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Synthesis of spacer-containing di- and tri-saccharides that represent parts of the capsular polysaccharide of *Streptococcus pneumoniae* type 6B

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Abstract

In the framework of studies towards oligosaccharide-conjugate-based vaccines against *Streptococcus pneumoniae*, the synthesis is reported of several spacer-containing oligosaccharides that represent parts of the capsular polysaccharide of *S. pneumoniae* serotype 6B, namely α-L-rhamnopyranosyl-(1 → 4)-5-*O*-(3-aminopropyl hydrogen phosphate)-D-ribitol, 3-aminopropyl D-ribitol-(5 → hydrogen phosphate → 2)-α-D-galactopyranoside, 3-aminopropyl α-L-rhamnopyranosyl-(1 → 4)-D-ribityl-(5 → hydrogen phosphate → 2)-α-D-galactopyranoside, and 3-aminopropyl D-ribityl-(5 → hydrogen phosphate → 2)-α-D-galactopyranosyl-(1 → 3)-α-D-glucopyranoside. Phosphorylations were carried out using the H-phosphonate method.

Keywords: Phosphorylated oligosaccharide; Capsular polysaccharide; *Streptococcus pneumoniae* 6B; Vaccines

1. Introduction

Since the discovery of antibiotic-resistant pneumococcal strains [1], polysaccharide-containing vaccines have been considered an adequate answer to bacterial infections with *Streptococcus pneumoniae*. The current polyvalent vaccine Pneumovax® 23 [2], which is constituted of the purified capsular polysaccharides of 23 of the 90 serotypes of *S. pneumoniae* [3] that have the highest incidence in pneumococcal infections in the United States, indeed is an effective protecting agent against these infections in adults in the USA [2]. In many other countries, though, a reformulation of the vaccine may be required [4–7]. To members of high risk groups such as infants under the age of two years, elderly people, and immunocompromised patients, the purified polysaccharides from several serotypes in the vaccine are only low-immunogenic [8] and, thus, do not offer the required protection. These low-immunogenic polysaccharides include the capsules of the serotypes 6A/6B, 14,

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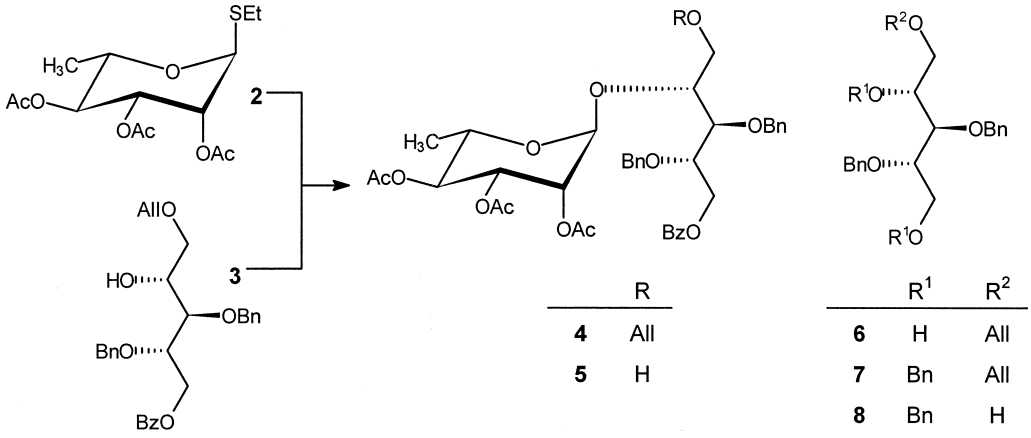
19F, and 23F. The induction of a Thymus-Independent (TI)-response by polysaccharides, which implies the lack of immunological memory development towards these antigens, and the generation of a certain tolerance of the immune system towards the administered polysaccharides [9], also add to the desire for the development of more effective vaccines. Polysaccharide–protein conjugates have proven their value in that they are able to convert the TI-response into a Thymus-Dependent (TD)-response, with the concomitant development of immunological memory [10–17]. However, antibodies produced against this kind of conjugate are often less effective in affording protection [18]. Vaccines consisting of oligosaccharide-conjugates are now being investigated for their ability to overcome these disadvantages [19–22]. The required size of oligosaccharides needed for an adequate immune response can be as small as one disaccharide repeating unit. For *Haemophilus influenzae* type b, di- and tetra-saccharide conjugates (one or two repeating units) were able to bind polysaccharide-specific antibodies if administered in sufficient amounts [23]. A tetrasaccharide repeating unit of the capsular polysaccharide of *S. pneumoniae* type 23F conjugated to KLH was shown to elicit antibodies with no major difference in epitope specificity compared to antibodies elicited against the native polysaccharide [21].

In previous reports, we have presented the synthesis of various oligosaccharide fragments of the capsular polysaccharides of the cross-reactive serotypes 6A and 6B [24–26], which strains are among the most virulent serotypes of *S. pneumoniae*. These compounds, however, could not be used in immunological studies towards oligosaccharide-conjugate vaccines because of the lack of a spacer unit for coupling to a carrier. More recently, we reported on the synthesis of a spacer-containing tetrasaccharide representing a repeating unit of the capsular polysaccharide (**1**) of serotype 6B, namely, α-D-galactopyranosyl-(1 → 3)-α-D-glucopyranosyl-(1 → 3)-α-L-rhamnopyranosyl-(1 → 4)-5-*O*-(3-aminopropyl hydrogen phosphate)-D-ribitol [27]. Here, we describe the preparation of a series of spacer-containing di- and trisaccharides (**38, 43, 47**, and **51**) related to the 6B capsular polysaccharide, all having a phosphate function.

[→ 2)-α-D-Gal*p*-(1 → 3)-α-D-Glc*p*-(1 → 3)-α-L-Rha*p*-(1 → 4)-D-Rib-ol-(5 → phosphate →]	**1**
α-L-Rha*p*-(1 → 4)-D-Rib-ol-(5 → phosphate → $(CH_2)_3NH_2$	**38**
D-Rib-ol-(5 → phosphate → 2)-α-D-Gal*p*-(1 → $O(CH_2)_3NH_2$	**43**
α-L-Rha*p*-(1 → 4)-D-Rib-ol-(5 → phosphate → 2)-α-D-Gal*p*-(1 → $O(CH_2)_3NH_2$	**47**
D-Rib-ol-(5 → phosphate → 2)-α-D-Gal*p*-(1 → 3)-α-D-Glc*p*-(1 → $O(CH_2)_3NH_2$	**51**

2. Results and discussion

In order to produce building blocks that can be used in the preparation of the aimed di- and tri-saccharide products with a 3-aminopropyl spacer, synthetic routes were devised towards suitably protected derivatives of α-L-rhamnopyranosyl-(1 → 4)-D-ribitol (→ **5**), D-ribitol (→ **8**), 3-aminopropyl α-D-galactopyranoside (→ **12**), and 3-aminopropyl α-D-galactopyranosyl-(1 → 3)-α-D-glucopyranoside (→ **33**). Combination of the appropriate fragments by phosphorylation and subsequent deprotection will result in



	R
4	All
5	H

	R^1	R^2
6	H	All
7	Bn	All
8	Bn	H

Scheme 1.

the target compounds **38, 43, 47**, and **51**. The protective group patterns used allow for future expansion of the strategy towards spacer-containing tetrasaccharide derivatives.

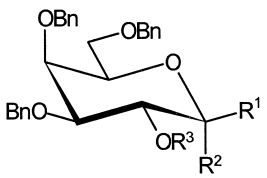
Preparation of building blocks.—The first building block (2,3,4-tri-*O*-acetyl-α-L-rhamnopyranosyl)-(1 → 4)-1-*O*-benzoyl-2,3-di-*O*-benzyl-D-ribitol (**5**) was prepared in two steps by coupling of ethyl 2,3,4-tri-*O*-acetyl-1-thio-α-L-rhamnopyranoside (**2**) [28] and 5-*O*-allyl-1-*O*-benzoyl-2,3-di-*O*-benzyl-D-ribitol (**3**) [27] in 1,2-dichloroethane-diethyl ether using *N*-iodosuccinimide (NIS)–triflic acid (TfOH) [29] (→ **4**, 74%), and subsequent deallylation of the resulting disaccharide (Wilkinson catalyst, then mercuric oxide–mercuric chloride; → **5**, 68%) (Scheme 1).

In order to obtain 1,2,3,4-tetra-*O*-benzyl-D-ribitol (**8**), 5-*O*-allyl-2,3-di-*O*-benzyl-D-ribitol (**6**) [30] was benzylated (→ **7**, 90%) and subsequently deallylated by stirring with potassium *t*-butoxide in DMF at 80 °C followed by cleavage of the resulting 1-propenyl function (→ **8**, 83%).

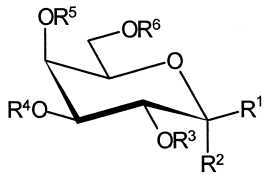
Preparation of the third building unit 3-*N*-benzyloxycarbonylaminopropyl 3,4,6-tri-*O*-benzyl-α-D-galactopyranoside (**12**) started with coupling of ethyl 3,4,6-tri-*O*-benzyl-2-*O*-*p*-methoxybenzyl-1-thio-β-D-galactopyranoside (**10**) [27] with 3-*N*-benzyloxycarbonylaminopropanol (**9**) [31] in dichloromethane–diethyl ether using methyl triflate (MeOTf) as a promoter, giving **11** (62%) (Scheme 2). The α:β ratio was estimated from the ^{13}C NMR spectrum to be 1:1. The use of iodonium dicollidineperchlorate (IDCP) [32] instead of methyl triflate gave a better α:β ratio (3:2) but lowered the yield of **11** (51%). Separation of the α and β anomers was possible only after de-*p*-methoxybenzylation using ammonium cerium(IV) nitrate, to give the desired compound **12** (58%), and **12**β (41%).

In an alternative reaction sequence, ethyl 1-thio-β-D-galactopyranoside (**13**) [33,34] was converted into **14** (71%) using 2,2-dimethoxypropane, affording a galactose moiety with a HO-2 group, that could be allylated (→ **15**, 67%) (Scheme 2). Deisopropylidenation of **15** using aqueous 50% CH_3COOH at 50 °C (→ **16**, 98%), followed by benzylation, yielded **17** (70%). Coupling of **17** with spacer **9** using iodonium dicollidineperchlorate in dichloromethane–diethyl ether gave **18** (73%) in an α:β ratio of 7:5, as shown by ^1H and ^{13}C NMR analysis. However, a methyl triflate-mediated coupling in diethyl ether gave the same products in a comparable α:β ratio of 6:5, but in a higher total yield (99%). Separation of the anomers of **18** was only possible after removal of the protecting group at C-2, so that **12** (38%) and **12**β (32%) were isolated after deallylation of **18** (Wilkinson catalyst, then mercuric oxide–mercuric chloride).

In an attempt to improve the α:β ratio in the preparation of the 3-aminopropyl α-D-galactopyranoside building block, by reduction of the reactivity of the donor molecule, another reaction scheme was



	R^1	R^2	R^3
10	SEt	H	pMBn
11	H,OspZ		pMBn
12	H	OspZ	H



	R^1	R^2	R^3	R^4	R^5	R^6
13	SEt	H	H	H	H	H
14	SEt	H	H	CMe_2		*i*PrOMe
15	SEt	H	All	CMe_2		*i*PrOMe
16	SEt	H	All	H	H	H
17	SEt	H	All	Bn	Bn	Bn
18	H,OspZ		All	Bn	Bn	Bn
19	SEt	H	All	Ac	Ac	Ac
20	H,OspZ		All	Ac	Ac	Ac

pMBn = *p*-methoxybenzyl, spZ = 3-*N*-benzyloxycarbonylaminopropyl, iPr = 2-propyl

Scheme 2.

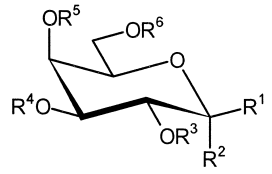
followed. Instead of benzyl, acetyl protective groups were introduced on the proper positions in the molecule.

Thus, **15** was deisopropylidenated using aqueous 50% CH_3COOH at 50 °C (→ **16**), then acetylated to give **19** (82% over 2 steps) (Scheme 2). Coupling of this donor to spacer **9** in dichloromethane-diethyl ether using methyl triflate as a promoter gave **20** (61%), with an $\alpha:\beta$ ratio of 1:2, as indicated by ^1H and ^{13}C NMR analysis. Attempted coupling of **19** to **9** using iodonium dicollidineperchlorate resulted in a complex reaction mixture.

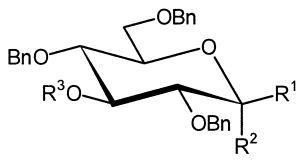
The ease of preparation of **17** and the better coupling results make this donor superior to **10** and **19** in the preparation of the protected Gal-spacer analogues, despite the modest yield of deallylation of **18**.

The preparation of building block 3-*N*-benzyloxycarbonylaminopropyl (3,4,6-tri-*O*-acetyl-α-D-galactopyranosyl)-(1 → 3)-2,4,6-tri-*O*-benzyl-α-D-glucopyranoside (**33**) could be accomplished via a stepwise route, by glycosylating 3-*N*-benzyloxycarbonylaminopropyl 2,4,6-tri-*O*-benzyl-α-D-glucopyranoside (**23**) with a suitable galactosyl donor (Scheme 3). First, **23** was prepared by glycosylation of spacer **9** with ethyl 3-*O*-allyl-2,4,6-tri-*O*-benzyl-1-thio-β-D-glucopyranoside (**21**) [24] in diethyl ether using methyl triflate, to give **22** (52%) and **22**β (30%). A coupling procedure using iodonium dicollidineperchlorate in dichloromethane–diethyl ether gave **22**αβ in a yield of 62% (α:β 3:1). Subsequent removal of the allyl function of **22** (Wilkinson catalyst, then mercuric oxide–mercuric chloride) gave compound **23** (91%).

In order to prepare a suitable galactosyl donor, *p*-methoxyphenyl 2,3,4,6-tetra-*O*-acetyl-β-D-galactopyranoside (**24**) [35] was deacetylated (→ **25**), and then isopropylidenated (→ **26**, 75% over 2 steps). Allylation of **26** with allyl bromide (→ **27**) and subsequent deisopropylidenation in aqueous 50% CH_3COOH at 50 °C gave **28** (97% from **26**), which was acetylated to give **29** (quant.). Removal of the *p*-methoxyphenyl function using ammonium cerium(IV) nitrate proved to be unexpectedly [35–37] difficult, resulting in a modest yield for **30** (47%). Activation of the anomeric centre with trichloroacetonitrile in the presence of potassium carbonate gave

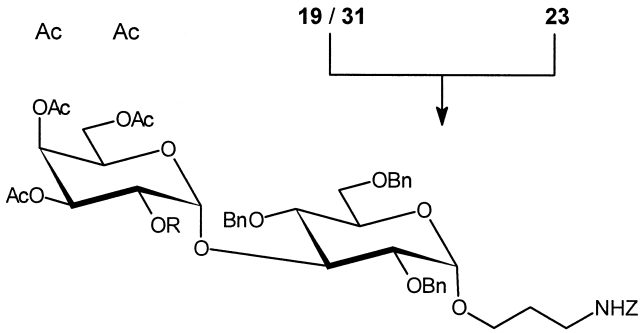


	R^1	R^2	R^3	R^4	R^5	R^6
24	OMP	H	Ac	Ac	Ac	Ac
25	OMP	H	H	H	H	H
26	OMP	H	H	CMe_2		*i*PrOMe
27	OMP	H	All	CMe_2		*i*PrOMe
28	OMP	H	All	H	H	H
29	OMP	H	All	Ac	Ac	Ac
30	H,OH		All	Ac	Ac	Ac
31	$H,OCNHCCl_3$		All	Ac	Ac	Ac



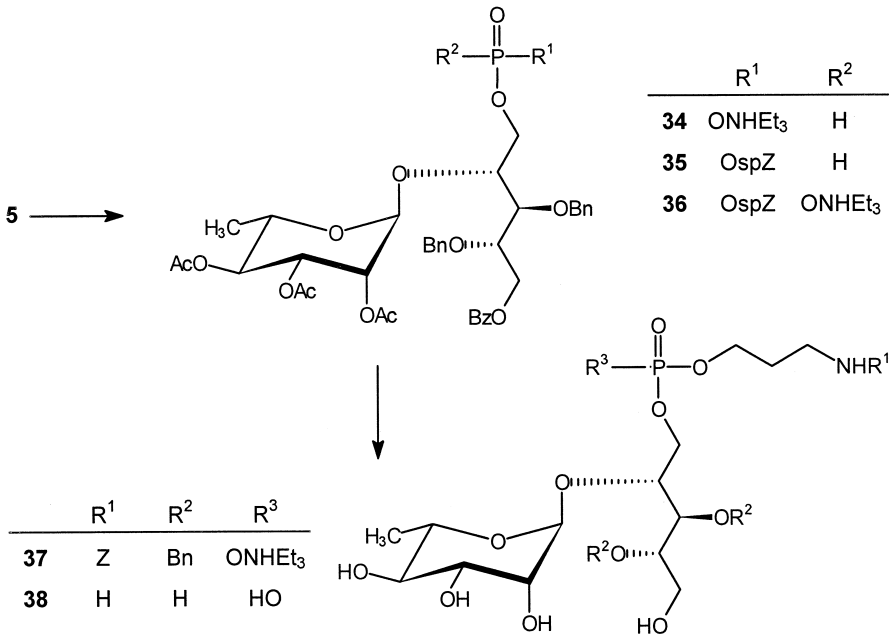
	R^1	R^2	R^3
21	SEt	H	All
22	H	OspZ	All
23	H	OspZ	H

	R
32	All
33	H



MP = *p*-methoxyphenyl, Z = benzyloxycarbonyl

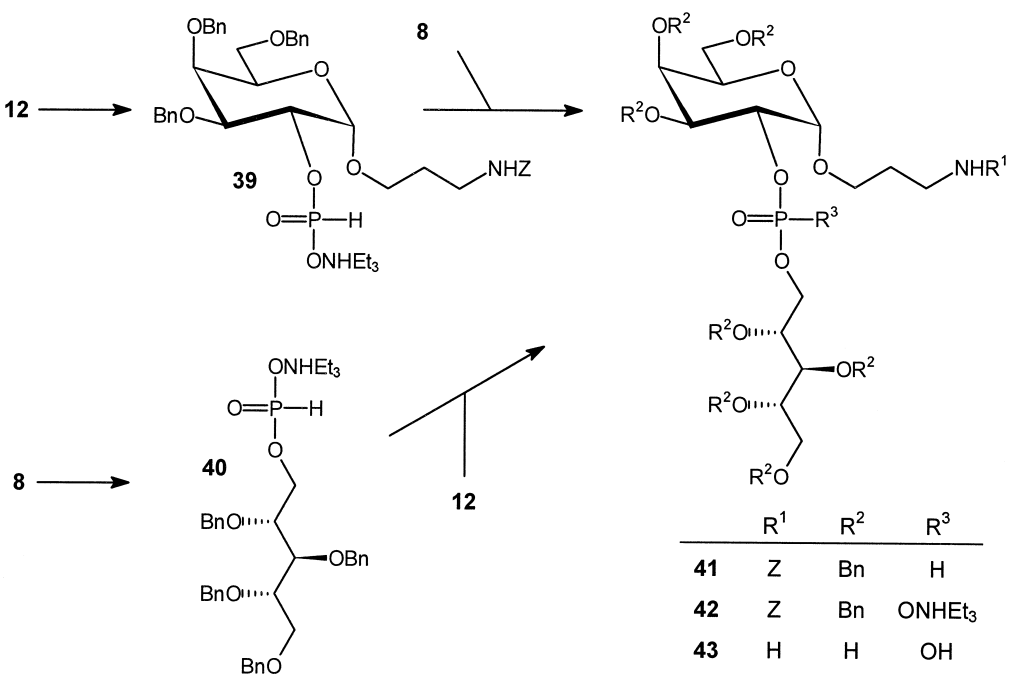
Scheme 3.



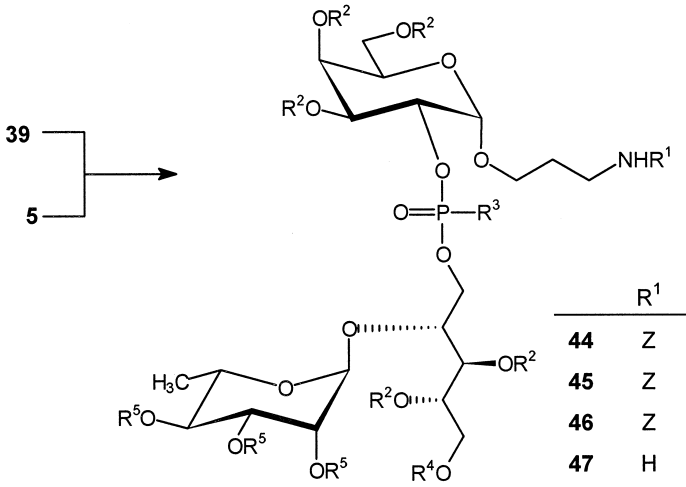
Scheme 4.

imidate **31** as a mixture of anomers (α:β 1:1, 97%). Glycosylation of glucosyl acceptor **23** with imidate donor **31** in diethyl ether using trimethylsilyl triflate as a promoter gave disaccharide derivative **32** (67%), and **32**β (28%). When using thioethyl donor **19** with methyl triflate as a promoter in diethyl ether, **32** was obtained in a yield of only 26% (and **32**β, 27%). Removal of the allyl function at O-2 of the galactose residue (Wilkinson catalyst, then mercuric oxide–mercuric chloride) gave **33** (64%).

Preparation and deprotection of phosphorylated compounds.—The phosphate function was intro-



Scheme 5.

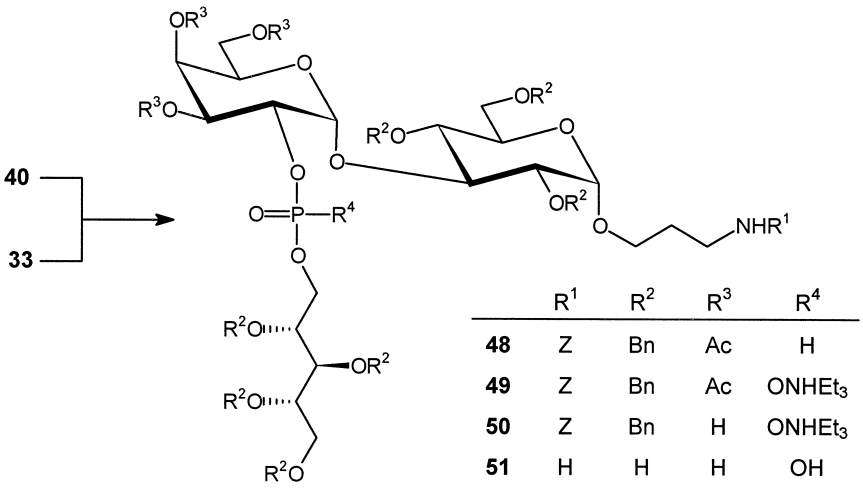


	R^1	R^2	R^3	R^4	R^5
44	Z	Bn	H	Bz	Ac
45	Z	Bn	$ONHEt_3$	Bz	Ac
46	Z	Bn	$ONHEt_3$	H	H
47	H	H	OH	H	H

Scheme 6.

duced in all molecules via the phosphonate method [38–43]. Thus, after preparation of the phosphonate ester of **5** (2-chloro-4*H*-1.3.2-benzodioxaphosphorin-4-one in pyridine–acetonitrile, → **34**, 68%), phosphonylation of spacer **9** in pyridine–acetonitrile with **34** in the presence of pivaloyl chloride [41] (→ **35**), and subsequent mild in situ oxidation of the resulting phosphonate diester using iodine in pyridine–water, gave **36** (43% over 2 steps) (Scheme 4). Deprotection of the resulting phosphate diester by deacylation (methanol–ammonia, → **37**), followed by removal of the benzyl and benzyloxycarbonyl functions (Pd–C, H_2) gave, after desalting on Bio-Gel P-2, target structure **38** in a yield of 74% (from **36**).

For the preparation of disaccharide 3-aminopropyl glycoside **43**, two pathways were followed (Scheme 5). First, **12** was phosphonylated (2-chloro-4*H*-1.3.2-benzodioxaphosphorin-4-one in pyridine–acetonitrile, → **39**, quant) and then coupled with **8** in pyridine–acetonitrile using pivaloyl chloride (→ **41**), followed by mild in situ oxidation using iodine in pyridine–water, giving **42** (38% over 2 steps). Alternatively, compound **8** was phosphonylated (2-chloro-4*H*-1.3.2-benzodioxaphosphorin-4-one in pyridine–acetonitrile, → **40**, quant) and then coupled with **12** in pyridine–acetonitrile using pivaloyl chloride (→ **41**), followed by mild in situ oxidation using iodine in pyridine–water, giving **42** (40% over 2 steps). Re-



	R^1	R^2	R^3	R^4
48	Z	Bn	Ac	H
49	Z	Bn	Ac	$ONHEt_3$
50	Z	Bn	H	$ONHEt_3$
51	H	H	H	OH

Scheme 7.

moval of the benzyl and benzyloxycarbonyl groups (Pd–C, H_2) and desalting on Bio-Gel P-2 gave **43** (77%).

For the preparation of trisaccharide 3-aminopropyl glycoside **47** (Scheme 6), disaccharide derivative **5** was coupled with compound **39** in pyridine–acetonitrile using pivaloyl chloride to give **44**, which was mildly oxidised in situ with iodine in pyridine–water to give **45** (89%). Deacylation (methanol–ammonia, → **46**), followed by removal of the benzyl and benzyloxycarbonyl functions (Pd–C, H_2), and desalting on Bio-Gel P-2, gave **47** (47% over 2 steps).

Finally, for the preparation of trisaccharide 3-aminopropyl glycoside **51**, compound **40** was coupled with disaccharide derivative **33** in pyridine–acetonitrile using pivaloyl chloride (→ **48**), followed by mild in situ oxidation of the resulting phosphonate diester using iodine in pyridine–water, giving **49** (77% over 2 steps) (Scheme 7). Deprotection as described above (methanol–ammonia, → **50**; then Pd–C, H_2) gave, after desalting on Bio-Gel P-2, product **51** (quant. over 2 steps).

Conjugation of the free, spacer-containing saccharides to carrier proteins and the results of immunological tests with the neoglycoconjugates will be published elsewhere.

3. Experimental

General methods.—^{1}H NMR spectra (300 and 500 MHz) were recorded at 25 °C with Bruker AC 300 and Bruker AMX 500 spectrometers. ^{13}C NMR spectra (50 and 75 MHz) were recorded at 25 °C with Bruker WP 200 and Bruker AC 300 spectrometers. ^{31}P NMR spectra (121 MHz) were recorded at 25 °C with a Bruker AC 300 spectrometer. Chemical shifts (δ) are given in ppm, for ^{1}H relative to the signal for internal Me_4Si ($CDCl_3$) or internal sodium 4,4-dimethyl-4-silapentane-1-sulfonate (D_2O; indirectly to internal acetone, δ 2.225), for ^{13}C relative to the signal for internal $CDCl_3$ (δ 76.9), and for ^{31}P relative to the signal for external aq 85% H_3PO_4. Column chromatography was performed on Kieselgel 60 (E. Merck, < 230 mesh or 70–230 mesh) and fractions were monitored by TLC on Kieselgel 60 F_{254} (E. Merck), using detection with UV light and then charring with aq 50% H_2SO_4. Optical rotations were measured at 20 °C for solutions in $CHCl_3$ (unless stated otherwise) with a Perkin–Elmer 241 polarimeter, using a 10-cm 1-mL cell. Melting points (uncorrected) were determined with a Kofler apparatus. Evaporations were conducted under reduced pressure at 40 °C (bath). Reactions were performed under dry conditions using an atmosphere of nitrogen or argon.

(*2,3,4-Tri*-O-*acetyl*-α-L-*rhamnopyranosyl*)-(*1* → *4*)-*5*-O-*allyl*-*1*-O-*benzoyl*-*2,3-di*-O-*benzyl*-D-*ribitol* (**4**).—A mixture of ethyl 2,3,4-tri-*O*-acetyl-1-thio-α-L-rhamnopyranoside (**2**) [28] (1.03 g, 3.08 mmol), 5-*O*-allyl-1-*O*-benzoyl-2,3-di-*O*-benzyl-D-ribitol (**3**) [27] (1.32 g, 2.77 mmol) and 4 Å molecular sieves in 1,2-dichloroethane (8.0 mL) was stirred for 30 min at 0 °C. Then, a mixture of NIS (0.70 g, 3.11 mmol) and TfOH (25 μL, 0.28 mmol) in 1:1 1,2-dichloroethane–Et_2O (25 mL) was added. After 1 min, TLC (9:1 toluene–EtOAc) showed the appearance of a single product (R_f 0.54), and the mixture was neutralised with Et_3N, filtered through Celite, diluted with CH_2Cl_2, washed with aq 10% $Na_2S_2O_3$ (2 ×) and water (3 ×), dried ($MgSO_4$), filtered, and concentrated. Column chromatography (9:1 toluene–EtOAc) of the residue afforded **4**, isolated in 74% as a syrup (1.53 g); $[\alpha]_D$ −25° (*c* 1); ^{1}H NMR ($CDCl_3$): δ 8.05–7.10 (m, 15 H, 3 Ph), 5.834 (m, 1 H, $OCH_2CH=CH_2$), 5.148 (d, 1 H, $J_{1',2'}$ 1.9 Hz, H-1′), 5.045 (t, 1 H, $J_{3',4'} = J_{4',5'} = 9.8$ Hz, H-4′), 2.143, 2.000, and 1.992 (3 s, each 3 H, 3 Ac), 1.001 (d, 3 H, $J_{5',6'}$ 6.2 Hz, 3 H-6′). Anal. Calcd for $C_{41}H_{48}O_{13}$: C, 65.76; H, 6.46. Found: C, 66.02; H, 6.42.

(*2,3,4-Tri*-O-*acetyl*-α-L-*rhamnopyranosyl*)-(*1* → *4*)-*1*-O-*benzoyl*-*2,3-di*-O-*benzyl*-D-*ribitol* (**5**).—To a soln of **4** (1.40 g, 1.86 mmol) and 1,4-diazabicyclo[2.2.2]octane (DABCO; 400 mg, 3.57 mmol) in 8:3:1 EtOH–toluene–water (120 mL) was added tris(triphenylphosphine)rhodium(I) chloride (250 mg). After boiling under reflux for 45 min, TLC (9:1 toluene–EtOAc) showed a complete conversion of the allyl into the 1-propenyl function. The mixture was diluted with CH_2Cl_2, washed with 1 M HCl and water (3 ×), and concentrated. To a soln of the residue in 9:1 acetone–water (50 mL) were added HgO (670 mg, 3.09 mmol) and $HgCl_2$ (780 mg, 2.87 mmol). After stirring the mixture for 30 min, TLC (9:1 toluene–EtOAc) showed the depropenylation to be completed. The mixture was diluted with CH_2Cl_2, filtered, washed with aq 5% KI, aq 10% $NaHCO_3$, and water, dried ($MgSO_4$), filtered, and concentrated. Column chromatography (85:15 toluene–acetone) of the residue afforded **5**, isolated as a syrup (0.89 g, 68%); $[\alpha]_D$ −56° (*c* 1); NMR ($CDCl_3$): ^{1}H, δ 8.02–7.15 (m, 15 H, 3 Ph), 5.052 (t, 1 H, $J_{3',4'} = J_{4',5'} = 9.7$ Hz, H-4′), 4.790, 4.774, 4.701, and 4.664 (4 d, each 1 H, 2 OCH_2Ph), 4.769 (dd, 1 H, $J_{4,5a}$ 2.2,

$J_{5a,5b}$ 12.1 Hz, H-5a), 4.491 (dd, 1 H, $J_{4,5b}$ 5.0 Hz, H-5b), 2.144, 2.006, and 2.000 (3 s, each 3 H, 3 Ac), 1.033 (d, 3 H, $J_{5',6'}$ 6.2 Hz, 3 H-6′); ^{13}C, δ 169.9–169.6 ($COCH_3$ and COPh), 96.2 (C-1′), 78.7, 76.8, 76.6, 70.7, 69.9, 69.1, and 67.0 (C-2,3,4,2′,3′,4′,5′), 73.6 and 72.4 (2 OCH_2Ph), 63.4 and 61.2 (C-1,5), 20.6 and 20.5 (2 C) (3 $COCH_3$), 17.0 (C-6′). Anal. Calcd for $C_{38}H_{44}O_{13} \cdot 1/2H_2O$: C, 63.59; H, 6.32. Found: C, 63.79; H, 6.45.

5-O-*Allyl-1,2,3,4-tetra*-O-*benzyl*-D-*ribitol* (**7**).—A soln of 5-*O*-allyl-2,3-di-*O*-benzyl-D-ribitol (**6**) [30] (2.0 g, 5.4 mmol) and benzyl bromide (1.53 mL, 12.8 mmol) in DMF (25 mL) was added dropwise to a stirred, cooled (0 °C) suspension of NaH (0.38 g, 15.8 mmol) in DMF (10 mL). TLC (8:2 hexane–EtOAc, R_f 0.65) indicated the benzylation to be completed in 1 h. After destroying the excess of NaH with MeOH, the mixture was diluted with EtOAc, washed with water (3 ×), dried ($MgSO_4$), filtered, and concentrated. Column chromatography (8:2 hexane–EtOAc) of the residue gave **7**, isolated in 90% yield as a syrup (2.66 g); $[\alpha]_D$ +3° (*c* 1); ^{1}H NMR ($CDCl_3$): δ 7.32–7.26 (m, 20 H, 4 Ph), 5.881 (m, 1 H, $OCH_2CH{=}CH_2$), 5.27–5.10 (m, 2 H, $OCH_2CH{=}CH_2$), 4.724, 4.707, 4.679, 4.656, 4.624, and 4.594 (6 d, each 1 H, 3 OCH_2Ph), 4.487 (s, 2 H, OCH_2Ph), 3.95–3.93 (m, 2 H, $OCH_2CH{=}CH_2$). Anal. Calcd for $C_{36}H_{40}O_5$: C, 78.23; H, 7.29. Found: C, 78.09; H, 7.21.

1,2,3,4-Tetra-O-benzyl-D-*ribitol* (**8**).—A soln of **7** (2.60 g, 4.70 mmol) in DMF (50 mL) was heated at 80 °C, and KO*t*Bu (620 mg, 5.52 mmol) was added, giving the soln a deep black colour. After 30 min, TLC (25:1 toluene–acetone) indicated the complete conversion of the allyl (R_f 0.69) into the 1-propenyl function (R_f 0.83). The mixture was cooled, diluted with CH_2Cl_2, washed with water (3 ×), and concentrated. The residue was dissolved in 9:1 acetone–0.1 M HCl (40 mL) and the soln was boiled under reflux for 30 min, when TLC (25:1 toluene–acetone) indicated a complete conversion of the 1-propenyl-containing compound into a lower moving spot (R_f 0.23). The mixture was neutralised with aq 25% NH_4OH, concentrated, diluted with CH_2Cl_2, washed with aq 10% $NaHCO_3$ and water, dried ($MgSO_4$), filtered, and concentrated. Column chromatography (25:1 toluene–EtOAc) of the residue afforded **8**, isolated in 83% as a syrup (2.01 g); $[\alpha]_D$ +6° (*c* 1); ^{1}H NMR ($CDCl_3$); δ 7.50–7.15 (m, 20 H, 4 Ph), 4.728, 4.708, 4.662, 4.623, 4.518, and 4.472 (6 d, each 1 H, 3 OCH_2Ph), 4.565 (s, 2 H, OCH_2Ph), 2.27 (bt, 1 H, HO-5).

3-N-*Benzyloxycarbonylaminopropyl 3,4,6-tri*-O-*benzyl-2*-O-p-*methoxybenzyl-α / β*-D-*galactopyranoside* (**11**) *and* 3-N-*benzyloxycarbonylaaminopropyl* 3,4,6-*tri*-O-*benzyl-α*-D-*galactopyranoside* (**12**).—(a) A mixture of ethyl 3,4,6-tri-*O*-benzyl-2-*O*-*p*-methoxybenzyl-1-thio-*β*-D-galactopyranoside (**10**) [27] (155 mg, 0.252 mmol), 3-*N*-benzyloxycarbonylaminopropanol (**9**) [31] (69 mg, 0.33 mmol) and 4 Å molecular sieves in 1:5 CH_2Cl_2–Et_2O (9 mL) was cooled to −40 °C, and stirred for 30 min. Then, MeOTf (70 μL, 0.62 mmol) was added. After 2 h, TLC did not show any reaction, and the temperature was raised to 0 °C. After 12 h, TLC (6:4 hexane–EtOAc) indicated the disappearance of **10** and the appearance of a product with R_f 0.79 (**11**). The mixture was neutralised with Et_3N, diluted with CH_2Cl_2, washed with water (3 ×), dried ($MgSO_4$), filtered, and concentrated. Column chromatography (6:4 hexane–EtOAc) of the residue afforded **11**, isolated as a syrup (119 mg, 62%, $\alpha:\beta$ 1:1). (b) A mixture of **10** (250 mg, 0.407 mmol), **9** (105 mg, 0.502 mmol), and 4 Å molecular sieves in 1:5 1,2-dichloroethane–Et_2O (4.2 mL) was stirred for 30 min. Then, IDCP (0.39 g, 0.83 mmol) was added. After 20 min, TLC (7:3 hexane–EtOAc) indicated the disappearance of **10** and the appearance of a new spot (**11**, R_f 0.32). The mixture was diluted with CH_2Cl_2, filtered through Celite, washed with aq 10% $Na_2S_2O_3$, water, aq 10% $NaHCO_3$, and water, dried ($MgSO_4$), filtered, and concentrated. Column chromatography (9:1 toluene–acetone) of the residue afforded **11**, isolated as a syrup (159 mg, 51%, $\alpha:\beta$ 3:2); ^{13}C NMR ($CDCl_3$): δ 156.4 ($NCOOCH_2$Ph), 103.3 (C-1β), 98.0 (C-1 α), 79.0, 75.8, 75.1, and 69.7 (C-2,3,4,5), 74.4, 73.1, and 72.9 (3 OCH_2Ph), 69.1 and 66.2 (2 C) ($NCOOCH_2$Ph, $OCH_2(CH_2)_2N$, and C-6), 55.0 ($C_6H_4OCH_3$), 39.4 [$O(CH_2)_2CH_2N$], 29.4 ($OCH_2CH_2CH_2N$).

(a) To a soln of **11** (200 mg, 0.262 mmol) in 3:6:1 toluene–acetonitrile–water (6 mL) was added ammonium cerium(IV) nitrate (CAN; 320 mg, 0.584 mmol). After stirring vigorously for 45 min, TLC (8:2 CH_2Cl_2–EtOAc) indicated the conversion of **11** into **12** (R_f 0.24) to be completed. The mixture was diluted with CH_2Cl_2, washed with water, aq 10% $NaHCO_3$, and water, dried ($MgSO_4$), filtered, and concentrated. Column chromatography (75:25 CH_2Cl_2–EtOAc) of the residue afforded **12**β (69 mg, 41%, R_f 0.49) and **12** (98 mg, 58%, R_f 0.39), both isolated as a syrup. (b) To a soln of **18** (213 mg, 0.312 mmol) and DABCO (155 mg, 1.38 mmol) in 8:3:1 EtOH–toluene–water (24 mL) was added

tris(triphenylphosphine)rhodium(I) chloride (70 mg). After boiling under reflux for 18 h, TLC (7:3 hexane–EtOAc) indicated a complete conversion of the allyl into the 1-propenyl function (R_f 0.51). The mixture was diluted with CH_2Cl_2, washed with 0.1 M HCl and water, and concentrated. The residue was dissolved in 9:1 acetone–water (20 mL), and to the soln were added $HgCl_2$ (500 mg, 1.84 mmol) and a catalytic amount of HgO (5.0 mg). After stirring the mixture for 18 h, TLC (75:25 hexane–EtOAc) indicated the depropenylation to be completed. The mixture was diluted with CH_2Cl_2, washed with water, aq 5% KI, water, aq 10% $NaHCO_3$, and water, dried ($MgSO_4$), filtered, and concentrated. Column chromatography (75:25 CH_2Cl_2–EtOAc) of the residue afforded **12**β (64 mg, 32%, R_f 0.49) and **12** (77 mg, 38%, R_f 0.39), both isolated as a syrup; for **12**: $[\alpha]_D$ +19° (c 1); NMR ($CDCl_3$): ^{1}H, δ 7.60–7.10 (m, 20 H, 4 Ph), 5.07 (bs, 2 H, COOCH_2Ph), 4.924 (d, 1 H, $J_{1,2}$ 4.0 Hz, H-1), 4.860, 4.679, 4.628, 4.533, 4.510, and 4.402 (6 d, each 1 H, 3 OCH_2Ph), 4.167 (ddd, 1 H, $J_{2,3}$ 10.0, $J_{H\text{-}2,OH}$ 7.1 Hz, H-2), 3.904 (dd, 1 H, $J_{3,4}$ 2.7, $J_{4,5}$ 2.9 Hz, H-4), 3.679 (dd, 1 H, H-3), 3.25–3.14 (m, 2 H, O$(CH_2)_2$CH_2N), 2.36 (bd, 1 H, HO-2), 1.90–1.74 (m, 2 H, OCH$_2$CH_2CH$_2$N); ^{13}C, δ 156.4 (N*C*OOCH$_2$Ph), 98.6 (C-1), 79.6, 74.0, 70.0, and 68.8 (C-2,3,4,5), 74.3, 73.3, and 72.4 (3 O*C*H$_2$Ph), 69.0, 66.3, and 66.1 (NCOO*C*H$_2$Ph, O*C*H$_2$(CH$_2$)$_2$N, and C-6), 38.6 [O(CH$_2$)$_2$*C*H$_2$N], 29.2 (OCH$_2$*C*H$_2$CH$_2$N). Anal. Calcd for $C_{38}H_{43}NO_8$: C, 71.12; H, 6.75. Found: C, 70.94; H, 6.83.

Ethyl 2-O-*allyl-3,4*-O-*isopropylidene-6*-O-*(2-methoxy-2-propyl)-1-thio-β*-D-*galactopyranoside* (**15**).—To a soln of ethyl 1-thio-β-D-galactopyranoside (**13**) [33,34] (3.79 g, 16.9 mmol) in 2,2-dimethoxypropane (155 mL) was added a catalytic amount of *p*-toluenesulfonic acid (300 mg). TLC (9:1 CH_2Cl_2–acetone) showed the formation of **14** to be complete in 18 h. The mixture was neutralised using Et_3N and concentrated. Column chromatography (91:8:1 CH_2Cl_2–acetone–Et_3N) of the residue afforded **14** as a white foam (4.04 g 71%). A soln of **14** (1.0 g, 3.0 mmol) and allyl bromide (0.31 mL, 3.6 mmol) in DMF (10 mL) was added dropwise to a stirred, cooled (0 °C) suspension of NaH (0.15 g, 6.3 mmol) in DMF (5 mL). TLC (95:5 CH_2Cl_2–acetone, R_f 0.35) showed the allylation to be completed in 30 min. After destroying the excess of NaH with MeOH, the mixture was diluted with EtOAc, washed with water (3×), dried ($MgSO_4$), filtered, and concentrated. Column chromatography (8:2 hexane–EtOAc) of the residue gave **15**, isolated in 67% as a syrup (0.75 g); $[\alpha]_D$ −12° (c 1); ^{1}H NMR ($CDCl_3$): δ 5.954 (m, 1 H, OCH$_2$C*H*=CH$_2$), 5.34–5.17 (m, 2 H, OCH$_2$CH=C*H*$_2$), 4.373 (d, 1 H, $J_{1,2}$ 9.7 Hz, H-1), 4.29–4.24 (m, 2 H, OC*H*$_2$CH=CH$_2$), 4.208 (dd, 1 H, $J_{3,4}$ 5.6, $J_{4,5}$ 2.0 Hz, H-4), 4.136 (dd, 1 H, $J_{2,3}$ 6.5 Hz, H-3), 3.798 (m, 1 H, $J_{5,6a} = J_{5,6b} = 6.2$ Hz, H-5), 3.398 (dd, 1 H, H-2), 3.222 (s, 3 H, C(CH$_3$)$_2$OC*H*$_3$), 2.79–2.63 (m, 2 H, SC*H*$_2$CH$_3$), 1.352 and 1.343 (2 s, each 3 H, C(C*H*$_3$)$_2$OCH$_3$), 1.304 (t, 3 H, SCH$_2$C*H*$_3$). Anal. Calcd for $C_{18}H_{32}O_6S$: C, 57.42; H, 8.57. Found: C, 57.33; H, 8.66.

Ethyl 2-O-*allyl-3,4,6-tri*-O-*benzyl-1-thio-β*-D-*galactopyranoside* (**17**).—A soln of **15** (4.0 g, 11 mmol) in aq 50% HOA$_c$ (250 mL) was stirred for 18 h at 50 °C, when TLC (85:15 CH_2Cl_2–acetone) indicated the deisopropylidenation to be completed. The mixture was concentrated, and co-concentrated with toluene (2×), EtOH (2×), and CH_2Cl_2 (2×), giving **16** as a syrup (2.75 g, 98%). A soln of **16** (2.30 g, 8.70 mmol) and benzyl bromide (3.7 mL, 31 mmol) in DMF (15 mL) was added dropwise to a stirred, cooled (0 °C) suspension of NaH (1.55 g, 64.6 mmol) in DMF (10 mL). TLC (7:3 hexane–EtOAc, R_f 0.37) showed the benzylation to be completed in 4 h. After destroying the excess of NaH with MeOH, the mixture was diluted with CH_2Cl_2, washed with water (3×), dried ($MgSO_4$), filtered, and concentrated. Column chromatography (7:1 hexane–EtOAc) of the residue gave **17**, as a syrup (3.25 g 70%); $[\alpha]_D$ −23° (c 1); ^{1}H NMR ($CDCl_3$): δ 7.40–7.24 (m, 15 H, 3 Ph), 5.986 (m, 1 H, OCH$_2$C*H*=CH$_2$), 5.31–5.13 (m, 2 H, OCH$_2$CH=C*H*$_2$), 4.918, 4.743, 4.697, 4.588, 4.449, and 4.400 (6 d, each 1 H, 3 OC*H*$_2$Ph), 4.361 (d, 1 H, $J_{1,2}$ 9.3 Hz, H-1), 4.38–4.26 (m, 2 H, OC*H*$_2$CH=CH$_2$), 3.920 (d, 1 H, $J_{3,4}$ 2.8, $J_{4,5}$ 0 Hz, H-4), 3.687 (t, 1 H, $J_{2,3}$ 9.3 Hz, H-2), 3.496 (dd, 1 H, H-3), 2.80–2.63 (m, 2 H, SC*H*$_2$CH$_3$), 1.275 (t, 3 H, SCH$_2$C*H*$_3$). Anal. Calcd for $C_{32}H_{38}O_5S$: C, 71.88; H, 7.16. Found: C, 71.79; H. 7.09.

3-N-*Benzyloxycarbonylaminopropyl2*-O-*allyl-3,4,6-tri*-O-*benzyl-α / β*-D-*galactopyranoside* (**18**).—(a) A mixture of **17** (385 mg, 0.720 mmol), **9** (210 mg, 1.00 mmol) and 4 Å molecular sieves in 1:5 CH_2Cl_2–Et_2O (6 mL) was stirred for 30 min, then IDCP (0.67 g, 1.5 mmol) was added. After 90 min, TLC (7:3 hexane–EtOAc) showed the disappearance of **17** and the appearance of a new spot (R_f 0.25). The mixture was diluted with CH_2Cl_2, filtered through Celite, washed with aq 10% $Na_2S_2O_3$, wa-

ter, aq 10% $NaHCO_3$, and water, dried ($MgSO_4$), filtered, and concentrated. Column chromatography (7:3 hexane–EtOAc) of the residue afforded **18**, isolated as a syrup (358 mg, 73%, $\alpha:\beta$ 7:5). (b) A mixture of **17** (960 mg, 1.80 mmol), **9** (620 mg, 2.96 mmol) and 4 Å molecular sieves in Et_2O (50 mL) was cooled to 0 °C, and stirred for 30 min. Then, MeOTf (0.98 mL, 8.7 mmol) was added. After 90 min, TLC (7:3 hexane–EtOAc) showed the disappearance of **17** and the appearance of a single spot (R_f 0.25), and the mixture was neutralised with Et_3N, diluted with CH_2Cl_2, washed with water, aq 10% $NaHCO_3$, and water, dried ($MgSO_4$), filtered, and concentrated. Column chromatography (65:35 hexane–EtOAc) of the residue afforded **18** as a syrup (1.22 g, 99%, $\alpha:\beta$ 6:5); NMR ($CDCl_3$): ^{1}H, δ 7.35–7.24 (m, 20 H, 4 Ph), 5.951 (m, 1 H, $OCH_2CH=CH_2$), 5.30–5.10 (m, 2 H, $OCH_2CH=CH_2$), 5.073 (s, 2 H, $COOCH_2Ph$), 4.906 (d, 1 H, $J_{1,2}$ 3.7 Hz, H-1, **18**α), 4.450 (d, 1 H, $J_{1,2}$ 7.2 Hz, H-1, **18**β), 3.944 (dd, 1 H, $J_{2,3}$ 9.6 Hz, H-2, **18**α), 3.851 (dd, 1 H, $J_{2,3}$ 8.4 Hz, H-2, **18**β), 3.35–3.20 (m, 2 H, $O(CH_2)_2CH_2N$), 1.85–1.70 (m, 2 H, $OCH_2CH_2CH_2N$); ^{13}C, δ 156.4 ($NCOOCH_2Ph$), 135.0 ($OCH_2CH=CH_2$, **18**β), 134.8 ($OCH_2CH=CH_2$, **18**α), 116.8 ($OCH_2CH=CH_2$, **18**α), 116.3 ($OCH_2CH=CH_2$, **18**β), 103.6 (C-1, **18**β), 97.9 (C-1, **18**α), 78.9, 76.1, 75.1, and 79.7 (C-2,3,4,5), 74.4, 73.2, 73.0, 72.2, 69.1, 67.2, and 66.1 (3 OCH_2Ph, $OCH_2CH=CH_2$, $OCH_2(CH_2)_2N$, $NCOOCH_2Ph$, and C-6), 39.2 [$O(CH_2)_2CH_2N$], 28.8 ($OCH_2CH_2CH_2N$).

Ethyl 3,4,6-tri-O-*acetyl-2*-O-*allyl-1-thio-β*-D-*galactopyranoside* (**19**).—A soln of **15** (0.74 g, 2.0 mmol) in aq 50% HOA_c (50 mL) was stirred for 5 h at 50 °C, when TLC (85:15 CH_2Cl_2–acetone) indicated the deisopropylidenation to be completed. The mixture was concentrated and co-concentrated with toluene (2×), EtOH (2×), and CH_2Cl_2 (2×), giving **16**, isolated as a syrup. Compound **16** was dissolved in 2:1 pyridine–Ac_2O (75 mL), and after 18 h, TLC (8:2 hexane–EtOAc) indicated a complete conversion of the starting material into **19** (R_f 0.23). Column chromatography (75:25 hexane–EtOAc) of the residue afforded **19** as a syrup (629 mg, 82%); $[\alpha]_D$ −9° (*c* 1); ^{1}H NMR ($CDCl_3$): δ 5.879 (m, 1 H, $OCH_2CH=CH_2$), 5.400 (dd, 1 H, $J_{3,4}$ 3.4, $J_{4,5}$ 1.1 Hz, H-4), 5.28–5.13. (m, 2 H, $OCH_2CH=CH_2$), 4.965 (dd, 1 H, $J_{2,3}$ 9.7 Hz, H-3), 4.490 (d, 1 H, $J_{1,2}$ 9.7 Hz, H-1), 4.33–4.26 and 4.14–4.07 (2 m, each 1 H, $OCH_2CH=CH_2$), 4.154 (dd, 1 H, $J_{5,6a}$ 6.7, $J_{6a,6b}$ 11.2 Hz, H-6a), 4.077 (dd, 1 H, $J_{5,6b}$ 6.5 Hz, H-6b), 3.870 (m, 1 H, H-5), 3.534 (t, 1 H, H-2), 2.84–2.67 (m, 2 H, SCH_2CH_3), 2.133, 2.033, and 2.022 (3 s, each 3 H, 3 Ac), 1.325 (t, 3 H, SCH_2CH_3). Anal. Calcd for $C_{17}H_{26}O_8S$: C, 52.30; H, 6.71. Found: C, 52.19; H, 6.62.

3-N-*Benzyloxycarbonylaminopropyl 3,4,6-tri*-O-*acetyl-2*-O-*allyl-α / β*-D-*galactopyranoside* (**20**).—A mixture of **19** (103 mg, 0.264 mmol), **9** (66 mg, 0.32 mmol) and 4 Å molecular sieves in 1:19 CH_2Cl_2–Et_2O (2 mL) was cooled (0 °C) and stirred for 30 min. Then, MeOTf (89 μL, 0.79 mmol) was added. After 1 h, TLC (6:4 hexane–EtOAc) showed almost no progression of the reaction, and the temperature was raised to room temperature. After 5 h, TLC (6:4 hexane–EtOAc) indicated the disappearance of **19** and the appearance of a single new spot (**20**, R_f 0.19), and the mixture was neutralised with Et_3N. After dilution with CH_2Cl_2, the soln was washed with aq 10% $NaHCO_3$ (2×) and water, dried ($MgSO_4$), filtered, and concentrated. Column chromatography (6:4 hexane–EtOAc) of the residue afforded **20**, isolated in 61% as a syrup (86 mg, $\alpha:\beta$ 1:2); NMR ($CDCl_3$): ^{1}H, δ 7.36–7.30 (m, 5 H, Ph), 5.826 (m, 1 H, $OCH_2CH=CH_2$), 5.41 (bd, 1 H, $J_{3,4}$ 3.4 Hz, H-4, **20**α), 5.34 (bd, 1 H, $J_{3,4}$ 3.4 Hz, H-4, **20**β), 5.09 (bs, 2 H, $COOCH_2Ph$), 4.902 (d, 1 H, $J_{1,2}$ 3.5 Hz, H-1, **20**α), 4.379 (d, 1 H, $J_{1,2}$ 7.7 Hz, H-1, **20**β), 3.772 (dd, 1 H, $J_{2,3}$ 10.5 Hz, H-2, **20**α), 3.69–3.61 (m, 2 H, $OCH_2(CH_2)_2N$), 3.501 (dd, 1 H, $J_{2,3}$ 10.1 Hz, H-2, **20**β), 2.128, 2.026, and 2.014 (3 s, each 3 H, 3 Ac, **20**β), 2.116, 2.026, and 1.987 (3 s, each 3 H, 3 Ac, **20**α), 1.82–1.78 (m, 2 H, $OCH_2CH_2CH_2N$); ^{13}C, δ 156.4 ($NCOOCH_2Ph$, **20**α), 156.2 ($NCOOCH_2Ph$, **20**β), 134.5 ($OCH_2CH=CH_2$), 117.1 ($OCH_2CH=CH_2$, **20**α), 116.4 ($OCH_2CH=CH_2$, **20**β), 103.4 (C-1, **20**β), 97.7 (C-1, **20**α), 75.9, 72.2, 70.4, and 67.3 (C-2,3,4,5, **20**β), 73.1, 69.6, 68.3, and 66.3 (C-2,3,4,5, **20**α), 61.7 ($OCH_2(CH_2)_2N$, **20**α), 61.3 ($OCH_2(CH_2)_2N$, **20**β), 38.9 ($O(CH_2)_2CH_2N$, **20**β), 38.3 ($O(CH_2)_2CH_2N$, **20**α), 29.5 ($OCH_2CH_2CH_2N$, **20**β), 28.9 ($OCH_2CH_2CH_2N$, **20**α), 20.4 ($COCH_3$).

3-N-*Benzyloxycarbonylaminopropyl 3*-O-*allyl-2,4,6-tri*-O-*benzyl-α*-D-*glucopyranoside* (**22**).—(a) A mixture of ethyl 3-*O*-allyl-2,4,6-tri-*O*-benzyl-1-thio-*β*-D-glucopyranoside (**21**) [23] (1.82 g, 3.40 mmol), **9** (1.10 g, 5.26 mmol) and 4 Å molecular sieves in Et_2O (30 mL) was stirred for 30 min. Then, MeOTf (1.9 mL, 17 mmol) was added. After 2 h, TLC (7:3 hexane–EtOAc) showed the disappearance of **21** and the appearance of a single new spot (**22**, R_f 0.26).

The mixture was neutralised with Et_3N, diluted with CH_2Cl_2, washed with water (3×), dried ($MgSO_4$), filtered, and concentrated. Column chromatography (65:35 hexane–EtOAc) of the residue afforded **22** (1.20 g, 52%) and **22**β (0.71 g, 30%), both isolated as a syrup. (b) A mixture of **21** (151 mg, 0.282 mmol), **9** (47 mg, 0.23 mmol) and 4 Å molecular sieves in 1:5 CH_2Cl_2–Et_2O (2.4 mL) was stirred for 30 min, then IDCP (210 mg, 0.448 mmol) was added. After 24 h, TLC (6:4 hexane–EtOAc) indicated the reaction to be incomplete, therefore, an additional amount of IDCP (105 mg, 0.224 mmol) in 1:5 CH_2Cl_2–Et_2O (2.4 mL) was added. TLC after another 18 h showed the disappearance of **21** and the appearance of a major new spot with R_f 0.54 (**22**). The mixture was diluted with CH_2Cl_2, filtered through Celite, washed with aq 10% $Na_2S_2O_3$ and water (2×), dried ($MgSO_4$), filtered, and concentrated. Column chromatography (65:35 hexane–EtOAc) of the residue afforded **22**$\alpha\beta$, isolated as a syrup (95 mg, 62%, α:β 3:1); for **22**: $[\alpha]_D$ +50° (*c* 1); NMR ($CDCl_3$): ^{1}H, δ 7.35–7.15 (m, 20 H, 4 Ph), 5.906 (m, 1 H, $OCH_2CH{=}CH_2$), 5.27–5.05 (m, 2 H, $OCH_2CH{=}CH_2$), 5.03 (bs, 2 H, $COOCH_2Ph$), 4.801, 4.727, 4.577, 4.556, 4.462, and 4.445 (6 d, each 1 H, 3 OCH_2Ph), 4.651 (d, 1 H, $J_{1,2}$ 3.7 Hz, H-1), 4.37–4.15 (m, 2 H, $OCH_2CH{=}CH_2$), 3.780 (t, 1 H, $J_{2,3} = J_{3,4} = 9.4$ Hz, H-3), 3.491 (dd, 1 H, $J_{4,5}$ 9.0 Hz, H-4), 3.454 (dd, 1 H, H-2), 3.24–3.13 (m, 2 H, $O(CH_2)_2CH_2N$), 1.87–1.68 (m, 2 H, $OCH_2CH_2CH_2N$); ^{13}C, δ 156.4 ($NCOOCH_2Ph$), 135.1 ($OCH_2CH{=}CH_2$), 116.1 ($OCH_2CH{=}CH_2$), 97.3 (C-1), 81.7, 79.4, 77.4, and 70.3 (C-2,3,4,5), 74.8, 74.0, 73.2, and 73.0 (3 OCH_2Ph and $OCH_2CH{=}CH_2$), 68.4, 66.3, and 66.2 (C-6, $OCH_2(CH_2)_2N$, and $NCOOCH_2Ph$), 39.4 [$O(CH_2)_2CH_2N$], 28.9 ($OCH_2CH_2CH_2N$). Anal. Calcd for $C_{41}H_{47}NO_8 \cdot 1/2H_2O$: C, 71.28; H, 7.00. Found: C, 71.82; H, 6.79.

3-N-*Benzyloxycarbonylaminopropyl 2,4,6-tri*-O-*benzyl*-α-D-*glucopyranoside* (**23**).—To a soln of **22** (1.20 g, 1.76 mmol) and DABCO (370 mg, 3.30 mmol) in 8:3:1 EtOH–toluene–water (120 mL) was added tris(triphenylphosphine)rhodium(I) chloride (230 mg). After boiling under reflux for 8 h, the mixture had turned black, and was diluted with CH_2Cl_2, washed with 0.1 M HCl and water (2×), and concentrated. The residue was dissolved in 9:1 acetone–water (120 mL), and to the soln were added $HgCl_2$ (2.8 g, 10 mmol) and a catalytic amount of HgO (19 mg). After stirring the mixture for 18 h, TLC (65:35 hexane–EtOAc) indicated the depropenylation to be completed with the formation of a single spot (**23**, R_f 0.27). The mixture was diluted with CH_2Cl_2, washed with water, aq 5% KI, water aq 10% $NaHCO_3$, and water, dried ($MgSO_4$), filtered, and concentrated. Column chromatography (6:4 hexane–EtOAc) of the residue afforded **23**, isolated as a syrup (1.03 g, 91%); $[\alpha]_D$ +62° (*c* 1); NMR ($CDCl_3$): ^{1}H, δ 7.35–7.18 (m, 20 H, 4 Ph), 5.05 (bs, 2 H, $COOCH_2Ph$), 4.810, 4.675, 4.611, 4.570, 4.507, and 4.475 (6 d, each 1 H, 3 OCH_2Ph), 4.701 (d, 1 H, $J_{1,2}$ 3.6 Hz, H-1), 4.035 (t, 1 H, $J_{2,3} = J_{3,4} = 9.4$ Hz, H-3), 3.478 (dd, 1 H, $J_{4,5}$ 9.0 Hz, H-4), 3.375 (dd, 1 H, H-2), 3.25–3.14 (m, 2 H, $O(CH_2)_2CH_2N$), 1.82–1.71 (m, 2 H, $OCH_2CH_2CH_2N$); ^{13}C, δ 156.4 ($NCOOCH_2Ph$), 96.8 (C-1), 79.5, 77.1, 73.7, and 70.7 (C-2,3,4,5), 74.5, 73.4, and 73.0 (3 OCH_2Ph), 68.6, 66.2, and 66.3 (C-6, $OCH_2(CH_2)_2N$, and $NCOOCH_2Ph$), 39.2 [$O(CH_2)_2CH_2N$], 29.1 ($OCH_2CH_2CH_2N$). Anal. Calcd for $C_{38}H_{43}NO_8 \cdot 1/2H_2O$: C, 70.13; H, 6.81. Found: C, 69.98; H, 6.73.

p-*Methoxyphenyl 2*-O-*allyl*-β-D-*galactopyranoside* (**28**).—To a solution of *p*-methoxyphenyl 2,3,4,6-tetra-*O*-acetyl-β-D-galactopyranoside (**24**) [34] (7.0 g, 15 mmol) in MeOH (150 mL) was added NaOMe (pH 12). After 18 h, TLC (10:2:1 EtOAc–EtOH–water) showed a complete conversion into **25** (R_f 0.47). The mixture was neutralised with Dowex-50 (H^+) resin, filtered, and concentrated. To a solution of the residue in 2,2-dimethoxypropane (180 mL) was added a catalytic amount of *p*-toluenesulfonic acid (270 mg). After 5 h, TLC (9:1 CH_2Cl_2–acetone) showed the appearance of a new spot (**26**, R_f 0.31). The mixture was neutralised with Et_3N and concentrated. Column chromatography (90:9:1 CH_2Cl_2–acetone–Et_3N) of the residue afforded **26**, isolated as a syrup (4.59 g, 75%). A soln of **26** (3.27 g, 8.21 mmol) and allyl bromide (1.10 mL, 12.7 mmol) in DMF (32 mL) was added dropwise to a stirred, cooled (0 °C) suspension of NaH (0.60 g, 25 mmol) in DMF (15 mL). TLC (95:5 CH_2Cl_2–acetone, R_f 0.43) indicated the allylation to be completed in 30 min. After destroying the excess of NaH with MeOH, the mixture was diluted with EtOAc, washed with water (3×), dried ($MgSO_4$), filtered, and concentrated. Column chromatography (95:5 CH_2Cl_2–acetone) of the residue gave **27** as a syrup (3.6 g). Compound **27** was dissolved in aq 50% HOA_c (150 mL) and the soln was stirred for 3 h at 50 °C, when TLC (85:15 CH_2Cl_2–acetone) indicated the deisopropylidenation (→ **28**, R_f 0.03) to be completed. The mixture was concentrated and co-concentrated

with toluene (3×), EtOH (3×) and CH_2Cl_2 (3×). Column chromatography (9:1 CH_2Cl_2–MeOH) of the residue afforded **28**, isolated as a white solid (2.60 g, 97%); $[\alpha]_D$ −14° (*c* 1); ^{1}H NMR ($CDCl_3$): δ 7.01–6.81 (m, 4 H, $C_6H_4OCH_3$), 5.959 (m, 1 H, $OCH_2CH=CH_2$), 5.35–5.19 (m, 2 H, $OCH_2CH=CH_2$), 4.833 (d, 1 H, $J_{1,2}$ 7.6 Hz, H-1), 4.515 and 4.284 (2 m, each 1 H, $OCH_2CH=CH_2$), 3.772 (s, 3 H, $C_6H_4OCH_3$), 3.611 (ddd, 1 H, H-5), 2.95, 2.80, and 2.30 (3 bs, each 1 H, 3 OH). Anal. Calcd for $C_{16}H_{22}O_7 \cdot H_2O$: C, 55.81; H, 7.02. Found: C, 56.04; H, 6.89.

p-*Methoxyphenyl 3,4,6-tri*-O-*acetyl-2*-O-*allyl-β*-D-*galactopyranoside* (**29**).—A soln of **28** (2.60 g, 7.97 mmol) in 2:1 pyridine–Ac_2O (150 mL) was stirred for 18 h, when TLC (95:5 CH_2Cl_2–acetone) indicated the acetylation to be completed (→ **29**, R_f 0.61). The mixture was concentrated and co-concentrated with toluene (3×), EtOH (3×), and CH_2Cl_2 (3×). Column chromatography (95:5 CH_2Cl_2–acetone) of the residue afforded **29**, as a syrup (3.60 g, quant); $[\alpha]_D$ −3° (*c* 1); ^{1}H NMR ($CDCl_3$): δ 7.02–7.00 and 6.85–6.81 (2 m, each 2 H, $C_6H_4OCH_3$), 5.890 (m, 1 H, $OCH_2CH=CH_2$), 5.406 (dd, 1 H, $J_{3,4}$ 3.5, $J_{4,5}$ 1.0 Hz, H-4), 5.30–5.14 (m, 2 H, $OCH_2CH=CH_2$), 5.006 (dd, 1 H, $J_{2,3}$ 10.2 Hz, H-3), 4.866 (d, 1 H, $J_{1,2}$ 7.7 Hz, H-1), 4.45–4.19 (m, 2 H, $OCH_2CH=CH_2$), 4.208 (dd, 1 H, $J_{5,6b}$ 6.8, $J_{6a,6b}$ 11.5 Hz, H-6b), 4.124 (dd, 1 H, $J_{5,6a}$ 6.4 Hz, H-6a), 3.947 (m, 1 H, H-5), 3.784 (dd, 1 H, H-2), 3.781 (s, 3 H, $C_6H_4OCH_3$), 2.163 and 2.045 (2 s, 3,6 H, 3 Ac). Anal. Calcd for $C_{22}H_{28}O_{10}$: C, 58.40; H, 6.24. Found: C, 58.42; H, 6.18.

3,4,6-Tri-O-*acetyl-2*-O-*allyl-α / β*-D-*galactopyranose* (**30**) *and* 3,4,6-*tri*-O-*acetyl*-2-O-*allyl-α / β*-D-*galactopyranosyl trichloroacetimidate* (**31**).—To a soln of **29** (117 mg, 0.259 mmol) in 3:6:1 toluene–acetonitrile–water (4.0 mL) was added CAN (425 mg, 0.775 mmol). After 4 h, TLC (85:15 CH_2Cl_2–acetone) showed the conversion of the starting compound (R_f 0.82) into a minor spot (R_f 0.77) and a major spot (**30**, R_f 0.46). The mixture was diluted with CH_2Cl_2 and washed with water, aq 5% $NaHSO_3$ aq 10% $NaHCO_3$, and water, dried ($MgSO_4$), filtered, and concentrated. Column chromatography (9:1 CH_2Cl_2–acetone) of the residue afforded **30** as a syrup (42 mg, 47%, α:β 2:1); ^{1}H NMR ($CDCl_3$): δ 5.882 (m, 1 H, $OCH_2CH=CH_2$), 5.436 (dd, 1 H, $J_{3,4}$ 3.4, $J_{4,5}$ 1.3 Hz, H-4, **30**α), 5.417 (d, 1 H, $J_{1,2}$ 3.6 Hz, H-1, **30**α), 5.371 (dd, 1 H, $J_{3,4}$ 3.5, $J_{4,5}$ 1.2 Hz, H-4, **30**β), 5.32–5.15 (m, 2 H, $OCH_2CH=CH_2$), 5.273 (dd, 1 H, $J_{2,3}$ 10.3 Hz, H-3, **30**α), 4.952 (dd, 1 H, $J_{2,3}$ 10.2 Hz, H-3, **30**β), 4.762 (d, 1 H, $J_{1,2}$ 7.6 Hz, H-1, **30**β), 4.448 (m, 1 H, $J_{5,6a} = J_{5,6b} = 6.7$ Hz, H-5, **30**α), 4.38–4.15 (m, 2 H, $OCH_2CH=CH_2$), 3.918 (m, 1 H, $J_{5,6a} = J_{5,6b} =$ 6.4 Hz, H-5, **30**β), 3.786 (dd, 1 H, H-2, **30**α), 3.513 (dd, 1 H, H-2, **30**β), 2.147 (s, 3 H, Ac, **30**β), 2.141 (s, 3 H, Ac, **30**α), 2.055 and 2.032 (2 s, each 3 H, 2 Ac).

To a solution of **30** (67 mg, 0.19 mmol) and trichloroacetonitrile (163 μL, 1.63 mmol) in CH_2Cl_2 (1.5 mL) was added freshly fused K_2CO_3 (133 mg). After 90 min, TLC (95:5 CH_2Cl_2–acetone) showed a complete conversion of **30** into **31** (R_f 0.51), and the mixture was concentrated and purified over a short silica column (9:1 CH_2Cl_2–acetone) to give **31**α (48 mg) and **31**β (44 mg), both isolated as a glass, in a total yield of 97%; for **31**α: $[\alpha]_D$ +33° (*c* 1); ^{1}H NMR ($CDCl_3$): δ 6.591 (d, 1 H, $J_{1,2}$ 3.6 Hz, H-1), 5.844 (m, 1 H, $OCH_2CH=CH_2$), 5.535 (dd, 1 H, $J_{3,4}$ 3.3, $J_{4,5}$ 1.4 Hz, H-4), 5.327 (dd, 1 H, $J_{2,3}$ 10.5 Hz, H-3), 5.32–5.16 (m, 2 H, $OCH_2CH=CH_2$), 4.414 (m, 1 H, $J_{5,6a} = J_{5,6b} = 6.6$ Hz, H-5), 3.974 (dd, 1 H, H-2), 2.154, 2.031, and 2.013 (3 s, each 3 H, 3 Ac); for **31**β: $[\alpha]_D$ +4° (*c* 1); ^{1}H NMR ($CDCl_3$): δ 5.838 (m, 1 H, $OCH_2CH=CH_2$), 5.776 (d, 1 H, $J_{1,2}$ 8.1 Hz, H-1), 5.424 (dd, 1 H, $J_{3,4}$ 3.5, $J_{4,5}$ 1.3 Hz, H-4), 5.26–5.12 (m, 2 H, $OCH_2CH=CH_2$), 5.046 (dd, 1 H, $J_{2,3}$ 10.1 Hz, H-3), 4.36–4.11 (m, 2 H, $OCH_2CH=CH_2$), 4.043 (ddd, 1 H, $J_{5,6a}$ 6.0, $J_{5,6b}$ 7.4 Hz, H-5), 3.799 (dd, 1 H, H-2), 2.164, 2.044, and 2.033 (3 s, each 3 H, 3 Ac).

3-N-*Benzyloxycarbonylaminopropyl (3,4,6-tri*-O-*acetyl-2*-O-*allyl-α*-D-*galactopyranosyl)-(1 → 3)-2,4,6-tri*-O-*benzyl-α*-D-*glucopyranoside* (**32**).—(a) A mixture of **19** (217 mg, 0.556 mmol), **23** (241 mg, 0.376 mmol) and 4 Å molecular sieves in Et_2O (10 mL) was stirred for 30 min. Then, MeOTf (125 μL, 1.10 mmol) was added. After 7 h, TLC (9:1 CH_2Cl_2–acetone) showed the disappearance of **23** and the appearance of a new spot (**32**, R_f 0.78), and the mixture was neutralised with Et_3N, diluted with CH_2Cl_2, washed with water (3×), dried ($MgSO_4$), filtered, and concentrated. Column chromatography (95:5 CH_2Cl_2–acetone) of the residue afforded **32** (96 mg, 26%) and **32**β (97 mg, 27%), both isolated as a syrup. (b) A mixture of **31** (145 mg, 0.295 mmol), **23** (140 mg, 0.218 mmol) and 4 Å molecular sieves in Et_2O (12.5 mL) was cooled to −10 °C, and stirred for 30 min. Then, TMSOTf (37 μL, 0.19 mmol) was added. After 20 min, TLC (9:1 CH_2Cl_2–acetone) showed the disappearance of **23** and the

appearance of a single product (R_f 0.78), and the mixture was neutralised with Et_3N, diluted with CH_2Cl_2, washed with water, aq 10% $NaHCO_3$, and water, dried ($MgSO_4$), filtered, and concentrated. Column chromatography (93:5:6.5 CH_2Cl_2–acetone) of the residue afforded **32** (141 mg, 67%) and **32**β (59 mg, 28%), both isolated as a syrup; for **32**: $[\alpha]_D$ +32° (*c* 1); NMR ($CDCl_3$): ^{1}H, δ 7.36–7.11 (m, 20 H, 4 Ph), 5.659 (m, 1 H, $OCH_2CH{=}CH_2$), 5.545 (d, 1 H, $J_{1',2'}$ 3.6 Hz, H-1′), 5.368 (dd, 1 H, $J_{2',3'}$ 10.6, $J_{3',4'}$ 3.1 Hz, H-3′), 5.292 (dd, 1 H, $J_{4',5'}$ 1.5 Hz, H-4′), 5.12–5.01 (m, 2 H, $OCH_2CH{=}CH_2$), 5.07 (bs, 2 H, $COOCH_2Ph$), 4.730 (d, 1 H, $J_{1,2}$ 3.7 Hz, H-1), 4.918, 4.629, 4.562, 4.538, and 4.448 (5 d, 1,1,1,1,2 H, 3 OCH_2Ph), 4.182 (dd, 1 H, $J_{2,3}$ 9.7, $J_{3,4}$ 8.0 Hz, H-3), 3.707 (t, 1 H, $J_{4,5}$ 8.0 Hz, H-4), 3.543 (dd, 1 H, H-2), 3.29–3.17 (m, 2 H, $O(CH_2)_2CH_2N$), 2.085, 2.012, and 1.918 (3 s, each 3 H, 3 Ac), 1.82–1.73 (m, 2 H, $OCH_2CH_2CH_2N$); ^{13}C, δ 170.2, 170.0, and 169.7 (3 $COCH_3$), 156.4 ($NCOOCH_2Ph$), 134.3 ($OCH_2CH{=}CH_2$), 117.4 ($OCH_2CH{=}CH_2$), 97.7 and 96.6 (C-1,1′), 78.8, 78.3, 75.7, 73.3, 70.3, 69.9, 68.9, and 66.0 (C-2,3,4,5,2′,3′,4′,5′), 73.6, 73.4, 73.1, 72.9, 68.3, 66.4 (2 C), and 61.5 (3 OCH_2Ph, C-6,6′, $OCH_2CH{=}CH_2$, $NCOOCH_2Ph$, $OCH_2(CH_2)_2N$), 38.8 [$O(CH_2)_2CH_2N$], 29.3 ($OCH_2CH_2CH_2N$), 20.7 and 20.5 (2 C)(3 $COCH_3$). Anal. Calcd for $C_{53}H_{63}NO_{16}$: C, 65.62; H, 6.55. Found: C, 65.38; H, 6.52.

3-N-*Benzyloxycarbonylaminopropyl (3,4,6-tri-O-acetyl-α*-D-*galactopyranosyl)-(1 → 3)-2,4,6-tri*-O-*benzyl-α*-D-*glucopyranoside* (**33**).—To a soln of **32** (96 mg, 99 μmol) and DABCO (100 mg, 891 μmol) in 8:3:1 EtOH–toluene–water (24 mL) was added tris(triphenylphosphine)rhodium(I) chloride (45 mg). After refluxing for 6 h, TLC (95:5 CH_2Cl_2–acetone) did not show any new spots. The mixture was concentrated, diluted with CH_2Cl_2, washed with 0.1 M HCl and water (2 ×), and concentrated. To a soln of the residue in 9:1 acetone–water (10 mL) were added $HgCl_2$ (160 mg, 0.589 mmol) and a catalytic amount of HgO (8 mg). After stirring for 18 h, TLC (6:4 hexane–EtOAc) showed the disappearance of the higher moving spot, indicating the rearrangement reaction and subsequent depropenylation to be completed. The mixture was diluted with CH_2Cl_2, filtered, washed with water, aq 5% KI, water, aq 10% $NaHCO_3$, and water, dried ($MgSO_4$), filtered, and concentrated. Column chromatography (93:7 CH_2Cl_2–acetone) of the residue afforded **33**, isolated as a syrup (59 mg, 64%); $[\alpha]_D$ +62° (*c* 1); ^{1}H NMR ($CDCl_3$): δ 7.34–7.11 (m, 20 H, 4 Ph), 5.441 (d, 1 H, $J_{1',2'}$ 3.5 Hz, H-1′), 5.300 (dd, 1 H, $J_{3',4'}$ 3.3, $J_{4',5'}$ 1.2 Hz, H-4′), 5.147 (dd, 1 H, H-3′), 5.08 and 5.02 (2 bd, each 1 H, $COOCH_2Ph$), 4.743, 4.673, 4.609, 4.534, 4.487, and 4.460 (6 d, each 1 H, 3 OCH_2Ph), 4.683 (d, 1 H, $J_{1,2}$ 3.8 Hz, H-1), 4.122 (dd, 1 H, $J_{2,3}$ 9.7, $J_{3,4}$ 9.4 Hz, H-3), 3.643 (dd, 1 H, $J_{4,5}$ 9.0 Hz, H-4), 3.472 (dd, 1 H, $J_{2',3'}$ 10.5 Hz, H-2′), 3.26–3.17 (m, 2 H, $O(CH_2)_2CH_2N$), 2.098, 2.038, and 1.930 (3 s, each 3 H, 3 Ac), 1.84–1.72 (m, 2 H, $OCH_2CH_2CH_2N$). Anal. Calcd for $C_{50}H_{59}NO_{16}$: C, 64.57; H, 6.39. Found: C, 64.55; **H**, 6.37.

(2,3,4-Tri-O-*acetyl-α*-L-*rhamnopyranosyl)-(1 → 4)-1*-O-*benzoyl-2,3-di*-O-*benzyl-5*-O-*(triethylammonium H-phosphonate)*-D-*ribitol* (**34**), (2,3,4-tri-O-acetyl-α-L-*rhamnopyranosyl)-(1 → 4)-1*-O-*benzoyl-2,3-di*-O-*benzyl-5*-O-*(3*-N-*benzyloxycarbonylaminopropyl triethylammonium phosphate)*-D-*ribitol* (**36**), α-L-*rhamnopyranosyl-(1 → 4)-2,3-di*-O-*benzyl-5*-O-(3-N-*benzyloxycarbonylaminopropyl triethylammonium phosphate)*-D-*ribitol* (**37**), and α-L-*rhamnopyranosyl-(1 → 4)-5*-O-*(3-aminopropyl hydrogen phosphate)*-D-*ribitol* (**38**).—To a soln of **5** (500 mg, 0.705 mmol) in 1:5 pyridine–acetonitrile (6 mL) was added 2-chloro-4*H*-1.3.2-benzodioxaphosphorin-4-one (171 mg, 0.844 mmol), and the mixture was stirred for 24 h, when TLC (9:1 CH_2Cl_2–acetone) revealed the disappearance of the starting material. After the addition of 1:1 pyridine–water (1 mL), the mixture was diluted with CH_2Cl_2, washed with 1 M triethylammonium bicarbonate (2 ×) and water, dried ($MgSO_4$), filtered, and concentrated. Column chromatography (80:19:1 CH_2Cl_2–acetone–Et_3N, then 80:19:1 CH_2Cl_2–MeOH–Et_3N) of the residue afforded **34**, isolated as a syrup (421 mg, 68%); ^{1}H NMR ($CDCl_3$): δ 7.97–6.77 (m, 15 H, 3 Ph), 6.832 (d, 1 H, J_{P-H} 613 Hz, P–H), 5.355 (dd, 1 H, $J_{1',2'}$ 1.7, $J_{2',3'}$ 3.4 Hz, H-2′), 5.261 (dd, 1 H, $J_{3',4'}$ 10.2 Hz, H-3′), 5.193 (d, 1 H, H-1′), 5.021 (t, 1 H, $J_{4',5'}$ 10.2 Hz, H-4′), 3.074 (q, 6 H, $N(CH_2CH_3)_3$), 2.176, 2.126, and 2.126 (3 s, each 3 H, 3 Ac), 1.333 (t, 9 H, $N(CH_2CH_3)_3$), 0.955 (d, 3 H, 3 H-6′).

A mixture of **34** (421 mg, 0.482 mmol) and **9** (282 mg, 1.35 mmol) in 1:5 pyridine–acetonitrile (7.9 mL) was stirred for 10 min, and pivaloyl chloride was added (83 μL, 0.67 mmol). After stirring for 20 min, an additional amount of pivaloyl chloride (50 μL, 0.41 mmol) was added. After 60 min, TLC (9:1 CH_2Cl_2–acetone) revealed the disappearance of **34** and the appearance of a new spot with R_f 0.31 (**35**). Then, a 0.5 M soln of iodine in 95:5 pyridine–water (100 μL) was added to the mixture, and after 20 min, TLC (9:1 CH_2Cl_2–acetone) indicated the disappear-

ance of **35** and a new spot on the baseline. The mixture was diluted with CH_2Cl_2, washed with aq 5% $Na_2S_2O_3$ and 1 M triethylammonium bicarbonate (2 ×), dried ($MgSO_4$), filtered, and concentrated. Column chromatography (90:9:1 CH_2Cl_2–acetone–Et_3N, then 90:9:1 CH_2Cl_2–MeOH–Et_3N) of the residue gave **36**, isolated as a glass (224 mg, 43%); ^{13}C NMR ($CDCl_3$): δ 169.8 (2 C) and 169.6 (3 $COCH_3$), 166.0 ($COPh$), 96.2 (C-1′), 77.2, 75.5, 75.3, 70.5, 69.5, 69.2, and 66.7 (C-2,3,4,2′,3′,4′,5′), 73.0 and 72.3 (2 OCH_2Ph), 66.0 and 63.7 ($NCOOCH_2Ph$ and C-1), 65.0 and 62.7 ($OCH_2(CH_2)_2N$ and C-5, $J_{P,OC\text{-}spacer} \approx J_{P,C\text{-}5} \approx 5.3$ Hz), 45.7 [$N(CH_2CH_3)_3$], 37.1 [$O(CH_2)_2CH_2N$], 30.2 ($OCH_2CH_2CH_2N$), 20.6 (2 C) and 20.5 (3 $COCH_3$), 16.9 (C-6′), 8.4 [$N(CH_2CH_3)_3$].

A soln of **36** (21.2 mg, 19.6 μmol) in 2:1 MeOH–aq 25% NH_4OH (12.5 mL) was heated for 24 h at 50 °C, and concentrated, and after repeating the de-*O*-acylation, crude **37** was obtained, which was purified on Sephadex LH-20 (50:50:1 CH_2Cl_2–MeOH–Et_3N); ^{13}C NMR (CD_3OD): δ 101.7 (C-1′), 81.2, 80.5, 77.7, 74.1, 72.4, 72.3, and 70.3 (C-2,3,4,2′,3′,4′,5′), 74.7 and 73.4 (2 OCH_2Ph), 67.4, 66.7, 64.3, and 62.1 ($NCOOCH_2Ph$, $OCH_2(CH_2)_2N$, and C-1,5), 38.7 [$O(CH_2)_2CH_2N$], 31.9 ($OCH_2CH_2CH_2N$), 18.0 (C-6′).

To a soln of **37** in 1:2:2 EtOAc–2-propanol–MeOH (5 mL) was added 10% Pd–C (10 mg), and the mixture was hydrogenolysed at atmospheric pressure for 16 h. After filtration, the mixture was concentrated, and the residue was purified by Bio-Gel P-2 gel-permeation chromatography using water as eluent, affording **38** as a white powder (6.3 mg, 74%); NMR (D_2O): ^1H, δ 5.074 (d, 1 H, $J_{1',2'}$ 1.8 Hz, H-1′), 3.465 (t, 1 H, $J_{3',4'} = J_{4',5'} = 9.6$ Hz, H-4′), 3.156 (t, 2 H, $O(CH_2)_2CH_2N$), 2.11–1.98 (m, 2 H, $OCH_2CH_2CH_2N$), 1.292 (d, 3 H, $J_{5',6'}$ 6.3 Hz, 3 H-6′); ^{13}C, δ 101.6 (C-1′), 78.4 (C-4, $J_{P,C\text{-}4}$ 7.6 Hz), 73.4 (2 C), 72.8, 71.7, 71.6, and 70.6 (C-2,3,2′,3′,4′,5′), 65.8 and 64.7 ($OCH_2(CH_2)_2N$ and C-5, $J_{P,OC\text{-}spacer} \approx J_{P,C\text{-}5} \approx 5.4$ Hz), 64.0 (C-1), 38.6 [$O(CH_2)_2CH_2N$], 29.2 ($OCH_2CH_2CH_2N$, $J_{P,OCC\text{-}spacer}$ 6.8 Hz); ^{31}P, δ 3.71 (PO_4). FABMS$^+$ Calcd for $C_{14}H_{30}NO_{12}P$: *m/z* 436.4 $[M + H]^+$. Found: *m/z* 436.4 $[M + H]^+$.

3-N-*Benzyloxycarbonylaminopropyl 3,4,6-tri*-O-*benzyl-2*-O-(*triethylammonium H-phosphonate*)-α-D-*galactopyranoside* (**39**).—To a soln of **12** (75 mg, 117 μmol) in 1:5 pyridine–acetonitrile (6 mL) was added 2-chloro-4*H*-1.3.2-benzodioxaphosphorin-4-one (32 mg, 158 μmol), and the mixture was stirred for 4 h, when TLC (9:1 CH_2Cl_2–acetone) indicated an incomplete reaction. Therefore, an additional amount of 2-chloro-4*H*-1.3.2-benzodioxaphosphorin-4-one (32 mg, 158 μmol) was added, and after 20 h TLC (9:1 CH_2Cl_2–acetone) revealed the disappearance of the starting material. After the addition of 1:1 pyridine–water (1 mL), the mixture was diluted with CH_2Cl_2, washed with 1 M triethylammonium bicarbonate (2 ×) and water, dried ($MgSO_4$), filtered, and concentrated. Column chromatography (80:19:1 CH_2Cl_2–acetone–Et_3N, then 80:19:1 CH_2Cl_2–MeOH–Et_3N) of the residue afforded **39**, isolated as a glass (97 mg, quant); ^1H NMR ($CDCl_3$): δ 7.47–6.74 (m, 20 H, 4 Ph), 6.953 (d, 1 H, J_{P-H} 629 Hz, P–H), 5.66–5.55 (m, 2 H, $COOCH_2Ph$), 5.615 (d, 1 H, $J_{1,2}$ 3.4 Hz, H-1), 5.435, 5.334, 5.165, 5.073, 5.040, and 4.931 (6 d, each 2 H, 3 OCH_2Ph), 3.029 (q, 6 H, $N(CH_2CH_3)_3$), 1.261 (t, 9 H, $N(CH_2CH_3)_3$).

1,2,3,4-Tetra-O-*benzyl-5*-O-(*triethylammonium H-phosphonate*)-D-*ribitol* (**40**).—To a soln of **8** (83 mg, 0.16 mmol) in 1:5 pyridine–acetonitrile (1.1 mL) was added 2-chloro-4*H*-1.3.2-benzodioxaphosphorin-4-one (70 mg, 0.35 mmol), and the mixture was stirred for 2 h, when TLC (1:1 hexane–EtOAc) indicated the disappearance of the starting material and the formation of a new spot on the baseline. After the addition of 1:1 pyridine–water (0.5 mL), the mixture was diluted with CH_2Cl_2, washed with 1 M triethylammonium bicarbonate (2 ×) and water, dried ($MgSO_4$), filtered, and concentrated. Column chromatography (80:19:1 CH_2Cl_2–acetone–Et_3N, then 80:19:1 CH_2Cl_2–MeOH–Et_3N) of the residue afforded **40**, isolated as a syrup (111 mg, quant); NMR ($CDCl_3$): ^1H, δ 7.42–7.08 (m, 20 H, 4 Ph), 6.904 (d, 1 H, J_{P-H} 614 Hz, P–H); ^{13}C, δ 78.6 (C-2,3,4), 73.6, 73.1, 72.3, 72.0, 70.3, and 63.0 (4 OCH_2Ph and C-1,5), 45.1 [$N(CH_2CH_3)_3$], 8.0 [$N(CH_2CH_3)_3$].

3-N-*Benzyloxycarbonylaminopropyl (1,2,3,4-tetra*-O-*benzyl*-D-*ribityl*)-(5 → *triethylammonium phosphate → 2)-3,4,6-tri*-O-*benzyl*-α-D-*galactopyrano-side* (**42**) *and 3-aminopropyl* D-*ribitol*-(*5 → hydrogen phosphate → 2*) - α - D - *galactopyranoside* (**43**).—(a) A mixture of **8** (46 mg, 89 μmol) and **39** (97 mg, 0.12 mmol) in 1:5 pyridine–acetonitrile (2.6 mL) was stirred for 10 min, and pivaloyl chloride (70 μL, 0.57 mmol) was added. After 17 h, an additional amount of pivaloyl chloride (50 μL, 0.41 mmol) was added. After 24 h TLC (9:1 CH_2Cl_2–acetone) revealed the disappearance of **8** and the appearance of a new spot with R_f 0.60 (**41**). A 0.5 M solution of iodine in 95:5 pyridine–water (360 μL) was added. After 18 h, TLC (9:1 CH_2Cl_2–acetone) showed the disappear-

ance of **41** and a new spot on the baseline. The mixture was diluted with CH_2Cl_2, washed with aq 5% $Na_2S_2O_3$ and 1 M triethylammonium bicarbonate (2 ×), dried ($MgSO_4$), filtered, and concentrated. Column chromatography (80:19:1 CH_2Cl_2–acetone–Et_3N, then 80:19:1 CH_2Cl_2–MeOH–Et_3N) of the residue gave **42**, isolated as a glass (45 mg, 38%). (b) A mixture of **40** (145 mg, 0.214 mmol) and **12** (106 mg, 0.165 mmol) in 1:5 pyridine–acetonitrile (5.4 mL) was stirred for 10 min, and pivaloyl chloride (100 μL, 0.813 mmol) was added. After 18 h, an additional amount of pivaloyl chloride (100 μL, 0.813 mmol) was added. After 20 h, TLC (9:1 CH_2Cl_2–acetone) revealed the disappearance of **12**. A 0.5 M solution of iodine in 95:5 pyridine–water (350 μL) was added. After 20 h, TLC (9:1 CH_2Cl_2–acetone) indicated the oxidation to be completed, and the mixture was diluted with CH_2Cl_2, washed with aq 5% $Na_2S_2O_3$ and 1 M triethylammonium bicarbonate (2 ×), dried ($MgSO_4$), filtered, and concentrated. Column chromatography (80:19:1 CH_2Cl_2–acetone–Et_3N, then 80:19:1 CH_2Cl_2–MeOH–Et_3N) of the residue gave **42**, isolated as a syrup (88 mg, 40%); ^{1}H NMR ($CDCl_3$): δ 7.31–7.15 (m, 40 H, 8 Ph), 5.265 (d, 1 H, $J_{1,2}$ 3.8 Hz, H-1), 5.062 and 4.979 (2 d, each 1 H, COOCH_2Ph), 4.840, 4.829, 4.711, 4.665, 4.634, 4.584, 4.523, 4.480, 4.449, and 4.374 (10 d, each 1 H, 5 OCH_2Ph), 4.633 and 4.421 (2 d, each 2 H, 2 OCH_2Ph), 2.952 (q, 6 H, N(CH_2CH$_3$)$_3$), 1.237 (t, 9 H, N(CH$_2$CH_3)$_3$).

To a soln of **42** (120 mg, 91.1 μmol) in 1:2:2:2 water–EtOAc–2-propanol–EtOH (7.5 mL) was added 10% Pd–C (20 mg), and the mixture was hydrogenolysed at 4 kg/cm^2 for 24 h. After filtration, the mixture was concentrated, and the residue was purified by Bio-Gel P-2 gel-permeation chromatography using water as eluent, affording **43**, isolated as a white powder (32 mg, 77%); ^{1}H NMR (D_2O): δ 5.178 (d, 1 H, $J_{1,2}$ 3.8 Hz, H-1), 3.28–3.11 (m, 2 H, O(CH$_2$)$_2$CH_2N), 2.07–1.96 (m, 2 H, OCH$_2$CH_2CH$_2$N), 1.331 (d, 3 H, $J_{5,6}$ 6.5 Hz, 3 H-6). FABMS$^+$ Calcd for $C_{14}H_{30}NO_{13}P$: *m/z* 452.4 $[M + H]^+$. Found: *m/z* 452.4 $[M + H]^+$.

3-N-*Benzyloxycarbonylaminopropyl (2,3,4-tri*-O-*acetyl-α*-D-*rhamnopyranosyl*)-(1 → *4*)-(*1*-O-*benzeyl-2,3 - di* - O - *benzyl* - D - *ribityl*) - (*5* → *triethylammonium phosphate* → *2)-3,4,6-tri*-O-*benzyl-α*-D-*galactopyranoside* (**45**).—A mixture of **39** (19 mg, 24 μmol) and **5** (11 mg, 16 μmol) in 1:5 pyridine–acetonitrile (1.6 mL) was stirred for 10 min, and pivaloyl chloride (20 μL, 0.16 mmol) was added. After 3 h, TLC (9:1 CH_2Cl_2–acetone) revealed the disappearance of **5** and the appearance of a new spot with R_f 0.47 (**44**). A 0.5 M solution of iodine in 95:5 pyridine–water (50 μL) was added, and after 3 h TLC (9:1 CH_2Cl_2–acetone) indicated the disappearance of **44**. The mixture was diluted with CH_2Cl_2, washed with aq 5% $Na_2S_2O_3$ and 1 M triethylammonium bicarbonate (2 ×), dried ($MgSO_4$), filtered, and concentrated. Column chromatography (80:19:1 toluene–acetone–Et_3N, then 80:19:1 toluene–MeOH–Et_3N) of the residue gave **45**, isolated as a glass (21 mg, 89%); NMR ($CDCl_3$): ^{1}H, δ 7.95–7.45 (m, 35 H, 7 Ph), 2.722 (q, 6 H, N(CH_2CH$_3$)$_3$), 2.020, 1.947, and 1.940 (3 s, each 3 H, 3 Ac), 1.112 (t, 9 H, N(CH$_2$CH_3)$_3$), 0.907 (d, 3 H, *J*5″,6″ 6.2 Hz, 3 H-6″); ^{13}C, δ 169.8 (*C*OCH3), 166.3 (*C*OPh), 156.7 (N*C*OOCH$_2$Ph), 98.7 and 95.8 (C-1,1″), 45.2 [N(*C*H$_2$CH$_3$)$_3$], 37.5 [O(CH$_2$)$_2$*C*H$_2$N], 29.5 (OCH$_2$*C*H$_2$CH$_2$N), 20.7 and 20.6 (2 C) (3 CO*C*H$_3$), 17.0 (C-6″), 8.3 [N(CH$_2$*C*H$_3$)$_3$]; ^{31}P, δ −2.57 (PO_4).

A soln of **45** (21 mg, 14 μmol) in 2:1 MeOH–aq 25% NH_4OH (5 mL) was heated for 24 h at 50 °C, then concentrated. This de-*O*-acylation procedure was repeated twice, to yield crude **46**, which was purified on Sephadex LH-20 (50:50:1 CH_2Cl_2–MeOH–Et_3N). To a soln of **46** in 1:2:2:2 water–EtOAc–2-propanol–EtOH (5 mL) was added 10% Pd–C (10 mg), and the mixture was hydrogenolysed at atmospheric pressure for 16 h, filtered, and concentrated. The hydrogenolysis procedure was repeated twice, and the crude product was purified by Bio-Gel P-2 gel-permeation chromatography using water as eluent, affording **47**, isolated as a white powder (3.9 mg, 47%); ^{1}H NMR (D_2O): δ 5.164 (d, 1 H, $J_{1,2}$ 4.0 Hz, H-1), 5.086 (d, 1 H, $J_{1″,2″}$ 1.7 Hz, H-1″), 3.462 (t, 1 H, $J_{3″,4″} = J_{4″,5″} = 9.7$ Hz, H-4″), 3.22–3.11 (m, 2 H, O(CH$_2$)$_2$CH_2N), 2.04–1.98 (m, 2 H, OCH$_2$CH_2CH$_2$N), 1.292 (d, 3 H, $J_{5″,6″}$ 6.3 Hz, 3 H-6″); ^{31}P, δ 0.65 (PO_4). FABMS$^+$ Calcd for $C_{20}H_{40}NO_{17}P$: *m/z* 598.5 $[M + H]^+$. Found: *m/z* 598.5 $[M + H]^+$.

3-N-*Benzyloxycarbonylaminopropyl (1,2,3,4-tetra*-O - *benzyl* - D - *ribityl*) - (*5* → *triethylammonium phosphate* → *2)-(3,4,6-tri*-O-*acetyl-α*-D-*galactopyranosyl*)-(*1* → *3)-2,4,6-tri*-O-*benzyl-α*-D-*glucopyranoside* (**49**) *and 3 - aminopropyl* D - *ribityl* - (*5* → *hydrogen phosphate* → *2)* - *α* - D - *galactopyranosyl* - (*1* → *3)* - *α* - D - *glucopyranoside* (**51**).—A mixture of **40** (37 mg, 55 μmol) and **33** (54 mg, 58 μmol) in 1:5 pyridine–acetonitrile (2.5 mL) was stirred for 15 min, and pivaloyl chloride (30 μL, 0.25 mmol) was added. After 5 h, an additional amount of pivaloyl chloride (30 μL, 0.25 mmol) was added, and after 18 h TLC

(9:1 CH_2Cl_2–acetone) revealed the disappearance of **33** and the formation of a new spot (**48**). A 0.5 M soln of iodine in 95:5 pyridine–water (82 μL) was added, and after 4 h TLC (8:2 CH_2Cl_2–acetone) showed the disappearance of **48**. The mixture was diluted with CH_2Cl_2, washed with aq 5% $Na_2S_2O_3$ and 1 M triethylammonium bicarbonate (2 ×), dried ($MgSO_4$), filtered, and concentrated. Column chromatography (80:19:1 CH_2Cl_2–acetone–Et_3N, then 80:19:1 CH_2Cl_2–MeOH–Et_3N) of the residue gave **49**, isolated as a glass (68 mg, 77%); ^{1}H NMR ($CDCl_3$): δ 7.33–7.16 (m, 40 H, 8 Ph), 5.872 (d, 1 H, $J_{1',2'}$ 2.5 Hz, H-1′), 5.478 (dd, 1 H, $J_{2',3'}$ 10.7 Hz, H-2′), (5.25 d, 1 H, $J_{3',4'} < 1$ Hz, H-3′), 5.072 and 4.983 (2 d, each 1 H, COOCH_2Ph), 4.664 (d, 1 H, $J_{1,2}$ 3.4 Hz, H-1), 4.230 (dd, 1 H, $J_{2,3}$ 9.4, $J_{3,4}$ 9.0 Hz, H-3), 3.424 (dd, 1 H, H-2), 2.947 (q, 6 H, N(CH_2CH$_3$)$_3$), 1.928 and 1.901 (2 s, 3,6 H, 3 Ac), 1.259 (t, 9 H, N(CH$_2$CH_3)$_3$).

A soln of **49** (42 mg, 26 μmol) in 2:1 MeOH–aq 25% NH_4OH (7.5 mL) was heated for 24 h at 50 °C, then concentrated to yield crude **50**, which was purified on Sephadex LH-20 (50:50:1 CH_2Cl_2–MeOH–Et_3N). To a soln of **50** in 1:2:2:2 water–EtOAc–2-propanol–EtOH (7.5 mL) was added 10% Pd–C (20 mg), and the mixture was hydrogenolysed at 392 kPa for 16 h, filtered, and concd. The hydrogenolysis procedure was repeated, and the crude product was purified by Bio-Gel P-2 gel-permeation chromatography using water as eluent, affording **51** as a white powder (17 mg, quant); NMR (D_2O): ^{1}H, δ 5.627 (d, 1 H, $J_{1',2'}$ 2.5 Hz, H-1′), 4.944 (d, 1 H, $J_{1,2}$ 2.4 Hz, H-1), 3.22–3.11 (m, 2 H, O(CH$_2$)$_2$CH_2N), 2.03–1.99 (m, 2 H, OCH$_2$CH_2CH$_2$N); ^{13}C, δ 99.8 and 98.6 (C-1,1′), 80.8, 73.4, 73.0 (2 C), 72.3, 71.9, 71.0, 70.7, 70.6, and 69.6 (C-2,3,4,5,2′,3′,4′,5′,2″,3″), 74.2 (C-4″, $J_{P,C-4''}$ 5.3 Hz), 68.1 (C-5″, $J_{P,C-5''}$ 5.8 Hz), 67.3, 63.7, 62.2, and 61.8 (OCH_2(CH$_2$)$_2$N and C-6,6′,1″), 39.3 [O(CH$_2$)$_2$$CH_2$N], 27.9 (OCH$_2$$CH_2CH_2$N); ^{31}P, δ 3.12 (PO_4). FABMS$^+$ Calcd for $C_{20}H_{40}NO_{18}P$: *m/z* 614.5 $[M + H]^+$. Found: *m/z* 614.5 $[M + H]^+$.

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References

[1] M. Finland, *Rev. Infect. Dis.*, 1 (1979) 4–21.
[2] J.B. Robbins, R. Austrian, C.-J. Lee, S.C. Rastogi, G. Schiffman, J. Henrichsen, P.H. Mäkelä, C.V. Broome, R.R. Facklam, R.H. Tiesjema, and J.C. Parke Jr, *J. Infect. Dis.*, 148 (1983) 1136–1159.
[3] J. Henrichsen, *J. Clin. Microbiol.*, 33 (1995) 2759–2762.
[4] M.I. El Mouzan, K. Twan-Danso, B.H. Al Awamy, G.A. Niazi, and M.T. Altorki, *Trop. Geogr. Med.*, 40 (1988) 213–217.
[5] T.D. Mastro, A. Ghafoor, N.K. Nomani, Z. Ishaq, F. Anwar, D.M. Granoff, J.S. Spika, C. Thornsberry, and R.R. Facklam, *Lancet*, 337 (1991) 156–159.
[6] I.D. Riley, D. Lehmann, and M.P. Alpers, *Rev. Infect. Dis.*, 13 suppl. 6 (1991) S535–S541.
[7] D.H. Sniadack, B. Schwartz, H. Lipman, J. Bogaerts, J.C. Butler, R. Dagan, G. Echaniz-Aviles, N. Lloyd-Evans, A. Fenoll, N.I. Girgis, J. Henrichsen, K. Klugman, D. Lehmann, A.K. Takala, J. Vandepitte, S. Gove, and R.F. Breiman, *Pediatr. Infect. Dis. J.*, 14 (1995) 503–510.
[8] P.H. Mäkelä, P. Karma, and M.K. Leinonen, *Bull. Eur. Physiophat. Resp.*, 19 (1983) 235–238.
[9] J.E.G. van Dam, A. Fleer, and H. Snippe, *Anthonie van Leeuwenhoek*, 58 (1990) 1–47.
[10] D.M. Granoff, S.J. Holmes, M.T. Osterholm, J.E. McHugh, A.H. Lucas, E.L. Anderson, R.B. Belshe, J.L. Jacobs, F. Medley, and T.V. Murphy, *J. Infect. Dis.*, 168 (1993) 663–671.
[11] W.E. Paul, D.H. Katz, and B. Benacerraf, *J. Immunol.*, 107 (1971) 685–688.
[12] H. Braley-Mullen, *J. Immunol.*, 113 (1974) 1909–1920; *Immunology*, 40 (1980) 521–527.
[13] E.C. Beuvery, F. van Rossum, and J. Nagel, *Infect. Immunol.*, 37 (1982) 15–22.
[14] R. Schneerson, J.B. Robbins, C. Chu, A. Sutton, W. Vann, J.C. Vickers, W.T. London, B. Curfman, M.C. Hardegree, J. Shiloach, and S.C. Rastogi, *Infect. Immunol.*, 45 (1984) 582–591.
[15] C.-J. Lee, Y. Takaoka, and T. Saito, *Rev. Infect. Dis.*, 9 (1987) 494–510.
[16] S. Marburg, D. Jorn, R.L. Tolman, B. Arison, J. McCauley, P.J. Kniskerm, A. Hagopian, and P.P. Vella, *J. Am. Chem. Soc.*, 108 (1986) 5282–5287.
[17] M. Koskela, M. Harris, and G.S. Giebink, *J. Clin. Microbiol.*, 30 (1992) 1485–1490.
[18] D.E. Moshier, A.J. Feeney, and P. Scherle, in R. Bell and G. Torriani (Eds.), *Towards Better Carbohydrate Vaccines*, Wiley, 1987, pp 243–261.
[19] E. Alonso de Velasco, A.F.M. Verheul, G.H. Veeneman, L.J.F. Gomes, J.H. van Boom, J. Verhoef, and H. Snippe, *Vaccine*, 11 (1993) 1429–1436.
[20] R. Booy and E.R. Moxon, *Arch. Dis. Child.*, 68 (1993) 440–441.
[21] E. Alonso de Velasco, A.F.M. Verheul, A.M.P. van Steijn, H.A.T. Dekker, R.G. Feldman, I.M. Fernandez, J.P. Kamerling, J.F.G. Vliegenthart, J. Verhoef, and H. Snippe, *Infect. Immunol.*, 62 (1994) 799–808.
[22] C. Barrios, C. Tougne, B.S. Polla, P.H. Lambert, and

G. del Guidice, *Clin. Exp. Immunol.*, 98 (1994) 224–228.
[23] S. Pillai, S. Ciciriello, M. Koster, and R. Eby, *Infect. Immunol.*, 59 (1991) 4371–4376.
[24] T.M. Slaghek, M.J. van Vliet, A.A.M. Maas, J.P. Kamerling, and J.F.G. Vliegenthart, *Carbohydr. Res.*, 195 (1989) 75–86.
[25] T.M. Slaghek, A.H. van Oijen, A.A.M. Maas, J.P. Kamerling, and J.F.G. Vliegenthart, *Carbohydr. Res.*, 207 (1990) 237–248.
[26] T.M. Slaghek, A.A.M. Maas, J.P. Kamerling, and J.F.G. Vliegenthart, *Carbohydr. Res.*, 211 (1991) 25–39.
[27] M.J.L. Thijssen, K.M. Halkes, J.P. Kamerling, and J.F.G. Vliegenthart, *Bioorg. Med. Chem.*, 2 (1994) 1309–1317.
[28] A.M.P. van Steijn, M. Jetten, J.P. Kamerling, and J.F.G. Vliegenthart, *Recl. Trav. Chim. Pays-Bas*, 108 (1989) 374–383.
[29] G.H. Veeneman, S.H. van Leeuwen, and J.H. van Boom, *Tetrahedron Lett.*, 31 (1990) 1331–1334.
[30] B. Grzeszczyk, A. Banaszek, and A. Zamojski, *Carbohydr. Res.*, 175 (1988) 215–226.
[31] P. Berntsson, A. Brändström, U. Junggren, L. Palmer, S.E. Sjöstrand, and G. Sundell, *Acta Pharm. Suec.*, 14 (1977) 229–236.
[32] G.H. Veeneman and J.H. van Boom, *Tetrahedron Lett.*, 31 (1990) 275–278.
[33] R.J. Ferrier and R.H. Furneaux, *Carbohydr. Res.*, 52 (1976) 63–68.
[34] G.H. Veeneman, S.H. van Leeuwen, H. Zuurmond, and J.H. van Boom, *J. Carbohydr. Chem.*, 9 (1990) 783–796.
[35] C. Murakata and T. Ogawa, *Carbohydr. Res.*, 235 (1992) 95–114.
[36] T.M. Slaghek, Y. Nakahara, and T. Ogawa, *Tetrahedron Lett.*, 33 (1992) 4971–4974.
[37] T.M. Slaghek, T.K. Hyppönen, T. Ogawa, J.P. Kamerling, and J.F.G. Vliegenthart, *Tetrahedron Lett.*, 34 (1993) 7939–7942.
[38] P.J. Garegg, T. Regberg, J. Strawinski, and R. Strömberg, *Chemica Scripta*, 26 (1986) 59–62.
[39] B.C. Froehler and M.D. Matteucci, *Tetrahedron Lett.*, 27 (1986) 469–472.
[40] R. Anschutz and W.O. Emery, *Liebigs Ann. Chem.*, 239 (1987) 301–333.
[41] J.E. Marugg, M. Tromp, E. Kuyl-Yeheskiely, G.A. van der Marel, and J.H. van Boom, *Tetrahedron Lett.*, 27 (1986) 2661–2664.
[42] P. Westerduin, G.H. Veeneman, G.A. van der Marel, and J.H. van Boom, *Tetrahedron Lett.*, 27 (1986) 6271–6274.
[43] M. Lindberg and T. Norberg, *J. Carbohydr. Chem.*, 7 (1988) 749–755.