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Enantioselective Synthesis of (-)-Canadensolide

Toshio Honda,* Yuji Kobayashi, and Masayoshi Tsubuki

Institute of Medicinal Chemistry, Hoshi University, Ebara 2-4-41, Shinagawa-ku, Tokyo 142, Japan

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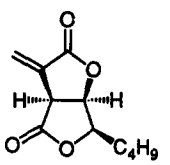
Abstract: Chiral synthesis of canadensolide has been achieved by using the Sharpless kinetic resolution of the 2-furylcarbinol derivative(**11**), followed by its oxidative conversion into the corresponding pyranone(**12**) as key reactions.

Canadesolide (**1**), an antibiotic isolated from *Penicillium canadense*,[1] has a unique structural feature related to avenaciolide (**2**), isoavenaciolide (**3**), and ethisolide (**4**) (Figure 1). Its relative stereochemistry has been determined by the total synthesis of its racemate in 1975 by Yoshikoshi and his co-workers.[2] Although a number of syntheses of canadensolide have been reported to date,[3-5] only two chiral syntheses have been achieved with the use of glucose as a chiral starting material.[6,7]



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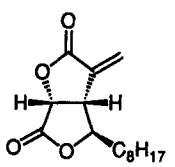

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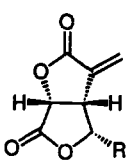
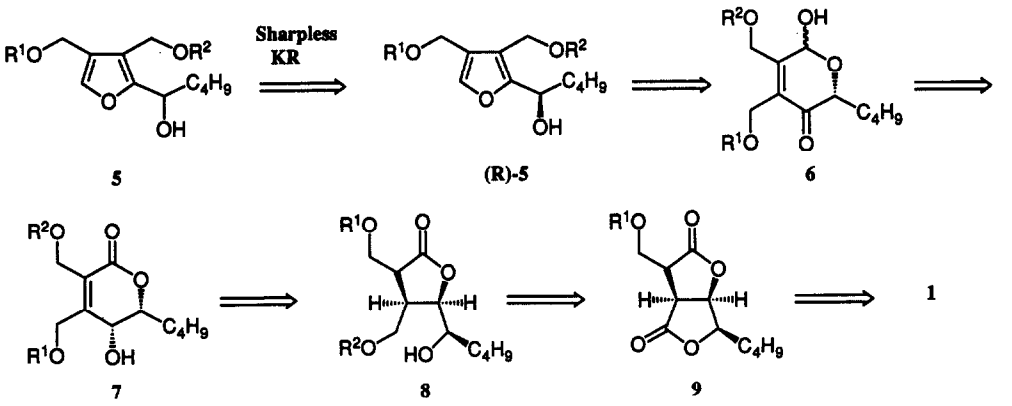


3 R=C_8H_{17}
4 R=C_2H_5

Figure 1.

Recently we have developed a synthetic strategy for the preparation of chiral 2-furylcarbinols by utilizing the Sharpless kinetic resolution of the corresponding racemates in good conversion yields with high enantioselectivities and this strategy was successfully applied to the syntheses of various types of physiologically active natural products.[8] As part of our study on the exploitation of 2-furylcarbinol in natural product synthesis, we are interested in the enantio- and stereoselective synthesis of (-)-canadensolide.[9]

The synthetic plan we first deviced is indicated in Scheme 1 which involves a trisubstituted furan derivative (**5**) having the all carbon unit for the synthesis of canadensolide as a starting material.



Scheme 1.

Thus the Sharpless kinetic resolution employing titanium tetra-isopropoxide, L-diisopropyl tartrate, and *tert*-butyl hydroperoxide was applied to the racemic **5a**. Although the absolute configuration of the recovered chiral **5a** could not be determined at this stage, its enantiomeric excess was only 55% e.e. based on the NMR analysis of the corresponding Mosher's ester. In order to improve the optical purity of the resolved starting material in this reaction, the protecting groups of the substituents on the furan ring were exchanged and the kinetic resolution was again attempted. The results obtained were summarized in Table with conversion yields and enantiomeric excesses. Although the Sharpless kinetic resolution of **5c** afforded the resolved **5c** in 44% yield with 62% e.e., such protecting groups were found to be unsuitable in later stage of its further conversion into canadensolide.

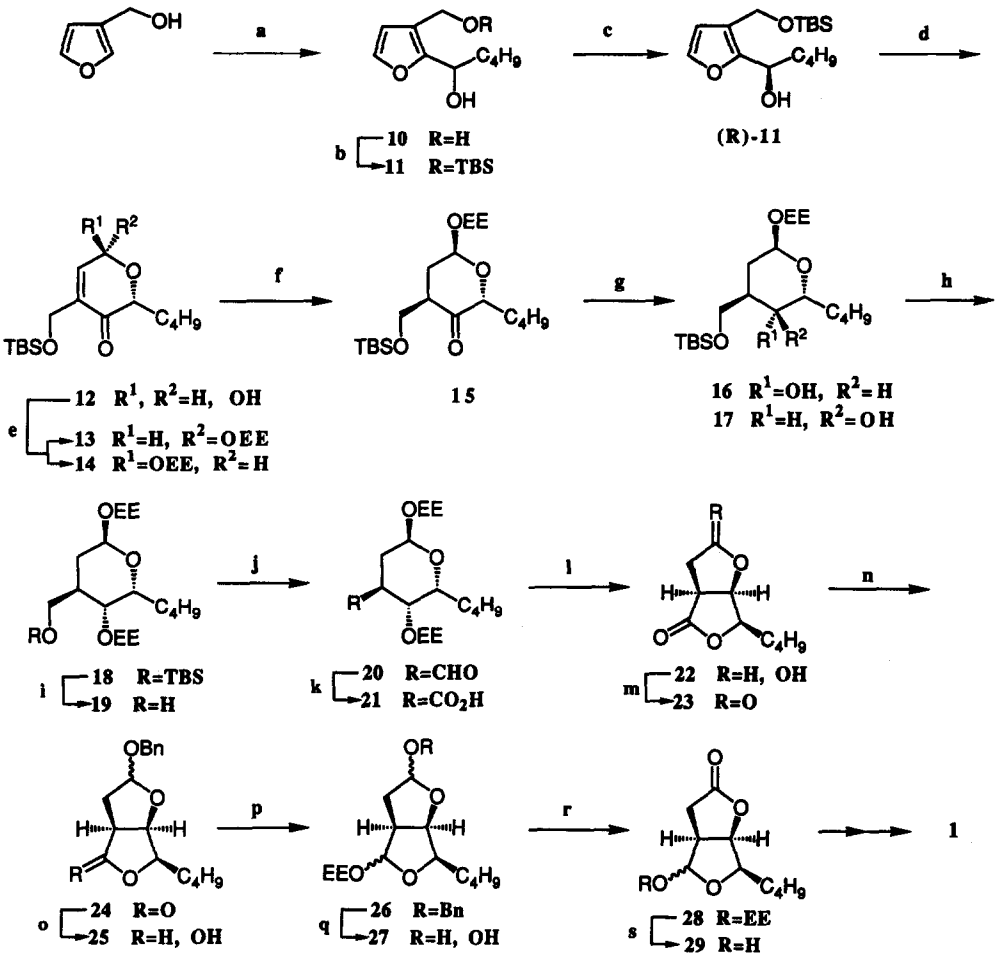
Table. Kinetic Resolution of 5 Using TBHP, $Ti(O^iPr)_4$, and L-(+)-DIPT [a]

	substrate 5			slow-reacting enantiomer	
	R^1	R^2	TBHP (equiv.)	yield (%)[b]	e.e.(%)[c]
a	MOM	TBS	2.0	32	55
b	MOM	SEM	3.0	54	31
c	TBS	Ac	0.7	44	62

[a] The reaction was carried out by using TBHP, $Ti(O^iPr)_4$ (1.0 equiv.), and L-(+)-DIPT (1.2 equiv.) in CH_2Cl_2 at -25°C in the presence of 3A molecular sieves. [b] Isolated yields based on racemic 5. [c] Determined by ^1H NMR analysis of the corresponding MTPA ester.

Since all the attempts for the Sharpless kinetic resolution of trisubstituted 2-furylcarbinols gave the unsatisfactory results in terms of optical purity, we decided to introduce the exo-methylene function of the γ-

lactone in the final step of the synthesis as reported in the previous papers[6,7] and 3-substituted 2-furylcarbinol was selected as a starting material (Scheme 2).



Scheme 2. *Reagents:* a) *n*-BuLi (2.2 eq.), THF then C_4H_9CHO (70 %); b) *t*-$BuMe_2SiCl$, imidazole, DMF (77 %); c) L-DIPT (0.24 eq.), $Ti(Oi\text{-}Pr)_4$(0.2 eq.), *t*-BuOOH (0.6 eq.), CH_2Cl_2, -25°C (41 %); d) *m*-CPBA, AcONa, $CHCl_3$ (77 %); e) CH_2=CHOEt, PPTS (95 %); f) H_2, 10 %Pd-C, AcOEt (96%); g) L-Selectride, THF, -78°C (94 %); h) CH_2=CHOEt, PPTS (98 %); i)*n*-Bu_4NF, THF (92 %); j) $(COCl)_2$, DMSO, CH_2Cl_2, -50°C then Et_3N (93 %); k) $NaClO_2$, 2-methyl-2-butene, KH_2PO_4, H_2O, *t*-BuOH (88 %); l) 2 %HCl, THF (93 %); m) PCC, AcONa, CH_2Cl_2 (94 %); n) BnOH, *p*-TsOH, CH_2Cl_2 (79 %); o) DIBAL, THF, -78°C (87 %); p) CH_2=CHOEt, PPTS (83 %); q) H_2, $Pd(OH)_2$, EtOH (78 %); r) PCC, AcONa, CH_2Cl_2 (74 %); s) 2 %HCl, THF (95 %).

The desired starting material (**11**) was prepared as follows. Reaction of 3-furanmethanol with 2.2 equiv. of *n*-butyllithium in dry tetrahydrofuran (THF) afforded the dilithiofuran which on treatment with *n*-valeraldehyde provided the 2-furylcarbinol (**10**), in 70% yield, siteselectively.[10] After protection of the primary hydroxy group of **10** as its *tert*-butyldimethylsilyl (TBS) ether, the alcohol (**11**) was subjected to the Sharpless

kinetic resolution by using 0.24 equiv. of titanium tetra-isopropoxide, 0.24 equiv. of L-diisopropyl tartrate, and 0.6 equiv. of *tert*-butyl hydroperoxide to give the desired (***R***)-2-furylcarbinol in 41% yield with >95% e.e. The absolute configurations of the resolved compound was assumed to be ***R*** based on the previous results[8,11] and unambiguously determined by its conversion into the known bislactone (**23**). Oxidative ring transformation of (***R***)-**11** with *m*-chloroperbenzoic acid in chloroform gave the lactol (**12**), in 77% yield, whose lactol hydroxy group was then protected as the ethoxyethyl ether to furnish the α-anomer (**13**) and the β-anomer (**14**)[12] in 95% yield in a ratio of 1:2.4. Catalytic reduction of the major β-anomer over 10% palladium on carbon under a hydrogen atmosphere afforded the ketone (**15**), in 96% yield, stereoselectively. The observed stereoselectivity can be rationalized by assuming that the attack of hydrogen occurred from the less hindered side of the enone (**14**) as shown in Figure 2.

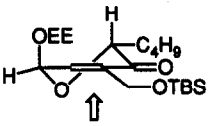


Figure 2.

Although the reduction of the ketone (**15**) with sodium borohydride gave the mixture of the diastereoisomeric secondary alcohols in a ratio of ca. 1:1, the desired (***R***)-stereoisomer (**16**) was predominantly obtained by employing L-Selectride as a reducing agent together with the (***S***)-isomer (**17**) in 81 and 13% yields, respectively. The stereochemistries at the C-3 position of the diastereoisomers (**16**) and (**17**) were tentatively assigned to be ***R*** and ***S*** respectively, since L-Selectride reduction of hindered ketones gave the corresponding less stable isomers.[13] The hydroxy function of the (***R***)-alcohol (**16**) was converted into the ethoxyethyl ether (**18**), in a usual manner, which on exposure to *n*-tetrabutylammonium fluoride gave the primary alcohol (**19**) in 90% yield from **16**. In order to construct a bis-γ-lactonic skeleton, the conversion of the primary hydroxy group of **19** to a carboxylic acid was achieved by Swern oxidation,[14] followed by further oxidation of the resulting aldehyde (**20**) with sodium chlorite[15] in 82% yield from **19**. Deprotection of the ethoxyethyl groups of the acid (**21**) by treatment with a catalytic amount of hydrochloric acid brought about a formation of γ-lactone ring, providing the bicyclic compound (**22**), in 93% yield, which on oxidation with pyridinium chlorochromate afforded the literature known bislactone (**23**), in 94% yield. The spectroscopic data of the synthetic lactone including the melting point and the specific optical rotation were identical with those reported.[7]

Transformation of the lactol (**22**) into (-)-canadensolide was achieved as follows. After protection of the lactol as its benzyl ether, the resulting lactone (**24**) was reduced with diisobutylaluminum hydride to give the lactol (**25**), which was then converted into the ethoxyethyl ether (**26**) in a usual manner. Debenzylation of **26** under a catalytic reduction condition over palladium hydroxide, followed by oxidation of the resulting lactol (**27**) with pyridinium chlorochromate furnished the known lactone (**28**), which was already converted into (-)-canadensolide.[7] Removal of the ethoxyethyl group in **28** by acid treatment afforded the lactol (**29**), whose spectroscopic data including the specific optical rotation were identical with those reported.[7]

Thus we could disclose an enantiocontrolled synthesis of (-)-canadensolide by employing the Sharpless kinetic resolution of the racemic 2-furylcarbinol as a key reaction, and this synthetic strategy would be applicable to the syntheses of other types of bislactone antibiotics.

EXPERIMENTAL

Melting points were measured with a Yanagimoto MP apparatus and are uncorrected. IR spectra were recorded on a Hitachi 260-10 spectrophotometer. ^{1}H NMR spectra were obtained for solution in $CDCl_3$ on a JEOL PMX GSX 270 instrument, and chemical shifts are reported in ppm on the δ scale from internal tetramethylsilane. J values are given in Hz. Mass spectra were measured with a JEOL JMS D-300 spectrometer. TLC was carried out on precoated 0.25 mm silica gel 70 F_{254} (Wako) plates.

General Procedures for the Sharpless Kinetic Resolution of the Racemic 2-Furylcarbinols --- To a solution of the racemic 2-furylcarbinol (**5**) (1 mol equiv.) and L-diisopropyl tartrate (1.2 mol equiv.) in dichloromethane (0.2 M in substrate) were added activated molecular sieves 3A (30 wt% based on the 2-furylcarbinol) at room temperature. The stirred mixture was cooled to -25°C, treated with titanium tetraisopropoxide (1 mol equiv.), and further stirred for 30 min at the same temperature. The reaction mixture was treated with *tert*-butyl hydroperoxide (3.0 M solution in 2,2,4-trimethylpentane) and stirred for 14 h. A freshly prepared solution of iron(II) sulfate heptahydrate (2 mol equiv.) and tartaric acid (12 mol equiv.) in deionized water was added to the reaction mixture at -25°C and the resulting mixture was stirred vigorously without cooling for 30 min. The organic layer was separated and the aqueous layer was extracted with dichloromethane. The combined layer was washed with brine and dried over Na_2SO_4. Evaporation of the solvent gave the crude product, which was purified by column chromatography on silica gel.

General Procedure for the Preparation of the Mosher Esters[16]--- A solution of the alcohol (10-20 mg) in pyridine (1 ml) was treated with (-)-α-methoxy-α-(trifluoromethyl)phenylacetyl chloride (1.2 mol equiv.). After 12 h at room temperature the reaction was quenched with water and the mixture was extracted with ether. The organic layer was washed successively with saturated aqueous potassium hydrogen sulfate, saturated aqueous sodium hydrogen carbonate, and brine, and dried over Na_2SO_4. Evaporation of the solvent gave the crude ester. ^{1}H-NMR analysis focused on the benzylic methine proton appeared at δ 5.80-6.00. The enantiomeric excess was calculated from integration of the signals.

Kinetic Resolution of the Racemic 2-Furylcarbinol (5a) --- The reaction was performed with *tert*-butyl hydroperoxide (2.0 equiv.) on a 15.3 mmol scale (5.7 g) to provide the chiral **5a** (1.8 g, 32%) with 55% e.e. $[\alpha]_D$ +2.2° (*c* 1.1, $CHCl_3$). IR($CHCl_3$) 3410 cm^{-1}. ^{1}H-NMR($CDCl_3$)δ 0.12 (6H, s, 2×Me), 0.87-0.95 (12H, m, Me and *tert*-Bu), 1.26-1.90 (6H, m, C_3H_6Me), 3.40 (3H, s, OMe), 4.44 (2H, d, *J*=1.2 Hz, CH_2OMOM), 4.65 (2H, s, CH_2OTBS), 4.66 (2H, s, OCH_2O), 4.74 (1H, t, *J*=6.7 Hz, C*H*(OH)C_4H_9), 7.29 (1H, s, H-5). MS *m/z* 372 (M^+)(Found 372.2324. Calcd for $C_{19}H_{36}O_5Si$: 372.2332). Anal. Calcd for $C_{19}H_{36}O_5Si$: C, 61.25; H, 9.74. Found: C, 60.88; H, 9.94.

Kinetic Resolution of the Racemic 2-Furylcarbinol (5b) --- The reaction was performed with *tert*-butyl hydroperoxide (3.0 equiv.) on a 0.4 mmol scale (0.14 g) to provide the chiral **5b** (75 mg, 54%) with 31% e.e.$[\alpha]_D$ +0.9° (*c* 0.2, $CHCl_3$). IR($CHCl_3$) 3400 cm^{-1}. ^{1}H-NMR($CDCl_3$)δ 0.01 (9H, s, $SiMe_3$), 0.87-0.95 (5H, m, Me and CH_2SiMe_3), 1.20-2.00 (7H, m, C_3H_6Me and OH), 3.41 (3H, s, OMe), 3.61 (2H, q, *J*=6.1 Hz, $OCH_2CH_2SiMe_3$), 4.48 (2H, s, CH_2OMOM), 4.55 (1H, d, *J*=12.2 Hz,CHHOSEM), 4.64 (1H, d, *J*=12.2 Hz,CHHOSEM), 4.68 (4H, s, 2xOCH_2O), 4.76 (1H, t, *J*=7.3 Hz, CH(OH)C_4H_9), 7.36 (1H, s, H-5). MS *m/z* 370 (M^+-18).

Kinetic Resolution of the Racemic 2-Furylcarbinol (5c) --- The reaction was performed with *tert*-butyl hydroperoxide (0.7 equiv.) on a 5.4 mmol scale (2.0 g) to provide the chiral **5c** (1.24 g, 44%) with 62% e.e.$[\alpha]_D$ -6.8° (*c* 1.2, $CHCl_3$). IR($CHCl_3$) 3400 and 1740 cm^{-1}. ^{1}H-NMR($CDCl_3$)δ 0.09 (3H, s, SiMe), 0.10 (3H, s, SiMe), 0.85-1.00 (12H, m, Me and *tert*-Bu), 1.20-1.95 (6H, m, C_3H_6Me), 2.04 (3H, s, OCOMe), 2.80 (1H, br s, OH), 4.60 (2H, br s, CH_2OTBS), 4.78-4.88 (1H, m, CH(OH)C_4H_9), 5.00 (1H, d, *J*=12.2 Hz, CHHOAc), 5.13 (1H, d, *J*=12.2 Hz, CHHOAc), 7.26 (1H, s, H-5). MS *m/z* 370 (M^+)(Found 370.2170. Calcd for $C_{19}H_{34}O_5Si$: 370.2173). Anal. Calcd for $C_{19}H_{34}O_5Si$: C, 61.58; H, 9.25. Found: C, 61.75; H, 9.55.

1-[2-(3-Hydroxymethylfuryl)]-1-pentanol (10) --- To a stirred solution of 3-furanmethanol (46.7 g) in dry THF (470 ml) was added *n*-butyllithium (1.60 mol in hexane, 654 ml) at -78°C under argon, and the solution was further stirred for 4 h at the same temperature and for 2 h at 0°C. This solution was again cooled to -78°C and a solution of *n*-valeraldehyde (44.6 g) in THF (50 ml) was added dropwise to this solution at the same temperature and the resulting mixture was stirred for 20 min at -78°C and for 40 min at room temperature. After quenching the reaction by addition of saturated ammonium chloride solution, the mixture was extracted with ethyl acetate. The extract was washed with water and dried over Na_2SO_4. Evaporation of the solvent gave a residue, which was subjected to column chromatography on silica gel. Elution with hexane-ethyl acetate (6:4 v/v) afforded the 2-furylcarbinol (**10**)(61.6 g, 70%) as a colorless oil. IR($CHCl_3$) 3400 cm^{-1}. ^{1}H-NMR($CDCl_3$) δ 0.88 (3H, t, *J*=6.7 Hz, Me), 1.10-1.35 (4H, m, $CH_2C_2H_4$Me), 1.81 (2H, q, *J*=6.7 Hz, CH(OH)$CH_2C_3H_7$), 4.09-4.13 (2H, br s, OH), 4.40 (2H, s, CH_2OH), 4.64 (1H, t, *J*=6.7 Hz, CH(OH)C_4H_9), 6.32 (1H, d, *J*=1.8 Hz, H-4), 7.27 (1H, d, *J*=1.8 Hz, H-5). MS *m/z* 184 (M^+)(Found 184.1095. Calcd for $C_{10}H_{16}O_3$: 184.1097).

1-[2-(3-*tert*-Butyldimethylsilyloxymethylfuryl)]-1-pentanol (11) --- A solution of the diol (**10**)(1.2 g), imidazole(0.9 g), and *tert*-butyldimethylsilyl chloride(1.1 g) in DMF(10 ml) was stirred for 1h at ambient temperature. After treatment with saturated ammonium chloride solution, the mixture was extracted with ether. The extract was washed with water and dried over Na_2SO_4. Evaporation of the solvent gave a residue, which was subjected to column chromatography on silica gel. Elution with hexane-ethyl acetate (95:5 v/v) afforded the silyl ether (**11**)(1.4 g, 77%) as a colorless oil. IR($CHCl_3$) 3350 cm^{-1}. ^{1}H-NMR($CDCl_3$)δ 0.11 (6H, s, 2×Me), 0.87-0.93 (12H, m, Me and *tert*-Bu), 1.24-1.43 (4H, m, $CH_2C_2H_4$Me), 1.87 (2H, q, *J*=6.7 Hz, CH(OH)$CH_2C_3H_7$), 2.90 (1H, br s, OH), 4.62 (2H, s, CH_2OSi), 4.74 (1H, t, *J*=6.7 Hz, CH(OH)C_4H_9), 6.28 (1H, d, *J*=1.8 Hz, H-4), 7.27 (1H, d, *J*=1.8 Hz, H-5).

(1*R*)-1-[2-(3-*tert*-Butyldimethylsilyloxymethylfuryl)]-1-pentanol (11) --- Kinetic resolution of the racemic 2-furylcarbinol (**11**)(5.0 g, mmol) was carried out as described procedure as above to provide the

(R)-isomer (**11**)(2.03 g, 41%) with >95% e.e. $[\alpha]_D$ +9.6° (*c* 2.0, $CHCl_3$). MS *m/z* 297 (M^+-1)(Found 297.1890. Calcd for $C_{16}H_{29}O_3Si$: 297.1885). ^{1}H-NMR of the corresponding MTPA ester ($CDCl_3$)δ 0.02(3H, s, Me), 0.03 (3H, s, Me), 0.81-0.90 (12H, m, Me and *tert*-Bu), 1.10-1.30 (4H, m, $CH_2C_2H_4$Me), 1.90-2.10 (2H, m, $CH_2C_3H_7$), 3.43 (3H, s, OMe), 4.54 (1H, d, *J*= 12.3 Hz, CHOSi), 4.62 (1H, d, *J*= 12.3 Hz, CHOSi), 5.92 (1H, t, *J*=7.3 Hz, COCO), 6.29 (1H, d, *J*=1.8 Hz, H-4), 7.18 (1H, d, *J*=1.8 Hz, H-5), 7.20-7.30 (5H, m, aromatic protons).

(2*R*)-2-Butyl-4-(*tert*-butyldimethylsilyloxymethyl)-6-hydroxy-6*H*-pyran-3(2*H*)-one (12) --- To a stirred solution of the (*R*)-carbinol (**11**)(1.00 g) and sodium acetate (0.33 g) in chloroform (12 ml) was added *m*-chloroperbenzoic acid (1.14 g) in portions at 0°C and the mixture was further stirred for 1 h at ambient temperature. The mixture was diluted with dichloromethane and washed successively with 5% sodium hydroxide solution and ammonium chloride solution, and dried over Na_2SO_4. Evaporation of the solvent gave a residue, which was subjected to column chromatography on silica gel. Elution with hexane-ethyl acetate (95:5 v/v) afforded the pyranone (**12**)(0.81 g, 77%) as a colorless oil. IR($CHCl_3$) 3300, 1660 cm^{-1}. ^{1}H-NMR ($CDCl_3$)δ 0.07 (6H, s, 2×Me), 0.86-0.90 (12H, m, Me and *tert*-Bu), 1.24-1.47 (4H, m, $CH_2C_2H_4$Me), 1.60-1.89 (2H, m, $CH_2C_3H_7$), 3.50 (0.75H, d, *J*=4.3 Hz, OH), 3.77 (0.25H, br s, OH), 4.00 (0.25H, ddd, *J*=1.2, 4.3, and 7.9 Hz, H-2), 4.34-4.36 (2H, m, CH_2OSi), 4.50 (0.75H, dd, *J*=3.7 and 7.9 Hz, H-2), 5.70 (1H, br s, H-6), 6.86-6.90 (1H, m, H-5). MS *m/z* 313 (M^+-1)(Found 313.1844. Calcd for $C_{16}H_{29}O_4Si$: 313.1834).

(2*R*, 6*R*)-2-Butyl-4-(*tert*-butyldimethylsilyloxymethyl)-6-(1-ethoxyethoxy)-6*H*-pyran-3(2*H*)-one (14) --- To a stirred solution of the lactol (**12**)(6.12 g) in dichloromethane (100 ml) containing pyridinium *p*-toluenesulfonate (1.03 g) was added ethyl vinyl ether (39.1 ml) at 0°C and the resulting mixture was further stirred at ambient temperature for 2.5 h. The solution was washed with saturated sodium hydrogen carbonate solution and dried over Na_2SO_4. Evaporation of the solvent gave a residue, which was subjected to column chromatography on silica gel. Elution with hexane-ethyl acetate (99:1 v/v) afforded the (2*R*, 6*S*)-α-anomer (**13**)(2.13 g, 28%) as a colorless oil. IR($CHCl_3$) 1660 cm^{-1}. ^{1}H-NMR($CDCl_3$)δ 0.05 (3H, s, SiMe), 0.06 (3H, s, SiMe), 0.83-0.90 (12H, m, Me and *tert*-Bu), 1.16-1.44 (10H, m, OCH*Me*OCH_2*Me* and $CH_2C_2H_4$Me), 1.61-2.00 (2H, m, $CH_2C_3H_7$), 3.47-3.98 (3H, m, H-2 and OCH_2Me), 4.25-4.41 (2H, m, CH_2OSi), 4.97 (0.5H, q, *J*=5.5 Hz, OCHMeO), 5.10 (0.5H, q, *J*=5.5 Hz, OCHMeO), 5.60-5.63 (1H, m, H-6), 6.79-6.86 (1H, m, H-5).

Further elution with the same solvent gave the (2*R*, 6*R*)-β-anomer (**14**)(5.06 g, 67%) as a colorless oil. IR($CHCl_3$) 1675 cm^{-1}. ^{1}H-NMR($CDCl_3$)δ 0.08 (6H, s, 2×SiMe), 0.88-0.97 (12H, m, Me and *tert*-Bu), 1.15-1.48 (10H, m, OCH*Me*OCH_2*Me* and $CH_2C_2H_4$Me), 1.61-1.69 (1H, m, CHHC$_3$H$_7$), 1.90-2.00 (1H, m, CHHC$_3$H$_7$), 3.50-3.84 (2H, m, OCH_2Me), 4.36 (0.5H, dd, *J*=3.7 and 7.9 Hz, H-2), 4.37 (2H, d, *J*=1.8 Hz, CH_2OSi), 4.46 (0.5H, dd, *J*=3.7 and 7.9 Hz, H-2), 4.96 (0.5H, q, *J*=5.5 Hz, OCHMeO), 5.03 (0.5H, q, *J*=5.5 Hz, OCHMeO), 5.59 (1H, m, H-6), 6.77 (0.5H, dt, *J*=1.8 and 3.7 Hz, H-5), 6.84 (0.5H, dt, *J*=1.8 and 3.7 Hz, H-5). Anal. Calcd for $C_{20}H_{38}O_5Si$: C, 62.14; H, 9.91. Found: C, 62.30; H, 10.30.

(2*R*, 4*R*, 6*R*)-2-Butyl-4-(*tert*-butyldimethylsilyloxymethyl)-6-(1-ethoxyethoxy)-4,5-dihydro-6*H*-pyran-3(2*H*)-one (15) --- A solution of the enone (**14**)(3.95 g) in ethyl acetate (80 ml) in the presence of 10% palladium-carbon (1.19 g) under an atmosphere of hydrogen was stirred for 1h at ambient temperature. After removal of the insoluble material by filtration, the filtrate was concentrated to leave a residue,

which was subjected to column chromatography on silica gel. Elution with hexane-ethyl acetate (97:3 v/v) afforded the ketone (**15**)(3.79 g, 96%) as a colorless oil. IR($CHCl_3$) 1720 cm^{-1}. ^{1}H-NMR($CDCl_3$)δ 0.04 (6H, s, 2×SiMe), 0.84 (12H, m, Me and *tert*-Bu), 1.21 (1.5H, t, *J*=7.3 Hz, OCH_2*Me*), 1.22 (1.5H, t, *J*=7.3 Hz, OCH_2*Me*), 1.34 (1.5H, t, *J*=5.5 Hz, OCH*Me*O), 1.37 (1.5H, t, *J*=5.5 Hz, OCH*Me*O), 1.30-1.40 (6H, m, C_3*H*$_6$Me), 1.73-1.85 (1H, m, H-5), 2.49-2.64 (2H, m, H-4 and H-5), 3.46-3.94 (4H, m, O*CH*$_2$Me and CH_2OSi), 4.07 (0.5H, dd, *J*=3.6 and 8.5 Hz, H-2), 4.17 (0.5H, dd, *J*=3.6 and 8.5 Hz, H-2), 4.91 (0.5H, q, *J*=5.5 Hz, O*CH*MeO), 4.99 (0.5H, q, *J*=5.5 Hz, O*CH*MeO), 5.33 (0.5H, t, *J*=6.7 Hz, H-6), 5.41 (0.5H, t, *J*=6.7 Hz, H-6).

(2*R*, 3*R*, 4*R*, 6*R*)-2-Butyl-4-(*tert*-butyldimethylsilyloxymethyl)-6-(1-ethoxyethoxy)-2,3,4,5-tetrahydropyran-3-ol (16) --- To a stirred solution of the ketone (**15**)(3.70 g) in THF (75 ml) was added dropwise L-Selectride (1.0 M solution in THF)(14.3 ml) at -78°C under argon atmosphere and the resulting mixture was further stirred for 1 h at the same temperature. Sodium hydroxide solution (5.0 M in water)(4.3 ml) and 30% hydrogen peroxide (4.3 ml) were added to the solution and the mixture was vigorously stirred for 0.5 h and extracted with ethyl acetate. The extract was washed with ammonium chloride solution, and dried over Na_2SO_4. Evaporation of the solvent gave a residue, which was subjected to column chromatography on silica gel. Elution with hexane-ethyl acetate (9:1 v/v) afforded the α-alcohol (**16**)(3.01 g, 81%) as a colorless oil. IR($CHCl_3$) 3400 cm^{-1}. ^{1}H-NMR($CDCl_3$)δ 0.03 (6H, s, 2×SiMe), 0.86 (9H, s, *tert*-Bu), 0.88 (3H, t, *J*=6.7 Hz, C_3H_6*Me*), 1.17 (1.5H, t, *J*=7.3 Hz, OCH_2*Me*), 1.18 (1.5H, t, *J*=7.3 Hz, OCH_2*Me*), 1.30 (3H, d, *J*=5.5 Hz, OCH*Me*O), 1.23-1.38 (6H, m, C_3*H*$_6$Me), 1.53-1.60 (1H, m, H-5), 1.84-2.01 (2H, m, H-4 and H-5), 2.37 (0.5H, d, *J*=6.1 Hz, OH), 2.43 (0.5H, d, *J*=6.1 Hz, OH), 3.41-3.91 (6H, m, H-2, H-3, O*CH*$_2$Me and CH_2OSi), 4.80 (0.5H, q, *J*=5.5 Hz, O*CH*MeO), 4.89 (0.5H, q, *J*=5.5 Hz, O*CH*MeO), 4.98 (0.5H, t, *J*=4.3 Hz, H-6), 5.07 (0.5H, t, *J*=4.3 Hz, H-6). Anal. Calcd for $C_{20}H_{42}O_5Si$: C, 61.49; H, 10.84. Found: C, 61.82; H, 11.29.

Further elution with the same solvent gave the β-alcohol (**17**)(0.49 g, 13%) as a colorless oil. IR($CHCl_3$) 3400 cm^{-1}. ^{1}H-NMR($CDCl_3$)δ 0.08 (6H, s, 2×SiMe), 0.89 (12H, s, C_3H_6*Me* and *tert*-Bu), 1.17-1.86 (14H, m, H-5, OCH*Me*OCH_2*Me*, and C_3*H*$_6$Me), 2.25-2.29 (1H, m, H-4), 3.44-3.84 (6H, m, H-2, H-3, O*CH*$_2$Me and CH_2OSi), 3.98 (0.5H, d, *J*=6.1 Hz, OH), 4.11 (0.5H, d, *J*=6.1 Hz, OH), 4.28 (1H, q, *J*=10.4 Hz, CH_2OSi), 4.82 (0.5H, q, *J*=5.5 Hz, O*CH*MeO), 4.90 (0.5H, q, *J*=5.5 Hz, O*CH*MeO), 4.91 (0.5H, t, *J*=3.7 Hz, H-6), 5.07 (0.5H, t, *J*=3.7 Hz, H-6).

(2*R*, 3*R*, 4*R*, 6*R*)-2-Butyl-4-(*tert*-butyldimethylsilyloxymethyl)-3,6-bis(1-ethoxyethoxy)-2,3,4,5-tetrahydropyran (18) --- A solution of the α-alcohol (**16**)(410 mg), pyridinium *p*-toluenesulfonate (53 mg), and ethyl vinyl ether (2.0 ml) in dichloromethane (8.0 ml) was stirred for 10 h at ambient temperature. The solution was diluted with dichloromethane and washed with saturated sodium hydrogen carbonate solution and dried over Na_2SO_4. Evaporation of the solvent gave a residue, which was subjected to column chromatography on silica gel. Elution with hexane-ethyl acetate (95:5 v/v) afforded the ether (**18**)(476 mg, 98%) as a colorless oil. ^{1}H-NMR($CDCl_3$)δ 0.05 (6H, s, 2×SiMe), 0.89 (3H, t, *J*=6.7 Hz, C_3H_6*Me*), 1.16-1.72 (28H, m, H-5, *tert*-Bu, 2×OCH*Me*OCH_2*Me*, and C_3*H*$_6$Me), 2.03-2.16 (2H, m, H-4 and H-5), 3.44-3.93 (8H, m, H-2, H-3, 2×O*CH*$_2$Me, and CH_2OSi), 4.66 (0.5H, q, *J*=5.5 Hz, O*CH*MeO), 4.73 (0.5H, q, *J*=5.5 Hz, O*CH*MeO), 4.81 (0.5H, q, *J*=5.5 Hz, O*CH*MeO), 4.88 (0.5H, q, *J*=5.5 Hz, O*CH*MeO), 5.01 (0.5H, m, H-6), 5.09 (0.5H, m, H-6).

(2*R*, 3*R*, 4*R*, 6*R*)-2-Butyl-3,6-bis(1-ethoxyethoxy)-4-hydroxymethyl-2,3,4,5-tetrahydropyran (19) --- To a stirred solution of the silyl ether (**18**)(490 mg) in THF (5.0 ml) was added a solution of *n*-tetrabutylammonium fluoride in THF (1.0 M solution)(1.1 ml) at 0°C and the resulting solution was further stirred for 1 h at room temperature. The solution was diluted with ethyl acetate and the mixture was washed with saturated ammonium chloride solution and dried over Na_2SO_4. Evaporation of the solvent gave a residue, which was subjected to column chromatography on silica gel. Elution with hexane-ethyl acetate (85:15 v/v) afforded the alcohol (**19**)(336.7 mg, 92%) as a colorless oil. IR($CHCl_3$) 3400 cm^{-1}. ^{1}H-NMR($CDCl_3$)δ 0.86 (1.5H, t, *J*=6.7 Hz, C_3H_6*Me*), 0.88 (1.5H, t, *J*=6.7 Hz, C_3H_6*Me*), 1.11-1.75 (19H, m, H-5, 2× OCH*Me*OCH_2*Me*, and C_3H_6Me), 1.97-2.14 (2H, m, H-4 and H-5), 2.75 (0.5H, br s, OH), 2.96 (0.5H, br s, OH), 3.37-3.99 (8H, m, H-2, H-3, 2×OCH_2Me, and CH_2OH), 4.64 (0.5H, q, *J*=5.5 Hz, OC*H*MeO), 4.74 (0.5H, q, *J*=5.5 Hz, OC*H*MeO), 4.76 (0.25H, q, *J*=5.5 Hz, OC*H*MeO), 4.79 (0.25H, q, *J*=5.5 Hz, OC*H*MeO), 4.86 (0.25H, q, *J*=5.5 Hz, OC*H*MeO), 4.88 (0.25H, q, *J*=5.5 Hz, OC*H*MeO), 4.99-5.08 (1H, m, H-6).

(2*R*, 3*R*, 4*R*, 6*R*)-2-Butyl-3,6-bis(1-ethoxyethoxy)-2,3,4,5-tetrahydro-4-pyrancarboxaldehyde (20) --- To a stirred solution of oxalyl chloride (0.14 ml) in dichloromethane (10 ml) was added a solution of dimethyl sulfoxide (0.15 ml) in dichloromethane (10 ml) at -78°C under argon atmosphere and the mixture was stirred for 10 min at the same temperature. A solution of the alcohol (**19**)(361 mg, mmol) in dichloromethane (10 ml) was then added to this solution at -78°C and further stirred for 20 min. After addition of triethylamine (0.72 ml), the resulting mixture was stirred for 5 min at -78°C and warmed to room temperature. The reaction mixture was treated with water and extracted with benzene. The organic layer was washed with water and dried over Na_2SO_4. Evaporation of the solvent gave a residue, which was subjected to column chromatography on silica gel. Elution with hexane-ethyl acetate (8:2 v/v) afforded the aldehyde (**20**)(332.8 mg, 93%) as a colorless oil. IR($CHCl_3$) 1715 cm^{-1}. ^{1}H-NMR($CDCl_3$)δ 0.91 (3H, t, *J*=6.7 Hz, C_3H_6*Me*), 1.19 (6H, t, *J*=6.7 Hz, 2×OCH_2*Me*), 1.33 (3H, d, *J*=5.5 Hz, OCH*Me*O), 1.35 (3H, d, *J*=5.5 Hz, OCH*Me*O), 1.14-1.72 (6H, m, C_3H_6Me), 1.98-2.09 (1H, m, H-3), 2.26-2.43 (1H, m, H-3), 2.63-2.67 (0.5H, m, H-4), 2.81-2.87 (0.5H, m, H-4), 3.34-3.90 (5H, m, H-5 and 2×OCH_2Me), 3.95 (0.5H, br s, H-6), 4.11 (0.5H, br s, H-6), 4.69 (0.5H, q, *J*=5.5 Hz, OC*H*MeO), 4.76 (0.5H, q, *J*=5.5 Hz, OC*H*MeO), 4.82 (0.5H, q, *J*=5.5 Hz, OC*H*MeO), 4.83 (0.5H, q, *J*=5.5 Hz, OC*H*MeO), 5.14 (0.5H, br s, H-2), 5.18 (0.5H, br s, H-2), 9.75 (1h, dd, *J*=6.1 and 10.4 Hz, CHO).

(2*R*, 3*R*, 4*R*, 6*R*)-2-Butyl-3,6-bis(1-ethoxyethoxy)-2,3,4,5-tetrahydro-4-pyrancarboxylic Acid (21) --- To a stirred solution of the aldehyde (**20**)(330 mg) in *tert*-butyl alcohol (33 ml) and 2-methyl-2-butene (1.3 ml) was added a solution of sodium chlorite (647 mg) and potassium phosphate (857 mg) in water (20 ml) at ambient temperature. After being stirred for 0.5 h, the solution was concentrated to leave a residue, which was extracted with dichloromethane. The organic layer was washed with water and dried over Na_2SO_4. Evaporation of the solvent gave a residue, which was subjected to column chromatography on silica gel. Elution with hexane-ethyl acetate (7:3 v/v) afforded the acid (**21**)(305 mg, 88%) as a colorless powder. IR($CHCl_3$) 3050, 1690 cm^{-1}. ^{1}H-NMR($CDCl_3$)δ 0.92 (3H, t, *J*=6.7 Hz, C_3H_6*Me*), 1.09-1.73 (18H, m, 2×OCH*Me*OCH_2*Me* and C_3H_6Me), 2.03-2.32 (2H, m, H-5), 2.79-2.85 (0.5H, m, H-4), 2.98-3.01 (0.5H, m,

H-4), 3.39-4.16 (6H, m, H-5, H-6 and 2×OC*H*$_2$Me), 4.70-4.92 (2H, m, 2×OC*H*MeO), 5.13 (0.5H, d, *J*=3.1 Hz, H-6), 5.15 (0.5H, d, *J*=3.1 Hz, H-6), 10.33 (1H, br s, COOH).

2, 3, 6-Trideoxy-3-C-carboxyl-6-C-propyl-D-galactofuranose γ-Lactone (22) --- A solution of the acid (**21**)(100 mg) and 2% hydrochloric acid (0.5 ml) in THF (6.0 ml) was stirred for 2.5 h at ambient temperature. After basified with saturated sodium hydrogen carbonate solution, the mixture was extracted with ethyl acetate and the extract was washed with water and dried over Na_2SO_4. Evaporation of the solvent gave a residue, which was subjected to column chromatography on silica gel. Elution with hexane-ethyl acetate (6:4 v/v) afforded a solid, which was recrystallized from hexane-ethyl acetate to give the lactone (**22**) (51.2 mg, 93%) as needles, mp 108-110°C. IR($CHCl_3$) 3400, 1760 cm^{-1}. ^{1}H-NMR($CDCl_3$)δ 0.94 (3H, t, *J*=6.7 Hz, C_3H_6*Me*), 1.26-1.59 (4H, m, CH_2C_2*H*$_4$Me), 1.71-1.90 (1H, m, C*H*HC_3H_7), 2.15-2.32 (1H, m, C*H*HC_3H_7), 2.50 (0.5H, br s, H-2), 2.55 (0.5H, br s, H-2), 2.61 (0.5H, br s, H-2), 2.68 (0.5H, br s, H-2), 3.25 (0.5H, dd, *J*=6.1 and 8.6 Hz, H-3), 3.33 (0.5H, ddd, *J*=2.4, 5.5, and 7.9 Hz, H-3), 4.44-4.50 (1H, m, H-5), 4.78 (0.5H, dd, *J*=3.7 and 5.5 Hz, H-4), 4.80 (0.5H, dd, *J*=3.7 and 5.5 Hz, H-4), 5.60-5.61 (0.5H, m, H-1), 5.65-5.67 (0.5H, m, H-1). MS *m/z* 200 (M^+)(Found 200.1052. Calcd for $C_{10}H_{16}O_4$: 200.1049). Anal. Calcd for $C_{10}H_{16}O_4$: C, 60.21; H, 8.26. Found: C, 59.98; H, 8.05.

(2*R*, 3*R*, 4*R*)-1,3:2,4-Octanebiscarbolactone (23) --- A mixture of the lactol (**22**)(64.5 mg), pyridinium chlorochromate (209 mg) and dichloromethane (5 ml) was stirred at ambient temperature for 10 h. After addition of an excess of ether, the insoluble material was removed by decantation and the ethereal layer was washed with water and dried over Na_2SO_4. Evaporation of the solvent gave a residue, which was subjected to column chromatography on silica gel. Elution with hexane-ethyl acetate (6:4 v/v) afforded a solid, which was recrystallized from ether to afford the bislactone (**23**)(60.1 mg, 94%) as needles, mp 87-88°C (lit.,[7] mp 87.5°C). IR($CHCl_3$) 1765 cm^{-1}. ^{1}H-NMR($CDCl_3$)δ 0.94 (3H, t, *J*=6.7 Hz, C_3H_6*Me*), 1.39-1.56 (4H, m, CH_2C_2*H*$_4$Me), 1.78-1.94 (2H, m, C*H*$_2C_3H_7$), 2.93 (2H, d, *J*=6.1 Hz, H-1), 3.51 (1H, q, *J*=6.1 Hz, H-2), 4.59 (1H, ddd, *J*=3.7, 6.7, and 7.9 Hz, H-4), 5.11 (1H, dd, *J*=3.7 and 6.1 Hz, H-3). $[\alpha]_D$ -32.9°(*c* 0.93, EtOH) {lit.,[7] $[\alpha]_D$ -33°(EtOH)}. These spectroscopic data are identical with those reported.[7]

Benzyl 2,3,6-Trideoxy-3-C-carboxyl-6-C-propyl-D-galactofuranoside γ-Lactone (24) --- To a stirred solution of the lactol (**22**)(82 mg) and *p*-toluenesulfonic acid (15.6 mg) in dichloromethane (2.0 ml) was added benzyl alcohol (0.01 ml) at 0°C under argon atmosphere and the resulting mixture was further stirred for 3 h at room temperature. The mixture was treated with brine and extracted with dichloromethane. The extract was washed with saturated sodium hydrogen carbonate solution and brine, and dried over Na_2SO_4. Evaporation of the solvent gave a residue, which was subjected to column chromatography on silica gel. Elution with hexane-ethyl acetate (3:1 v/v) afforded the benzyl ether (**24**)(75.8 mg, 79%) as a colorless oil. IR($CHCl_3$) 1765 cm^{-1}. ^{1}H-NMR($CDCl_3$)δ 0.90 (3H, t, *J*=7.3 Hz, C_3H_6*Me*), 1.26-1.50 (4H, m, CH_2C_2*H*$_4$Me), 1.76-1.86 (2H, m, C*H*$_2C_3H_7$), 2.18 (1H, ddd, *J*=4.9, 8.6, and 12.8 Hz, H-2), 2.54 (1H, d, *J*=12.8 Hz, H-2), 3.23 (1H, dd, *J*=6.4 and 8.6 Hz, H-3), 4.43 (1H, dt, *J*=4.3 and 7.4 Hz, H-5), 4.46 (1H, d, *J*=12.2 Hz, OC*H*HPh), 4.76 (1H, dd, *J*=4.3 and 6.4 Hz, H-4), 4.78 (1H, d, *J*=12.2 Hz, OC*H*HPh), 5.21 (1H, d, *J*=4.9 Hz, H-1), 7.22-7.36 (5H, m, aromatic protons). MS *m/z* 290 (M^+)(Found 290.1517. Calcd for $C_{17}H_{22}O_4$: 290.1517).

Benzyl 2,3,6-Trideoxy-3-C-formyl-6-C-propyl-D-galactofuranoside γ-Lactone (25) --- To a stirred solution of the lactone (**24**)(10 mg) in THF (0.5 ml) was added 1.0M toluene solution of diisobutyl-

aluminum hydride (0.03 ml) at -78°C under argon atmosphere and the solution was further stirred for 0.5 h at the same temperature. A mixture of methanol and water (1:1 v/v)(ml) was added to this solution and the stirring was continued another 0.5 h at room temperature. After removal of the solvent, the residue was extracted with ethyl acetate and the organic layer was washed with brine, and dried over Na_2SO_4. Evaporation of the solvent gave a residue, which was subjected to column chromatography on silica gel. Elution with hexane-ethyl acetate (8:2 v/v) afforded the lactol (**25**)(8.8 mg, 87%) as a colorless oil. ^{1}H-NMR($CDCl_3$)δ 0.92 (3H, t, *J*=7.3 Hz, C_3H_6*Me*), 1.26-1.80 (6H, m, C_3*H*$_6$Me), 2.04-2.33 (2H, m, H-2), 2.53 (1H, br s, OH), 2.79-2.84 (1H, m, H-3), 3.67 (0.25H, dt, *J*=3.1 and 7.3 Hz, H-5), 4.18 (0.75H, dt, *J*=3.1 and 7.3 Hz, H-5), 4.39 (0.75H, d, *J*=11.6 Hz, OC*H*HPh), 4.47 (0.25H, d, *J*=11.6 Hz, OC*H*HPh), 4.57 (0.25H, dd, *J*=3.1 and 6.1 Hz, H-4), 4.65 (0.75H, dd, *J*=3.1 and 6.1 Hz, H-4), 4.77 (0.25H, d, *J*=11.6 Hz, OC*H*HPh), 4.81 (0.75H, d, *J*=11.6 Hz, OC*H*HPh), 5.20 (0.75H, d, *J*=5.5 Hz, H-1), 5.22 (0.25H, d, *J*=5.5 Hz, H-1), 5.49 (1H, br s, C*H*(OH)O), 7.26-7.35 (5H, m, aromatic protons).

Benzyl 2,3,6-Trideoxy-3-C-formyl-6-C-propyl-D-galactofuranoside 1-Ethoxyethyl Hemiacetal (26) --- A solution of the lactol (**25**)(34 mg), pyridinium *p*-toluenesulfonate (5.8 mg), and ethyl vinyl ether (0.22 ml) in dichloromethane (1.0 ml) was stirred for 5 h at ambient temperature. The solution was washed with saturated sodium hydrogen carbonate solution and brine, and dried over Na_2SO_4. Evaporation of the solvent gave a residue, which was subjected to column chromatography on silica gel. Elution with hexane-ethyl acetate (95:5 v/v) afforded the ethoxyethyl ether (**26**)(36.1 mg, 83%) as a colorless oil. ^{1}H-NMR($CDCl_3$) δ 0.92 (3H, t, *J*=7.3 Hz, C_3H_6*Me*), 1.17-1.56 (10H, m, CH_2C_2*H*$_4$Me and OCH*Me*OCH$_2$*Me*), 2.13-2.20 (2H, m, C*H*$_2C_3H_7$), 2.84-2.90 (2H, m, H-2), 3.43-3.82 (2H, m, OC*H*$_2$Me), 3.98 (0.5H, dt, *J*=3.1 and 7.3 Hz, H-5), 4.07 (0.5H, dt, *J*=3.1 and 7.3 Hz, H-5), 4.42 (1H, d, *J*=12.2 Hz, OC*H*HPh), 4.62 (1H, dd, *J*=3.1 and 6.1 Hz, H-4), 4.80 (0.5H, q, *J*=5.5 Hz, OC*H*MeO), 4.81 (1H, d, *J*=12.2 Hz, OC*H*HPh), 4.87 (0.5H, q, *J*=5.5 Hz, OC*H*MeO), 5.17 (1H, br s, H-1), 5.19 (0.5H, br s, OCHO), 5.31 (0.5H, br s, OCHO), 7.26-7.39 (5H, m, aromatic protons).

2,3,6-Trideoxy-3-C-formyl-6-C-propyl-D-galactofuranoside 1-Ethoxyethyl Hemiacetal (27) --- A solution of the ether (**26**)(45 mg) in ethanol (0.5 ml) in the presence of palladium hydroxide (20 mg) was stirred for 3 h under an atmosphere of hydrogen. After removal of the insoluble material by filtration, the filtrate was concentrated to leave a residue, which was subjected to column chromatography on silica gel. Elution with hexane-ethyl acetate (8:2 v/v) afforded the lactol (**27**)(26.5 mg, 78%) as a colorless oil. ^{1}H-NMR ($CDCl_3$)δ 0.92 (3H, t, *J*=7.3 Hz, C_3H_6*Me*), 1.18-1.85 (12H, m, C_3*H*$_6$Me and OCH*Me*OCH$_2$*Me*), 2.01 (1H, m, H-2), 2.12-2.25 (1H, m, H-2), 3.43-3.78 (2H, m, OC*H*$_2$Me), 3.92-3.99 (0.5H, m, H-5), 4.01-4.10 (0.5H, m, H-5), 4.62-4.68 (0.5H, m, H-4), 4.70 (0.25H, dd, *J*=3.7 and 7.3 Hz, H-4), 4.73 (0.25H, dd, *J*=3.7 and 7.3 Hz, H-4), 4.78 (0.5H, q, *J*=5.5 Hz, OC*H*MeO), 4.83 (0.5H, q, *J*=5.5 Hz, OC*H*MeO), 4.95 (0.25H, s, OCHO), 5.07 (0.25H, s, OCHO), 5.16 (0.25H, s, OCHO), 5.26 (0.25H, s, OCHO), 5.34-5.43 (0.5H, m, H-1), 5.58 (0.5H, d, *J*=4.3 Hz, H-1).

2,3,6-Trideoxy-3-C-formyl-6-C-propyl-D-galacto-1,4-lactone 1-Ethoxyethyl Hemiacetal (28) --- A mixture of the lactol (**27**)(26 mg), sodium acetate (23 mg), pyridinium chlorochromate (61 mg), and dichloromethane (4 ml) was stirred for 8 h at ambient temperature. After addition of an excess of ether, the

insoluble material was removed by decantation and the ethereal layer was washed with water and dried over Na_2SO_4. Evaporation of the solvent gave a residue, which was subjected to column chromatography on silica gel. Elution with hexane-ethyl acetate (8:2 v/v) afforded the lactone (**28**)(19.2 mg, 74%) as a colorless oil. IR($CHCl_3$) 1775 cm^{-1}. ^{1}H-NMR($CDCl_3$)δ 0.92 (3H, t, *J*=7.3 Hz, C_3H_6*Me*), 1.18-1.72 (12H, m, C_3*H*$_6$Me and OCH*Me*OCH$_2$*Me*), 2.49 (0.5H, dd, *J*=3.7 and 18.9 Hz, H-2), 2.50 (1H, dd, *J*=3.7 and 18.9 Hz, H-2), 2.82 (0.5H, dd, *J*=1.2 and 18.9 Hz, H-2), 2.86 (0.5H, dd, *J*=1.2 and 18.9 Hz, H-2), 3.03-3.14 (1H, m, H-3), 3.44-3.76 (2H, m, OC*H*$_2$Me), 4.03 (0.5H, dt, *J*=3.7 and 7.3 Hz, H-5), 4.13 (0.5H, dt, *J*=3.7 and 7.3 Hz, H-5), 4.80 (0.5H, q, *J*=5.5 Hz, OC*H*MeO), 4.85 (0.5H, q, *J*=5.5 Hz, OC*H*MeO), 4.96 (0.5H, dd, *J*=3.7 and 6.7 Hz, H-4), 4.97 (0.5H, dd, *J*=3.7 and 6.7 Hz, H-4), 5.07 (0.5H, s, H-1), 5.18 (0.5H, s, H-1).

2,5-Dideoxy-2-C-carboxymethyl-5-C-propyl-D-lyxofuranose γ-lactone (29) ---The same procedure as for **21** was applied to **28** (19 mg) to afford the title compound (**29**) (13.3 mg, 95%) as a colorless oil. $[\alpha]_D$ -15.2°(*c* 0.3, $CHCl_3$) {lit.,[7] $[\alpha]_D$ -14.9°(*c* 1.0, $CHCl_3$)}. The spectroscopic data are identical with those reported.[7]

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