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Stereoselective Synthesis of Rare (D and L) mono and disaccharides of 5-deoxy hexofuranosiduronic acids by a Facile intramolecular Rearrangement of Hemiacetal Heptanolactone Alcohols.

Hari Babu Mereyala* **and Sreenivasulu Guntha**
Indian Institute of Chemical Technology, Hyderabad 500 007, India

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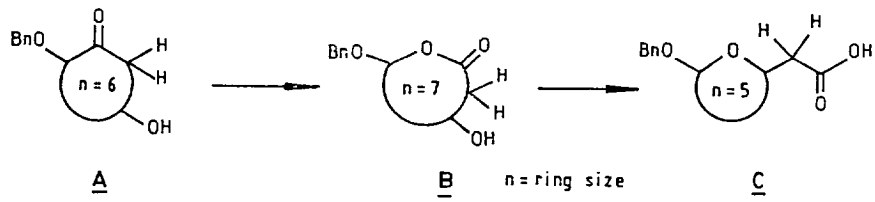
Abstract : Transformation of D-glucose, 2-O-, 3-O- and 4-O-linked disaccharides **6,7** and **35** to the corresponding cyclohexanone alcohols **1a/b, 17,18, 29, 30** and **36** respectively is described. Stereospecific conversion of these cyclohexanone alcohols to the corresponding hemiacetal heptanolactone alcohols **2a/b, 19, 21, 31, 33** and **37** respectively by Baeyer-Villiger oxidation is described. Facile, stereospecific acid catalysed rearrangement of the hemiacetal heptanolactone alcohols **2a/b, 19, 21, 31** and **33** to the corresponding 5-deoxy hexofuranosiduronic acids **3a/b, 20, 22, 32** and **34** is described. On the contrary, the heptano lactone alcohol **36** obtained from the 4-O-linked disaccharide **35** undergoes interglycosidic cleavage during the acid catalysed rearrangement resulting in the formation of monosaccharides **38** and **39.** Possible mechanistic pathway for the interglycosidic cleavage is proposed.

Stereoselective synthesis of oligosaccharides continues to command interest owing to their significant role in bioregulatory processes[1]. Synthesis of 5-deoxy hexofuranosyl derivatives have arosed interest due to their utility in the synthesis of 5-deoxy-hexofuranonucleosides because of their potential as chemotherapeutic agents[2]. Thus, synthesis of 5'-C-substituted analogs of adenosine was carried out to study their structure activity relationship. 9-(5-Deoxy--D-ribo-hexofuranosyl)adenine has been shown to exhibit biological properties of interest in cancer research[2]. 5-Deoxy hexofuranosyl adenine derivatives have been earlier synthesized mainly by hydroboration of the corresponding 5,6-enohexofuranosyl adenine derivatives in low yield[3]. Szareck et al[4] have synthesized homonucleoside analogs of 5-deoxy-hexofuranosyl adenine derivatives involving anti-Markovnikov hydration of the corresponding 5,6-eno-hexofuranoside derivative with silver trifluoroacetate, I_2 and subsequent reduction with Raney Nickel.

Inspite of the availability of the above methods for this specific purpose there still exists ample scope for the development of new methods[5]. Our continued interest in this direction resulted in the development of a general route for the synthesis of rare (D and L) saccharides of 5-deoxy-hexofuranosiduronic acids wherein the hemiacetal heptanolactone alcohols B undergo a facile intramolecular nucleophilic displacement to form D- and L-furanosaccharides C (Scheme 1). Lactone alcohols B themselves are easily accessible by regio- and stereospecific oxidation of the cyclohexanone alcohol A. Steps i and ii have been found to be highly

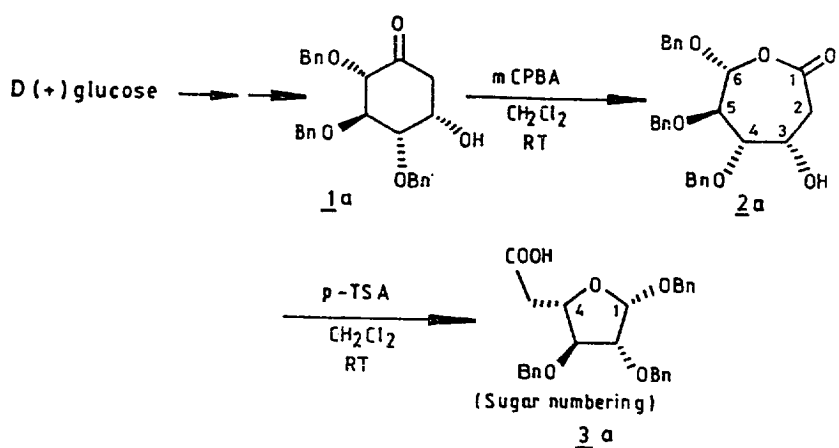
stereospecific leading to the formation of rare saccharides that are hitherto difficult to synthesize[6].



A B C

Scheme - 1

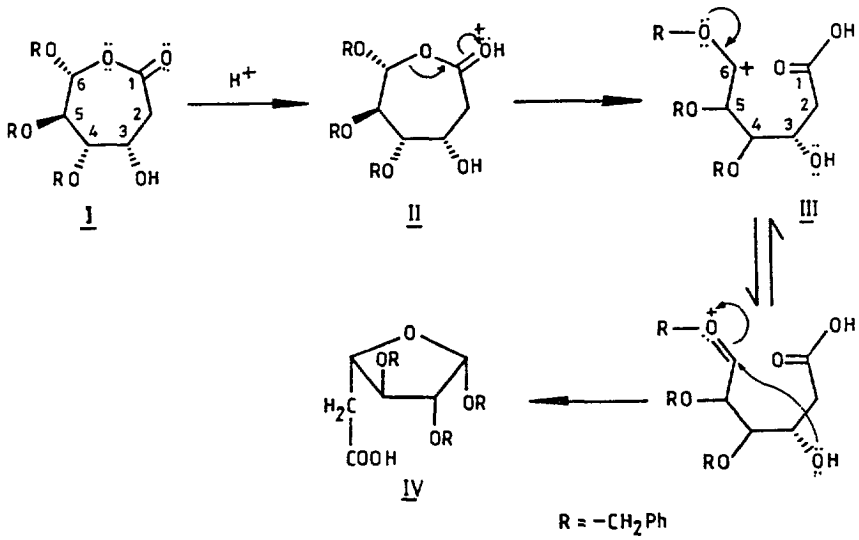
For the implementation of the above scheme D-glucose was converted to 2S,3R,4S, 5S/5R-tribenzyloxy-5-hydroxy-cyclohexanones (**1a/1b**) in a ratio of 4:1 respectively by known methods[7]. **1a** and **1b** were separated by column chromatography, and were characterised from the comparison of spectral data and m.p. with that reported in literature[8]. The α-isomer **1a** was reacted with 1.2 mole equivalents of metachloroperoxybenzoic acid (mCPBA) in dichloromethane at RT for 6 h (Scheme 2) to obtain 3S,4S,5R,6R-4,5,6-tris(benzyloxy)-7-heptanolide (**2a**) in 92% yield as a crystalline solid (m.p. 95°C), $[\alpha]_D$ -53.4 (c 1.0, $CHCl_3$). Baeyer-Villiger oxidation[9] of **1a** was found to be regiospecific due to the presence of electron rich benzyloxy neighbouring group[10] and stereospecific due to the migration of the C-C bond attached to the benzyloxy substituent at C-2. **2a** was characterised from the appearence of the hemiacetal proton H-6 at δ 5.31 as a doublet with a coupling constant $J_{5,6}$ = 7.8 Hz. The regioselectivity



Scheme - 2

was also evident from the appearence of C-2 methylene protons at δ3.0-2.63 that remained unchanged during the oxidation. ^{13}C NMR data was also in agreement with the structure proposed for **2a** from the appearence of a singlet at δ170.1 for the lactone carbonyl, a doublet at δ102.0 for the hemiacetal carbon C-6 and C-2 methylene at δ38.2 as a triplet. IR spectrum also indicated absorptions at 1745 cm^{-1} for the lactone, and 3540 cm^{-1} for the hydroxyl group.

2a on reaction with catalytic amount of p-toluene sulfonic acid in CH_2Cl_2 at RT spontaneously rearranged to 5-deoxy-β-L-arabino-hexofuranosiduronic acid **3a** in 89% yield and was obtained as a crystalline solid, m.p. 58-60°C, $[\alpha]_D$ -56.7 (c 1.0, $CHCl_3$) (Scheme 2). **3a** was characterised from the appearence of H-1 at δ5.05 as a doublet ($J_{1,2}$ = 0.8 Hz) which was characteristic of β-linked L-furanosides (1,2-cis)[11]. ^{13}C NMR was also in consonance with the structure **3a** from the appearence of anomeric C-1 at δ 104.9 as a doublet, which was characteristic of β-L-arabinofuranosaccharides[11], carbonyl carbon of COOH appeared at δ 176.3 as a singlet. Thus the stereochemistry at the anomeric position of **3a** was confirmed as β-1,2-cis. High levo optical rotation of -56.7° also confirmed the formation of β-L-furanoside **3a**. IR absorption at 1705 cm^{-1} also indicated the presence of COOH in **3a**. The stereospecific formation of the β-anomer (1,2-cis) **3a** has been rationalised from the following mechanism (Scheme 3). Reaction of **2a** with p-TSA would result in the protonation of the

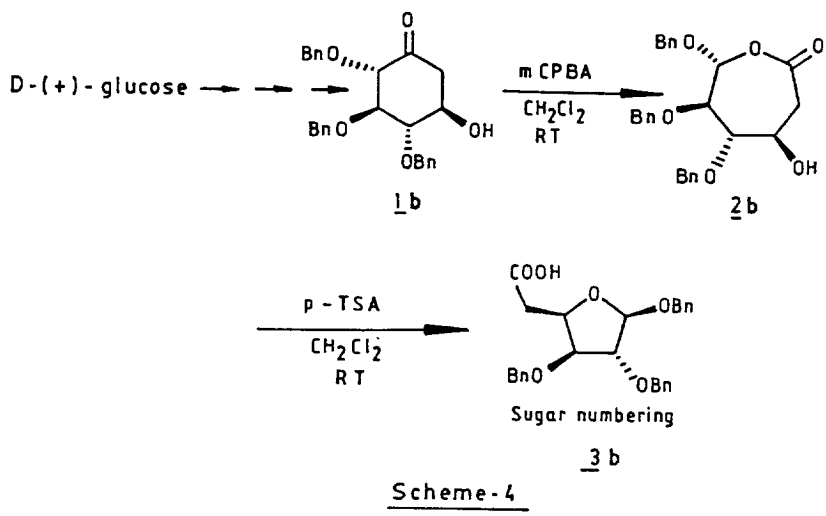


Scheme-3

lactone carbonyl (I), leading to the formation of a stable carbocation at C-6 (III), due to its stabilization by the electron rich C6-benzyloxy substituent (Scheme 3). This cation (III) inturn is stereospecifically captured intramolecularly by the C-3 hydroxyl group in a 'kinetically controlled'[12] reaction to yield the more stable β-anomer of the L-furanoside (IV). The

possibility of a SN^2 reaction was ruled out as the molecular model of **2a** indicated the C-3 hydroxyl group to be very much away from the C-6 carbocation to attack from the rear side.

Likewise, Baeyer-Villeger reaction of **1b** with mCPBA in dichloromethane for 4 h at RT gave 3R,4S,5R,6R-4,5,6-tris(benzyloxy)-7-heptanolide (**2b**) in 91% yield as a crystalline solid, m.p. 84°C, $[\alpha]_D$ -12.2° (c 1.0, $CHCl_3$) (Scheme 4). As anticipated, Baeyer-Villiger oxidation of **1b** proceeded regio- and stereoselectively. **2b** was characterised from the ^1H NMR spectrum from the appearence of H-6 as a doublet at δ 5.32 with a coupling constant $J_{5,6}$ = 6.16 Hz, indicating trans disposition of H-5,6 substituents. The C-2 methylene protons appeared between δ 3.11-2.71 as a pair of double doublets. ^{13}C NMR data also justified the structure for **2b** from the appearence of lactone carbonyl at δ169.1 (s), hemiacetal C-6 carbon at δ 101.58 (d) and the C-2 methylene at δ39.3 (t). Appearence of carbonyl absorption at 1750 cm^{-1} in the IR spectrum also confirmed the structure for **2b**.



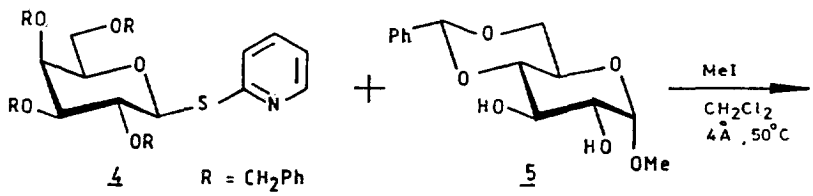
Scheme-4

2b was reacted with catalytic amount of p-TSA in dichloromethane at RT to obtain 5-deoxy-β-D-xylo-hexofuranosiduronic acid (**3b**) (Scheme 4) in 92% yield as a crystalline solid, m.p. 47°, $[\alpha]_D$ - 16.4° (c 1.0, $CHCl_3$). **3b** was characterised fully from ^1H NMR, ^{13}C and IR spectral data. The anomeric proton H-1 of the furanoside **3b** appeared at δ5.10 as a doublet with a coupling of $J_{1,2}$=1.5 Hz indicating the 1,2-trans linkage, H_{5a}, H_{5b} appeared between δ 2.85-2.6 indicating the rearrangement of the lactone to the furanosaccharide. COOH proton was not observed probably due to rapid exchange, however IR spectrum indicated the presence of carboxylic acid group from the absorption at 1701 cm^{-1}. ^{13}C NMR also justified the structure **3b** from the appearance of anomeric C-1 at δ 105.8 (d) that was characteristic of β

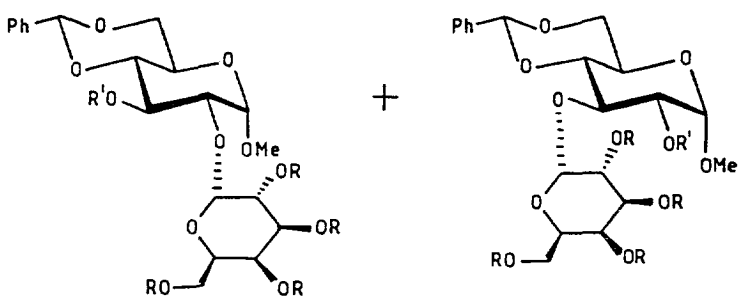
-D-furanosides[11] and a singlet at δ 175.8 for the carbonyl carbon of COOH group. Low levo rotatary value of -16.4° also indicated the formation of β-D-furanoside **3b**.

The stereospecific formation of the β-anomer **3b** also can be explained from the mechanism described for **2a** (Scheme 3) where 'kinetic control' has been explained as the driving force for the exclusive formation of the β-anomer.

Having demonstrated the transformation of simple hemiacetal heptanolactone alcohol to the rare D and L furano monosaccharides, we looked at the synthesis of more complex

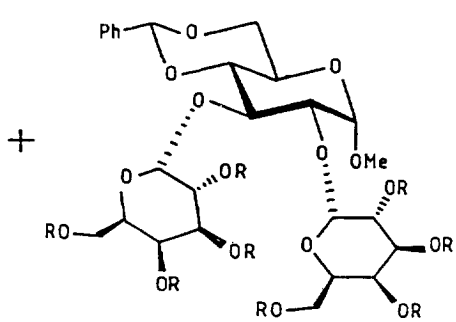


4 R = CH_2Ph 5



6 R' = H
9 R' = $COCH_3$

7 R' = H
10 R' = $COCH_3$



8

Scheme - 5

furanodisaccharides **20,22,32** and **34** to give a wide applicability to the protocol developed by us.

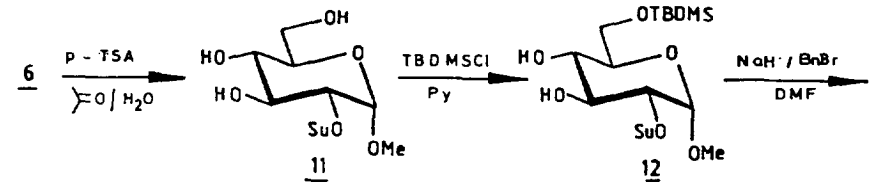
In order to prepare such disaccharides, glycoside coupling of 2-pyridyl 2,3,4,6-tetra-O-benzyl-1-thio-β-D-galactopyranoside (**4**)[5] with the glycosyl acceptor, methyl 4,6-O-benzylidene-α-D-glucopyranoside (**5**)[13] by use of methyl iodide as an activator, according to the procedure developed by us[5] (CH_2Cl_2/50°C/5 days) was performed to obtain methyl 4,6-O-benzylidene-2-O-(2',3',4',6'-tetra-O-benzyl- α-D-galactopyranosyl)- α-D-glucopyranoside (**6**) as a syrup in 26% yield, methyl 4,6-O-benzylidene 3-O-(2',3',4',6'-tetra-O-benzyl- α-D-galactopyranosyl)-α-D-glucopyranoside (**7**) as a syrup in 51% yield and the trisaccharide, methyl 4,6-O-benzylidene 2,3-di-O-(2',3',4',6'-tetra-O-benzyl- α-D-galactopyranosyl)- α-D-glucopyranoside (**8**) as a syrup in 1.2% yield after separation by column chromatography. It was observed that glycosylation of **4** with diol **5** was not completely regioselective thereby resulting in the formation of two monogalactosylated derivatives **6** and **7**, and a digalactosylated derivative **8** (Scheme 5).

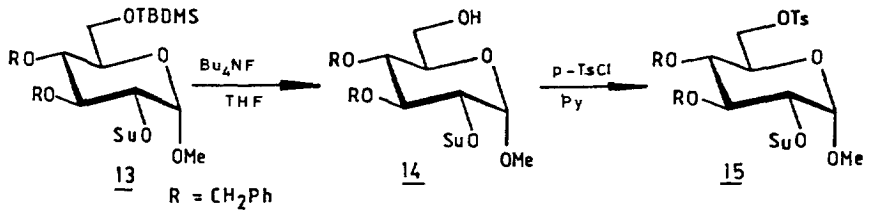
For characterisation, the monogalactosylated saccharides **6** and **7** were individually acetylated to their corresponding acetyl derivatives **9** and **10** respectively to know the regioselectivity during galactosylation. In the ^1H NMR spectrum of **9**, H-3 proton appeared at δ 5.52 as a triplet ($J_{2,3} = J_{3,4} = 9.36$ Hz) shifted downfield due to acetylation, confirming **9** as the 2-O-linked saccharide. In the ^1H NMR spectrum of **10**, H-2 proton appeared downfield at δ 4.98 as a double doublet ($J_{1,2} = 3.99$ Hz, $J_{2,3} = 7.1$ Hz) confirming **10** as the 3-O-linked saccharide. After assigning the regioselectivity for **6** and **7**, they were further characterised from ^1H and ^{13}C NMR spectra. **6** was characterised from the appearence of benzylidene carbon ($C_6H_5\underline{C}HO_2$) at δ 101.9 as a doublet, and C-1,1' at δ 98.5, 97.1 as two doublets indicating α-linkage (axial) at the newly formed glycosidic bond at C-1' in the ^{13}C NMR spectrum. In the ^1H NMR spectrum, **6** exhibited benzylidene proton at δ 5.52 as a singlet and OCH_3 as a singlet at δ 3.41. The anomeric H-1,1' signals were submerged between δ 5.05-3.3. High positive optical rotation of $[\alpha]_D$ +48.5 (c 1.0, $CHCl_3$) for **6** also indicated α-linkage at the anomeric position. **7** was characterised from ^{13}C NMR spectrum from the appearence of benzylidene carbon ($PhC\underline{H}O_2$) at δ 101.9 as a doublet, C-1,1' anomeric carbons at δ 100.5, 96.9 indicating α-linkages. α-Linkage was also evident from high positive optical rotation $[\alpha]_D$ +64.1 (c 1.0, $CHCl_3$).

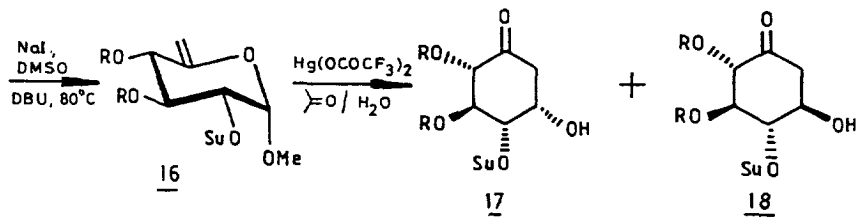
The trisaccharide **8** was characterised based on the ^1H and ^{13}C NMR spectra. In the ^1H NMR spectrum the anomeric protons H-1", H-1' and H-1 appeared at δ5.8 as a doublet ($J_{1",2"} = 3.5$ Hz), δ5.22 as a doublet ($J_{1',2'} = 3.6$ Hz) and δ 5.05 as a doublet ($J_{1,2} = 3.2$ Hz) respectively. The benzylidene proton ($PhC\underline{H}O_2$) appeared as a singlet at δ 5.42 and the OCH_3 as a singlet at δ 3.34 indicating the formation of trisaccharide during galactosylation. ^{13}C spectrum also justified the given structure for **8** from the appearence of benzylidene carbon at δ 101.6 and anomeric C-1,1',1" at δ 97.7, 96.0, 94.9 that were characteristic of α-axial interglycoside linkages in **8**. Positive optical rotation value of $[\alpha]_D$ +49.5° (c 1.0, $CHCl_3$) also indicated α-linked structure for **8**.

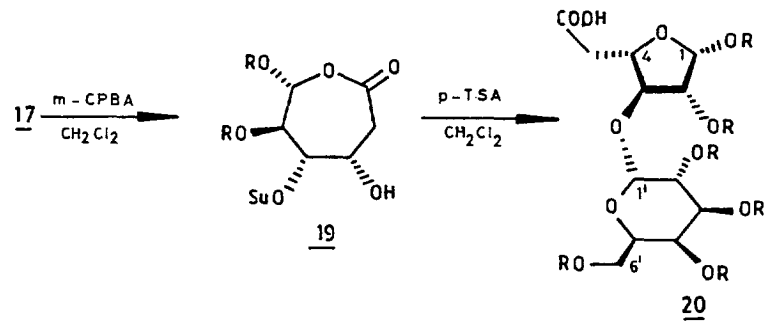
The disaccharides **6** and **7** were processed further to obtain the 5-deoxy hexofuranosiduronic acids **20** and **22** respectively. Thus treatment of **6** with catalytic amount of pTSA

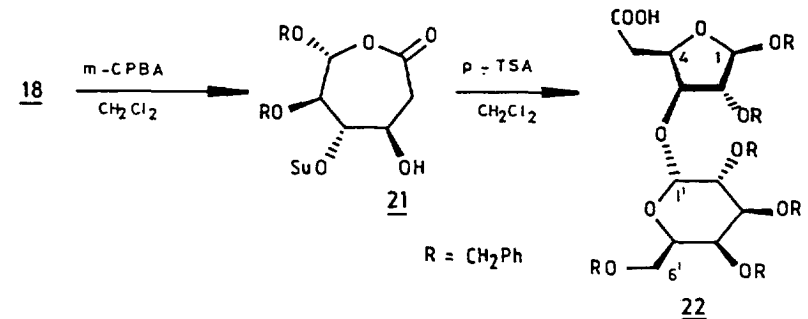
in acetone/water (10:1) at room temperature for 4 h to give the triol, methyl 2-O-(2',3',4',6'-tetra-O-benzyl-α-D-galactopyranosyl)-α-D-glucopyranoside (**11**) in 92% yield as a crystalline solid, m.p. 98°C (Scheme 6). **11** was characterised by the disappearence of benzylidene proton signals in the ^{1}H NMR spectrum. **11** on reaction with TBDMSCl in pyridine at RT gave methyl 6-O-tert.butyldimethylsilyl-2-O-(2',3',4',6'-tetra-O-benzyl-α -D-galactopyranosyl)-α -D-glucopyranoside (**12**) as a syrup in 96% yield. **12** was benzylated (BnBr/NaH/DMF) to obtain methyl 3,4-di-O-benzyl-6-O-tert.butyldimethylsilyl-2-O-(2',3',4',6'-tetra-O-benzyl-α -D-galactopyranosyl)-α-D-glucopyranoside (**13**) as a syrup in quantitative yield. **13** was desilylated by treatment with Bu_4NF/THF at RT for 1.5 h to obtain **14** in quantitative yield as a syrup. **14** on reaction with p-toluene sulfonyl chloride in pyridine gave the 6-O-tosyl derivative **15** in quantitative yield as a syrup. **15** on reaction with NaI, Bu_4NI, DBU (1,8-diazabicyclo[5.5.0]undec-7-ene)[14] in dry DMSO at 80°C after workup gave the 5,6-enosaccharide **16** as a syrup in 86% yield. **16** was characterised from its ^{1}H, ^{13}C NMR spectra. **16** was treated with catalytic amount of $Hg(OCOCF_3)_2$ in acetone-water (2:1) to affect 'Ferrier carbocyclization' reaction[6,15] at room temperature for 14 h to yield the galactosyl cyclohexanone alcohols **17/18** (α,β-alcohols at C-5) in 79% yield as a syrup. C-5 epimeric alcohols **17** and **18** were separated by column chromatography to obtain the C-5, α-alcohol **17** (m.p. 150-152°C) and C-5, β-alcohol **18** (m.p. 148°C) in 52% and 26% yields respectively. **17** was characterised from the appearence of H-6 methylene protons (2H) as double doublets at δ 2.75 (dd, 1H, $J_{6,6\ gem}$ = 13.9 Hz, $J_{5,6}$ = 5.71 Hz, H-6e) and δ 2.45 (dd, 1H, $J_{5,6}$ = 3.73 Hz, H-6a) in the ^{1}H NMR spectrum. ^{13}C NMR also indicated the formation of cyclohexanone moiety from the appearence of carbonyl carbon at δ 204.4 (s); presence of α-linked galactosyl derivative was also indicated from the appearence of anomeric C-1' at δ96.8 (d). IR spectrum also indicated the presence of a cyclohexanone carbonyl from the absorption at 1720 cm^{-1}. Thus, during this crucial carbocyclization reaction the sensitive interglycosidic linkage remained unaffected. Having performed the crucial carbocyclisation reaction, **17** was then treated with m-CPBA in CH_2Cl_2 (Baeyer-Villiger reaction) at room temperature to obtain the hemiacetal heptanolactone alcohol **19**. Conversion of **17** to **19** by Baeyer-Villiger reaction proceeded regioselectively as was observed for **2a** and **2b**, with stereospecific migration of the C-C bond attached to the electron rich benzyloxy substituent on C-2. **19** was fully characterised from the ^{1}H NMR spectrum from the appearence of H-6 proton of the hemiacetal at δ 5.17 as a doublet with $J_{5,6}$ 6.58 Hz. ^{13}C NMR spectrum also indicated the presence of a lactone carbonyl at δ 169.7 (s, COO), hemiacetal carbon at δ 102.1 (d, C-6), and anomeric carbon of the galactosyl moiety at δ 101.1 (d, C-1'). IR spectrum also indicated a lactone carbonyl absorption at 1750 cm^{-1}. **19** was treated with catalytic amount of p-TSA in CH_2Cl_2 to affect the rearrangement that proceeded with high 'kinetic control' to yield benzyl 2-O-benzyl-5-deoxy-3-O-(2',3',4',6'-tetra-O-benzyl-α-D-galactopyranosyl)-β-L-arabino-hexofuranosiduronic acid (**20**) in 82% yield as a syrup. **20** was well characterised from ^{1}H, ^{13}C NMR and IR spectral data. The characteristic ^{1}H NMR signals were, H-5a,b (2H) as a multiplet between δ2.8-2.65, anomeric H-1' of galactopyranosyl moiety was submerged betweenδ4.9-3.8 and the newly formed anomeric H-1 proton of the furanoside at δ5.03 as a singlet. Carboxylic proton could not be observed probably due to rapid exchange.


6
p - TSA
>C=O / H2O
11
TBDMSCl
Py
12
NaH / BnBr
DMF
Su= 2,3,4,6 - tert - o - benzyl - α - D - galactopyranosyl


13
R = CH2Ph
Bu4NF
THF
14
p-TsCl
Py
15


NaI, DMSO
DBU, 80°C
16
Hg(OCOCF3)2
>C=O / H2O
17
18


17
m - CPBA
CH2Cl2
19
p-TSA
CH2Cl2
20

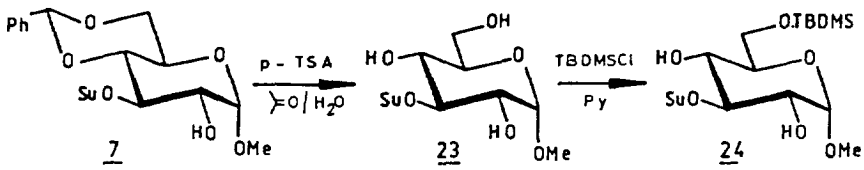

18
m-CPBA
CH2Cl2
21
p - TSA
CH2Cl2
R = CH2Ph
22

Scheme-6

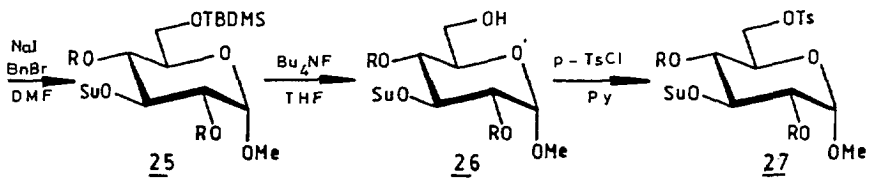
^{13}C NMR spectrum indicated the presence of a carboxylic carbonyl at δ 173.5 (s), anomeric carbon of the galactosyl moiety at δ 99.3 (d) and the newly formed furanosidic anomeric carbon at δ 105.3 (d). IR spectrum indicated the presence of CO_2H group at 1710 cm^{-1}. Low positive optical rotation $[\alpha]_D$ +6.5° (c 1.0, $CHCl_3$) was also once again in agreement with the proposed structure for **20**.

After having successfully transformed the disaccharide **6** to the rare saccharide **20**, the β-epimeric alcohol **18** was taken up to study the generality of the above transformation (Scheme 6). Thus, **18** underwent regio- and stereoselective transformation to the hemiacetal heptanolactone alcohol **21** by Baeyer-Villiger oxidation (m-CPBA/CH_2Cl_2/RT/12 h). **21** was obtained as a syrup in 89% yield and was fully characterised from spectral data (^1H, ^{13}C NMR, IR). Structure assignments were made analogous to **19**. **21** was reacted with catalytic amount of p-TSA in CH_2Cl_2 at RT (5 min) to obtain the furanosaccharide **22** in 80% yield as a syrup. **22** was characterised from the appearence of H-5a, H-5b protons (^1H NMR) (2H) as double doublets at δ 2.74 ($J_{5a,b}$ = 13.6 Hz, $J_{4,5a}$ = 5.4 Hz), 2.88 ($J_{4,5b}$ = 8.4 Hz) respectively, galactosyl anomeric proton H-1' at δ 4.98 as a doublet with a coupling of $J_{1',2'}$ = 4.4 Hz and the newly formed β -anomeric proton of the furanoside H-1 at δ 5.06 as a singlet. ^{13}C NMR data was also in consonance with the structure **22** from the appearence of $\underline{C}O_2H$ at δ 171.2 (s), galactosyl anomeric carbon C-1' (d) at δ 99.4 and the newly formed β-furanosidic anomeric carbon at δ 105.6 (d). IR spectrum indicated the presence of a carboxylic acid (COOH) group due to the absorption at 1702 cm^{-1}, positive optical rotation of $[\alpha]_D$ +28.4° also suggested the β-(D)-linkage at the newly formed anomeric carbon C-1.

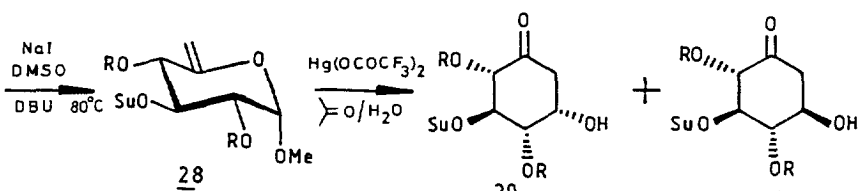
For greater refinement of this protocol designed and executed by us, it required to transform even the 3-O-linked disaccharide **7** to the corresponding D and L rare saccharides **32** and **34**. Hence **7** was treated with p-TSA in acetone-H_2O (10:1) to obtain the benzylidene deprotected triol **23** as a syrup in 95% yield (Scheme 7). **23** was regioselectively silylated at 6-OH (TBDMSCl/pyridine/RT/2h) to obtain the silyl derivative **24** as a syrup in 96% yield. **24** was benzylated by known procedure to yield the di-O-benzylated 6-O-silyl derivative **25** in 97% yield as a syrup. **25** was treated with Bu_4NF in THF to obtain the 6-O-desilylated derivative **26** in 95% yield. **26** on reaction with p-toluenesulfonyl chloride in pyridine gave the 6-O-tolylsulfonyl derivative **27** in 97% yield as a syrup. The products **23-27** were characterised by spectral data. **27** was converted to the 5,6-enosaccharide **28** in a one pot reaction with NaI, DMSO, DBU, at 80°C. ^{13}C NMR spectrum was indicative of the formation of a C-5,6 double bond from the appearence of C-5 at δ 153.2 (s) and C-6 at δ 98.8 (t) that was characteristic of enolether carbons, the two anomeric carbons, C-1,1' appeared at δ 97.5, 97.0 as doublets. Crucial carbocyclisation of **28** was carried out in acetone-water (2:1) at RT in presence of catalytic amount of $Hg(OCOCF_3)_2$ for 12 h to yield the cyclohexanone derivatives **29** and **30** as an epimeric mixture of C-5 alcohols. **29** and **30** (α,β-alcohols) were separated by column chromatography to obtain first **30** (C-5, β-alcohol) in 19% yield as a crystalline solid, m.p. 127°C, followed by **29** (C-5, α-alcohol) in 61% yield as a crystalline solid, m.p. 134°C (Scheme 7). **29** was processed further by treatment with m-CPBA in CH_2Cl_2 at RT to obtain the Baeyer-Villiger oxidation product, the hemiacetal heptanolactone alcohol

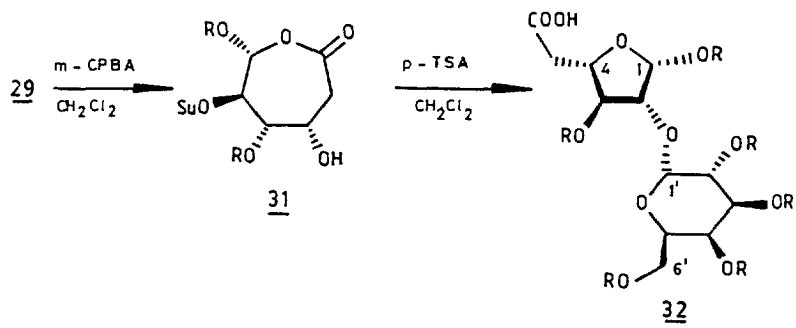


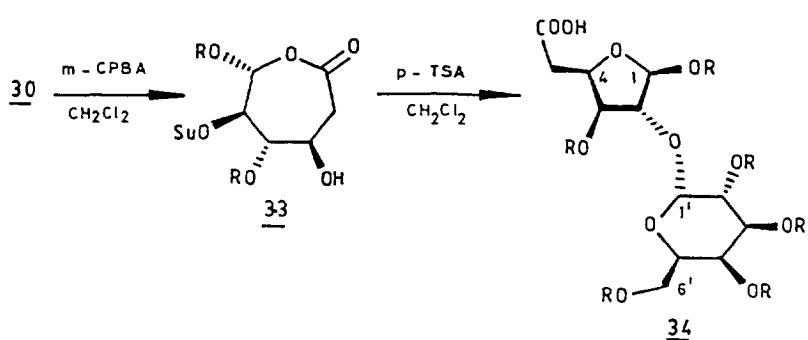
Su = 2,3,4,6-tetra-o-benzyl-α-D-galactopyranosyl , R = CH_2Ph



R = CH_2Ph







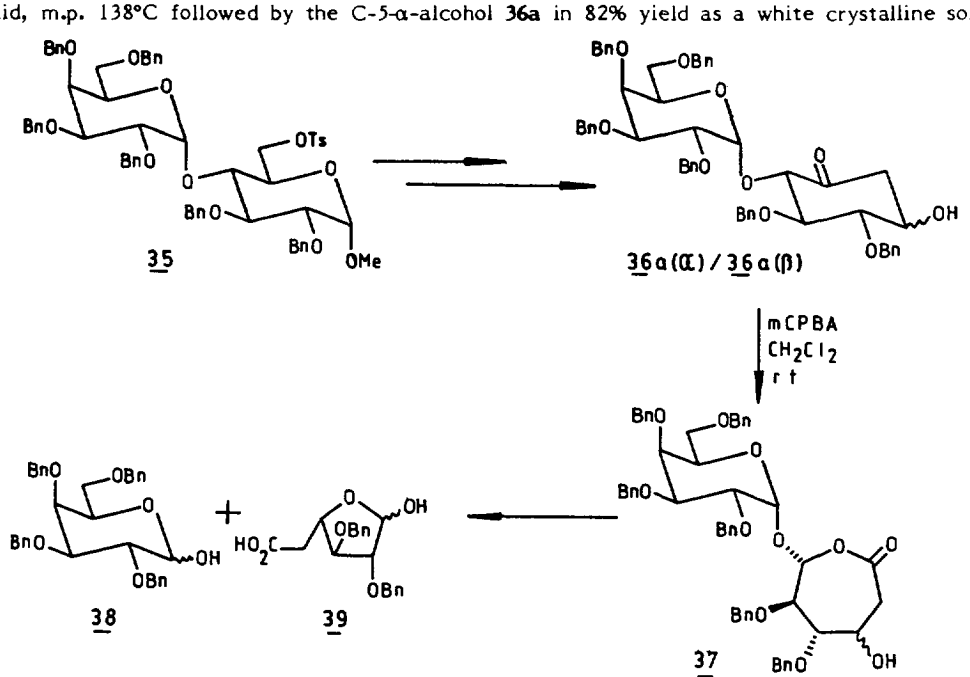
Scheme-7

31 in 71% yield as a syrup. Formation of **31** from **29** was regioselective and stereospecific as in the case of **17**. **31** was also characterised analogous to **19** based on ^{1}H, ^{13}C NMR spectra. **31** was reacted with catalytic amount of p-TSA in CH_2Cl_2 at RT for 10 min to obtain the benzyl 3-O-benzyl-5-deoxy-2-O-(2',3',4',6'-tetra-O-benzyl- α -D-galactopyranosyl)- β -L-arabino-hexofuranosiduronic acid (**32**) in 72% yield as a syrup. **32** was characterised from ^{1}H NMR data from the appearence of δ 5.07 (s) for the anomeric proton H-1 of the newly formed furanoside. H-5,5' (2H) methylene protons appeared as multiplets between δ 2.35-2.02 and CO_2H proton could not observed. IR spectrum also indicated the presence of a carboxylic group from the absorption at 1705 cm^{-1}.

Likewise **30** was also converted to the heptanolactone alcohol **33** by treatment with m-CPBA in CH_2Cl_2 at room temperature and was in situ rearranged to the required benzyl 3-O-benzyl-5-deoxy-2-O-(2',3',4',6'-tetra-O-benzyl- α -D-galactopyranosyl)- β -D-xylo-hexofuranosiduronic acid (**34**) as a syrup in 70% yield (Scheme 7). **34** was characterised from ^{1}H NMR data analogous to compound **32**.

After transforming the 2-O- and 3-O-linked galactosyl saccharides **6** and **7** to the corresponding rare sugars **20, 22** and **32, 34** respectively; it remained to check the validity of this protocol for the transformation of the 4-O-linked saccharide to the corresponding 5-deoxy hexofuranosiduronic acid derivatives.

Hence, synthesis of 4-O-galactosylated saccharide **35** was carried out as earlier reported by us[15]. **35** was further transformed (Scheme 8) to the cyclohexanone derivative **36** in 90% yield. **36** was an epimeric mixture of alcohols **36a/36b** (α / β , 10/1) and were separated by column chromatography to obtain first the C-5-β -alcohol **36b** in 8% yield as a crystalline solid, m.p. 138°C followed by the C-5-α-alcohol **36a** in 82% yield as a white crystalline solid,

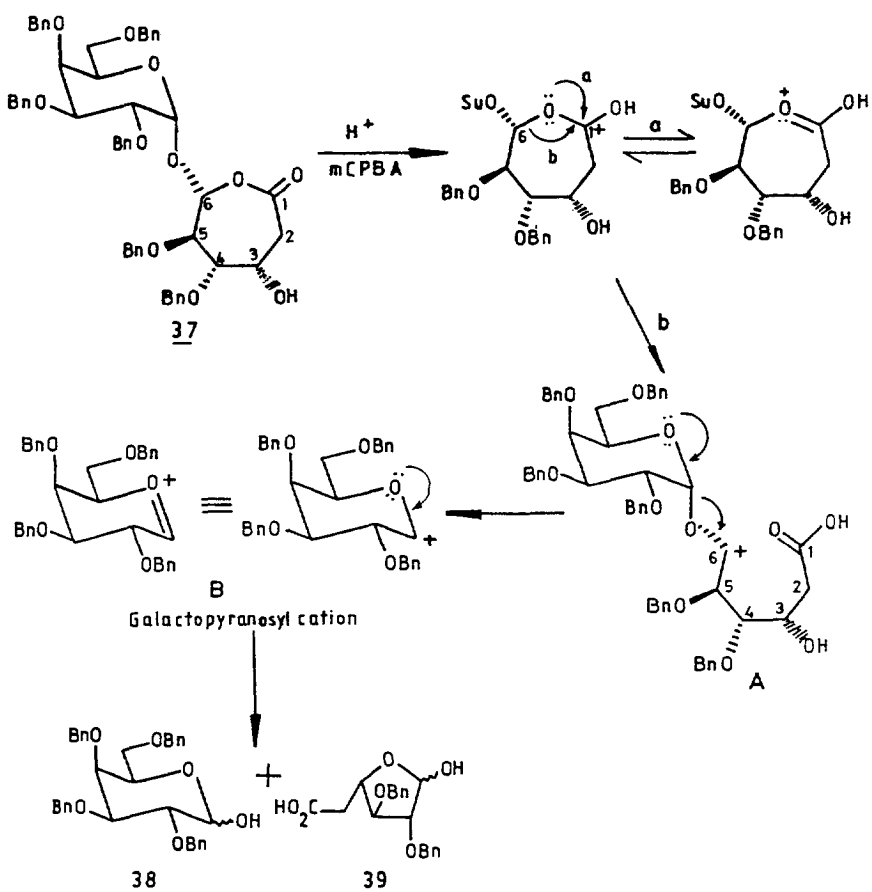


35 36α(α) / 36α(β) 38 39 37

Scheme- 8

m.p. 146°C. **36a** and **36b** were characterised from ^{1}H NMR, ^{13}C NMR and IR spectra. ^{1}H NMR spectrum of **36a** indicated the presence of anomeric proton of the galactopyranoside H-1' at δ5.35 as a doublet ($J_{1',2'}$ = 3.2 Hz) and H-6e at δ 2.61 as a double doublet ($J_{6,6gem}$ = 14.24 Hz, $J_{5,6e}$ = 3.92 Hz) and H-6a at δ2.19 as a double doublet ($J_{5,6a}$ = 3.56 Hz), likewise, **36b** indicated the presence of H-1' at δ 5.31 as a doublet ($J_{1',2'}$ = 3.6 Hz) and the H-6a,e (2H) methylene protons appeared as multiplet between δ 2.65-2.3. **36a** was further reacted with m-CPBA in CH_2Cl_2 at RT for 3h. It was observed (t.l.c.) that substrate **36a** was consumed during the Baeyer-Villiger oxidation but efforts to isolate the heptanolactone alcohol **37** met with failure. The only isolable product of this reaction was 2,3,4,6-tetra-O-benzyl-α/β-D-galacto-pyranoside (**38**), which was characterised by comparison with an authentic sample prepared from hydrolysis of methyl 2,3,4,6-tetra-O-benzyl-α-D-galactopyranoside. However, ^{1}H NMR of the crude reaction mixture indicated the presence of **38** and 2,3-di-O-benzyl-5-deoxy-hexo-

Proposed mechanism:



Scheme - 9

furanosiduronic acid (**39**). Thus Baeyer-Villiger reaction of the cyclohexanone **36a** lead to the cleavage of the galactopyranosyl moiety resulting in the formation of **38** and **39**. The following mechanistic pathway has been proposed to explain the cleavage of the glycosides during the Baeyer-Villiger reaction. **36a** on reaction with m-CPBA leads to the formation of the heptanolactone alcohol **37** which rapidly gets protonated resulting in the formation of carbocation at C-6 hemiacetal carbon (A) (Scheme 9). Acyclic carbocation A gets further stabilised by the formation of a more stable galactopyranosyl cation (B) thus triggering the cleavage of the O-glycosidic bond before it is captured intramolecularly by hydroxyl group resulting in the formation of **38** and **39**. The 4-O- and 5-O-linked heptanolactone glycosides **19, 21, 31** and **33** on the other hand do not undergo such cleavage as they are not attached to the carbocation forming carbon C-6.

EXPERIMENTAL

^1H NMR spectra were measured with a Varian Gemini (200 MHz) spectrometer, with tetramethylsilane as internal standard for solutions in deuteriochloroform, unless otherwise stated; J values are given in Hz. ^{13}C NMR spectra were taken on a Varian Gemini (50 MHz) spectrometer with $^{13}CDCl_3$ as internal standard (δ_C 77.0(for solutions in deuteriochloroform. Optical rotations were measured with a JASCO DIP-370 instrument, and $[\alpha]_D$-values are in units of 10^{-1} deg cm^2 g^{-1}. IR spectra were taken with a Perkin-Elmer 1310 spectrometer. Organic solutions were dried over anhydrous Na_2SO_4 and concentrated below 40°C. Melting points were determined on a Fisher-John's melting point apparatus and are uncorrected.

(3S,4S,5R,6R)-4,5,6-Tris(benzyloxy)-7-heptanolide (2a).- Compound **1a** (0.5 g, 1.15 mmol) was dissolved in CH_2Cl_2 (5 ml) and treated with metachloroperoxybenzoic acid (m-CPBA, 70%) (0.43 g, 1.73 mmol) at room temperature for 6 h. The reaction was monitored by t.l.c, appearence of a slower moving spot and simultaneous disappearence of starting material indicated completion of the reaction. The reaction mixture was diluted with CH_2Cl_2 (50 ml), washed with aq. $NaHCO_3$. Organic layer was dried (Na_2SO_4), concentrated in vacuo to obtain the crude compound, which was filtered on a bed of SiO_2 (60-120 mesh, 3:1, hexane-ethyl acetate) to obtain **2a** (0.48 g) in 92% yield as a crystalline solid. m.p. 95°C, $[\alpha]_D$ -53.4° (c 1.0, $CHCl_3$); IR ($CHCl_3$): 1745, 3540 cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$): δ 7.4-7.1 (m, 15H, aromatic), 5.31 (d, 1H, $J_{5,6}$ = 7.8 Hz, H-6), 4.95-4.4 (m, 6H, $OC\underline{H}_2Phx3$), 4.12 (m, 1H, H-3), 3.85 (t, 1H, $J_{5,6}$ = $J_{4,5}$ = 7.8 Hz, H-5), 3.55 (dd, 1H, $J_{3,4}$ = 2.63 Hz, H-4), 3.00 (dd, 1H, $J_{2a,2e}$ = 14.2 Hz, $J_{2,3}$ = 3.3 Hz, H-2e), 2.63 (dd, 2H, $J_{2,3}$ = 7.7 Hz, H-2a, OH submerged); ^{13}C NMR (50 MHz, $CDCl_3$): 170.1 (s, $\underline{C}OO$), 138.2, 137.5, 136.2, 128.9, 128.6, 128.3 (aromatic), 102.0 (d, C-6), 82.0, 78.0, 76.2, 74.5, 72.1, 65.2 (3t, 3d, C-3,4,5, $O\underline{C}H_2Phx3$), 38.2 (t, C-2); Anal. Calcd. for $C_{27}H_{28}O_6$: C, 72.30; H, 6.29. Found: C, 72.25; H, 6.22%.

Benzyl 2,3-di-O-benzyl-5-deoxy-β-L-arabino-hexofuranosidurnoic acid (3a).- Compound **2a** (0.45 g, 1.0 mmol) was dissolved in CH_2Cl_2 (5 ml) and treated with catalytic amount of anhydrous p-toluenesulfonic acid (5 mg). Reaction was monitered by t.l.c, after 10 min at RT, solid $NaHCO_3$ was added and stirred for 5 min. The reaction mixture was filtered on a bed of celite and concentrated in vacuo to obtain the crude **3a** which was crystallised from CH_2Cl_2/

petroleum ether to afford the title compound (0.4 g, 89% yield) as a crystalline solid; m.p. 58-60°C, $[\alpha]_D$ -56.7° (c 1.0, $CHCl_3$); IR ($CHCl_3$): 1705 cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$): δ 7.40-7.15 (m, 15H, aromatic), 5.05 (d, 1H, $J_{1,2}$ = 0.8 Hz, H-1), 4.8-4.3 (m, 7H, H-3 and OCH_2Phx3), 4.04 (dd, 1H, H-2), 3.75 (ddd, 1H, $J_{3,4}$ = 2.95 Hz, $J_{4,5a}$ = 8.1 Hz, $J_{4,5b}$ = 5.4 Hz, H-4), 2.69 (dd, 1H, $J_{5a,5b}$ = 13.4 Hz, H-5b), 2.58 (dd, 1H, H-5a), (CO_2H not observed); ^{13}C NMR (50 MHz, $CDCl_3$); δ 176.3 (s, COOH), 137.6, 137.3, 128.4, 127.9, 127.8 (aromatic), 104.9 (d, C-1), 88.1, 86.4, 77.0, 72.2x2, 68.9 (3d, 3s, C-2,3,4, OCH_2Phx3), 38.1 (t, C-5); Anal. Calcd. for $C_{27}H_{28}O_6$: C, 72.30; H, 6.29. Found: C, 72.29; H, 6.23%.

(3R,4S,5R,6R)-4,5,6-Tris(benzyloxy)-7-heptanolide (2b).- (As in procedure described for **2a**) **1b** (0.125 g, 0.29 mmol) CH_2Cl_2 (2 ml) mCPBA (70%) (0.107 g, 0.43 mmol) were reacted for 4h at RT and was filtered on a bed of SiO_2 (hexane-ethyl acetate; 4:1) to obtain **2b** (0.117 g, 91%) as a crystalline solid m.p. 84°C; $[\alpha]_D$ -12.2° (c 1.0, $CHCl_3$); IR ($CHCl_3$): 1750, 3550 cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$): δ 7.4-7.1 (m, 15H, aromatic), 5.32 (d, 1H, $J_{5,6}$ = 6.16 Hz, H-6), 5.05-4.5 (m, 6H, OCH_2Phx3), 3.96 (m, 1H, H-3), 3.78 (t, 1H, $J_{4,5}$=$J_{5,6}$ = 6.16 Hz, H-5), 3.62 (t, 1H, $J_{3,4}$ = $J_{4,5}$ = 6.16 Hz, H-4), 3.11 (dd, 1H, $J_{2a,2e}$ = 15.4 Hz, $J_{2e,3}$ = 3.18 Hz, H-2e), 2.71 (dd, 1H, $J_{2a,3}$ = 7.7 Hz, H-2a); ^{13}C NMR (50 MHz, $CDCl_3$): δ 169.1 (s, COO), 137.6, 137.31, 128.4, 127.9, 127.8 (aromatic), 101.58 (d, C-6), 82.0, 80.2, 77.6, 74.4, 71.5, 67.8 (3t, 3d, C-3,4,5, OCH_2Phx3), 39.2 (t, C-2); Anal. Calcd. for $C_{27}H_{28}O_6$: C, 72.30; H, 6.29. Found: C, 72.26; H, 6.25%.

Benzyl 2,3-di-O-benzyl-5-deoxy-β-D-xylo-hexofuranosiduronic acid (3b).- (as in procedure described for **3a**) **2b** (0.110 g, 0.02 mmol), CH_2Cl_2 (1.5 ml), pTSA (2 mg) were reacted for 10 min at RT to obtain a solid which was recrystallised from CH_2Cl_2/petroleum ether to obtain **3b** (0.101 g, 92%); m.p. 47°C; $[\alpha]_D$ -16.4° (c 1.0, $CHCl_3$); IR ($CHCl_3$): 1701 cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$): δ7.4-7.2 (m, 15H, aromatic), 5.10 (d, 1H, $J_{1,2}$ = 1.5 Hz, H-1), 4.85-4.35 (m, 7H, H-3 and OCH_2Phx3), 4.20-4.02 (m, 2H, H-2,4), 2.85-2.6 (m, 2H, H-5a, 5b), (CO_2H not observed); ^{13}C NMR (50 MHz, $CDCl_3$): δ 175.8 (s, COOH), 137.5-127.5 (aromatic), 105.8 (d, C-1), 87.8, 83.0, 77.2, 72.1x2, 70.1x2, 70.1 (3d, 3t, C-2,3,4, OCH_2Phx3), 36.4 (t, C-5); Anal. Calcd. for $C_{27}H_{28}O_6$: C, 72.30; H, 6.29. Found: C, 72.27; H, 6.24%.

Methyl 4,6-O-benzylidene 2-O-(2',3',4',6'-tetra-O-benzyl-α-D-galactopyranosyl)-α-D-glucopyranoside (6), Methyl 4,6-O-benzylidene-3-O-(2',3',4',6'-tetra-O-benzyl- α -D-galactopyranosyl)-α-D-glucopyranoside (7) and Methyl 4,6-O-benzylidene-2,3-di-O-(2',3',4',6'-tetra-O-benzyl-α-D-galactopyranosyl)-α-D-glucopyranoside (8).- A mixture of 2-pyridyl 2,3,4,6-tetra-O-benzyl-1-thio-β-D-galactopyranoside (4)[5] (6.0 g, 9.48 mmol), diol 5[3] (2.68 g, 9.48 mmol) and molecular sieves (4A, 2.0 g) in dry dichloromethane (80 ml) (containing 5% iodomethane) was heated to 50°C for 5 days. Reaction was monitered by t.l.c. and when complete the mixture was filtered on celite, washed with ethyl acetate (20 ml), and concentrated to obtain a residue, which was chromatographed [SiO_2, 200 mesh; hexane-ethyl acetate (4:1)]. Eluted first was **8** (0.15 g, 1.2%) as a syrup; second eluted was **6** (1.98 g, 26%) as a syrup and third eluted was **7** (3.9 g, 51%) as a syrup; **6** - $[\alpha]_D$ +48.5° (c 1.0, $CHCl_3$): ^1H NMR (200 MHz, $CDCl_3$): δ7.6-7.2 (m, 25H, aromatic), 5.52 (s, 1H, $PhCHO_2$), 5.05-3.30 (m, 22H, H-1-6,1'-6', OCH_2Phx4), 3.41 (s, 3H, OCH_3); ^{13}C NMR (50 MHz, $CDCl_3$): δ 138.7-126.5 (aromatic), 101.9 (d, $PhCHO_2$),

98.5, 97.1 (2d, C-1,1'), 81.4, 79.5, 78.8, 76.2, 74.7x2, 73.4, 73.2, 72.8, 70.0, 69.3x2, 69.1, 62.3, 55.4 (1q, 6t, 8d, C-2-6,2'-6', $O\underline{C}H_3$, $O\underline{C}H_2$Phx4); Anal. Calcd. for $C_{48}H_{52}O_{11}$: C, 70.22; H, 6.38. Found: C, 70.19; H, 6.31%; **7** $[\alpha]_D$ +64.1° (c 1.0, $CHCl_3$): ^{1}H NMR (200 MHz, $CDCl_3$): **7**- δ 7.4-6.9 (m, 25H, aromatic), 5.48-5.41 (d, s, 2H, H-1', $PhC\underline{H}O_2$ merged), 5.0-3.2 (m, 21H, H-1-6,2'-6', $OC\underline{H}_2$Phx4), 3.29 (s, 3H, $OC\underline{H}_3$); ^{13}C NMR (50 MHz, $CDCl_3$): δ 138.9-126.3 (aromatic), 101.9 (d, $PhCHO_2$), 100.5, 96.9 (2d, H-1,1'), 81.7, 78.9, 77.8, 75.4, 74.8, 74.6, 74.4, 73.6, 73.4, 71.4x2, 70.9, 69.5, 69.1, 62.6, 55.4 (1q, 6t, 8d, C-2-5,2'-5', 6,6', $O\underline{C}H_2$Phx4, $O\underline{C}H_3$); Anal. Calcd. for $C_{48}H_{52}O_{11}$: C, 70.22; H, 6.38. Found: C, 70.19; H, 6.32%; **8** $[\alpha]_D$ +49.5° (c 1.0, $CHCl_3$): ^{1}H NMR (200 MHz, $CDCl_3$): **8**- δ 7.4-7.0 (m, 45H, aromatic), 5.8 (d, 1H, $J_{1'',2''}$ = 3.5 Hz, H-1''), 5.42 (s, 1H, $PhC\underline{H}O_2$), 5.22 (d, 1H, $J_{1',2'}$ = 3.6 Hz, H-1'), 5.05 (d, 1H, $J_{1,2}$ = 3.2 Hz, H-1), 4.95-3.4 (m, 34H, H-2-6,2'-6', 2''-6'', $OC\underline{H}_2$Phx8), 3.34 (s, 3H, $OC\underline{H}_3$); ^{13}C NMR (50 MHz, $CDCl_3$): δ 138.9-126.1 (aromatic), 101.6 (d, $PhC\underline{H}O_2$), 97.7, 96.0, 94.9 (3d, C-1,1',1''), 83.3-54.9 (1q, 11t, 12d, C-2-6, 2'-6', 2''-6'', $O\underline{C}H_2$Phx8, $O\underline{C}H_3$); Anal. Calcd. for $C_{82}H_{86}O_{16}$: C, 74.18; H, 6.53. Found: C, 74.11; H, 6.49%.

Methyl 3-O-acetyl-4,6-O-benzylidene-2-O-(2',3',4',6'-tetra-O-benzyl- α -D-galactopyranosyl)-α -D-glucopyranoside (9).- To the compound **6** (0.150 g, 0.186 mmol) in dry pyridine (0.2 ml) was added acetic anhydride (Ac_2O) (0.1 ml) and catalytic amount of dimethyl amino pyridine (DMAP (2 mg) and left at room temperature for 30 min. t.l.c indicated the formation of a faster moving spot, indicating completion of the reaction; then 0.5 ml of water was added, stirred for 5 min. then more water (10 ml) was added and extracted into ethyl acetate (10 ml). The organic layer was dried (Na_2SO_4), concentrated to a syrup which was filtered on a bed of SiO_2 [60-120 mesh, hexane-ethyl acetate (4:1)] to obtain the acetate **9** (0.146 g) in 93% yield as a syrup; ^{1}H NMR (200 MHz, $CDCl_3$): δ 7.5-7.2 (m, 25H, aromatic), 5.52 (t, 1H, $J_{2,3}$ = $J_{3,4}$ = 9.36 Hz, H-3), 5.43 (s, 1H, $PhC\underline{H}O_2$), 5.0-3.4 (m, 21H, H-1,2,4,5,6,1'-6', $OC\underline{H}_2$Phx4), 3.32 (s, 3H, $OC\underline{H}_3$), 1.98 (s, 3H, $OCOC\underline{H}_3$).

Methyl 2-O-acetyl-4,6-O-benzylidene-3-O-(2',3',4',6'-tetra-O-benzyl- α -D-galactopyranosyl)-α -D-glucopyranoside (10).- (As in procedure described for **9**). **7** (0.30 g, 0.371 mmol) was treated with pyridine (0.4 ml), Ac_2O (0.2 ml) and DMAP (2 mg) for 1h at R.T. and filtration of the crude residue on a bed of SiO_2 [60-120 mesh, hexane-ethyl acetate, (5:1)] gave **10** (0.28 g) in 87% yield as a syrup; ^{1}H NMR (200 MHz, $CDCl_3$): δ 7.4-6.9 (m, 25H, aromatic), 5.53 (d, 1H, $J_{1',2'}$ = 3.99 Hz, H-1'), 5.34 (s, 1H, $PhC\underline{H}O_2$), 4.98 (dd, 1H, $J_{1,2}$ = 3.2 Hz, $J_{2,3}$ = 7.1 Hz, H-2), 4.9-3.3 (m, 20H, H-1,3-6, 2'-6', $OC\underline{H}_2$Phx4), 3.4 (s, 3H, $OC\underline{H}_3$), 2.03 (s, 3H, $OCOC\underline{H}_3$).

Methyl 2-O-(2',3',4',6'-tetra-O-benzyl- α -D-galactopyranosyl)-α -D-glucopyranoside (11).- Compound **6** (1.5 g, 1.86 mmol) was dissolved in acetone-water (15 ml, 10:1) and catalytic amount of p-TSA (50 mg) was added and stirred for 4 h at room temeprature. T.L.C. indicated the disappearance of starting material and appearance of a slower moving spot. Then solvent was removed in vacuo and the residue was extracted into ethyl acetate (50 ml). The organic layer was washed with water, dried (Na_2SO_4), concentrated and column chromatography was performed on a bed of SiO_2 [(60-120 mesh, hexane-ethyl acetate (3:1)] to obtain the title compound **11** (1.2 g) in 92.3% yield as a crystalline solid, m.p. 98°C; $[\alpha]_D$ +69.8° (c 1.0, $CHCl_3$); ^{1}H NMR (200 MHz, $CDCl_3$): δ7.4-7.1 (m, 20H, aromatic), 5.0-3.2 (m, 22H, H-1-6,1'-6', $OC\underline{H}_2$-

Phx4), 3.35 (s, 3H, OCH_3), 2.91 (brs, 3H, OHx3); ^{13}C NMR (50 MHz, $CDCl_3$): δ 138-127.4 (aromatic), 97.7, 96.3 (2d, C-1,1'), 78.7, 77.9, 77.8, 74.9, 74.6x2, 73.4, 72.9, 72.4, 71.2, 70.0, 69.7, 69.0, 61.6, 55.1 (1q, 6t, 8d, C-2-6,2'-6', $O\underline{C}H_3$, $O\underline{C}H_2Phx4$); Anal. Calcd. for $C_{41}H_{48}O_{11}$: C, 68.69; H, 6.75. Found: C, 68.62; H, 6.72%.

Methyl 6-O-tert.butyldimethylsilyl-2-O-(2',3',4',6'-tetra-O-benzyl-α-D-galactopyranosyl)-α-D-glucopyranoside (12).- At 0°C, TBDMSCl (0.230 g, 1.53 mmol) was added to **11** (1.0 g, 1.3 mmol) in dry pyridine (2 ml) in the presence of catalytic amount of 4-dimethylamino pyridine (DMAP) (5 mg) and stirred at room temperature for 30 min. Reaction was monitered by t.l.c. Conversion of the substrate **11** to a faster moving spot indicated the completion of reaction, water (5 ml) was added and stirred for 5 min, then was diluted with more water (50 ml) and extracted into diethylether (100 ml). Organic layer was dried (Na_2SO_4), concentrated in vacuo to obtain **12** (1.1 g) in 95% yield as a syrup; $[\alpha]_D$ +60° (c 1.0, $CHCl_3$); ^1H NMR (200 MHz, $CDCl_3$): δ7.4-7.1 (m, 20H, aromatic), 5.0-3.2 (m, 22H, H-1-6,1'-6', $OC\underline{H}_2Phx4$), 3.32 (s, 3H, OCH_3), 0.8 (s, 9H, $(C\underline{H}_3)_3C$-Si), 0.03 (s, 6H, $(C\underline{H}_3)_2Si$); ^{13}C NMR (50 MHz, $CDCl_3$): δ 138.6-127.5 (aromatic), 98.1, 97.5 (2d, C-1,1'), 80.0, 76.4, 74.7, 74.6, 73.5, 73.2, 72.9, 72.4, 71.3, 70.8, 70.1, 69.8, 69.5, 63.4, 54.9 (1q, 6t, 8d, C-2-6,2'-6', $O\underline{C}H_3$, $O\underline{C}H_2Phx4$), 25.9 (3q, $(\underline{C}H_3)_3CSi$), -5.3 (2q, $(\underline{C}H_3)_2Si$); Anal. Calcd. for $C_{47}H_{62}O_{11}Si$: C, 67.92; H, 7.52. Found: C, 67.89; H, 7.49%.

Methyl 3,4-di-O-benzyl-6-O-tert.butyldimethylsilyl-2-O-(2',3',4',6'-tetra-O-benzyl- α-D-galactopyranosyl)-α-D-glucopyranoside (13).- To hexane washed sodium hydride (NaH) (0.14 g, 3.6 mmol) at 0°C in DMF was added compound **12** (1.0 g, 1.2 mmol) in dimethylformamide (DMF) (5 ml) and stirred at room temperature for 10 min, then benzylbromide (0.36 ml, 3.0 mmol) was added slowly and stirred for 30 min at room temperature. After completion of the reaction cold water (50 ml) was added slowly to the reaction mixture and extracted into diethyl ether (50 ml). The organic phase was washed with water, dried (Na_2SO_4), concentrated in vacuo, to obtain a syrup which was filtered on a bed of SiO_2[(60-120 mesh, hexane-ethyl acetate (10:1)] to obtain **13** (1.2 g, 98% yield) as a syrup; $[\alpha]_D$ +52.4° (c 1.0, $CHCl_3$); ^1H NMR (200 MHz, $CDCl_3$): δ 7.4-7.1 (m, 30H, aromatic), 5.0-3.3 (m, 26H, H-1-6,1'-6', $OC\underline{H}_2Phx6$), 3.32 (s, 3H, OCH_3), 0.85 (s, 9H, $(C\underline{H}_3)_3CSi$), 0.02 (s, 6H, $(C\underline{H}_3)_2Si$); ^{13}C NMR (50 MHz, $CDCl_3$): δ 138.7-127.5 (aromatic), 96.3, 94.8 (2d, C-1,1'), 80.9, 78.8, 77.9, 75.9, 75.5, 74.9x2, 74.8, 74.7, 72.8x2, 71.5x2, 69.1, 68.7, 62.3, 54.5 (8d, 8t, 1q, C-2-6,2'-6', $O\underline{C}H_2Phx6$, $O\underline{C}H_3$), 25.9 (3q, $(\underline{C}H_3)_3CSi$), -5.4, -5.2 (2q, $(\underline{C}H_3)_2Si$); Anal. Calcd. for $C_{61}H_{74}O_{11}Si$: C, 72.44; H, 7.37. Found: C, 72.38; H, 7.32%.

Methyl 3,4-di-O-benzyl-2-O-(2',3',4',6'-tetra-O-benzyl-α-D-galactopyranosyl)-α-D-glucopyranoside (14).- Compound **15** (1.0 g, 0.99 mmol) was dissolved in dry tetrahydrofuran (THF) 10 ml) and treated with tetrabutylammonium fluoride (TBAF) (1 ml, 1M solution in THF) at room temperature for 1.5 h. Reaction mixture was concentrated and the residue so obtained was filtered on a bed of SiO_2 [60-120 mesh, hexane-ethyl acetate (2:1)] to obtain **14** (0.88 g in 98% yield) as a syrup; $[\alpha]_D$ +59.1° (c 1.0, $CHCl_3$); ^1H NMR (200 MHz, $CDCl_3$): δ 7.4-7.1 (m, 30H, aromatic), 5.0-3.2 (m, 26H, H-1-6, 1'-6', $OC\underline{H}_2Phx6$), 3.35 (s, 3H, $OC\underline{H}_3$); ^{13}C NMR (50 MHz, $CDCl_3$): δ 138.6-127.4 (aromatic), 96.5, 94.6 (2d, C-1,1'), 80.6, 78.6, 77.6x2, 76.9,

76.3, 75.8, 75.4, 74.9, 74.6, 72.8x2, 70.7, 69.1, 68.8, 61.7, 54.8 (1q, 8t, 8d, C-2-6, 2'-6', $O\underline{C}H_2$-Phx6, $O\underline{C}H_3$); Anal. Calcd. for $C_{55}H_{60}O_{11}$: C, 73.63; H, 6.74. Found: C, 73.58; H, 6.69%.

Methyl 3,4-di-O-benzyl-2-O-(2',3',4',6'-tetra-O-benzyl- α-D-galactopyranosyl)-6-O-(p-tolylsulfonyl)- α-D-glucopyranoside (15).- p-Tolylsulfonylchloride (p-TSCl) (0.204 g, 1.07 mmol) was added to the compound **14** (0.8 g, 0.983 mmol) in dry pyridine (2 ml) in the presence of catalytic amount of DMAP (10 mg) at 0°C, and stirred for 12 h. Water (25 ml) was added to the reaction mixture and extracted into diethylether (50 ml). The organic layer was washed with water, dried (Na_2SO_4), concentrated in vacuo to obtain a syrup which was filtered on a bed of SiO_2 [60-120 mesh, hexane-ethyl acetate (4:1)] to obtain **15** (0.9 g) in 96% yield as a syrup; $[\alpha]_D$ +50.8° (c 1.0, $CHCl_3$); ^1H NMR (200 MHz, $CDCl_3$): δ 7.8-7.0 (m, 34H, aromatic), 5.0-3.25 (m, 26H, H-1-6, 1'-6', $OC\underline{H}_2$Phx6), 3.31 (s, 3H, OCH_3), 2.41 (s, 3H, $-SO_2C_6H_4-C\underline{H}_3$); ^{13}C NMR (50 MHz, $CDCl_3$): δ 139-126 (aromatic), 98.5, 97.5 (2d, C-1,1'), 80.5, 78.4, 76.4, 76.2, 76.0, 75.8, 75.4, 75.1, 74.0, 73.8, 73.0, 69.8, 69.5, 69.0, 68.5, 68.1, 54.9 (8d, 8t, 1q, C-2-6, 2'-6', $OC\underline{H}_2$Phx6, $O\underline{C}H_3$); Anal. Calcd. for $C_{62}H_{66}O_{13}S$: C, 70.89; H, 6.34. Found: C, 70.81; H, 6.31%.

Methyl 3,4-di-O-benzyl-6-deoxy-2-O-(2',3',4',6'-tetra-O-benzyl-α-D-galactopyranosyl)-α-D-*xylo*-hex-5-enopyranoside (16).- A mixture of compound **15** (0.9 g, 0.86 mmol), Bu_4NI (0.158 g, 0.42 mmol), sodium iodide (0.21 g, 4.2 mmol), and powdered molecular sieves (4A, 250 mg) in dry dimethylsulfoxide (DMSO) (10 ml) was heated to 80°C. After 2 h, 1,8-diazabicyclo[5.4.0]-undec-7-ene (DBU) (0.156 gm, 1.0 mmol) was added and the mixture was heated for another 2 h. When t.l.c. indicated completion of the reaction the mixture was filtered on celite, washed with ethyl acetate (5 ml), diluted with water (80 ml), and extracted into ethyl acetate (50 ml). The extract was washed with water, dried (Na_2SO_4), concentrated to obtain the title compound **16** (0.65 g) in 86% yield as a syrup; $[\alpha]_D$ +43.4° (c 1.0, $CHCl_3$); ^1H NMR (200 MHz, $CDCl_3$): δ 7.4-7.2 (m, 30H, aromatic), 5.0-3.3 (m, 25H, H-1-6,6, 1'-6', $OC\underline{H}_2$Phx6), 3.43 (s, 3H, $O\underline{C}H_3$); ^{13}C NMR (50 MHz, $CDCl_3$): δ 153.5 (s, C-5), 138.7-126.6 (aromatic), 98.2, 97.6, 94.9 (2d, 1t, C-1,1',C-6), 80.6, 78.6, 76.9, 76.3, 75.8, 75.4, 75.2, 75.1, 74.9, 74.6, 73.8, 73.7, 73.5, 72.9, 56.2 (1q, 7t, 7d, C-2-4, 2'-6', $O\underline{C}H_2$Phx6, $O\underline{C}H_3$); Anal. Calcd. for $C_{55}H_{58}O_{10}$: C, 75.14; H, 6.65. Found: C, 75.09; H, 6.61%.

(2S,3R,4S,5S/5R)-2,3-Dibenzyloxy-5-hydroxy-4-(2',3',4',6'-tetra-O-benzyl- α-D-galactopyranosyloxy)cyclohexanone (18 and 17).- A catalytic amount of mercury(II) trifluoroacetate (10 mg was added to a solution of the enol ether **16** (0.6 g, 0.68 mmol) in acetone-water (12 ml; 2:1) and the mixture was left at room temperature overnight (14 h). It was then concentrated to 4 ml, diluted with water (20 ml) and extracted into ethyl acetate (20 ml). The extract was washed successively with aq. KI (10%), aq. 'hypo' (sodium thiosulfate) (20%) and saturated aq. $NaHCO_3$. The organic phase was dried (Na_2SO_4), and concentrated to obtain a residue which was chromatographed [(SiO_2, 200 mesh, hexane-ethyl acetate (2:1)]. Eluted first was **18** (β-isomer) (0.155 g, in 26% yield as a crystalline solid m.p. 148°C.

Second eluted was **17** (α -isomer) (0.310 g) in 52% yield as a crystalline solid m.p. 150-152°C; $[\alpha]_D$ +35.3°(c 1.0, $CHCl_3$); IR ($CHCl_3$): 1720 cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$): δ 7.5-7.1 (m, 30H, aromatic), 5.0-3.25 (m, 23H, H-2-5, 1'-6', $OC\underline{H}_2$Phx6), 2.75 (dd, 1H, $J_{6,6gem}$

= 13.9 Hz, $J_{5,6e}$ = 5.71 Hz, H-6e), 2.45 (dd, 1H, $J_{5,6a}$ = 3.73 Hz, H-6a); ^{13}C NMR (50 MHz, $CDCl_3$): δ 204.4 (s, CO), 138.5-126.7 (aromatic), 96.8 (d, C-1'), 84.4, 80.1, 79.1, 78.6, 75.8, 75.1, 74.9, 74.5x2, 73.1, 72.5, 69.7, 68.8, 68.3, 42.3 (8t, 8d, C-2-6, C-2'-6', OCH_2Phx6); Anal. Calcd. for $C_{54}H_{56}O_{10}$: C, 74.97; H, 6.52. Found: C, 74.93; H, 6.49%; **18** $[\alpha]_D$ +19.5° (c 1.0, $CHCl_3$); IR ($CHCl_3$): 1720 cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$): δ 7.5-7.1 (m, 30H, aroamtic), 5.15 (d, 1H, $J_{1',2'}$ = 4.2 Hz, H-1'), 5.0-3.15 (m, 22H, H-2-5,2'-6', OCH_2Phx6), 2.82 (dd, 1H, $J_{6,6gem}$ = 13.0 Hz, $J_{5,6e}$ = 4.99 Hz, H-6e), 2.55 (dd, 1H, $J_{5,6a}$ = 10.5 Hz, H-6a); Anal. Calcd. for $C_{54}H_{56}O_{10}$: C, 74.97; H, 6.52. Found: C, 74.93; H, 6.49%.

(3S,4S,5R,6R)-4-O-(2',3',4',6'-tetra-O-benzyl-α-D-galactopyranosyl)-5,6-di(benzyloxy)-7-heptanolide (19).- Compound **17** (0.3 g, 0.35 mmol) was dissolved in CH_2Cl_2 (3 ml) and treated with metachloroperoxybenzoic acid (mCPBA, 70%) (0.089 g, 0.52 mmol) at room temperature for 18 h. The reaction was monitered by t.l.c. disappearence of starting material and appearence of slower moving spot on t.l.c. indicated completion of the reaction. The reaction mixture was diluted with CH_2Cl_2 (20 ml) washed with saturated $NaHCO_3$. Organic layer was dried (Na_2SO_4) concentrated in vacuo to obtain the title compound **19** (0.264 g in 87% yield) as a syrup. $[\alpha]_D$ +24.5° (c 1.0, $CHCl_3$). IR ($CHCl_3$): 1750 cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$): δ7.4-7.1 (m, 30H, aromatic), 5.17 (d, 1H, $J_{5,6}$ = 6.58 Hz, H-6), 4.9-3.0 (m, 23H, H-2e, 3-5, H-1'-6', OCH_2Phx6), 2.78 (dd, 1H, $J_{2,2}$ = 13.6 Hz, $J_{2a,3}$ = 4.25 Hz, H-2a); ^{13}C NMR (50 MHz, $CDCl_3$): δ 169.7 (s, COO), 138.4-126.7 (aromatic), 102.1, 101.1 (2d, C-6,1'), 82.7, 79.7, 76.4, 75.8, 74.5, 74.4, 74.3, 73.9, 73.8x2, 72.6, 72.3, 70.2, 69.8, 65.0, 40.5 (8t, 7d, C-2-5, C-2'-6', OCH_2Phx6); Anal. Calcd. for $C_{54}H_{56}O_{11}$: C, 73.6; H, 6.40. Found: C, 73.55; H, 6.37%.

Benzyl 2-O-benzyl-5-deoxy-3-O-(2',3',4',6'-tetra-O-benzyl-α-D-galactopyranosyl)-β-L-arabino-hexofuranosiduronic acid (20).- Compound **19** (0.25 g, 0.29 mmol) was dissolved in CH_2Cl_2 (2 ml) and treated with catalytic amount of anhydrous p-toluene sulfonic acid (pTSA) (2 mg) for 5 min at room temperature. Reaction was monitered by t.l.c. after completion solid $NaHCO_3$ was added and stirred for 5 min, then the reaction mixture was filtered on celite, filtrate was concentrated in vacuo to obtain the crude product, which was chromatographed [SiO_2, 60-120 mesh, hexane-ethyl acetate (4:1)] to obtain **20** (0.2 g in 82% yield) as a syrup; $[\alpha]_D$ +6.5° (c 1.0, $CHCl_3$); IR ($CHCl_3$): 1710 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ 7.3-7.15 (m, 30H, aroamtic), 5.03 (s, 1H, H-1), 4.9-3.8 (m, 23H, H-2-4, 1'-5', OCH_2Phx6), 3.55-3.38 (m, 2H, H-6'a,6'b), 2.8-2.65 (m, 2H, H-5a,5b), (COOH not observed); ^{13}C NMR (50 MHz, $CDCl_3$): δ173.5 (s, COOH), 138.5-127.4 (aromatic), 105.3 (d, C-1), 99.3 (d, C-1'), 87.7, 87.2, 78.8, 77.9, 77.8, 77.7, 74.7, 73.4, 73.2, 72.9, 72.1, 69.8, 69.0, 68.7, 37.9 (8t, 7d, C-2-5, 2'-6', OCH_2Phx6); Anal. Calcd. for $C_{54}H_{56}O_{11}$: C, 73.6; H, 6.40. Found: C, 73.53; H, 6.33%.

(3R,4S,5R,6R)-4-O-(2',3',4',6'-tetra-O-benzyl-α-D-galactopyranosyl)-5,6-di-(benzyloxy)-7-heptanolide (21).- (As in procedure described for **19**). Compound **18** (0.1 g, 0.12 mmol), mCPBA (0.03 g, 0.17 mmol), CH_2Cl_2 (1 ml) were reacted for 12 h at room temperature to give **21** (0.090 g) in 89% yield as a syrup. $[\alpha]_D$ +16.2° (c 1.0, $CHCl_3$); ^1H NMR (200 MHz, $CDCl_3$): δ 7.4-7.1 (m, 30H, aromatic), 5.18 (d, 1H, $J_{5,6}$ = 6.8 Hz, H-6), 5.0-3.2 (m, 22H, H-3-5,1'-6', OCH_2Phx6), 2.98 (dd, 1H, $J_{2,2}$ = 13.6 Hz, $J_{2e,3}$ = 3.18 Hz, H-2e), 2.72 (dd, 1H, $J_{2a,3}$ = 9.4 Hz, H-2a); Anal. Calcd. for $C_{54}H_{56}O_{11}$: C, 73.6; H, 6.40. Found: C, 73.52; H, 6.33%.

Benzyl 2-O-benzyl-5-deoxy-3-O-(2',3',4',6'-tetra-O-benzyl-α-D-galactopyranosyl)-β-D-xylo-hexofuranosiduronic acid (22).- (As in procedure described for **20**). Compound **21** (0.080 g, 0.9 mmol) p-TSA (2 mg), CH_2Cl_2 (1 ml) were reacted at room temeprature for 5 min. Column chromatography of the residue [SiO_2, 60-120 mesh, hexane-ethyl acetate (5:1)] gave **22** (0.064 g) in 80% yield as a syrup. $[\alpha]_D$ +28.4° (c 1.0, $CHCl_3$); IR ($CHCl_3$): 1702 cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$): δ 7.3-7.15 (m, 30H, aromatic), 5.06 (s, 1H, H-1), 4.98 (d, 1H, $J_{1',2'}$ = 4.4 Hz, H-1'), 4.9-3.8 (m, 22H, H-2-4, H-2'-5', OCH_2Phx6), 3.75-3.65 (m, 2H, H-6'a,6'b), 2.88 (dd, 1H, $J_{4,5b}$ = 8.4 Hz, H-5b), 2.74 (dd, 1H, $J_{5a,5b}$ = 13.6 Hz, $J_{4,5a}$ = 5.4 Hz, H-5a), (COOH not observed); ^{13}C NMR (50 MHz, $CDCl_3$): δ 171.2 (s, COOH), 138.0-127.1 (aromatic), 105.6 (d, C-1), 99.4 (d, C-1'), 87.7, 87.3, 78.6, 78.2, 77.9, 77.6, 74.9, 74.0, 73.3, 72.8, 72.3, 69.7, 69.0, 68.7, 37.6 (8t, 7d, C-2-5,2'-6', OCH_2Phx6); Anal. Calcd. for $C_{54}H_{56}O_{11}$: C, 73.6; H, 6.40. Found: C, 73.52; H, 6.37%.

Methyl 3-O-(2',3',4',6'-tetra-O-benzyl-α-D-galactopyranosyl)-α-D-glucopyranoside (23).- (As in procedure described for **11**). Compound **7** (3.8 g, 4.7 mmol) in acetone/water (35 ml, 10:1), p-TSA (100 mg) was stirred for 8 h at room temperature. Column chromatography of the residue [SiO_2, 60-120 mesh, hexane-ethyl acetate (3:1)] gave **23** (3.2 g) in 95% yield as a syrup. $[\alpha]_D$ +70.6° (c 1.0, $CHCl_3$); ^1H NMR (200 MHz, $CDCl_3$): δ 7.4-7.1 (m 20H, aromatic), 5.0-3.2 (m, 22H, H-1-6,1'-6', OCH_2Phx4), 3.44 (s, 3H, OCH_3), 2.7-2.4 (brs, 3H, OHx3); ^{13}C NMR (50 MHz, $CDCl_3$): δ 138.3-127.6 (aromatic), 99.8, 99.7 (2d, C-1,1'), 79.5, 76.3, 74.7, 74.5, 74.3, 73.5, 72.8, 70.6x3, 70.2, 69.5, 62.5, 55.1 (1q, 6t, 8d, C-2-6,2'-6', OCH_2Phx4, OCH_3); Anal. Calcd. for $C_{41}H_{48}O_{11}$: C, 68.69; H, 6.75. Found: C, 68.59; H, 6.69%.

Methyl 6-O-tert.butyldimethylsilyl-3-O-(2',3',4',6'-tetra-O-benzyl-α-D-galactopyranosyl)-α-D-glucopyranoside (24).- (As in procedure described for **12**). **24** (3.0 g, 4.18 mmol), TBDMSCl (0.69 g, 4.6 mmol), pyridine (6 ml) DMAP (5 mg) were reacted for 2 h at RT to obtain **24** (3.3 g) in 96% yield as a syrup. $[\alpha]_D$ +62.8° (c 1.0, $CHCl_3$); ^1H NMR (200 MHz, $CDCl_3$): δ 7.4-7.1 (m, 20H, aromatic), 5.05-3.2 (m, 22H, H-1-6, 1'-6', OCH_2Phx4), 3.39 (s, 3H, OCH_3), 2.55 (br.s, 2H, OHx2), 1.93 (s, 9H, $(CH_3)_3CSi$), 0.06 (s, 6H, $(CH_3)_2Si$); Anal. Calcd. for $C_{47}H_{62}O_{11}Si$: C, 67.92; H, 7.52. Found: C, 67.89; H, 7.49%.

Methyl 2,4-di-O-benzyl-6-O-tert.butyldimethylsilyl-3-O-(2',3',4',6'-tetra-O-benzyl-α-D-galactopyranosyl)-α-D-glucopyranoside (25).- (As in procedure described for **13**). **24** (3.0 g, 3.6 mmol), NaH (60%) (0.43 g, 10.8 mmol), DMF (15 ml) and benzylbromide (1.1 ml, 9.0 mmol) were reacted for 30 min at room temperature. Column chromatography of the residue [SiO_2, 60-120 mesh, hexane-ethyl acetate (10:1)] gave **25** (3.5 g) in 97% yield as a syrup. $[\alpha]_D$ +51.8° (c 1.0, $CHCl_3$); ^1H NMR (200 MHz, $CDCl_3$): δ 7.5-7.0 (m, 30H, aromatic), 5.55 (d, 1H, $J_{1',2'}$ = 3.2 Hz, H-1'), 5.0-3.2 (m, 25H, H-1-6,2'-6', OCH_2Phx6), 3.25 (s, 3H, OCH_3), 0.91 (s, 9H, $(CH_3)_3CSi$), 0.06 (s, 6H, $(CH_3)_2Si$); Anal. Calcd. for $C_{61}H_{74}O_{11}Si$: C, 72.44; H, 7.37. Found: C, 72.37; H, 7.28%.

Methyl 2,4-di-O-benzyl 3-O-(2',3',4',6'-tetra-O-benzyl-α-D-galactopyranosyl)-α-D-glucopyranoside (26).- (As in procedure described for **14**). Compound **25** (3.2 g, 3.16 mmol), Bu_4NF (3.16 ml, 1 molar solution in THF), THF (20 ml) were reacted for 1.5 h at room temperature. Column chromatography of the residue [SiO_2, 60-120 mesh, hexane-ethyl acetate (2:1)] gave **26** (2.7

g) in 95% yield as a syrup. $[\alpha]_D$ +60.2° (c 1.0, $CHCl_3$); ^1H NMR (200 MHz, $CDCl_3$): δ 7.5-7.0 (m, 30H, aromatic), 5.52 (d, 1H, $J_{1',2'}$ = 3.35 Hz, H-1'), 5.0-3.3 (m, 25H, H-2'-6',1-6, OCH_2-Phx6), 3.25 (s, 3H, OCH_3), 1.5 (br.s, 1H, OH); Anal. Calcd. for $C_{55}H_{60}O_{11}$: C, 73.63; H, 6.74. Found: C, 73.59; H, 6.69%.

Methyl 2,4-di-O-benzyl-3-O-(2',3',4',6'-tetra-O-benzyl- α-D-galactopyranosyl)-6-O-(p-tolylsulfonyl)-α-D-glucopyranoside (27).- (As in procedure described for **15**). Compound **26** (2.6 g, 2.9 mmol), p-TSCl (0.66 g, 3.4 mmol), pyridine (10 ml) DMAP (20 mg) were reacted for 12 h at room temperature. Column chromatography of the residue [SiO_2, 60-120 mesh, hexane-ethyl acetate (4:1)] gave **27** (2.9 g) in 97% yield as a syrup. $[\alpha]_D$ 43.6° (c 1.0, $CHCl_3$); ^1H NMR (200 MHz, $CDCl_3$): δ 7.8-6.8 (m, 34H, aromatic), 5.48 (d, 1H, $J_{1',2'}$ = 3.3 Hz, H-1'), 5.0-3.3 (m, 25H, H-1-6,2'-6', OCH_2Phx6), 3.15 (s, 3H, OCH_3), 2.42 (s, 3H, $-SO_2C_6H_4CH_3$); Anal. Calcd. for $C_{62}H_{66}O_{13}S$: C, 70.89; H, 6.34. Found: C, 70.75; H, 6.29%.

Methyl 2,4-di-O-benzyl-6-deoxy-3-O-(2',3',4',6'-tetra-O-benzyl-α-D-galactopyranosyl)-α-D-xylo-hex-5-enopyranoside (28).- (As in procedure described for **16**). Compound **27** (2.5 g, 2.38 mmol), NaI (0.6 g, 11.9 mmol), Bu_4NI (0.43 g, 1.19 mmol), molecular sieves (4A, 0.5 g) DMSO (20 ml), DBU (0.434, 2.85 mmol) were reacted for 4 h at 80°C. Column chromatography of the residue [SiO_2, 60-120 mesh, hexane-ethyl acetate (6:1)] gave **28** (1.7 g) in 81% yield as a syrup. $[\alpha]_D$ +55.6° (c 1.0, $CHCl_3$); ^1H NMR (200 MHz, $CDCl_3$): δ 7.5-7.0 (m, 30H, aromatic), 5.52 (d, 1H, $J_{1',2'}$ = 3.4 Hz, H-1'), 5.23 (d, 1H, $J_{1,2}$ = 4.1 Hz, H-1), 5.1-3.25 (m, 23H, H-2-4, 6, 2'-6', OCH_2Phx6), 3.22 (s, 3H, OCH_3); ^{13}C NMR (50 MHz, $CDCl_3$): δ 153.2 (s, C-5), 139.0-126.8 (aromatic), 98.8 (t, C-6), 97.5, 97.0 (2d, C-1,1'), 80.9, 79.2, 78.7, 78.2, 75.4, 75.1, 74.0, 73.3x2, 73.1, 72.9, 72.8, 68.9, 68.7, 55.4 (1q, 7t, 7d, C-2-4, 2'-6', OCH_2Phx6, OCH_3); Anal. Calcd. for $C_{55}H_{58}O_{10}$: C, 75.14; H, 6.65. Found: C, 75.02; H, 6.57%.

(2S,3R,4S,5S/5R)2,4-Dibenzyloxy-5-hydroxy-3-(2',3',4',6'-tetra-O-benzyl- α-D-galactopyranosyloxy)-cyclohexanones (30 and 29).- (As in procedure described for **18** and **17**). Compound **28** (1.6 g, 1.85 mmol), Hg $(CF_3COO)_2$ (10 mg), acetone/water (30 ml) (2:1) were reacted for 12 h at room temperature. Column chromatography of the residue [SiO_2, 200 mesh, hexane-ethyl acetate (3:1)] gave first **30** (β-isomer) (0.296 g) in 19% yield as a crystalline solid, m.p. 127°C. $[\alpha]_D$ +5.8° (c 1.0, $CHCl_3$), followed by **29** (α-isomer) (0.96 g) in 61% yield as a crystalline solid, m.p. 134°C, $[\alpha]_D$ 12.4° (c 1.0, $CHCl_3$); ^1H NMR (200 MHz, $CDCl_3$): δ 7.5-7.0 (m, 30H, aromatic), 5.57 (d, 1H, $J_{1',2'}$ = 4.1 Hz, H-1'), 4.9-3.2 (m, 22H, H-2-5,2'-6', OCH_2-Phx6), 2.62 (dd, 1H, $J_{6,6gem}$ = 13.2 Hz, $J_{5,6e}$ = 4.2 Hz, H-6e), 2.35 (dd, 1H, $J_{5,6a}$ = 3.6 Hz, H-6a), 1.82 (br.s, 1H, OH); ^{13}C NMR (50 MHz, $CDCl_3$): δ 203.4 (s, CO), 138-126.4 (aromatic), 96.8 (d, C-1'), 86.1, 80.7, 78.6, 75.7, 74.9, 74.6, 74.5, 74.3, 73.1, 72.5x2, 72.4, 69.1x2, 65.6, 42.5 (8t, 8d, C-2-6, 2'-6', OCH_2Phx6); Anal. Calcd. for $C_{54}H_{56}O_{10}$: C, 74.97; H, 6.52. Found: C, 74.82; H, 6.43%; **30**: ^1H NMR (200 MHz, $CDCl_3$): δ 7.4-7.0 (m, 30H, aromatic), 5.44 (d, 1H, $J_{1',2'}$ = 3.9 Hz, H-1'), 4.9-3.2 (m, 22H, H-2-5, 2'-6', OCH_2Phx6), 2.63 (dd, 1H, $J_{6,6}$ = 13.3 Hz, $J_{5,6e}$ = 5.6 Hz, H-6e), 2.39 (dd, 1H, $J_{5,6a}$ = 8.2 Hz, H-6a), 2.0 (br.s, 1H, OH); ^{13}C NMR (50 MHz, $CDCl_3$): δ 203.6 (s, CO), 138.5-127.4 (aromatic), 96.8 (d, C-1'), 85.4, 82.3, 79.0, 78.3, 75.9, 74.9, 74.6, 74.4, 73.2, 72.8, 72.0, 70.4, 69.9, 69.4, 68.4, 29.6 (8t, 8d, C-2-6, 2'-6', OCH_2Phx6); Anal. Calcd. for $C_{54}H_{56}O_{10}$: C, 74.97; H, 6.52. Found: C, 74.91; H, 6.46%.

(3S,4S,5R,6R)-5-O-(2',3',4',6'-tetra-O-benzyl- α -D-galactopyranosyl)-4,6-di(benzyloxy)-7-heptanolide (31).- (As in procedure described for **19**). Compound **29** (0.4 g, 0.45 mmol), mCPBA (70%) (0.12 g, 0.68 mmol), CH_2Cl_2 (5 ml) were reacted for 16 h at room temperature to obtain **31** (0.29 g) in 71% yield as a syrup. ^1H NMR (200 MHz, $CDCl_3$): δ 7.5-7.1 (m, 30H, aromatic), 5.4-5.2 (m, 2H, H-6,1'), 5.1-3.3 (m, 21H, H-3-5, 2'-6', OCH_2Phx6), 3.13 (dd, 1H, $J_{2,2}$ = 14.2 Hz, $J_{2e,3}$ = 7.5 Hz, H-2e), 2.85 (dd, 1H, $J_{2a,3}$ = 4.4 Hz, H-2a), 1.7 (br.s, 1H, OH); Anal. Calcd. for $C_{54}H_{56}O_{10}$: C, 73.6; H, 6.40. Found: C, 73.51; H, 6.31%.

Benzyl 3-O-benzyl-5-deoxy-2-O-(2',3',4',6'-tetra-O-benzyl-α-D-galactopyranosyl)-β-L-arabino-hexofuranosiduronic acid (32).- (As in procedure described for **20**). Compound **31** (0.28 g, 0.32 mmol), p-TSA (3 mg), CH_2Cl_2 (3 ml) were reacted for 10 min at room temperature. Column chromatography of the residue [SiO_2, 60-120 mesh, hexane-ethyl acetate (5:1)] gave **32** (0.2 g) in 72% yield as a syrup. $[\alpha]_D$ +7.6° (c 1.0, $CHCl_3$); IR ($CHCl_3$): 1705 cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$): δ7.4-7.0 (m, 30H, aromatic), 5.07 (s, 1H, H-1), 5.0-3.3 (m, 22H, H-2-4, 1'-6', OCH_2Phx6), 2.35-2.2 (m, 2H, H-5a,5b), (COOH was not observed); Anal. Calcd. for $C_{54}H_{56}O_{11}$: C, 73.6; H, 6.40. Found: C, 73.49; H, 6.29%.

Benzyl 3-O-benzyl-5-deoxy-2-O-(2',3',4',6'-tetra-O-benzyl- α-D-galactopyranosyl-β -D-xylo-hexofuranosiduronic acid (34).- Compound **30** (0.2 g, 0.24 mmol) was treated with mCPBA (0.06 g, 0.34 mmol) in CH_2Cl_2 (2 ml) for 14 h at room temperature. Appearence of a slower moving spot on t.l.c. indicated the formation of **33**. Since isolation of **33** was difficult due to its decomposition it was in situ reacted with catalytic amount of PTSA (5 mg) for 5 min at RT, then solid $NaHCO_3$ was added, stirred for 5 min. and filtered on celite. The filtrate was concentrated and purified by column chromatography [SiO_2, 60-120 mesh, hexane-ethyl acetate (6:1)] to obtain **34** (0.142 g) as a syrup in 70% yield. $[\alpha]_D$ +32.2° (c 1.0, $CHCl_3$); IR ($CHCl_3$): 1706 cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$): δ 7.45-7.0 (m, 30H, aromatic), 5.12 (s, 1H, H-1), 5.0-3.8 (m, 23H, H-2-4, H-1'-5', OCH_2Phx6), 3.4-3.65 (m, 2H, H-6'a,6'b), 2.80-2.65 (m, 2H, H-5a,5b); Anal. Calcd. for $C_{54}H_{56}O_{11}$: C, 73.6; H, 6.40. Found: C, 73.47; H, 6.29%.

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