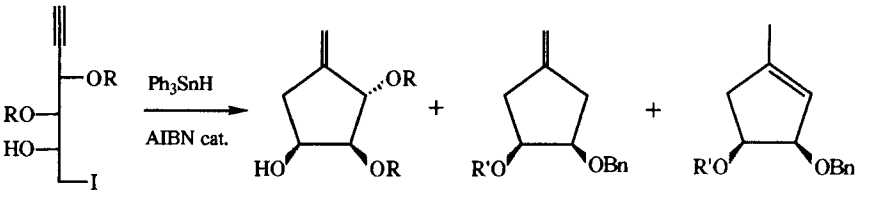
RESULTS AND DISCUSSION

To initiate our study, inexpensive arabinose was chosen as the starting pentose because of its commercial avaibility in both enantiomeric forms. From 2,3-di-*O*-benzyl-4,5-*O*-isopropylidene-aldehydo-L-arabinose **(4a)**, readily available in four steps from L-arabinose,[4] we first prepared the radical precursor 3,4-di-*O*-benzyl-1,2,6-trideoxy-6-iodo-L-*arabino*-hex-1-ynitol **(9a)** following the sequence of Scheme 1.



SCHEME 1

Using a Wittig reaction, **4a** was transformed into a mixture of the isomeric 3,4-di-*O*-benzyl-1-chloro-1,2-dideoxy-5,6-di-*O*-isopropylidene-L-*arabino*-hex-1-enitols **(5a-E)** and **(5a-Z)** which were then treated with *n*-butyllithium to give 3,4-di-*O*-benzyl-1,2-dideoxy-5,6-*O*-isopropylidene-L-*arabino*-hex-1-ynitol **(6a)**.[5] After removal of the protecting isopropylidene groups, further standard transformations of the terminal α-diol permitted us to complete the preparation of **9a**. When submitted to radical cyclisation conditions,[6] **9a** yielded only a small amount of the expected (1*S*, 2*S*, 3*S*)-2,3-dibenzyloxy-4-methylenecyclopentan-1-ol **(10a)** (8%). The remainder (80%) consisted of an unseparable mixture of isomeric (1*S*, 2*R*)-2-benzyloxy-4-methylenecyclopentan-1-ol **(11a)** and (1*S*, 2*R*)-2-benzyloxy-4-methylcyclopent-3-en-1-ol **(12a)** (ratio **11a/12a** = 22/78 as determined from the ^{1}H NMR spectrum) (Scheme 2). Esterification of the mixture of **11a** and **12a** with acetic anhydride gave the mixture of corresponding acetates from which we could isolate, in pure form, the major isomer (1*S*, 2*R*)-1-acetoxy-2-benzyloxy-4-methylcyclopent-3-ene **(12b)** (56% from **9a**) after careful flash chromatography.



9a R = Bn
9b R = Me
9c R = H

10a R = Bn
10b R = Me
10c R = H

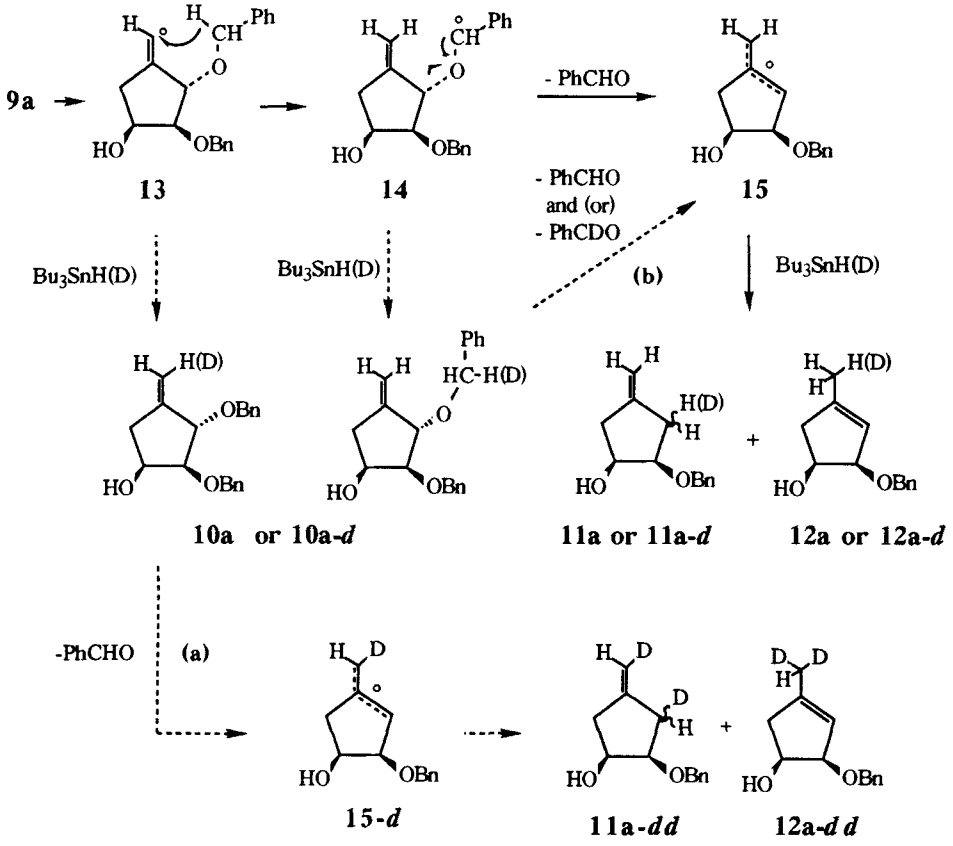
11a R' = H
11b R' = Ac

12a R' = H
12b R' = Ac

SCHEME 2

To explain the formation of the compounds **11a** and **12a** we proposed a three-step mechanism (Scheme 3). The vinylic radical **13**, resulting from the initial 5-*exo*-dig cyclisation, could evolve to the benzylic radical **14** after [1,5] intramolecular hydrogen-atom migration[7] and finally, with loss of benzaldehyde, to the stabilized allylic species **15** which gives rise to compounds **11a** and **12a**. However it could not be excluded that radical **14** could also be formed by abstraction of a benzylic hydrogen in **10a**, this compound being formed either from **13** or **14**. In order to choose between these two possible origins for **11a** and **12a**, we carried out the cyclisation of **9a** using tributyltin deuteride (Scheme 3). From the crude product we isolate the unseparable mixture of

compounds **11a-*d*** and **12a-*d***, whose structures were unambiguously established from ^{1}H and ^{13}C NMR spectra data (see experimental section) and undeuteriated benzaldehyde. This result confirmed the proposed mechanism for the formation of **11a** and **12a**. Indeed, if **11a** and **12a** had been formed from **10a** we would have obtained either the deuteriated-compounds **11a-*dd*** and **12a-*dd***, incorporating two deuterium atoms, if **10a** was formed *via* **13** (route-**a**), or the same monodeuteriated **11a-d** and **12a-d** along with deuteriated (or partially deuteriated) benzaldehyde if **10a** was formed *via* **14** (route-**b**).[8]



SCHEME 3

In order to prevent the above fragmentation, the propargylic alcoholic function had to be either differently protected or left free. However the strong basic conditions required for the formation of the carbon-carbon triple bond restricted the choice to ethers or acetals as protecting groups in intermediate vinylic chlorides **5**.

Thus, from 4,5-*O*-isopropylidene-L-arabinose diethyl dithioacetal **(2)**[4] we then prepared 4,5-*O*-isopropylidene-2,3-di-*O*-methyl-aldehydo-L-arabinose **(4b)** which was transformed into 1,2,6-trideoxy-3,4-di-*O*-methyl-6-iodo-L-*arabino*-hex-1-ynitol **(9b)**, following the same sequence as already used for the synthesis of **9a** (Scheme 1). When submitted to radical cyclisation conditions, **9b** gave rise to the expected (1*S*, 2*S*, 3*S*)-2,3-dimethoxy-4-methylenecyclopentan-1-ol **(10b)** in 70% yield (Scheme 2).

We then focused on the preparation of interesting (1*S*, 2*S*, 3*S*)-4-methylene cyclopentan-1,2,3-triol **(10c)**. Deprotection of the methyl ethers in **10b** would not, *a priori*, affect the exocyclic carbon-carbon double bond and lead to **10c**. However we decided to develop a more direct access to this compound. From diethyl dithioacetal-L-arabinose **(1)**[9] we prepared the known[10] 2,3:4,5-di-*O*-isopropylidene-aldehydo-L-arabinose **(4c)** which was then converted into 1,2-dideoxy-3,4:5,6-di-*O*-isopropylidene-L-*arabino*-hex-1-ynitol **(6c)** in the usual way. The two isopropylidene groups were then removed leading to 1,2-dideoxy-L-*arabino*-hex-1-ynitol **(7c)**. Esterification of this polyol with *p*-toluenesulfonyl chloride resulted in a mixture of several compounds but using 2,4,6-tri-isopropylbenzene-sulfonyl chloride we obtained 1,2-dideoxy-6-*O*-trisyl-L-*arabino*-hex-1-ynitol **(8c)** regioselectively. This sulfonate was then converted into 1,2,6-trideoxy-6-iodo-L-*arabino*-hex-1-ynitol **(9c)** (Scheme 1). Submitted to radical cyclisation conditions **9c** furnished **10c** in 77% yield (Scheme 2).

In conclusion, the results presented here confirm the usefulness of 5-exo-dig radical cyclisations to prepare polyoxygenated cyclopentane derivatives.[11] To our knowledge, the preparation of exocyclic methylene cyclopentanes **10** has not yet been reported. It seems to us that **10c** is an interesting chiral polyfunctionnal compound for further development. It could give rise to diversely functionalized cyclopentanes after simultaneous protection of the alcoholic function in position 1 and 2, as an acetal, and functional transformations of the remaining allylic alcohol. We are currently examining some of these transformations.

EXPERIMENTAL

General Procedures. All solvents were distilled before use; THF from Na-benzophenone, Et_2O from KOH, petroleum-ether from P_2O_5, AcOEt from K_2CO_3, pyridine from CaH_2, MeOH from Mg. Solutions in organic solvents were dried with anhydrous sodium sulfate and concentrated on a rotary evaporator at 40 °C/15 mm Hg. (unless otherwise stated). Merck silica gel 60 F_{254} (0.2 mm) was used for TLC, detection being carried-out by spraying with an alcoholic solution (3%) of phosphomolybdic acid, followed by heating. Flash column chromatography was performed on silica gel Amicon

35-70 μ (ratio crude-product/silicagel : 1/80). Melting points were determined on a Kofler block apparatus. IR spectra were recorded with a Perkin-Elmer Model 1310 spectrophotometer (calibration : polystyrene film) and are expressed in cm^{-1}. NMR spectra were recorded in $CDCl_3$ on a Bruker AM 300 (300 MHz for ^1H and 75.47 MHz for ^{13}C) unless otherwise specified. Chemical shifts are expressed in parts per million downfield from TMS. Splitting pattern abbreviations are: s, singlet; d, doublet; q, quartet; sept, septuplet; m, multiplet; br, broad. Optical rotations were determined with a Perkin-Elmer Model 241 polarimeter at 22 ± 2 °C. MS and GCMS (OV 1701 25m) were recorded on a Nermag R1010S (70 eV) spectrometer. Elemental analyses were performed by "Service Central de Microanalyses du CNRS" 69 Solaize (France).

4,5-*O*-Isopropylidene-2,3-di-*O*-methyl-L-arabinose Diethyl Dithioacetal (3b). A 50% oil suspension of sodium hydride (4 g, 83 mmol) was washed by successively stirring and decanting with dry petroleum ether (3 x 10 mL) and dry tetrahydrofuran (15 mL), under a nitrogen atmosphere. After cooling to 0 °C, dry tetrahydrofuran (50 mL) and then a solution of 4,5-di-*O*-isopropylidene-L-arabinose diethyl dithioacetal (2[4], 8 g, 27 mmol) in dry tetrahydrofuran (100 mL) and a crystal of imidazole were added. The evolution of H_2 was complete when the reaction mixture became homogeneous, at which time methyl iodide (6 mL, 94 mmol) was added, followed by tetra-*n*-butylammonium iodide (0.5 g, 1.35 mmol). The reaction mixture was allowed to warm up to room temperature, stirred for 15 h and then hydrolyzed at 0 °C with a saturated aqueous solution of ammonium chloride (40 mL). After extraction with diethyl ether (100 mL), the combined organic phases were dried and concentrated. The crude product was purified by column chromatography on silica gel using a mixture of diethyl ether-pentane (1/1) as the eluent. We thus obtained 8.4 g (96%) of **3b**: $[\alpha]_D$ -25° (*c* 0.7, chloroform); **IR**$_{film}$ 2990, 2925, 2830, 1450, 1370, 1260, 1210, 1100, 850; **^1H NMR** δ 4.16 (ddd, 1H, $J_{4,3}$ = 6.2 Hz, $J_{4,5}$ = 6.0 Hz, $J_{4,5'}$ = 5.0 Hz, H-4), 4.12 (ABd, 1H, J_{AB} = 12.5 Hz, H-5), 4.09 (d, 1H, $J_{1,2}$ = 8.3 Hz, H-1), 3.99 (ABd, 1H, H-5'), 3.89 (dd, 1H, $J_{3,2}$ = 2.7 Hz, H-3), 3.6 (s, 3H, OCH_3), 3.56 (s, 3H, OCH_3), 3.44 (dd, 1H, H-2), 2.73 (m, 4H, 2 -S-C*H*$_2$-CH_3), 1.43 (s, 3H, -C(CH_3)$_2$-), 1.37 (s, 3H, -C(CH_3)$_2$-), 1.29 and 1.28 (t, 3H, J = 7.4 Hz,-S-CH_2C*H*$_3$); **^{13}C NMR** δ 108.45 (s*, -*C*(CH_3)$_2$-), 84.38** (d, C-3), 81.10** (d, C-2), 76.22 (d, C-4), 66.58 (t, C-5), 60.99 (q, OCH_3), 60.83 (q, OCH_3), 52.42 (d, C-1), 26.51 (q, -C(*C*H_3)$_2$-), 25.99 (t, S-*C*H_2CH$_3$), 25.34 (q, -C(*C*H_3)$_2$-), 24.27 (t,S-*C*H_2CH$_3$), 14.32 (q, 2 S-CH_2*C*H_3). (* multiplicity DEPT; **these values may be inverted); **GCMS** 324 (M^+) (5%); 309 (M^+-15) (8%); 205 (8%); 191 (40%); 135 (100%).

Anal. Calcd for $C_{14}H_{28}O_4S_2$: C, 51.82; H, 8.70; O, 19.72; S, 19.76. Found: C, 51.53; H, 8.79; O, 20.43; S, 19.23.

2,3:4,5-Di-*O*-isopropylidene-L-arabinose Diethyl Dithioacetal (3c). To a suspension of diethyl dithioacetal-L-arabinose ([19], 20 g, 78 mmol) in 900 mL of dry acetone was added 2,2-dimethoxypropane (25 mL, 200 mmol) and then *p*-toluenesulfonic acid (1 g, 5.25 mmol). After stirring at room temperature for 30 min and then at 40 °C for 2 h, the reaction mixture was concentrated and water (50 mL) and a few drops of a 0.5 M aqueous solution of sodium hydroxyde were added. After extraction with dichloromethane (2 x 100 mL), the combined extracts were dried and concentrated. The crude product gave a single spot on TLC (pentane-diethyl ether, 3:7) and was used in the next step without purification. $[\alpha]_D$ -75° (*c* 2, chloroform) [lit [10] -79° (chloroform)].

Aldehydes 4. For the deprotection of the dithioacetals **3a**, **3b** and **3c**, we used, with slight modifications, the procedure proposed by Just and Potvin[4] for **3a**. To a well stirred solution of the dithioacetal **3** (26 mmol) in acetone (150 mL) at 0 °C was added water (10 mL) and sodium bicarbonate (4.8 g, 57 mmol) and then, in small portions, iodine (7.5 g, 29.5 mmol). The mixture was allowed to warm up to room temperature and to stir for 6 h. Iodine (7.5 g) and sodium bicarbonate (4.8 g) were then added portionwise on a period of about 10 h, until total disappearance of the starting material at which time the excess iodine was destroyed by adding saturated sodium thiosulfate solution until the colour of iodine disappear. After partial evaporation of the acetone, the product was extracted with ethyl acetate (3 x 100 mL) and the combined extracts were dried. After evaporation of solvent the crude product (quantitative yield) was used in the next step without purification since these aldehydes are not stable on silica gel as already mentionned [4] for **4a**. However an analytical sample of **4b** could be obtained by preparative GC (SE-30-10%, 6m, 180 °C).

2,3-Di-*O*-benzyl-4,5-*O*-isopropylidene-aldehydo-L-arabinose (4a). Crude product. **IR**$_{film}$ 3050, 3020, 2880, 1730, 1610, 1590, 1500, 1460, 1380, 1370, 1260, 1220, 1080, 860; **^{1}H NMR** (80 MHz, $CDCl_3$) 9.70 (d, $J_{1,2}$ = 0.9 Hz, H-1), 7.34 and 7.28 (s, $10H_{arom}$), 4.80 and 4.60 (AB, 2H, J_{AB} = 11.8 Hz, OCH_2Ph), 4.36-3.80 (m, 5H), 1.39 (s, 3H) 1.32 (s, 3H). In agreement with literature[4] data.

4,5-*O*-Isopropoylidene-2,3-di-*O*-methyl-aldehydo-L-arabinose (4b). $[\alpha]_D$ -4° (*c* 1.1, chloroform); **IR**$_{film}$ 2990, 2930, 2820, 1720, 1450, 1380, 1370, 1250, 1220, 1150, 1090, 840; **^{1}H NMR** δ 9.89 (d, 1H, $J_{1,2}$ = 1Hz, H-1), 4.19 (ddd, 1H, $J_{4,3}$ = 7.1 Hz, $J_{4,5}$ = 6.1 Hz, $J_{4,5'}$ = 5.5 Hz, H-4), 4.08 (ABd, 1H, J_{AB} = 8.6 Hz, H-5), 3.96 (ABd, 1H, H-5'), 3.81 (dd, 1H, $J_{2,3}$ = 2.4 Hz, H-2), 3.65 (dd, 1H, H-3), 3.56 (s, 3H, OCH_3), 3.37 (s, 3H, OCH_3), 1.43 (s, 3H, $-C(CH_3)_2-$), 1.35 (s, 3H, $-C(CH_3)_2-$); **^{13}C NMR** δ 203.97 (d, C-1), 109.14 (s, $-C(CH_3)_2-$), 85.84 (d, C-2), 82.01 (d, C-3), 74.89 (d, C-4), 66.64 (t, C-5), 60.61 (q, OCH_3), 59.72 (q, OCH_3), 26.75 (q, $-C(CH_3)_2-$), 25.33 (q,$-C(CH_3)_2-$).

Anal. Calcd for $C_{10}H_{18}O_5$: C, 55.03; H, 8.31; O, 36.66. Found: C, 55.04; H, 8.18; O, 36.70.

2,3:4,5-Di-*O*-isopropylidene-aldehydo-L-arabinose (4c). Crude product. **IR**$_{film}$ 2990, 2920, 1730, 1450, 1370, 1250, 1220, 1150, 1070; **^{1}H NMR** (200 MHz, $CDCl_3$) δ 9.76 (d, 1H, $J_{1,2}$ = 1 Hz, H-1), 4.41 (dd, 1H, $J_{2,3}$ = 6 Hz, H-2), 4.2-3.8 (m, 4H, H-3, H-4, H-5, H-5'), 1.48 (s, 3H, -C(CH_3)$_2$), 1.43 (s, 3H, -C(CH_3)$_2$-), 1.38 (s, 3H, -C(CH_3)$_2$-), 1.35 (s, 3H, -C(CH_3)$_2$-). In agreement with literature[12] data for D-isomer.

Vinylic chloride 5. To a suspension of chloromethyltriphenylphophonium chloride (11.25 g, 32 mmol) in dry tetrahydrofuran (100 mL) cooled at 0 °C, was added dropwise, under a nitrogen atmosphere, a commercially available (ALDRICH-France) 1.6 M solution of *n*-butyllithium in hexanes (20 mL, 32 mmol), and the reaction mixture was allowed to reach ambient temperature. Tetramethylethylenediamine (TMEDA) (4.7 mL, 31 mmol) was then added and the stirring maintained for 30 min before addition of 16 mmol of aldehyde **3**. After 1 h the reaction mixture was cooled to 0 °C and hydrolyzed with a saturated aqueous solution of ammonium chloride (50 mL). The aqueous phase was extracted with dichlorometane (2 x 50 mL) and the combined organic extracts dried and concentrated. The majority of phosphonium salts was precipited by addition of diethyl ether (100 mL), and removed by filtration. After concentration of the filtrate, the crude compound **5** was purified by column chromatography on silica gel using a mixture of pentane-diethyl ether (8:2 for **5a** and **5b**; 1:1 for **5c**) as the eluent. We thus isolated **5a** (Z/E = 60/40 as determined from the ^{1}H NMR spectrum; 85% from **3a**), **5b** (Z/E = 80/20; 71% from **3b**) and **5c** (Z/E = 65/35; 65% from **3c**).

3,4-Di-*O*-benzyl-1-chloro-1,2-dideoxy-5,6-*O*-isopropylidene-L-arabino-hex-1-enitol (5a). **IR**$_{film}$ **(Z+E)** 3060, 3040, 2990, 2880, 1630, 1610, 1590, 1500, 1460, 1385, 1375, 1250, 1225, 1060; **^{1}H NMR 5a-Z** δ 7.33 (m 10 H_{arom}), 6.21 (dd, 1H, $J_{1,2}$ = 8.6 Hz, H-1), 5.92 (dd, 1H, $J_{2,3}$ = 7.3 Hz, H-2), 4.78 and 4.70 (AB, 2H, J_{AB} = 11.4 Hz, OCH_2Ph), 4.57 (ddd, 1H, $J_{3,4}$ = 3.9 Hz, H-3),4.63 and 4.37 (AB, 2H, J_{AB} = 11.8 Hz, OCH_2Ph), 4.25 (m, 1H, H-5), 4.06 (ABd, 1H, J_{AB} = 7 Hz, $J_{6,5}$ = 4.5 Hz, H-6), 3.99 (ABd, 1H, $J_{6',5}$ = 2.2 Hz, H-6') , 3.82 (dd, 1H, $J_{4,5}$ = 4.1 Hz, H-4), 1.45 (s, 3H, -C(CH_3)$_2$-), 1.37 (s, 3H, -C(CH_3)$_2$-); **5a-E** δ 7.34 (m, 10H_{arom}), 6.22 (dd, 1H, $J_{1,2}$ = 13.4 Hz, $J_{1,3}$ = 0.7 Hz, H-1), 6.0 (dd, 1H, $J_{2,3}$ = 7.6 Hz, H-2), 4.75 and 4.67 (AB, 1H, J_{AB} = 11.3 Hz, OCH_2Ph), 4.62 and 4.35 (AB, 2H, J_{AB} = 12 Hz, OCH_2Ph), 4.25 (m, 1H, H-5), 4.06 (ABd, 1H, J_{AB} = 7 Hz, $J_{6,5}$ = 2.2 Hz, H-6), 3.99 (ABd, 1H, $J_{6',5}$ = 4.5 Hz, H-6'), 3.93 (ddd, 1H, $J_{3,4}$ = 3.8 Hz, H-3), 3.72 (dd, $J_{4,5}$ = 4 Hz, H-4), 1.45 (s, 3H,-C(CH_3)$_2$-), 1.37 (s, 3H, -C(CH_3)$_2$-); **^{13}C NMR 5a-Z** δ 137.94, 138.19 (s, C_{arom}), 128.57 (d, C-2), 128.30, 128.19, 127.98, 127.74,

127.60 (d, C_{arom}), 121.45 (d, C-1), 108.22 (s, -*C*$(CH_3)_2$-), 80.35 (d, C-4), 76.53 (d, C-5), 75.13 (t, OCH_2Ph), 74.69 (d, C-3), 71.02 (t, OCH_2Ph), 65.62 (t, C-6), 26.46 (q, -C(*C*$H_3)_2$-), 25.30 (q, -C(*C*$H_3)_2$-); **5a-E** δ 138.09, 137.79 (s, C_{arom}),130.01 (d, C-2), 128.28, 128.04, 127.82, 127.70, 127.51 (d, C_{arom}), 121.42 (d, C-1), 108.11 (s, -*C*$(CH_3)_2$-), 80.72 (d, C-4), 77.83 (d, C-3), 76.06 (d, C-5), 74.99 (t, OCH_2Ph), 70.86 (t, OCH_2Ph), 65.56 (t, C-6) 25.49 (q, -C(*C*$H_3)_2$-), 25.22 (q, -C(*C*$H_3)_2$-); **MS** 387 and 389 (M^+-15) (4%); 311 and 313 (10%); 253 and 255 (17%); 237 (11%).

Anal. Calcd for $C_{23}H_{27}O_4Cl$: C, 68.56; H, 6.76; Cl 8.80. Found: C, 67.07; H, 6.60; Cl, 9.07

1-Chloro-1,2-dideoxy-5,6-*O*-isopropylidene-3,4-di-*O*-methyl-L-arabino-hex-1-enitol (5b). **IR**$_{film}$ **(Z+E)** 2990, 2930, 2820, 1620, 1450, 1380, 1370, 1250, 1210, 1155, 1090, 950; **^{1}H NMR 5b-Z** δ 6.38 (dd, 1H, $J_{1,2}$ = 7.3 Hz, $J_{1,3}$ = 1.1 Hz, H-1), 5.99 (dd, 1H, $J_{2,3}$ = 8.5 Hz, H-2), 4.42 (ddd, 1H, $J_{3,4}$ = 3 Hz, H-3), 4.27 (ddd, 1H, $J_{5,6}$ = 6.1 Hz, $J_{5,6'}$ = 6.3 Hz, $J_{5,4}$ = 5.4 Hz, H-5), 4.09 (ABd, 1H, J_{AB} = 8.5 Hz, H-6), 4.03 (ABd,1H, H-6'), 3.57 (s, 3H, OCH_3), 3.45 (dd, 1H, H-4), 3.37 (s, 3H, OCH_3), 1.5 (s, 3H, -C$(CH_3)_2$-), 1.42 (s, 3H, -C$(CH_3)_2$-); **5b-E** δ 6.32 (dd, 1H, $J_{1,2}$ = 13.4 Hz, $J_{1,3}$ = 0.7 Hz, H-1), 6.02 (dd, 1H, $J_{2,3}$ = 8 Hz, H-2), 4.23 (ddd, 1H, $J_{5,6}$ = 7.08 Hz, $J_{5,6'}$ = 6.6 Hz, H-5) , 4.08 (ABd, 1H, J_{AB} = 8.5 Hz, H-6), 3.98 (ABd, 1H, H-6'), 3.8 (ddd, 1H, $J_{3,4}$ = 3Hz, H-3), 3.56 (s, 3H, OCH_3), 3.45 (dd, 1H, H-4), 3.36 (s, 3H, OCH_3), 1.47 (s, 3H, -C$(CH_3)_2$-), 1.41 (s, 3H, -C$(CH_3)_2$-); **^{13}C NMR 5b-Z** δ 130.13 (d, C-2), 121.62 (d, C-1), 108.49 (s, -*C*$(CH_3)_2$-), 82.73 (d, C-4), 76.35 (d, C-3), 76.26 (d, C-5), 65.78 (t, C-6), 61.62 (q, OCH_3), 57.15 (q, OCH_3), 26.57 and 25.48 (q, -C(*C*$H_3)_2$-); **5b-E** δ 130.83 (d, C-2), 121.47 (d, C-1), 108.49 (s, -*C*$(CH_3)_2$-), 83.45 (d, C-4), 79.96 (d, C-3), 75.78 (d, C-5), 65.78 (t, C-6), 61.62 (q, OCH_3), 57.10 (q, OCH_3), 26.53 (q, -C(*C*$H_3)_2$-), 25.35 (q, -C(*C*$H_3)_2$-).

Anal. Calcd for $C_{11}H_{19}O_4Cl$: C, 52.70; H, 7.64; O, 25.52; Cl, 14.14. Found: C, 52.52; H, 7.45; O, 26.03; Cl, 14.0.

1-Chloro-1,2-dideoxy-3,4:5,6-di-*O*-isopropylidene-L-arabino-hex-1-enitol (5c). **IR**$_{film}$ **(Z+E)** 2990, 2940, 2890, 1640, 1450, 1380, 1370, 1240, 1220, 1360, 1070; **^{1}H NMR 5c-Z** δ 6.28 (dd, 1H, $J_{1,2}$ = 7.3 Hz, $J_{1,3}$ = 1Hz, H-1), 5.84 (dd, 1H, $J_{2,3}$ = 8.5 Hz, H-2), 4.85 (ddd, 1H, $J_{3,4}$ = 7.6 Hz, H-3), 4.18 (ddd, 1H, $J_{5,6}$ = 5.7, $J_{5,4}$ = 6.1 Hz, $J_{5,6'}$ = 6.2 Hz, H-5), 3.82 (dd, 1H, H-4), 4.1 (ABd , 1H, J_{AB} = 8.2 Hz, H-6), 3.95 (ABd, 1H, H-6'), 1.43 (s, 3H, -C$(CH_3)_2$-), 1.42 (s, 3H, -C$(CH_3)_2$-), 1.40 (s, 3H), 1.35 (s, 3H); **^{13}C NMR** δ 122.95 (d, C-1), 129.03 (d, C-2), 109.99 (s, -*C*$(CH_3)_2$-), 109.83 (s, -*C*$(CH_3)_2$-), 80.60 (d, C-4) 75.85 (d, C-5) 74.23 (d, C-3) 66.35 (t, C-6), 27.07 (q, -C(*C*$H_3)_2$-), 26.91 (q, -C(*C*$H_3)_2$-), 26.59 (q, -C(*C*$H_3)_2$-), 25.30 (q, -C(*C*$H_3)_2$-); **GCMS** 249 and 247 (M^+-15) (14%); 134 and 132 (11%); 103 and 101

(21%); 97 (19%); 75 and 73 (6%); 43 (100%). **5c-E ^{1}H NMR** δ 6.35 (dd, 1H, $J_{1,2}$ = 13.3 Hz, $J_{1,3}$ = 1.2 Hz, H-1), 6.01 (dd, 1H, $J_{2,3}$ = 6.2 Hz, H-2), 4.40 (ddd, 1H, $J_{3,4}$ = 7.7 Hz, H-3), 4.1 (m, 1H, H-5), 4.1 (ABd, 1H, H-6), 3.93 (ABd, 1H, H-6'), 3.67 (m, 1H, H-4) 1.41 (s, 3H, -C(CH_3)$_2$-), 1.40 (s, 6H,-C(CH_3)$_2$-), 1.34 (s, 3H,-C(CH_3)$_2$-); **^{13}C NMR** δ 131.21 (d, C-2) 121.24 (d, C-1), 109.79 (s,-*C*(CH_3)$_2$-), 109.81 (s, -*C*(CH_3)$_2$-), 81.10 (d, C-4), 78.45 (d, C-5), 76.77 (d, C-3), 67.35 (t, C-6), 26.82 (q, -C(*C*H_3)$_2$-), 26.74 (q, -C(*C*H_3)$_2$-), 26.67 (q, -C(*C*H_3)$_2$-), 25.17 (q, -C(*C*H_3)$_2$-); **GCMS** 249 and 247 (9%); 189 (4%); 134 and 132 (16%); 103 and 101 (22%); 97 (22%); 75 and 73 (6%); 59 and 57 (17%); 43 (100%).

Alkynes 6. To a solution of **5** (12.5 mmol) in dry tetrahydrofuran (100 mL) cooled at -78 °C (acetone, dry-ice), was added under a nitrogen atmosphere, a 1.6 M solution of *n*-butyllithium in hexanes (16.5 mL, 26.4 mmol). After 1 h the reaction mixture was warmed to -50 °C stirred 10 min at this temperature and hydrolyzed with a saturated aqueous solution of ammonium chloride (30 mL). The aqueous phase was extracted with diethyl ether (2 x 50 mL), and the combined extracts dried and concentrated. The residue was chromatographed on silica gel using a mixture of diethyl ether-pentane (3:7 for **6a**, 4:6 for **6b**, 2:8 for **6c**) as the eluent. We thus obtained **6a** (74%), **6b** (60%) and **6c** (85%).

3,4-Di-*O*-benzyl-1,2-dideoxy-5,6-*O*-isopropylidene-L-arabino-hex-1-ynitol (6a). $[\alpha]_D$ +31° (*c* 1.75, chloroform); **IR**$_{film}$ 3300, 3000, 2980, 2120, 1600, 1500, 1460, 1385, 1375, 1260, 1215, 1070; **^{1}H NMR** δ 7.31 (m, 10H_{arom}), 4.88 and 4.52 (AB, 2H, J_{AB} = 11.9 Hz, OCH_2Ph), 4.83 and 4.78 (AB, 2H, J_{AB} = 11.5 Hz, OCH_2Ph), 4.36 (ddd, 1H, $J_{5,4}$ = 3.9 Hz, $J_{5,6}$ = 6.9 Hz, $J_{5,6'}$ = 6.5 Hz, H-5), 4.21 (dd, 1H, $J_{3,4}$ = 4.2 Hz, $J_{3,1}$ = 2.2 Hz, H-3), 4.03 (ABd, 1H, J_{AB} = 8.2 Hz, H-6), 3.94 (ABd, 1H, H-6'), 3.82 (dd, 1H, H-4), 2.53 (d, 1H, H-1), 1.32 and 1.37 (s, 3H,-C(CH_3)$_2$-); **^{13}C NMR** δ 138.11, 137.28 (s, C_{arom}), 128.28, 128.22, 128.02, 127.99, 127.86, 127.73, 127.66, 127.53 (d, C_{arom}), 108.40 (s, -*C*(CH_3)$_2$-), 80.73 (s, C-2), 80.42 (d, C-4), 76.04 (d, C-1), 75.48 (d, C-5), 74.70 (t, OCH_2Ph), 70.82 (t, OCH_2Ph)), 68.32 (d, C-3), 65.50 (t, C-6), 26.45 and 25.27 (q, -C(*C*H_3)$_2$-).

Anal. Calcd for $C_{23}H_{26}O_4$: C, 75.38; H, 7.15; O, 17.47. Found: C, 75.55; H, 7.18; O, 17.27.

1,2-Dideoxy-5,6-*O*-isopropylidene-3,4-di-*O*-methyl-L-arabino-hex-1-ynitol (6b). $[\alpha]_D$ +20° (*c* 1.98, chloroform); **IR**$_{film}$ 3250, 2990, 2930, 2895, 2820, 2100, 1500, 1325, 1315, 1250, 1220, 1160, 1090, 850; **^{1}H NMR** δ 4.26 (ddd,1H, $J_{5,6}$ = 6.1 Hz, $J_{5,6'}$ = 5.9 Hz, $J_{5,4}$ = 5.7 Hz, H-5), 4.10 (dd, 1H, $J_{3,1}$ = 2.2 Hz, $J_{3,4}$ = 3.2 Hz, H-3), 4.04 (ABd, 1H, J_{AB} = 8.4 Hz, H-6), 3.98 (ABd, 1H, H-6'), 3.63 (s, 3H, OCH_3), 3.48 (dd,1H, H-4), 3.47 (s, 3H, OCH_3), 2.54 (d, 1H, H-1), 1.43

(s, 3H, -C(CH_3)$_2$-), 1.42 (s, 3H, -C(CH_3)$_2$-); **^{13}C NMR** δ 108.71 (s, -*C*(CH_3)$_2$-), 83.05 (d, C-4), 80.38 (s, C-2), 75.72 (d, C-1), 75.25 (d, C-5), 70.44 (d, C-3), 65.76 (t, C-6), 61.29 (q, OCH_3), 57.19 (q, OCH_3), 26.61 (q, -C(*C*H_3)$_2$-), 25.35 (q, -C(*C*H_3)$_2$-); **GCMS** 199 (M^+-15, 36%); 145 (10%); 141 (18%); 115 (6%); 114 (7%); 11 (7%); 101 (49%); 87 (88%); 82 (17%); 69 (45%); 43 (100%).

1,2-Dideoxy-3,4:5,6-di-*O*-isopropylidene-L-arabino-hex-1-ynitol (6c). $[\alpha]_D$ -21° (*c* 1, chloroform); **IR**$_{film}$ 2990, 2290, 2940, 2890, 2110, 1450, 1280, 1370, 1260, 1210, 1150, 1070, 840; **^{1}H NMR** δ 4.63 (dd, 1H, $J_{3,1}$ = 2.1 Hz, $J_{3,4}$ = 5.2 Hz, H-3), 4.1 (m, 1H, H-4), 3.98 (dt, 1H, J_{5-6} = 6.5 Hz, $J_{5-6'}$ = 4.1 Hz, H-5), 4.08 (d, 2H, H-6, H-6'), 2.58 (d, 1H, H-1), 1.50 (s, 3H, -C(CH_3)$_2$-), 1.45 (s, 3H, C(CH_3)$_2$-), 1.41 (s, 3H, -C(CH_3)$_2$-), 1.35 (s, 3H, -C(CH_3)$_2$-); **^{13}C NMR** δ 111.11 (s, -*C*(CH_3)$_2$-), 109.90 (s, -*C*(CH_3)$_2$-), 82.14 (d, C-4), 81.83 (s, C-2), 76.16 (d, C-5), 74.56 (d, C-1), 68.04 (d, C-3), 66.74 (t, C-6), 26.97 (q, -C(*C*H_3)$_2$-), 26.66 (q, C(*C*H_3)$_2$-), 26.01 (q, -C(*C*H_3)$_2$-), 25.19 (q, -C(*C*H_3)$_2$-); **GCMS** 211 (M^+-15, 35%); 101 (21%); 96 (9%); 67 (7%); 59 (8%), 43 (100%).

Diols 7. To a solution of **6a** or **6b** (4.6 mmol) in dry methanol (40 mL) was added *p*-toluenesulfonic acid (1 g, 0.48 mmol) and the reaction mixture was stirred for 48 h at room temperature and 6 h at 40 °C. The methanol was then removed under reduced pressure (10^{-1} torr) and the residue dissolved in ethyl acetate (150 mL). The organic phase was washed with saturated aqueous solution of sodium hydrogenocarbonate (10 mL) and a saturated aqueous solution of sodium chloride (2 x 10 mL) dried and concentrated. The crude product was applied to a column of silica gel using diethyl ether as an eluent. We thus obtained **7a** (87%) and **7b** (86%). In the case of **6c**, the crude product obtained after evaporation of methanol was washed with diethyl ether (2 x 20 mL) and then crystallized from acetonitrile, furnishing **7c** (86%).

3,4-Di-*O*-benzyl-1,2-dideoxy-L-arabino-hex-1-ynitol (7a). $[\alpha]_D$ +19° (*c* 1, chloroform); **IR**$_{film}$ 3430, 3300, 2980, 2110, 1610, 1500, 1460, 1400, 1345, 1215, 1100, 1070, 1030; **^{1}H NMR** δ 7.30 (m, 10H_{arom}), 4.81 and 4.50 (AB, 2H, J_{AB} = 11.7 Hz, OCH_2Ph), 4.76 and 4.60 (AB, 2H, J_{AB} = 11.4 Hz, OCH_2Ph), 4.36 (dd, 1H, $J_{3,4}$ = 4.2 Hz, $J_{3,1}$ = 6.5 Hz, H-3), 4.0 (m, 1H, H-5), 3.68 (m, 1H, H-4), 3.75-3.62 (m, 2H, H-6, H-6'), 3.29 (br s, 2H, OH), 2.55 (d, 1H, H-1); **^{13}C NMR** δ 137.55, 136.75 (s, C_{arom}), 128.27, 128.18, 128.06, 128.0, 127.94, 127.80, 127.68 (d, C_{arom}), 79.82 (d, C-4), 79.66 (s, C-2), 76.46 (d, C-1), 74.12 (t, OCH_2Ph)), 71.01 (d, C-5), 70.81 (t, OCH_2Ph), 68.96 (d, C-3), 62.88 (t, C-6).

1,2-Dideoxy-3,4-di-*O*-methyl-L-arabino-hex-1-ynitol (7b). $[\alpha]_D$ +16° (*c* 1.5, chloroform); **IR**$_{film}$ 3450, 3300, 2930, 2820, 2100, 1450, 1190, 1080, 970; **^{1}H NMR** δ 4.30 (dd, 1H, $J_{3,4}$ = 3.9 Hz, $J_{3,1}$ = 2.2 Hz, H-3), 3.94 (ddd, 1H, $J_{5,4}$ = 7.4 Hz,

$J_{5,6'}$ = 4.7 Hz, $J_{5,6}$ = 3.3 Hz, H-5), 3.79 (ABd, 1H, J_{AB} = 11.5 Hz, H-6), 3.72 (ABd, 1H, H-6'), 3.57 (s, 3H), 3.48 (s, 3H), 3.44 (dd, 1H, H-4), 3.25 (br s, 2H, OH), 2.58 (d, 1H, H-1); **^{13}C NMR** δ 81.85 (d, C-4), 79.51 (s, C-2), 76.13 (d,C-1), 71.25 (d, C-3), 70.93 (d, C-5), 63.09 (t, C-6), 60.37 (q, OCH_3), 57.18 (q, OCH_3); **GCMS** 143 (M^+-31) (5%); 111 (30%); 87 (41%); 82 (46%); 75 (90 %); 69 (49%); 45 (100%).

1,2-Dideoxy-L-arabino-hex-1-ynitol (7c). mp 132-134 °C; $[\alpha]_D$ +5° (*c* 1, methanol) and +10° (*c* 1, water); **IR** (KBr) 3450-3300, 3290, 2940, 2100, 1460, 1320, 1280, 1100, 1070, 1035; **^{1}H NMR** (DMSO-d_6) δ 5.1 (br s, 1H, OH), 4.65 (br s, 3H, OH), 4.38 (dd, 1H, $J_{3,4}$ = 2.5 Hz, $J_{3,1}$ = 2 Hz, H-3), 3.57 (ABd, 1H, J_{AB} = 10.5 Hz, $J_{6,5}$ = 3 Hz, H-6), 3.52 (m, 1H, H-5), 3.31 (ABd, 1H, $J_{6',5}$ = 5.6 Hz, H-6'), 3.31 (dd, 1H, $J_{4,5}$ = 7.2 Hz, H-4), 3.18 (d, 1H, H-1); **^{13}C NMR** (DMSO d_6) δ 85.34 (s, C-2), 74.35 (d, C-1), 74.00 (d, C-4), 70.93 (d, C-5), 62.93 (t, C-6), 61.38 (d, C-3).

Anal. Calcd for $C_6H_{10}O_4$: C, 49.31; H, 6.90; O, 43.79. Found: C, 49.94; H, 6.93; O, 43.27.

Sulfonates 8. To a solution of **7a** or **7b** (4.05 mmol) in dry pyridine (10 mL), was added, dropwise, a solution of *p*-toluenesulfonyl chloride (1 g, 5.24 mmol) in dichloromethane (5 mL) and the reaction mixture was stirred for 24 h at room temperature. Pyridine was then removed under reduced pressure (10^{-1} torr) and the residue dissolved in dichloromethane (60 mL). The organic phase was washed with a saturated aqueous solution of ammonium chloride (20 mL) and water and then dried and concentrated. The crude product was purified by chromatography on silica gel using a mixture of dichloromethane-diethyl ether (95:5) as the eluent. A small amount of ditosylate was first eluted and then **8a** (66%) or **8b** (76%). To a solution of **7c** (390 mg, 2.6 mmol) in dry pyridine (10 mL) cooled at 0 °C was added 2,4,6 triisopropyl-benzene-sulfonyl chloride (TPSCl) (800 mg, 2.6 mmol). At the end of the addition the reaction mixture was warmed to room temperature. An additional quantity of TPSCl (1.8 g) was then slowly added by small portions on a period of about 15 h until complete disappearance of starting material (TLC dichloromethane-ethyl acetate : 1:1). The pyridine was then removed and the residue was extracted with ethyl acetate (4 x 40 mL). After evaporation of solvents, **8c** (860 mg, 80%) crystallized upon addition of 50 mL of a mixture of diethyl ether-pentane (1:1).

3,4-Di-*O*-benzyl-1,2-dideoxy-6-*O*-tosyl-L-arabino-hex-1-ynitol (8a). $[\alpha]_D$ +15° (*c* 0.7, chloroform); **IR_{film}** 3520, 3300, 2890, 2120, 1600, 1500, 1460, 1360, 1195, 1180, 1100, 1070; **^{1}H NMR** δ 7.76 (d, 2H, J = 8.2 Hz, H_{arom}), 7.3 (m, 12H, H_{arom}), 4.84 and 4.50 (AB, 2H, J_{AB} = 11.7 Hz, OCH_2Ph), 4.73 and 4.57 (AB, 2H, J_{AB} = 11.3 Hz, OCH_2Ph), 4.36 (dd, 1H, $J_{3,4}$ = 3.8 Hz, $J_{3,1}$ = 2.2 Hz, H-3), 4.18 (d, 2H, H-6, H-6'), 4.15 (m, 1H, H-5), 3.69 (dd, $J_{3,4}$ = 5.5 Hz, H-4), 2.57 (d, 1H, H-1), 2.43 (br s, 1H, OH), 2.42 (s, 3H); **^{13}C NMR** δ 144.86, 137.34 (s, C_{arom}),

136.63, 132.70, 131.17, 129.84, 128.56, 128.41, 128.27, 128.20, 128.17, 128.02 (d, C_{arom}), 79.38 (s, C-2), 78.56 (d, C-4), 76.71 (d, C-1), 74.14 (t, OCH_2Ph), 71.09* (t, C-6), 71.05* (t, OCH_2Ph), 69.51 (d, C-5), 68.50 (d, C-3), 21.64 (q, Ph-CH_3). *These values may be inverted.

1,2 Dideoxy-3,4-di-*O*-methyl-6-*O*-tosyl-L-arabino-hex-1-ynitol (8b). $[\alpha]_D$ -1° (*c* 1, chloroform); **IR**$_{film}$ 3500, 3290, 2940, 2830, 2100, 1600, 1450, 1360, 1170, 1090, 970, 940, 820; **^{1}H NMR** δ 7.82 (d, 2H, J = 8.4 Hz, H_{arom}), 7.36 (d, 2H, H_{arom}), 4.29 (dd, 1H, $J_{3,4}$ = 3.4 Hz, $J_{3,1}$ = 2.1 Hz, H-3), 4.21 (d, 2H, $J_{6,5}$ = $J_{6',5}$ = 3.7 Hz, H-6, H-6'), 4.07 (dt, 1H, H-5), 3.42 (dd, 1H, $J_{4,5}$ = 7.7 Hz, H-4), 2.54 (d, 1H, H-1), 3.50 (s, 3H, OCH_3), 3.45 (s, 3H, OCH_3), 2.8 (br s,1H, OH), 2.46 (s, 3H, Ph-CH_3); **^{13}C NMR** δ 144.89, 132.54 (s, C_{arom}), 129.80, 127.92 (d, C_{arom}), 80.73 (d, C-4), 79.26 (s, C-2), 76.23 (d, C-1), 71.02 (t, C-6), 70.55 (d, C-3), 69.09 (d, C-5), 60.17 (q, OCH_3), 57.20 (q, OCH_3), 21.54 (q, Ph-CH_3).

Anal. Calcd for $C_{15}H_{20}O_6S$: C, 54.87; H, 6.14; O, 29.22; S, 9.77. Found: C, 54.71; H, 6.20; O, 29.74; S, 9.35.

1,2-Dideoxy-6-*O*-trisyl-L-arabino-hex-1-ynitol (8c). mp 100-104 °C; $[\alpha]_D$ -5° (*c* 1.5, methanol) $[\alpha]_D$ -6° (*c* 1.4, chloroform); **IR**(KBr) 3580, 3300, 2960, 1600, 1560, 1450, 1340, 1170, 1080, 970; **^{1}H NMR** δ 7.20 (s, 2H, H_{arom}), 4.68 (dd, 1H, $J_{3,4}$ = 2.9 Hz, $J_{3,1}$ = 2.2 Hz, H-3), 4.32 (ABd,1H, J_{AB} = 10.3 Hz $J_{6',5}$ = 3.2 Hz, H-6'), 4.28 (ABd, 1H, $J_{6,5}$ = 5.2 Hz, H-6) 4.10 (sept., 2H, J = 6.82 Hz, *o*-iPr-Ph), 4.09 (ddd, 1H, H-5) 3.73 (dd, 1H, $J_{4,5}$ = 8.1 Hz, H-4), 2.92 (sept., 1H, *p*-iPr-Ph), 2.62 (br s, 3H, OH), 2.5 (d, 1H, H-1), 1.27 (d, 12H, $CH(CH_3)_2$), 1.26 (d, 6H, J = 6.9 Hz, $CH(CH_3)_2$); **^{13}C NMR** δ 154.12, 150.97 (s, C_{arom}), 128.79, 123.92 (d, C_{arom}), 81.97 (s, C-2) 74.71 (d, C-1), 73.05 (d, C-4), 70.72 (t, C-6), 69.64 (d, C-5), 62.58 (d, C-3), 34.27 (d, $CH(CH_3)_2$), 29.71 (d, $CH(CH_3)_2$), 24.73 (q, $CH(CH_3)_2$), 23.52 (q, $CH(CH_3)_2$).

Anal. Calcd for $C_{21}H_{32}O_6S$: C, 61.14; H, 7.82; O, 23.27; S, 7.77. Found: C, 61.30; H, 7.84; O, 23.10; S, 7.74.

Iodides 9. To a solution of sulfonate **8a** or **8b** (2.7 mmol) in dry acetone (40 mL) was added sodium iodide (0.9 g, 6 mmol) and the reaction mixture was refluxed for 6 h. Solvent was evaporated and the residue extracted with 50 mL of a mixture of diethyl ether-pentane (1:1). After concentration of the extracts, the crude product was purified by column chromatography using a mixture of diethyl ether-pentane (1:1 for **9a**; 6:4 for **9b**) as the eluent. We thus obtained **9a** (83%) and **9b** (82%). The same procedure was used for the preparation of **9c** (76%), except that the crude product obtained after acetone evaporation was extracted and chromatographed using a mixture of ethyl acetate-dichloromethane (7:3).

3,4-Di-*O*-benzyl-1,2,6-trideoxy-6-iodo-L-arabino-hex-1-ynitol (9a). $[\alpha]_D$ +16° (*c* 1.4, chloroform); **IR**$_{film}$ 3495, 3295, 3025, 2870, 2115, 1600, 1450, 1365, 1210, 1180, 1060, 735, 700; **^{1}H NMR** δ 7.28 (m, 10H$_{arom}$), 4.87 and 4.54 (AB, 2H, J_{AB} = 11.7 Hz, OCH_2Ph), 4.82 and 4.67 (AB, 2H, J_{AB} = 11.2 Hz, OCH_2Ph), 4.43 (dd, 1H, $J_{3,4}$ = 3.9 Hz, $J_{3,1}$ = 2.2 Hz, H-3), 3.80 (ddd, 1H, $J_{5,4}$ = 7.5 Hz, $J_{5,6}$ = 5.4 Hz, $J_{5,6'}$ = 3.9 Hz, H-5), 3.62 (dd, 1H, H-4), 3.47 (ABd, 1H, J_{AB}= 10.4 Hz, H-6), 3.42 (ABd, 1H, H-6'), 2.80 (br s, 1H, OH), 2.60 (d, 1H, H-1); **^{13}C NMR** δ 137.42, 136.54 (s, C$_{arom}$), 128.55, 128.44, 128.28, 128.21, 128.03 (d, C$_{arom}$), 81.17 (d, C-4), 79.55 (s, C-2), 76.82 (d, C-1), 74.19 (t, OCH_2Ph), 71.13 (t, OCH_2Ph), 70.12 (d, C-5), 68.60 (d, C-3), 12.72 (t, C-6).

Anal. Calcd for $C_{20}H_{21}O_3I$: C, 55.06; H, 4.85; O, 11.00; I, 29.09. Found: C, 55.73; H, 4.84; O, 11.06; I, 28.37.

1,2,6-Trideoxy-6-iodo-3,4-di-*O*-methyl-L-arabino-hex-1-ynitol (9b). $[\alpha]_D$ -15° (*c* 0.95, chloroform); **IR**$_{film}$ 3450, 3300, 2930, 2820, 2100, 1450, 1410, 1340, 1300, 1180, 1080, 1000; **^{1}H NMR** δ 4.35 (dd, 1H, $J_{3,4}$ = 3.4 Hz, $J_{3,1}$ = 2.2 Hz, H-3), 3.67 (dt, 1H, $J_{5,6}$ = $J_{5,6'}$ = 4.3 Hz, H-5), 3.62 (s, 3H, OCH_3), 3.35 (dd, 1H, $J_{4,5}$ = 7.7 Hz, H-4), 3.52 (d, 2H, H-6, H-6'), 3.50 (s, 3H, OCH_3), 2.93 (br s, 1H, OH), 2.58 (d, 1H, H-1); **^{13}C NMR** δ 83.37 (d, C-4), 79.48 (s, C-2), 76.44 (d, C-1), 70.87 (d, C-3), 69.81 (d, C-5), 60.35 (q, OCH_3), 57.38 (q, OCH_3), 13.24 (t, C-6).

Anal. Calcd for $C_8H_{13}O_3I$: C, 33.82; H, 4.61; O, 16.82. Found: C, 34.76; H, 4.73; O, 17.44.

1,2,6-Trideoxy-6-iodo-L-arabino-hex-1-ynitol (9c). mp 80-82 °C; $[\alpha]_D$ -11° (*c* 0.7, methanol); **IR** (KBr) 3540, 3300, 2930, 2100, 1420, 1080, 1030, 760, 680, 660; **^{1}H NMR** (DMSO *d_6*) δ 5.23 (d, 1H, $J_{OH,H-3}$ = 7.2 Hz, OH), 5.22 (d, 1H, $J_{OH,H-5}$= 5.2 Hz, OH), 5.00 (d, 1H, $J_{OH,H-4}$ = 7.3 Hz, OH), 4.41 (ddd, 1H, $J_{3,4}$ = 2.5 Hz, $J_{3,1}$ = 2.3 Hz, H-3), 3.48 (ABd, 1H, $J_{6',5}$ = 5.5 Hz, H-6'), 3.33 (m, 1H, H-5), 3.33 (ABd , 1H, J_{AB} = 12.8 Hz, $J_{6,5}$ = 6.13 Hz, H-6), 3.22 (d, 1H, H-1), 3.2 (ddd, 1H, $J_{4,5}$ = 7.3 Hz, H-4); **^{13}C NMR** (DMSO *d_6*) δ 85.10 (s, C-2), 76.17 (d, C-4), 74.55 (d, C-1), 69.06 (d, C-5), 61.01 (d, C-3), 15.88 (t, C-6).

Anal. Calcd for $C_6H_9O_3I$: C, 28.12; H, 3.51; O, 18.75; I, 49.60. Found: C, 28.35; H, 3.58; O, 18.87; I, 49.56.

Radical cyclisation. To a refluxing solution of iodide **9a** or **9b** (1.2 mmol) in dry benzene (30 mL) , was added, under a nitrogen atmosphere, with a syringe pump 9 mL of a 0.16 M solution of triphenyltin hydride in dry benzene containing 10% of azoisobutyronitrile (AIBN) over a period of about 6 h (0.25 mmol/h). Reflux was still maintained 30 min after the end of the addition and then the solvant was evaporated and the crude product purified by chromatography using a mixture of diethyl ether-pentane (1:1).

The same procedure was used for the cyclisation of **9c** except that the crude product was purified using a mixture of ethyl acetate-dichloromethane (7:3) and then ethyl acetate-dichloromethane-methanol (7: 1.5: 1.5) as eluent.

(1*S*, 2*S*, 3*S*)-2,3-Dibenzyloxy-4-methylenecyclopentan-1-ol (10a). R_f 0.28 (diethyl ether/pentane, 1:1); **IR**$_{film}$ 3500, 3080, 2930, 1640, 1590, 1480, 1430, 1080; **^{1}H NMR** δ 7.35 (m, 10H, H_{arom}), 5.23 (m, 1H, $=CH_2$), 5.12 (m, 1H, $=CH_2$), 4.70 (br s, 2H, OCH_2Ph), 4.65 (br s, 2H, OCH_2Ph), 4.4 (m, 1H, H-3), 4.21 (m, 1H, H-1), 3.88 (dd, 1H, $J_{2,3}$ = 6.1 Hz, $J_{2,1}$ = 4.5 Hz, H-2), 2.66 and 2.47 (ABm, 1H, J_{AB} = 17.4 Hz, H-5, H-5'), 1.95 (br s, 1H, OH); **^{13}C NMR** δ 145.5 (s, C-4), 138.4, 137.6 (s, C_{arom}), 128.60, 128.39, 128.09, 127.88, 127.76, 127.63 (d, C_{arom}), 111.8 (t, $=CH_2$), 85.5 (d, C-3), 82.5 (d, C-2), 72.2 (t, OCH_2Ph), 71.8 (t, OCH_2Ph), 68.50 (d, C-1), 36.74 (t, C-5).

(1*S*, 2*R*)-2-Benzyloxy-4-methylenecyclopentan-1-ol (11a). R_f 0.33 (diethyl ether/pentane, 1:1); **IR**$_{film}$ **(11a + 12a)** 3460, 3080, 2930, 1640, 1590, 1480, 1430, 1080. **11a ^{1}H NMR** δ 7.35 (m, 5H, H_{arom}), 4.93 (m, 2H, $=CH_2$), 4.65 and 4.55 (AB, 2H, J_{AB} = 11.8 Hz, OCH_2Ph), 4.2 (m, 1H, H-1), 3.90 (m, 1H, H-2), 2.63 (d, $J_{OH,H-1}$ = 4.0 Hz, OH), 2.55 (m, 2H, H-5, H-5'), 2.5 (m, 2H, H-3, H-3'); **^{13}C NMR** δ 145.98 (s, C-4), 138.03 (s, C_{arom}), 128.07, 127.92, 127.81 (d, C_{arom}), 108.57 (t, $=CH_2$), 80.56 (d, C-2), 71.92 (d, C-1), 71.53 (t, OCH_2Ph), 38.80 (t, C-5), 35.37 (t, C-3); **GCMS (11a + 12a)** 204 (M^+, 2%), 160 (4%), 113 (48%), 91 (100%).

(1*S*, 2*R*)-3-Deutero-2-benzyloxy-4-methylenecyclopentan-1-ol (11a-*d*). **^{1}H NMR** δ 7.35 (m, 5H, H_{arom}), 4.93 (m, 2H, $=CH_2$), 4.65, 4.55 (AB, 2H, J_{AB} = 12 Hz, OCH_2Ph), 4.20 (m, 1H, H-1), 3.90 **(m *,** 1H, H-2), 2.55 (d, 1H, $J_{OH,H-1}$ = 4 Hz, OH), 2.55 (m, 2H, H-5 H-5') 2.5 **(m *, 1H,** H-3); **^{13}C NMR** (selected data) δ 145.81 (s, C-4), 108.52 (t, $=CH_2$), 80.40 (d, C-2), 71.44 (d, C-1), 38.69 (t, C-5), **34.92 (d** -DEPT-, (1,1,1) **t, $J_{C,D}$ = 20 Hz, C-3).** ***** These multiplets were modified compared to the signals of **11a**.

(1*S*, 2*R*)-2-Benzyloxy-4-methylcyclopent-3-ene-1-ol (12a). R_f 0.33 (diethyl ether/pentane, 1:1); **^{1}H NMR** δ 7.35 (m, 5H, H_{arom}), 5.48 (m, 1H, H-3), 4.63 (br s, 2H, OCH_2Ph), 4.37 (m, 1H, H-2), 4.35 (m, 1H, H-1), 3.01 (d, J_{OH-H-1} = 6.3 Hz, OH), 2.35 and 2.33 (ABm, 2H, J_{AB} = 16.5 Hz, H-5, H-5'), 1.78 (s, 3H, CH_3).**^{13}C NMR** δ 144.70 (s, C-4), 138.28 (s, C_{arom}), 128.55, 128.33, 127.89 (d, C_{arom}), 123.16 (d, C-3), 83.30 (d, C-2), 71.88 (t, OCH_2Ph), 71.11 (d, C-1), 44.31 (t, C-5), 17.37 (q, CH_3).

(1*S*, 2*R*)-2-Benzyloxy-3-deutero-4-methylcyclopent-3-ene-1-ol (12a-*d*). **^{1}H NMR** δ 7.35 (m, 5H, H_{arom}), 5.48 (m, 1H, H-3), 4.63 (br s, 2H, OCH_2Ph), 4.37 (m, 1H, H-2), 4.35 (m, 1H, H-1), 2.95 (d, $J_{OH,H-1}$ = 6.2 Hz, OH), 2.35 and 2.33

(ABm, 2H, J_{AB} = 16.5 Hz, H-5, H-5'), 1.78 (**d, 2H, $J_{H,D}$= 1.4 Hz, CH_2D**); ^{13}C **NMR** (selected data) d 144.63 (s, C-4), 122.03 (d, C-3), 83.20 (d, C-2), 70.99 (d, C-1), 44.20 (t, C-5), **17.00 (t** -DEPT-, (1,1,1) **t , $J_{C,D}$ = 19.4 Hz, CH_2D)**.

(1*S*, 2*R*)-1-Acetoxy-2-benzyloxy-4-methylenecyclopentane (11b). R_f 0.3 (pentane/diethyl ether, 8:2); ^{1}**H NMR** (from the mixture of **11b** and **12b**) δ 7.35 (m, 5H), 5.3 (pseudo q, 1H, J = 6 Hz, H-1), 4.96 (m, 1H, $=CH_2$), 4.91 (m, 1H, $=CH_2$), 4.61 and 4.52 (AB, 2H, J_{AB} = 12 Hz, OCH_2Ph), 3.99 (m, 1H, H-2), 2.57 (m, 2H, H-5, H-5'), 2.51 (m, 2H, H-3, H-3'), 2.1 (s, 3H, CH_3CO); ^{13}**C NMR** δ 170.80 (s, CH_3CO), 144.37 (s, C-4), 138.26 (s, C_{arom}), 128.37, 127.61, 127.48 (d, C_{arom}), 108.68 (t, $=CH_2$), 79.0 (d, C-2), 73.19 (d, C-1), 71.86 (t, OCH_2Ph), 36.28 (t, C-5), 36.20 (t, C-3), 21.2 (q, CH_3CO).

(1*S*, 2*R*)-1-Acetoxy-2-benzyloxy-4-methylcyclopent-3-ene (12b). R_f 0.25 (pentane/diethyl ether, 8:2); $[\alpha]_D$ -88 ° (*c* 1.5, chloroform); **IR**$_{film}$ 3050, 3020, 2920, 2850, 1730, 1640, 1490, 1430, 1370, 1235, 1180, 1170, 1060; ^{1}**H NMR** δ 7.35 (m, 5H, H_{arom}), 5.48 (m, 1H, H-3), 5.3 (pseudo q, 1H, J = 6 Hz, H-1), 4.57 and 4.48 (AB, 2H, J_{AB} = 11.7 Hz, OCH_2Ph), 4.55 (m, 1H, H-2), 2.5 (m, 2H, H-5, H-5'), 2.08 (s, 3H, CH_3CO), 1.78 (br s, 3H, CH_3); ^{13}**C NMR** δ 171.01 (s, CH_3CO), 143.28 (s, C-4), 138.72 (s, C_{arom}), 128.27, 127.66, 127.47 (d, C_{arom}), 123.99 (d, C-3), 81.74 (d, C-2), 73.19 (d, C-1), 71.86 (t, OCH_2Ph), 40.56 (t, C-5), 21.06 (q, CH_3CO), 17.06 (q, CH_3).

Anal. Calcd for $C_{15}H_{18}O_3$: C, 73.14; H, 7.37; O, 19.49. Found: C, 73.25; H, 6.95; O, 19.80.

(1*S*, 2*S*, 3*S*)-2,3-Dimethoxy-4-methylenecyclopentan-1-ol (10b). R_f 0.33 (ethyl acetate/pentane, 8:2); $[\alpha]_D$ -67° (*c* 0.4, chloroform); **IR**$_{film}$ 3450, 3070, 2990, 2930, 2820, 1660, 1450, 1320, 1190, 1110, 1060, 1010, 970, 910, 880; ^{1}**H NMR** δ 5.20 (pseudo-q, 1H, J = 2.2 Hz, $=CH_2$), 5.13 (pseudo qd, 1H, J = 2.2 Hz, J = 0.6 Hz, $=CH_2$), 4.25 (ddd, 1H, $J_{3,5}$ = 5.7 Hz $J_{3,2}$ = 4.4 Hz, $J_{3,5'}$ = 3.2 Hz, H-3), 4.09 (ddd, 1H, $J_{1,2}$ = 5.8 Hz, $J_{1,5}$ = 4 0 Hz, $J_{1,5'}$ = 2 Hz, H-1), 3.55 (dd, 1H, H-2), 3.50 (s, 3H, OCH_3) 3.48 (s, 3H, OCH_3), 2.65 (ABm, 1H, J_{AB} = 17.4 Hz, H-5), 2.43 (AB pseudo q,1H, H-5'), 2.33 (br s, 1H, OH); ^{13}**C NMR** δ 145.73 (s, C-4), 112.09 (t, $=CH_2$), 87.30 (d, C-3), 84.41 (d, C-2), 68.54 (d, C-1), 57.92 (q, OCH_3), 57.59 (q, OCH_3), 36.96 (t, C-5).

Anal. Calcd for $C_8H_{14}O_3$: C, 60.74; H, 8.92; O, 30.34. Found: C, 60.87; H, 8.94; O, 30.18.

(1*S*, 2*S*, 3*S*)-4-Methylenecyclopentan-1,2,3-triol (10c). R_f 0.36 (ethyl acetate/dichloromethane/methanol, 7:1.5:1.5); mp 125-126 °C; $[\alpha]_D$ -95 °(*c* 0.9, methanol); **IR** (KBr) 3300, 3070, 2920, 1660, 1430, 1130, 1090, 1040, 890; ^{1}**H NMR**

(DMSO d_6) δ 5.03 (m, 1H, $=CH_2$), 4.94 (d, 1H, $J_{OH,H-3}$ = 6.1 Hz, OH), 4.87 (m, 1H, $=CH_2$), 4.68 (d, 1H, $J_{OH,H-2}$ = 5.7 Hz, OH), 4.42 (d, 1H, $J_{OH,H-1}$ = 3.6 Hz, OH), 4.11 (m, 1H, H-3), 3.88 (m, 1H, H-1), 3.45 (ddd, 1H, $J_{2,3}$ = 4.9 Hz, $J_{2,1}$ = 6.9 Hz, H-2), 2.50 (ABm, 1H, J_{AB} = 17.4 Hz, H-5), 2.21 (ABm, 1H, H-5'); **^{13}C NMR** (DMSO d_6) δ 150.18 (s, C-4), 108.06 (t, $=CH_2$), 78.30* (d, C-3), 76.23* (d, C-2), 68.69 (d, C-1), 36.28 (t, C-5). *These values may be inverted.

Anal. Calcd for $C_6H_{10}O_3$: C, 55.37; H, 7.75; O, 36.88. Found: C, 55.37; H, 7.93; O, 36.82.

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