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THE SYNTHESIS OF MONODEOXY DERIVATIVES OF LACTO-*N*-BIOSE I AND *N*-ACETYL-LACTOSAMINE TO SERVE AS SUBSTRATES FOR THE DIFFERENTIATION OF α-L-FUCOSYL TRANSFERASES

DEVESHWARI P. KHARE, OLE HINDSGAUL, AND RAYMOND U. LEMIEUX*
Department of Chemistry, University of Alberta, Edmonton, Alberta T6G 2G2 (Canada)
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ABSTRACT

The chemical synthesis of β-D-Gal-(1→3)-4-deoxy-β-D-GlcNAcOR and β-D-Gal-(1→4)-3-deoxy-β-D-GlcNAcOR, wherein R = $(CH_2)_8COOMe$ and Me, are reported. Also, 2-deoxy-β-D-Gal-(1→3)-β-D-GlcNAc$O(CH_2)_8COOMe$ and 2-deoxy-β-D-Gal-(1→4)-β-D-GlcNAc$O(CH_2)_8COOMe$ were synthesized. Preliminary results from other laboratories are reported on the behaviour of these compounds as acceptors of β-D-*Gal*- and β-D-*GlcNAc*-α-L-fucosyl transferases. It is suggested that the enzymes accept the substrates in near their most favorable conformations and that the binding involves both polar and nonpolar interactions with topographical features near the hydroxyl group which undergoes substitution. It appears that, depending on the transferase, the recognition may or may not include both the sugar units.

INTRODUCTION

α-L-Fucosyl transferases are widely distributed in tissues and body fluids and catalyze the transfer of fucose from GDP-fucose to a wide range of acceptor molecules[1]. The transferases related to the biosynthesis of the ABO and Lewis blood-group determinants (Fig. 1) have received particular attention because of their importance to tissue transplantation, including blood transfusion[2].

Blood-group determinants which terminate with an α-L-Fuc-(1→2)-β-D-Gal unit occur in three now well-recognized varieties, the so-called H types 1, 2, and 3. The H type 1 blood-group determinant, α-L-Fuc-(1→2)-β-D-Gal-(1→3)-β-D-GlcNAc---, is characteristic of the epithelial cells of so-called ABH secretors[3–5]. These people, who represent ~80% of a population, secrete high levels of A, B, or H antigenic activities into body fluids such as saliva, tears, and perspiration. The H type 1 determinant has been referred to as the Lewis d determinant[5] since it is the precursor to the Lewis b determinant[4].

Approximately 70% of people are Lewis b and 20% are Lewis a. These individuals express the Lewis gene responsible for the β-D-*GlcNAc*-(1→4)-α-L-fucosyl transferase which acts on both the H type 1 structure to form the Lewis b determi-

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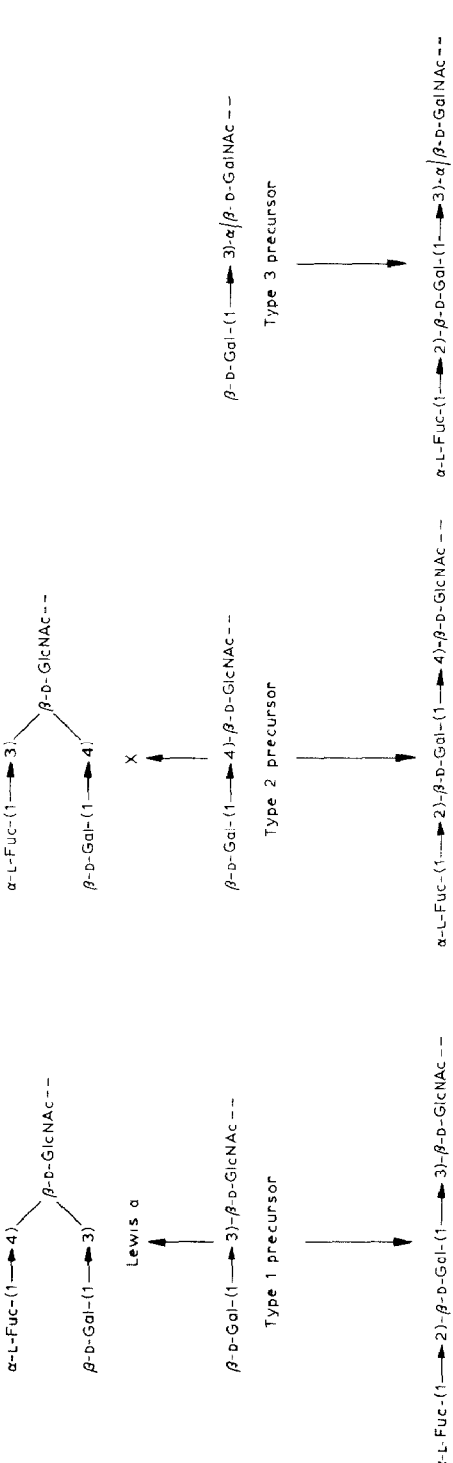


Fig. 1. The fucose-containing human blood-group determinants that are discussed herein. The H structures are the precursors to the A and B blood-group determinants.

nant, and its precursor β-D-Gal-(1→3)-β-D-GlcNAc--- to form the Lewis a determinant[4]. Evidence that a glycoside of β-D-Gal-(1→3)-β-D-GlcNAc (lacto-*N*-biose I) provides the antigenic activity known as Lewis c has recently been presented[6]. Like the H type 1 antigens, the Lewis a and b antigens are characteristic of epithelial cells and are transported by the blood to other tissues[3,4]. Among the ABH nonsecretors, ~90% are Lewis a phenotype. The remainder are Lewis negative and most probably[4] Lewis c.

The H type 2 or O blood-group determinant is characteristic of red cells and other endothelial cells of O blood-group individuals[3]. It is well established that O persons are either ABH secretors or ABH nonsecretors, depending on whether they express, in their epithelia, the gene responsible for the synthesis of H type 1

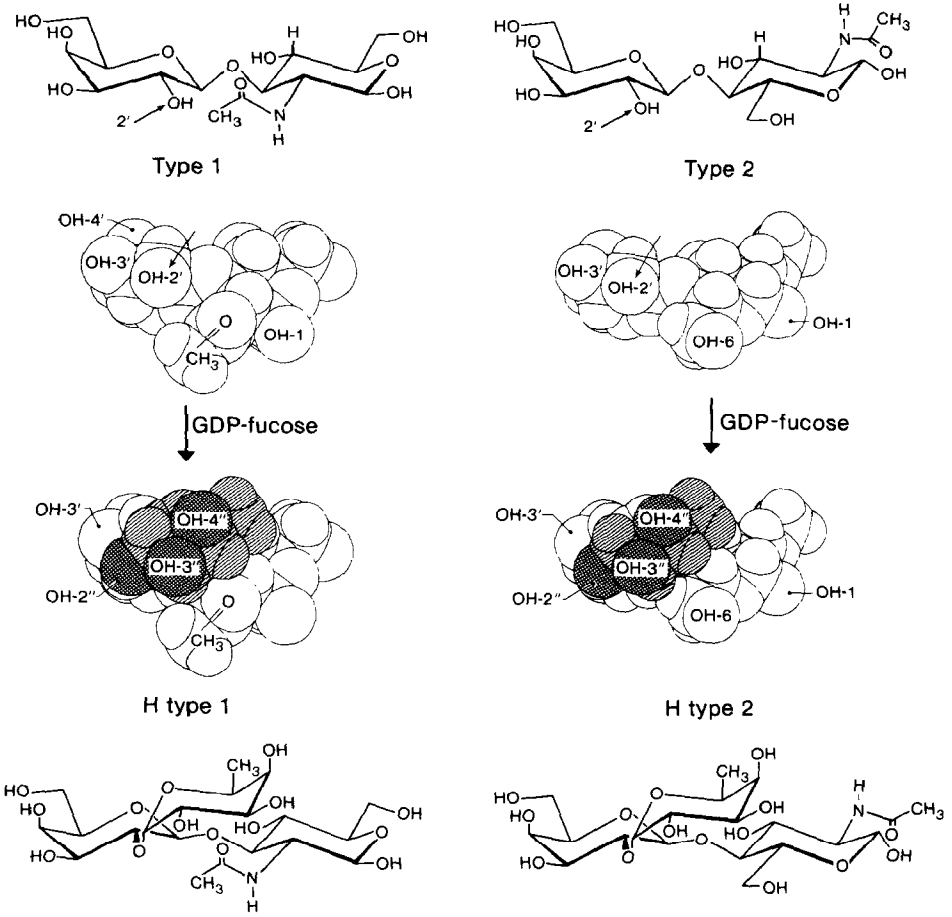


Fig. 2. Acceptors for H-related β-D-*Gal*-(1→2)-α-L-Fuc transferases and computer drawings of the disaccharides in the conformational preferences derived by HSEA calculation in order to display the immediate environments of OH-2′ in the type 1 and type 2 structures. The donation of an α-L-Fuc group in the direction indicated provides the H type 1 and H type 2 trisaccharides in their preferred conformations.

antigens[5]. There exists a β-D-*GlcNAc*-(1→3)-α-L-fucosyl transferase of widespread occurrence in tissues and body fluids that catalyzes, in the presence of GDP-fucose, the formation of the so-called X determinant from structures which terminate with an *N*-acetyl-β-lactosamine unit [β-D-Gal-(1→4)-β-D-GlcNAc---][7]. This transferase also possesses the ability to convert the H type 2 determinant into the so-called Y determinant[7]. Our conformational studies have established that the Lewis b and Y determinants have substantial topographic features in common. Indeed, on the basis of this consideration, the Y determinant was tested and found to react strongly with a population of polyclonal anti-Lewis b antibodies[8]. Furthermore, the lectin IV of *Griffonia simplicifolia* which binds the Lewis b determinant[9] also binds the Y structure[8].

The H type 3 blood-group determinant has become well recognized only in recent years and appears to be related to the fucosylation of *O*-linked glycoproteins[10]. This investigation is not concerned with this determinant except in the sense that the 4-deoxy derivatives of H type 1 and H type 3 are identical. Whether the biosynthesis of the H type 1 and H type 3 determinants involves the same β-D-*Gal*-(1→2)-α-L-fucosyl transferase does not appear to have been established.

Our conformational analyses of the H determinants require that all three types offer, as can be appreciated from Fig. 2, essentially identical topographies about OH-3′ of their β-D-Gal units[11,12]. It is not surprising, therefore, that these are all good acceptors for the α-L-Fuc-(1→2)-β-D-*Gal*-(1→3)-α-D-GalNAc- and α-L-Fuc-(1→2)-β-D-*Gal*-(1→3)-α-D-Gal transferases which form the A and B blood group determinants, respectively[13]. Such a high degree of similarity in the topographies offered for molecular recognition does not, however, exist for the type 1 and type 2 disaccharide units as precursors for the H determinants. The molecular models presented in Fig. 2 display the environments about OH-2′ of their β-D-Gal units for the disaccharides in the conformations expected to be favored in aqueous solution[11,14]. Taking into consideration the *exo*-anomeric effect[11], these structures are expected to populate conformations of similar torsion angles about the glycosidic bond in deep and quite narrow (near ±15° for a 1.0 kcal/mol cut-off) potential-energy wells in the region $\phi^H/\psi^H = 55°/15°$ for the type 1 and $\phi^H/\psi^H = 55°/0°$ for the type 2 disaccharide. On this basis, for each disaccharide, O-5′ of the β-D-Gal unit can be expected to be made available for intramolecular hydrogen-bonding to the neighboring hydroxyl group of the β-D-GlcNAc unit, as occurs[14] in the binding of the type 2 structure by anti-I Ma. Of course, higher energy conformers are available from changes in the ring conformations of the sugar units as well as changes in the ϕ and ψ torsion angles for atoms about the glycosidic bond which, even though present in extremely low abundance, may be selected for binding by the enzyme. However, substantial energy would have to be provided by the enzyme to hold such conformers in the complex and we submit that, in all probability, the disaccharides are accepted by the various fucosyl transferases to form the H type 1, Lewis a, H type 2, and X determinants in conformations close to those depicted in Figs. 2 and 3. This contention is strongly supported by the fact that the transferase

which converts the type 1 disaccharide into the Lewis a determinant also converts H type 1 into the Lewis b determinant. Also, the transferase responsible for forming the X determinant accepts the H type 2 determinant to form the Y structure[7]. These facts are supportive, since the orientations of the β-D-GlcNAc units relative to the β-D-Gal units of the H-trisaccharide are strongly held in the conformations [ϕ^H/ψ^H = 60°/10° (H type 1) and 55°/0° (H type 2)[10]][11] that are very similar to those preferred by the disaccharide precursors. A fucosyl transferase is known[7] which accepts lactose, α-L-Fuc-(1→2)-β-D-Gal-(1→4)-D-Glc, *N*-acetyl-lactosamine, and α-L-Fuc-(1→2)-β-D-Gal-(1→4)-D-GlcNAc (H type 2) to transfer fucose to the 3-position of each of the four structures.

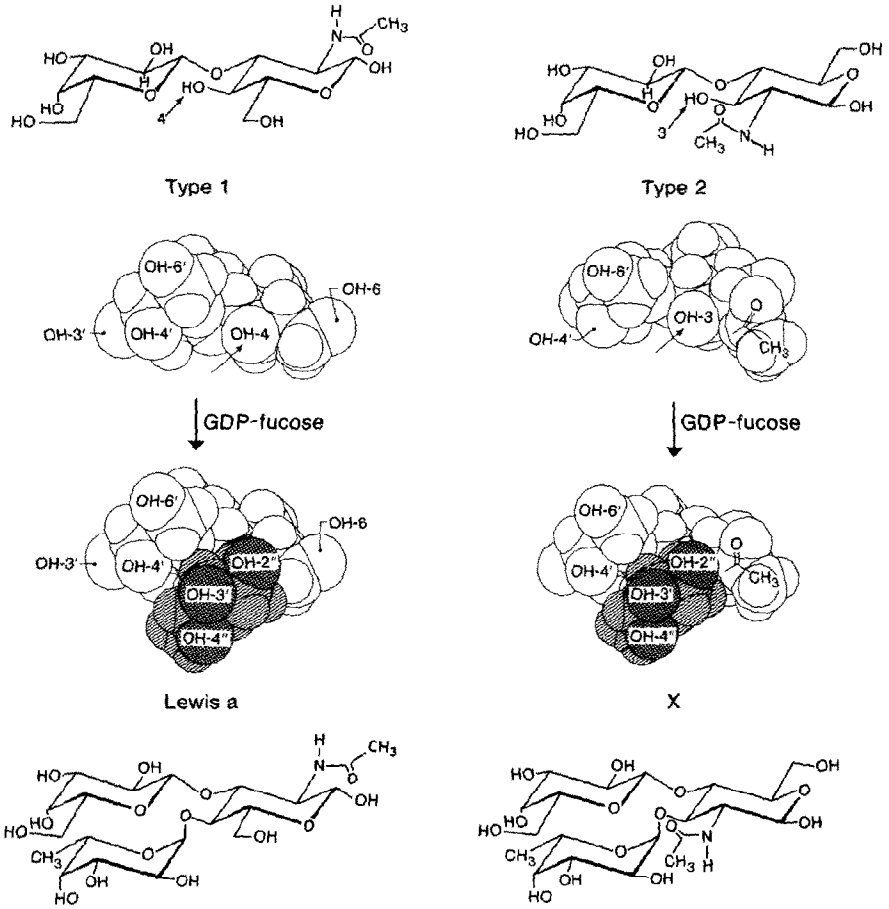


Fig. 3. Acceptors for the Lewis-related β-D-*GlcNAc*-(1→4)-α-L-Fuc and β-D-*GlcNAc*-(1→3)-α-L-Fuc transferases. The computer drawings are to display the compounds in the conformational preferences indicated by HSEA calculation in order to compare the immediate environment of OH-4 in the type 1 disaccharide with that of OH-3 in the type 2 isomer. The donation of the α-L-Fuc group in the direction indicated provides the Lewis a and X trisaccharides in their preferred conformations.

The purpose of this communication is to report the syntheses of 2-deoxy-β-D-Gal-(1→3)-β-D-GlcNAcOR (**7**) and 2-deoxy-β-D-Gal-(1→4)-β-D-GlcNAcOR (**21**), wherein R is the potential linking-arm $(CH_2)_8COOMe$. Also, the syntheses of β-D-Gal-(1→3)-4-deoxy-β-D-GlcNAcOR and β-D-Gal-(1→4)-3-deoxy-β-D-GlcNAcOR, wherein R = $(CH_2)_8COOMe$ (**13** and **33**, respectively) and R = Me (**26** and **40**, respectively) are reported. In view of the foregoing discussion, the 4-deoxy type 1 compounds (**13** and **33**) cannot be acceptors for the Lewis-related β-D-*GlcNAc*-(1→4)-α-L-fucosyl transferase and, similarly, the X-related β-D-*GlcNAc*-(1→3)-α-L-fucosyl transferase cannot glycosylate the 3-deoxy type 2 compounds (**26** and **40**) since the required hydroxyl groups are not present in these structures. On the other hand, these compounds should still serve as acceptors for the H blood-group related β-D-*Gal*-(1→2)-α-L-fucosyl transferases. Because of the different environments for OH-2′ in the type 1 and type 2 disaccharides (Fig. 2), it was suggested[15] that the fucosyl transferase that accepts one of these structures may not accept the other.

α-L-Fucosyltransferases are notably difficult to purify since they often occur as mixtures and may[16] or may not[1] be extremely fragile. The preparation of the above deoxy compounds was expected to provide substrates which could discriminate between different fucosyl transferases with specificities for different hydroxyl groups on the same oligosaccharides. Thus, the deoxy compounds should allow the use of crude sera for the detection and study of these enzymes *in situ*. This possibility has now been examined in the laboratories of Dr. Winifred Watkins* and Drs. R. Oriol and J.-P. Cartron** who have provided the following preliminary results [R = $(CH_2)_8COOMe$]: (*1*) 2-deoxy-β-D-Gal-(1→3)-β-D-GlcNAcOR (**7**) was as good an acceptor as β-D-Gal-(1→3)-β-D-GlcNAcOR for a Lewis-gene-dependent fucosyl transferase from human milk*; (*2*) 2-deoxy-β-D-Gal-(1→4)-β-D-GlcNAcOR (**21**) was a better acceptor than β-D-Gal-(1→4)-β-D-GlcNAcOR for a fucosyl transferase purified from human serum*; (*3*) both the 3- and 4-deoxy compounds (**26** and **13**) were not acceptors for the Lewis-gene-dependent fucosyl transferase from milk*; (*4*) β-D-Gal-(1→3)-4-deoxy-β-D-GlcNAcOMe (**33**) was an acceptor for the β-D-*Gal*-(1→2)-α-L-fucosyl transferase present in the serum of an H-deficient secretor but, although more weakly, an acceptor for the H-type-2-related fucosyl transferase in the sera of H-normal nonsecretors**; (*5*) although β-D-Gal-(1→4)-3-deoxy-β-D-GlcNAcOMe (**40**) was a good acceptor for the β-D-*Gal*-(1→2)-α-L-fucosyl transferase in the sera of H-normal nonsecretors, it was not an acceptor for the similar fucosyl transferase present in the serum of the H-deficient secretor**.

The deoxy compounds **7** and **21** also proved useful in an investigation of β-D-*GlcNAc*-(1→3)-α-L-fucosyl transferases of two ovary mutants LEC11 and LEC12 of Chinese hamster, which proved to be structurally distinct enzymes. It was found that the type 2 compound **21** was as good a substrate as the parent disaccharide for

*Personal communications.
**J. LePendu, personal communication.

both the transferases*. The fact that **7** was not fucosylated indicated the absence of a β-D-*GlcNAc*-(1→4)-α-L-fucosyl transferase in the cell extracts.

It is expected that it should be useful to the future investigation of these enzymic reactions to examine at this time how the fucosyl transferases may accept the disaccharide units, since the interactions involved are undoubtedly similar in kind to those involved for the binding of oligosaccharides by lectins and antibodies[17]. It now appears to be unequivocally established[14,18–22] that the latter complexes involve important interactions between weakly polar–nonpolar complementary surfaces in addition to an interaction between two polar groupings. For antibodies and lectins, the replacement of an hydroxyl group of an oligosaccharide that is involved in the binding reaction leads to a completely inactive compound[14,18,20]. Therefore, since both the 2′-deoxy and 2′-*O*-α-L-Fuc derivatives of β-D-Gal-(1→3)-β-D-GlcNAcOR are good acceptors for the Lewis-blood-group-related β-D-*GlcNAc*-(1→4)-α-L-fucosyl transferase, the recognition of the acceptor must occur only on the side of the molecule which is occupied by OH-4. This region is displayed in Fig. 3, where it is seen that OH-4 is flanked on both sides by the methylene groups of the two hydroxymethyl groups. The same considerations apply to the X-related β-D-*GlcNAc*-(1→3)-α-L-fucosyl transferase. However, in this instance, OH-3 is flanked on one side by the acetamido group. Thus, in both instances, the hydroxyl group that undergoes fucosylation is in an environment that, in principle, can interact with hydrophobic surfaces within the active sites. Although the two reacting hydroxyl groups are in similar environments, OH-3 of the type 2 structure is more sheltered by the acetamido group than is OH-4 of the type 1 isomer. Thus, it is not surprising that transferases exist which discriminate between the two structures[7]. On the other hand, a fucosyl transferase was detected which transfers fucose to the 3-position of both *N*-acetyl-lactosamine and lactose. Since we consider that *N*-acetyl-lactosamine is accepted in a conformation close to that depicted in Fig. 3 for **21**, and a similar conformation is expected for lactose, it is apparent that this enzyme does not bind either the 2-acetamido group of *N*-acetyl-lactosamine or OH-2 of lactose. It would follow, therefore, that the binding by this enzyme is restricted primarily to the β-D-Gal residue.

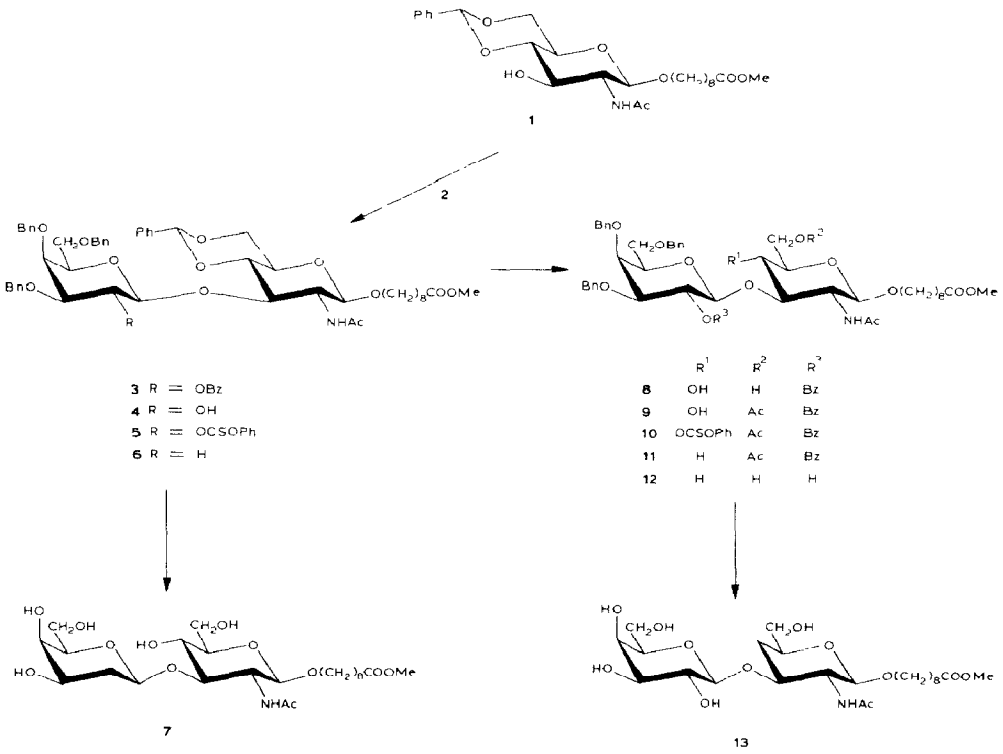
The stereochemical situation, presented in Fig. 2, for the action of β-D-*Gal*-(1→2)-α-L-fucosyl transferases to form the H determinants is very similar to that discussed with reference to Fig. 3. For the type 1 determinant, OH-2′ is flanked on one side by the acetamido group, whereas this position is occupied by a hydroxymethyl group in the type 2 structure. Otherwise, the two OH-2′ groups are in essentially identical environments, each being flanked on the other side by the polar OH-3′ group. As was mentioned above, the transferase present in the sera of H-normal nonsecretors appeared able to accept structures of both the 4-deoxy type 1 (**13**) and the 3-deoxy type 2 (**26**). On the other hand, **26** was not an acceptor for the transferase present in the serum of an H-deficient secretor. Thus, it is apparent that

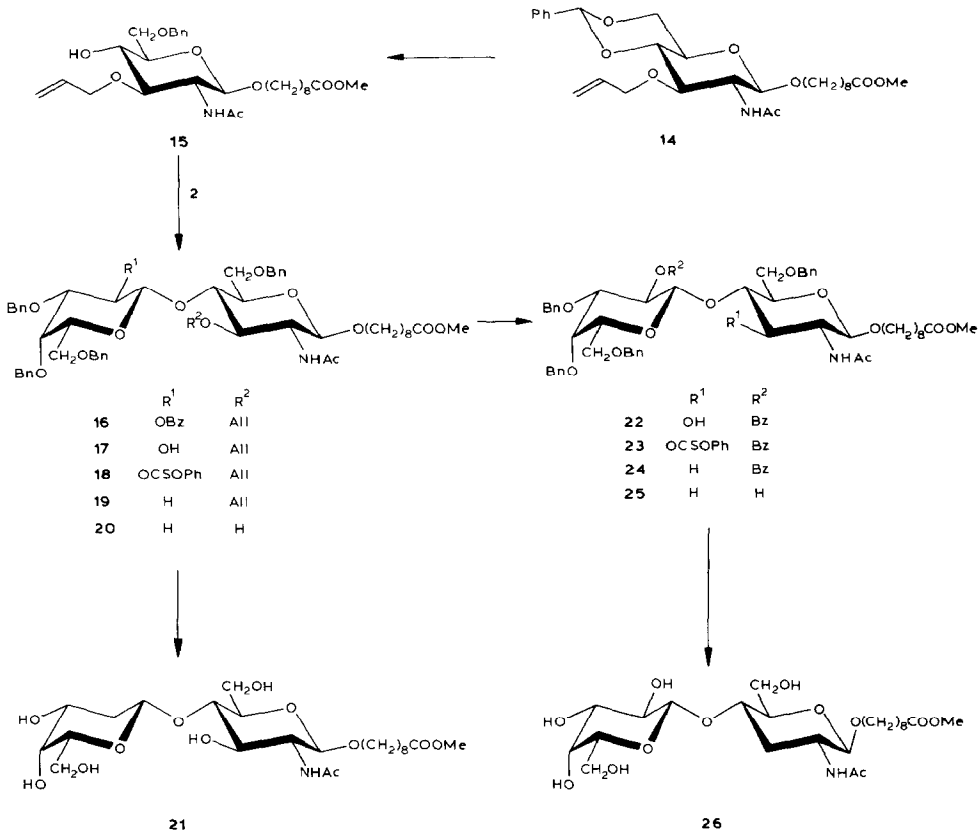
*C. Campbell and P. Stanley, personal communication.

(as for the Lewis gene-associated β-D-*GlcNAc*-(1→4)-α-L-fucosyl transferase, which utilizes *N*-acetyl-lactosamine, lactose, α-L-Fuc-(1→2)-β-D-Gal-(1→4)-D-GlcNAc (H type 2), and α-L-Fuc-(1→2)-β-D-Gal-(1→4)-D-Glc as substrates)[7] the H-related β-D-*Gal*-(1→2)-α-L-fucosyl transferase of H normal nonsecretors has a binding specificity that is primarily restricted to the β-D-Gal unit. It is of interest to note in these regards that, as displayed in Figs. 2 and 3, in all instances, the fucosyl unit is donated to the reacting hydroxyl group on its least sterically hindered side. The polar interaction leading to the GDP-fucose:transferase:disaccharide complex must surely involve both OH-2′ and OH-3′, and perhaps OH-4′, for the β-D-*Gal*-(1→2)-α-L-fucosyl transferase. These observations provide a working hypothesis for the further examination of these enzymic reactions which is being pursued.

RESULTS AND DISCUSSION

Glycosylation of 8-methoxycarbonyloctyl 2-acetamido-4,6-*O*-benzylidene-2-deoxy-β-D-glucopyranoside[23] (**1**) with 2-*O*-benzoyl-3,4,6-tri-*O*-benzyl-α-D-galacto-pyranosyl bromide[24] (**2**) under standard Helferich conditions[23,25] provided 90% of the β-linked disaccharide derivative **3**. This material was used for the preparation of compounds **7** and **13** (having 2′-deoxy and 4-deoxy type 1 structures) by application of the Barton–McCombie reaction[26], as modified by Robins and Wilson[27] for





the deoxygenation of alcohols by reductive cleavage of the corresponding phenylthionocarbonate derivatives.

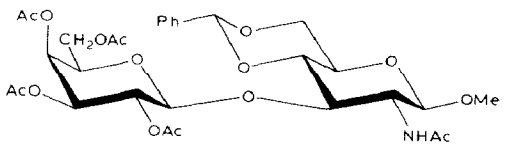
Debenzoylation of **3** provided the alcohol **4**, which reacted with phenyl chlorothionocarbonate, in the presence of 4-dimethylaminopyridine, to give the thionocarbonate **5**. Reduction of **5** with tributylstannane afforded the 2′-deoxy disaccharide derivative **6** (54% from **4**). Removal of the benzyl and benzylidene protecting-groups of **6** by hydrogenolysis over Pd/C then provided the 2′-deoxy type 1 disaccharide, 8-methoxycarbonyloctyl 2-acetamido-2-deoxy-3-*O*-(2-deoxy-β-D-*lyxo*-hexopyranosyl)-β-D-glucopyranoside (**7**).

Preparation of the corresponding 4-deoxy type 1 disaccharide **13** required the liberation of OH-4 of **3** for thionocarbonylation and subsequent deoxygenation. This was conveniently achieved by hydrolysis of the benzylidene ring of **3**, to produce the diol **8** which was then selectively acetylated[23] at the primary position to give **9**. Phenylthionocarbonylation of **9** provided **10** which was reduced to the 4-deoxy-disaccharide derivative **11** (49% from **9**). Deacylation of **11** gave the diol **12** which, on catalytic hydrogenolysis, furnished the 4-deoxy type 1 disaccharide, 8-

methoxycarbonyloctyl 2-acetamido-2,4-dideoxy-3-*O*-(β-D-galactopyranosyl)-β-D-*xylo*-hexopyranoside (**13**).

Preparation of the type-2 deoxy structures, by an approach similar to that described above for the type 1 disaccharides, required a 2-acetamido-2-deoxy-glucose derivative with OH-4 available for glycosylation and a protecting group at position 3 which could be selectively removed at the disaccharide level. Such compounds have now become readily accessible following the demonstration by Garegg and Hultberg[28] that the reductive opening of the 4,6-*O*-benzylidene rings of hexose derivatives by sodium cyanoborohydride under acidic conditions provides, selectively, the corresponding 6-*O*-benzyl-4-hydroxy compounds. Following their procedure, reductive opening of the benzylidene ring of the 3-*O*-allyl structure **14** produced the alcohol **15** (87%). The position of the free hydroxyl group in **15** was established by its reaction with trichloroacetyl isocyanate (TCAI)[29] to provide the urethane derivative for which the signal for H-4 appeared at δ 5.030 ($J_{3,4} = J_{4,5} =$ 9.0 Hz), *i.e.*, >1 p.p.m. downfield from the position of the corresponding signal in the alcohol. Glycosylation of **15** with the galactosyl bromide **2**, in the presence of mercuric cyanide, then afforded the protected type 2 disaccharide **16** (88%). Debenzoylation of **16** gave the alcohol **17**, the thionocarbonate **18** of which was subsequently deoxygenated to give **19** (45% from **17**). Removal[30] of the allyl protecting-group from **19** afforded **20** which, on catalytic hydrogenolysis, gave the 2′-deoxy type 2 structure, 8-methoxycarbonyloctyl 2-acetamido-2-deoxy-4-*O*-(2-deoxy-β-D-*lyxo*-hexopyranosyl)-β-D-glucopyranoside (**21**).

The corresponding 3-deoxy structure **26** was obtained from **16** by selective removal of the 3-*O*-allyl group to provide the alcohol **22** which, on thiocarbonylation and subsequent reduction gave the deoxy derivative **24** (64%). Debenzoylation of **24** followed by hydrogenolysis of the benzyl ether groups furnished the 3-deoxy



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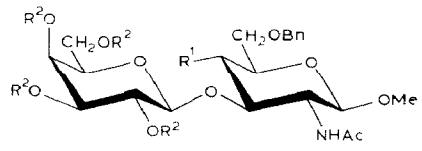
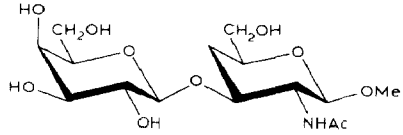


	R^1	R^2
29	OH	Ac
30	OCSOPh	Ac
31	H	Ac
32	H	H



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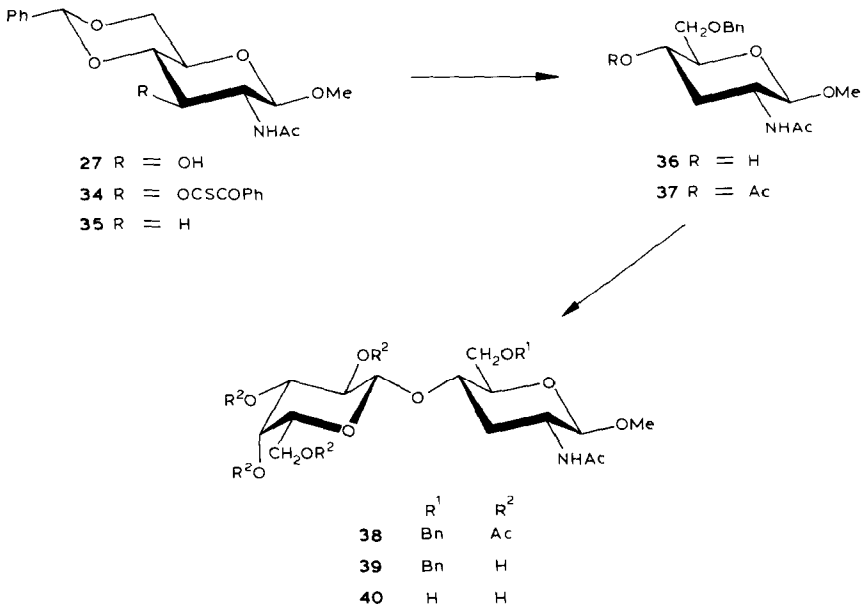

type 2 structure, 8-methoxycarbonyloctyl 2-acetamido-2,3-dideoxy-4-*O*-β-D-galactopyranosyl-β-D-*ribo*-hexopyranoside (**26**).

The synthesis of the 4-deoxy type 1 structure as its methyl glycoside **33** proceeded *via* the disaccharide **28**, which was obtained in 85% yield by reaction of the alcohol **27**[31] with 2,3,4,6-tetra-*O*-acetyl-α-D-galactopyranosyl bromide in the presence of mercuric cyanide. Reductive opening[28] of the benzylidene ring in **28** afforded the 4-hydroxy compound **29** which was deoxygenated *via* its phenylthionocarbonate **30** to give **31** (24% from **29**). Removal of the acetate and benzyl ether protecting-groups from **31** afforded the 4-deoxy type 1 disaccharide, methyl 2-acetamido-2,4-dideoxy-3-*O*-β-D-galactopyranosyl-β-D-*xylo*-hexopyranoside (**33**).

A somewhat different approach was briefly examined for the synthesis of the methyl glycoside of the 3-deoxy type 2 disaccharide **40**. Since the overall yields for the deoxygenation sequence were only moderate and highly variable (24–64%), glycosylation of the appropriate deoxymonosaccharide appeared to offer an attractive alternative route to **40**. Deoxygenation of **27** *via* its phenylthionocarbonate **34** gave the 3-deoxy derivative **35** (66%). Reductive opening of the benzylidene ring in **35** provided the 6-*O*-benzyl-4-hydroxy compound **36** which was treated with 2,3,4,6-tetra-*O*-acetyl-α-D-galactopyranosyl bromide under standard Helferich conditions. The expected β-linked disaccharide derivative **38** was isolated in only 19% yield, the major reaction being *O*-acetylation of **36** to produce **37** (49%). The structure of **37** was evident from its ^{1}H-n.m.r. spectrum and was confirmed by its reversion to **36** on transesterification by methanolic sodium methoxide. Although this well-known side-reaction[32–34] could probably have been suppressed by the use of different conditions in the glycosylation reaction, **38** was obtained in sufficient

quantity and no further reaction conditions were explored. Deprotection of **38** proceeded *via* **39** to provide the 3-deoxy type 2 structure, methyl 2-acetamido-2,3-dideoxy-4-*O*-β-D-galactopyranosyl-β-D-*ribo*-hexopyranoside (**40**).

EXPERIMENTAL

General methods. — All solvents and reagents were purified and dried according to standard procedures[35]. The molecular sieve (B.D.H., 4 Å) was dried for 24 h at 180° just prior to use. Solution transfers were conducted under dry nitrogen by standard syringe techniques[36]. T.l.c. was performed on silica gel 60-F_{254} (Merck) with detection by quenching of fluorescence and/or by charring with sulphuric acid. For column chromatography, the loading was in the range 1:50 to 1:100 on Kieselgel 60 (Merck, 230–400 mesh) and distilled solvents were used to develop the chromatograms. Melting points are uncorrected.

N.m.r. spectra were recorded using a Bruker WH-200, WM-360, or WH-400 instrument for solutions in $CDCl_3$ or Me_2SO-d_6 (internal Me_4Si) or D_2O [internal acetone (2.225 p.p.m.) and 1,4-dioxane (67.4 p.p.m.)]. Optical rotations were determined using a Perkin–Elmer 241 polarimeter at the sodium D-line at 22 ±2°.

8-Methoxycarbonyloctyl 2-acetamido-3-O-(2-O-benzoyl-3,4,6-tri-O-benzyl-β-D-galactopyranosyl)-4,6-O-benzylidene-2-deoxy-β-D-glucopyranoside (**3**). — A solution of 2-*O*-benzoyl-3,4,6-tri-*O*-benzyl-α-D-galactopyranosyl bromide (**2**; 1.66 g, 2.8 mmol) in benzene–nitromethane (1:1, 5 mL) was added to a stirred mixture of **1** (0.67 g, 1.4 mmol), mercuric cyanide (0.7 g, 2.8 mmol), and powdered calcium sulfate (2.2 g) in the same solvent mixture (75 mL). After 30 min, t.l.c. (dichloromethane–methanol, 4:1) indicated the complete disappearance of **2**. The mixture was filtered, insoluble material was washed with dichloromethane (150 mL), and the combined filtrate and washings were washed with aqueous 30% potassium iodide (2 × 100 mL), saturated aqueous sodium hydrogencarbonate (200 mL), and water (200 mL). Removal of the solvent left a white foam (1.9 g) which was purified by column chromatography (dichloromethane–methanol, 4:1) to give, as the major fraction (R_F 0.55), **3** (1.3 g, 90%), m.p. 114–116° (from ethyl acetate–hexane), $[\alpha]_D$ +21° (*c* 1, dichloromethane). N.m.r. data ($CDCl_3$): ^1H, δ 5.570 (dd, 1 H, $J_{1',2'}$ 8.5, $J_{2',3'}$ 10.0 Hz, H-2'), 5.175 (d, 1 H, H-1'), 4.688 (d, 1 H, $J_{1,2}$ 8.5 Hz, H-1); ^{13}C, δ 101.27, 101.07, 99.06 (C-1,1', and Ph*C*H=).

Anal. Calc. for $C_{59}H_{69}NO_{14}$: C, 69.73; H, 6.84; N, 1.38. Found: C, 69.18; H, 6.84; N, 1.52.

8-Methoxycarbonyloctyl 2-acetamido-4,6-O-benzylidene-2-deoxy-3-O-(3,4,6-tri-O-benzyl-β-D-galactopyranosyl)-β-D-glucopyranoside (**4**). — A solution of **3** (1.0 g) in methanolic 0.01M sodium methoxide was kept at 40° for 18 h. Neutralization with Amberlite IR-120(H^+) resin followed by removal of the solvent left a solid residue which was purified by column chromatography (ethyl acetate–hexane, 3:2) to give, as the major fraction, **4** as a white solid (650 mg, 72%). The ^1H-n.m.r. spectrum of **4** was similar to that of **3** except for the signal for H-2' which had moved upfield by >1 p.p.m.

8-Methoxycarbonyloctyl 2-acetamido-4,6-O-benzylidene-2-deoxy-3-O-(3,4,6-tri-O-benzyl-2-O-phenoxythiocarbonyl-β-D-galactopyranosyl)-β-D-glucopyranoside (**5**). — A mixture of **4** (510 mg, 0.56 mmol), 4-dimethylaminopyridine (2.36 g, 19.3 mmol), and phenyl chlorothionocarbonate (1.6 mL, 11.6 mmol) in dry acetonitrile (25 mL) was boiled under reflux for 5 h, and then left at room temperature for 16 h. The mixture was diluted with dichloromethane (75 mL), and washed sequentially with ice-cold 0.5M hydrochloric acid (100 mL), saturated aqueous sodium hydrogencarbonate (100 mL), and water (100 mL). Evaporation of the solvent followed by column chromatography of the residue (ethyl acetate–hexane, 1:1) gave **5** (500 mg, 85%), m.p. 84–85°, $[\alpha]_D$ −29° (*c* 1.4, dichloromethane), R_F 0.53. ^{1}H-N.m.r. data ($CDCl_3$): δ 5.860 (dd, 1 H, $J_{1',2'}$ 8.5, $J_{2',3'}$ 10.0 Hz, H-2′), 5.257 (d, 1 H, H-1′).

Anal. Calc. for $C_{59}H_{69}NO_{14}S$: C, 67.60; H, 6.63; N, 1.34; S, 3.06. Found: C, 67.53; H, 6.70; N, 1.45; S, 3.06.

8-Methoxycarbonyloctyl 2-acetamido-4,6-O-benzylidene-2-deoxy-3-O-(3,4,6-tri-O-benzyl-2-deoxy-β-D-lyxo-hexopyranosyl)-β-D-glucopyranoside (**6**). — A solution of **5** (500 mg, 0.47 mmol) in dry toluene (22 mL) was heated to 80° under nitrogen, and then α,α′-azobisisobutyronitrile (85 mg, 0.51 mmol) was added followed by tributylstannane (1.82 mL, 6.76 mmol). After 2 h at 80°, the mixture was allowed to cool to room temperature and the solvent was evaporated. Column chromatography of the residue (ethyl acetate–hexane, 7:3) provided **6** (274 mg, 64%) as a white solid, m.p. 165–166°, $[\alpha]_D$ −37° (*c* 0.5, dichloromethane), R_F 0.50 (ethyl acetate–hexane, 1:1). N.m.r. data ($CDCl_3$): ^{1}H, δ 5.930 (d, 1 H, $J_{NH,2}$ 7.5 Hz, NH), 5.510 (s, 1 H, PhC*H*), 5.000 (d, 1 H, $J_{1,2}$ 8.5 Hz, H-1), 4.652 (dd, 1 H, $J_{1',2'a}$ 10.0, $J_{1',2'e}$ 2.5 Hz, H-1′), 2.087 (m, 1 H, $J_{2'a,2'e}$ 12.0, $J_{2'a,3'}$ 12 Hz, H-2′*a*), 2.003 (m, 1 H, $J_{2',3'}$ 4.5 Hz, H-2′*e*), 1.800 (s, 3 H, NAc); ^{13}C, δ 101.16, 100.56, 100.31 (C-1,1′ and Ph*C*H=), 32.97 (C-2′).

Anal. Calc. for $C_{52}H_{65}NO_{12}$: C, 69.70; H, 7.31; N, 1.56. Found: C, 69.06; H, 7.14; N, 1.37.

8-Methoxycarbonyloctyl 2-acetamido-2-deoxy-3-O-(2-deoxy-β-D-lyxo-hexopyranosyl)-β-D-glucopyranoside (**7**). — A solution of **6** (274 mg, 0.30 mmol) in aqueous 95% ethanol (26 mL) containing 5% Pd/C (540 mg) was hydrogenated at 100 p.s.i. for 60 h at room temperature. The catalyst was collected on Celite and washed with several portions of hot aqueous 95% ethanol, and the combined filtrates and washings were concentrated to dryness. The product was precipitated from methanol–ethyl acetate, and then eluted from a column of Biogel-P2 with aqueous 10% ethanol to give **7** (66 mg, 51%) as the major fraction, m.p. 197–199° (from methanol), $[\alpha]_D$ −31° (*c* 0.8, water). N.m.r. data (D_2O): ^{1}H, δ 4.708 (dd, 1 H, $J_{1',2'a}$ 10.0, $J_{1',2'e}$ 2.0 Hz, H-1′), 4.560 (d, 1 H, $J_{1,2}$ 8.5 Hz, H-1), 3.950–3.820 (m, 3 H, including H-6 at 3.920, $J_{6a,b}$ 12.0, $J_{5,6}$ 2.0 Hz, and H-3′ at 3.865), 3.810–3.720 (m, 5 H, including H-4′ at 3.763, $J_{3',4'}$ 3.5 Hz, and H-2,3,6′a,6′b), 3.650–3.561 (m, 3 H, including H-5′), 3.541–3.414 (m, 2 H, including H-4 at 3.500, $J_{4,5} = J_{3,4} = 9.0$ Hz, and H-5 at 3.473), 1.911 (ddd, 1 H, $J_{2'e,2'a}$ 12.0, $J_{2'e,3'}$ 5.0, $J_{2'e,1'}$ 2.0 Hz, H-2′*e*),

1.684 (ddd, 1 H, $J_{2'e,2'a}$ 12.5, $J_{2'a,3'}$ 12.5, $J_{2'a,1'}$ 10.0 Hz, H-2'*a*). ^{13}C, δ 174.82 (C=O), 101.74 and 101.44 (C-1,1'), 83.64, 76.42, 76.35, 71.27, 69.55, 68.60, 67.59, 62.27, 61.67, 55.62, 52.89 (OMe), 34.64 (C-2'), 34.53, 29.38, 29.13, 28.98, 25.85, 25.12, 22.95 ($NHCOCH_3$).

*8-Methoxycarbonyloctyl 2-acetamido-3-*O*-(2-*O*-benzoyl-3,4,6-tri-*O*-benzyl-β-*D*-galactopyranosyl)-2-deoxy-β-*D*-glucopyranoside* (**8**). — A solution of **3** (1.8 g, 1.77 mmol) in acetic acid–water (9:1, 100 mL) was kept at 70° for 2 h. Removal of the solvent left a residue which was precipitated with ethyl acetate–hexane to give **8** (1.5 g, 91%), m.p. 193–194°, $[\alpha]_D$ +29.5° (*c* 0.98, dichloromethane). ^{1}H-N.m.r. data ($CDCl_3$): δ 5.625 (dd, 1 H, $J_{1',2'}$ 8.5, $J_{2',3'}$ 10.0 Hz, H-2'), 5.325 (d, 1 H, $J_{NH,2}$ 7.0 Hz, NH), 5.030 (d, 1 H, $J_{1',2'}$ 8.5 Hz, H-1'), 1.240 (s, 3 H, NAc).

Anal. Calc. for $C_{52}H_{65}NO_{14}$: C, 67.29; H, 7.06; N, 1.51. Found: C, 67.68; H, 7.26; N, 1.40.

*8-Methoxycarbonyloctyl 2-acetamido-6-*O*-acetyl-3-*O*-(2-*O*-benzoyl-3,4,6-tri-*O*-benzyl-β-*D*-galactopyranosyl)-2-deoxy-β-*D*-glucopyranoside* (**9**). — A solution of acetyl chloride (1.0 mL, 14.76 mmol) in dichloromethane (12 mL) was added dropwise at −75° during 2 h to a stirred solution of **8** (1.3 g, 1.5 mmol) and pyridine (1.15 mL, 14.72 mmol) in dichloromethane (23 mL). The mixture was then poured into water (75 mL) and extracted with dichloromethane (75 mL). The extract was washed with water (2 × 75 mL) and concentrated, and the product was subjected to column chromatography (ethyl acetate–hexane, 1:1 and then 7:3) to give, as the main fraction, **9** (1.0 g, 73%), m.p. 175–176°, $[\alpha]_D$ +26° (*c* 0.9, dichloromethane). ^{1}H-N.m.r. data ($CDCl_3$): δ 5.630 (dd, 1 H, $J_{1',2'}$ 8.5, $J_{2',3'}$ 10.0 Hz, H-2'), 4.995 (d, 1 H, $J_{1',2'}$ 8.5 Hz, H-1'). 2.060 (s, 3 H, OAc), 1.220 (s, 3 H, NAc).

Anal. Calc. for $C_{54}H_{67}NO_{15}$: C, 66.86; H, 6.96; N, 1.44. Found: C, 67.00; H, 6.92; N, 1.44.

*8-Methoxycarbonyloctyl 2-acetamido-6-*O*-acetyl-3-*O*-(2-*O*-benzoyl-3,4,6-tri-*O*-benzyl-β-*D*-galactopyranosyl)-2-deoxy-4-*O*-phenoxythiocarbonyl-β-*D*-glucopyranoside* (**10**). — Compound **9** (575 mg, 0.59 mmol) was treated with phenyl chlorothionocarbonate (1.79 mL, 12.9 mmol) as described for the preparation of **5**. The product was subjected to column chromatography (ethyl acetate–hexane, 3:2). Concentration of the appropriate fractions (R_F 0.65) gave **10** (506 mg, 77%), $[\alpha]_D$ +30° (*c* 0.47, dichloromethane). ^{1}H-N.m.r. data ($CDCl_3$): δ 5.530 (2 dd, 2 H, H-2',4), 5.375 (d, 1 H, $J_{NH,2}$ 8.0 Hz, NH), 5.047 (d, 1 H, $J_{1',2'}$ 8.5 Hz, H-1'), 2.040 (s, 3 H, OAc), 1.560 (s, 3 H, NAc).

*8-Methoxycarbonyloctyl 2-acetamido-6-*O*-acetyl-3-*O*-(2-*O*-benzoyl-3,4,6-tri-*O*-benzyl-β-*D*-galactopyranosyl)-2,4-dideoxy-β-*D*-xylo-hexopyranoside* (**11**). — Compound **10** (506 mg, 0.45 mmol) was deoxygenated as described for the preparation of **6**, to give **11** (269 mg, 61%), isolated by column chromatography (dichloromethane–methanol, 49:1), m.p. 176–178°, $[\alpha]_D$ +20° (*c* 0.49, dichloromethane). ^{1}H-N.m.r. data ($CDCl_3$): δ 5.575 (dd, 1 H, $J_{1',2'}$ 8.5, $J_{2',3'}$ 10.0 Hz, H-2'), 5.367 (d, 1 H, $J_{NH,2}$ 6.5 Hz, NH), 4.945 (d, 1 H, $J_{1',2'}$ 8.5 Hz, H-1'), 4.570 (d, 1 H, $J_{1,2}$ 8.5 Hz, H-1), 2.150 (m, 1 H, $J_{4a,4e}$ 13.0 Hz, H-4*e*), 2.022 (s, 3 H, OAc), 1.600 (m, 3 H including H-4*a*), 1.340 (s, 3 H, NAc).

Anal. Calc. for $C_{54}H_{67}NO_{16}$: C, 65.77; H, 6.85; N, 1.42. Found: C, 66.28; H, 6.80; N, 1.35.

8-Methoxycarbonyloctyl 2-acetamido-2,4-dideoxy-3-O-(β-D-galactopyranosyl)-β-D-xylo-hexopyranoside (**13**). — Compound **11** was treated with methanolic 0.5M sodium methoxide for 6 days at room temperature. The mixture was neutralized with Amberlite IR-120(H^+) resin, the methanol was evaporated, and the residue was eluted from a short column of silica gel using dichloromethane–methanol (49:1). The early fractions (R_F 0.28; 16 mg, 6%) consisted of the intermediate which still retained the 2′-benzoate group, as evidenced by the n.m.r. signal for H-2′ at 5.570 ($J_{1',2'}$ 8.2, $J_{2',3'}$ 10.0 Hz), but which lacked the 6-*O*-acetyl group. Concentration of the later fractions (R_F 0.20) provided 8-methoxycarbonyloctyl 2-acetamido-2,4-dideoxy-3-*O*-(3,4,6-tri-*O*-benzyl-β-D-galactopyranosyl)-β-D-*xylo*-hexopyranoside (**12**; 161 mg, 70%). Compound **12** was hydrogenolysed over 5% Pd/C (300 mg) under the conditions described for the preparation of **7**, to give **13** (96 mg, 89% from **12**) as a white lyophilyzed powder after chromatography on Biogel-P2; m.p. 180–181°, $[\alpha]_D$ −7° (*c* 1.1, water). N.m.r. data (D_2O): ^1H, δ 4.452 (d, 1 H, $J_{1,2}$ 8.5 Hz, H-1), 4.440 (d, 1 H, $J_{1',2'}$ 8.0 Hz, H-1′), 3.983–3.847 (m, 3 H, including H-4′ at 3.902, $J_{3',4'}$ 3.0 Hz, and H-3), 3.800–3.538 (m, 12 H, including OMe at 3.684, H-5 at 3.673, H-3′ at 3.600, $J_{2',3'}$ 10.5, $J_{3',4'}$ 3.5 Hz, and H-2,6a,b,6′a,b), 3.469 (dd, 1 H, $J_{2',3'}$ 10.0, $J_{1',2'}$ 8.0 Hz, H-2′), 2.220 (ddd, 1 H, $J_{4a,4e}$ 12.0, $J_{4e,3}$ 5.0, $J_{4e,5}$ 2.0 Hz, H-4*e*), 1.515 (m, 5 H, including H-4*a* at 1.515, *J* 12.0 and 11.5 Hz); ^{13}C, δ 178.60 and 175.27 (2 C=O), 105.12 and 102.16 (C-1,1′), 78.68, 75.88, 73.45, 73.17, 71.51, 71.16, 69.38, 64.49, 61.78, 56.61, 52.88 (OMe), 35.37 (C-4), 34.54, 29.43, 29.14, 28.99, 25.85, 25.12, 23.14 ($NHCOCH_3$).

8-Methoxycarbonyloctyl 2-acetamido-3-O-allyl-6-O-benzyl-2-deoxy-β-D-glucopyranoside (**15**). — To a solution at 0° of **14** (2.5 g, 5 mmol) and sodium cyanoborohydride (2.84 g, 45 mmol) in dry tetrahydrofuran (75 mL) containing 3 Å molecular sieve (10 g) and a crystal of Methyl Orange indicator was added saturated ethereal hydrogen chloride dropwise until the solution became acidic (color change yellow to pink). Addition was then continued very slowly until t.l.c. indicated the complete disappearance of **14**. At this time (usually 0.5 h), the mixture was diluted with dichloromethane (200 mL), insoluble material was collected on Celite and washed with dichloromethane, and the combined filtrate and washings were washed with saturated aqueous sodium hydrogencarbonate (2 × 150 mL) and then with water (200 mL), and concentrated *in vacuo*. The residue was purified by column chromatography (dichloromethane–methanol, 19:1) to give **15** as a white solid (2.18 g, 87%), m.p. 105–106°, $[\alpha]_D$ −25° (*c* 0.43, dichloromethane). ^1H-N.m.r. data ($CDCl_3$): δ 4.903 (d, 1 H, $J_{1,2}$ 8.0 Hz, H-1), 4.590 (AB, 2 H, J_{AB} 12 Hz, OCH_2Ph). Addition of trichloroacetyl isocyanate to the n.m.r. tube resulted in a new spectrum in which the signal for H-4 was shifted downfield to δ 5.030 ($J_{3,4} = J_{4,5} = 9.0$ Hz).

Anal. Calc. for $C_{28}H_{43}NO_8$: C, 64.47; H, 8.31; N, 2.68. Found: C, 64.62; H, 8.15; N, 2.69.

8-Methoxycarbonyloctyl 2-acetamido-3-O-allyl-4-O-(2-O-benzoyl-3,4,6-tri-O-benzyl-β-D-galactopyranosyl)-6-O-benzyl-2-deoxy-β-D-glucopyranoside (**16**). — A solution of the bromide **2** (4.8 g, 8.4 mmol) in benzene–nitromethane (1:1, 20 mL) was added with stirring to a mixture of **15** (2.13 g, 4.2 mmol), mercuric cyanide (2.33 g, 9.24 mmol), and 4 Å molecular sieve (5 g) in the same solvent mixture (50 mL). After stirring for 16 h at room temperature, the mixture was diluted with dichloromethane and washed sequentially with aqueous 30% potassium bromide (300 mL), saturated aqueous sodium hydrogencarbonate (300 mL), and water, and then concentrated. The syrupy residue was purified by column chromatography (ethyl acetate–hexane, 1:1) to give, as the major fraction (R_F 0.62, ethyl acetate–hexane, 3:2), **16** as a white powder (3.6 g, 88%), m.p. 65–66°, $[\alpha]_D$ −5° (*c* 1, dichloromethane). N.m.r. data ($CDCl_3$): ^1H, δ 6.165 (d, 1 H, $J_{NH,2}$ 9.0 Hz, NH), 5.795 (m, 1 H, $OCH_2CH{=}CH_2$), 5.575 (dd, 1 H, $J_{1',2'}$ 8.5, $J_{2',3'}$ 10.0 Hz, H-2'), 5.175 and 5.053 (2 m, 2 H, $C{=}CH_2$), 4.060 (d, 1 H, $J_{3',4'}$ 2.5 Hz, H-4'), 2.037 (s, 3 H, NAc); ^{13}C, δ 100.67 and 99.3 (C-1,1').

Anal. Calc. for $C_{62}H_{75}NO_{14}$: C, 70.37; H, 7.14; N, 1.32. Found: C, 70.09; H, 7.27; N, 1.28.

8-Methoxycarbonyloctyl 2-acetamido-3-O-allyl-6-O-benzyl-2-deoxy-4-O-(3,4,6-tri-O-benzyl-β-D-galactopyranosyl)-β-D-glucopyranoside (**17**). — A solution of **16** (1.0 g, 0.94 mmol) in methanolic 0.01M sodium methoxide was kept for 6 days at room temperature. T.l.c. then showed that debenzoylation was essentially complete. After neutralization with Amberlite IR-120 (H^+) resin and evaporation of the solvent, the residue was eluted from a short column of silica gel using ethyl acetate–hexane (3:2). Concentration of the appropriate fractions provided **17** (765 mg, 85%), m.p. 69–70°, $[\alpha]_D$ +1.2° (*c* 0.65, dichloromethane).

Anal. Calc. for $C_{55}H_{71}NO_{13}$: C, 69.23; H, 7.50; N, 1.47. Found: C, 69.01; H, 7.50; N, 1.51.

8-Methoxycarbonyloctyl 2-acetamido-3-O-allyl-6-O-benzyl-2-deoxy-4-O-(3,4,6-tri-O-benzyl-2-O-phenoxythiocarbonyl-β-D-galactopyranosyl)-β-D-glucopyranoside (**18**). — Crude **17** (765 mg, 0.8 mmol) was acylated using phenyl chlorothionocarbonate (16.2 mmol) under the conditions described for the preparation of **5**. Column chromatography of the crude product (ethyl acetate–hexane, 1:1) gave, as the major fraction, **18** (700 mg, 79%), m.p. 104° (from ethyl acetate–hexane), $[\alpha]_D$ −23° (*c* 1.3, dichloromethane). ^1H-N.m.r. data ($CDCl_3$): δ 5.952 (d, 1 H, $J_{NH,2}$ 9.0 Hz, NH), 5.895 (dd, 1 H, $J_{1',2'}$ 8.5, $J_{2',3'}$ 10.0 Hz, H-2'), 5.810 (m, 1 H, $OCH_2CH{=}CH_2$), 1.880 (s, 3 H, NAc).

Anal. Calc. for $C_{62}H_{75}NO_{14}S$: C, 68.30; H, 6.93; N, 1.28; S, 2.94. Found: C, 68.34; H, 6.93; N, 1.33; S, 2.74.

8-Methoxycarbonyloctyl 2-acetamido-6-O-benzyl-2-deoxy-4-O-(3,4,6-tri-O-benzyl-2-deoxy-β-D-lyxo-hexopyranosyl)-β-D-glucopyranoside (**20**). — Compound **18** (700 mg, 0.71 mmol) was reduced with tributylstannane (9.4 mmol) as described for the preparation of **6**. Column chromatography of the products (ethyl acetate–hexane, 7:3) provided **19** (340 mg, 57%; R_F 0.50, dichloromethane–ethyl acetate–

hexane–ethanol, 10:5:5:2) contaminated by small amounts of a co-migrating compound. A sample, purified by preparative t.l.c. (dichloromethane–methanol, 19:1), was obtained as an amorphous white solid, m.p. 51–52°, $[\alpha]_D$ −17° (*c* 0.82, dichloromethane). N.m.r. data ($CDCl_3$): ^1H, δ 5.900 (d, 1 H, $J_{NH,2}$ 7.5 Hz, NH), 4.797 (d, 1 H, $J_{1,2}$ 7.0 Hz, H-1), 4.530 (dd, 1 H, $J_{1',2'a}$ 9.0, $J_{1',2'e}$ 2.5 Hz, H-1'), 2.070–1.937 (m, 2 H, H-2'*a*,2'*e*); ^{13}C, δ 100.54, 99.85 (C-1,1'), 33.22 (C-2'), 23.50 ($NCOCH_3$).

Anal. Calc. for $C_{55}H_{71}NO_{12}$: C, 70.41; H, 7.63; N, 1.49. Found: C, 70.18; H, 7.59; N, 1.56.

A solution of the remaining impure **19** in ethanol–benzene–water (7:3:1, 14 mL) containing tris(triphenylphosphine)rhodium(I) chloride (34 mg) was boiled under reflux for 16 h. Evaporation of the solvent then left a residue which was dissolved in acetone (3 mL) containing a trace amount of mercuric oxide, and a solution of mercuric chloride (200 mg) in acetone–water (9:1, 2 mL) was added. After 30 min at room temperature, the mixture was concentrated, and a solution of the residue in dichloromethane (50 mL) was washed sequentially with aqueous 30% potassium bromide and water, and then concentrated. The syrup was purified by column chromatography (ethyl acetate–hexane, 7:3) to give, as the major fraction (R_F 0.34, dichlormethane–ethyl acetate–hexane–ethanol, 10:5:5:2), a product (200 mg, 35% from **18**) which crystallized from ethyl acetate–hexane–ether as white needles of **20**, m.p. 88–90°, $[\alpha]_D$ −14° (*c* 0.88, dichloromethane). ^1H-N.m.r. data ($CDCl_3$): δ 5.625 (d, 1 H, $J_{NH,2}$ 7.5 Hz, NH), 4.805 (d, 1 H, $J_{1,2}$ 8.5 Hz, H-1), 4.328 (d, 1 H, $J_{1',2'a}$ 10 Hz, H-1'), 2.015 (m, 1 H, H-2'*a*), 1.962 (s, 3 H, NAc).

*8-Methoxycarbonyloctyl 2-acetamido-2-deoxy-4-*O*-(2-deoxy-β-*D*-lyxo-hexopyranosyl)-β-*D*-glucopyranoside* (**21**). — A solution of **20** (190 mg, 0.23 mmol) in aqueous 95% ethanol (19 mL) containing 5% Pd/C (380 mg) was hydrogenated at 100 p.s.i. for 60 h. The mixture was then filtered and concentrated, and the product was obtained as a white solid by precipitation from methanol–ethyl acetate. Elution of this material from a column of Biogel P-2, using water–ethanol (9:1), followed by lyophilization of the appropriate fractions provided **21** as a white powder (62 mg, 60%), m.p. 197–198°, $[\alpha]_D$ −14° (*c* 0.38, water). N.m.r. data (D_2O): ^1H, δ 4.718 (dd, 1 H, $J_{1',2'a}$ 9.5, $J_{1',2'e}$ 2.0 Hz, H-1'), 4.511 (d, 1 H, $J_{1,2}$ 8.2 Hz, H-1), 3.930–3.860 (m, 4 H, including H-4' at 3.910, $J_{3',4'}$ 3.5 Hz, and H-3",6), 3.828–3.650 (m, 9 H, including OMe at 3.691 and H-2,3,4,6,6'*a*,6'*b*), 3.650–3.553 (m, 2 H, including H-5'), 3.523 (m, 1 H, H-5), 2.085 (ddd, 1 H, $J_{2'e,2'a}$ 12.5, $J_{2'e,3'}$ 5.0, $J_{2'e,1'}$ 2.0 Hz, H-2'*e*), 1.698 (ddd, 1 H, $J_{2'e,2'a}$ 12.0, $J_{2'a,3'}$ 12.0, $J_{2'a,1'}$ 9.5 Hz, H-2'*a*); ^{13}C, δ 175.09 (C=O), 101.88 and 101.24 (C-1,1'), 79.46, 76.44, 75.51, 73.28, 71.33, 68.52, 67.54, 62.20, 61.14, 56.03, 52.87 (OCH_3), 34.52, 34.32 (C-2'), 29.36, 29.09, 28.95, 25.80, 25.10, 23.06 ($NHCOCH_3$).

*8-Methoxycarbonyloctyl 2-acetamido-4-*O*-(2-*O*-benzoyl-3,4,6-tri-*O*-benzyl-β-*D*-galactopyranosyl)-6-*O*-benzyl-2-deoxy-β-*D*-glucopyranoside* (**22**). — A solution of **16** (800 mg, 0.78 mmol) and tris(triphenylphosphine)rhodium(I) chloride (80 mg) in ethanol–benzene–water (7:3:1, 44 mL) was boiled under reflux for 16 h.

After evaporation of the solvent, the residue was dissolved in acetone (10 mL) containing a trace of mercuric oxide, and a solution of mercuric chloride (800 mg) in acetone–water (9:1, 8 mL) was added. After 30 min at room temperature, the solvent was evaporated, and a solution of the residue in dichloromethane (100 mL) was washed sequentially with aqueous 30% potassium bromide and water, and then concentrated. Column chromatography (ethyl acetate–hexane, 7:3) of the residue provided **22** (450 mg, 59%), m.p. 122–123°, $[\alpha]_D$ +18° (*c* 2.25, dichloromethane). ^{1}H-N.m.r. data ($CDCl_3$): δ 5.642 (dd, 1 H, $J_{1',2'}$ 8.2, $J_{2',3'}$ 10.0 Hz, H-2'), 5.560 (d, 1 H, $J_{NH,2}$ 8.0 Hz, NH), 1.960 (s, 3 H, NAc), 1.730 (b, 1 H, OH); there were no signals corresponding to the allyl group.

Anal. Calc. for $C_{59}H_{71}NO_{14}$: C, 69.60; H, 7.03; N, 1.37. Found: C, 69.94; H, 6.88; N, 1.24.

*8-Methoxycarbonyloctyl 2-acetamido-4-O-(2-O-benzoyl-3,4,6-tri-O-benzyl-β-*D*-galactopyranosyl)-6-O-benzyl-2-deoxy-3-O-phenoxythiocarbonyl-β-*D*-glucopyranoside* (**23**). — Compound **22** (430 mg, 0.47 mmol) was treated with phenyl chlorothionocarbonate (9.28 mmol) as described for the preparation of **5**. The crude product was purified by column chromatography (ethyl acetate–hexane, 3:2) to provide **23** (411 mg, 83%) as an amorphous solid, m.p. 98–100°, $[\alpha]_D$ −1.7° (*c* 0.36, dichloromethane). ^{1}H-N.m.r. data ($CDCl_3$): δ 5.852 (d, 1 H, $J_{NH,2}$ 8.5 Hz, NH), 5.675 (dd, 1 H, *J* 7.5 and 8.5 Hz, H-3), 5.580 (dd, 1 H, $J_{1',2'}$ 8.2, $J_{2',3'}$ 10.0 Hz, H-2'), 1.970 (s, 3 H, NAc).

Anal. Calc. for $C_{66}H_{75}NO_{15}S$: C, 68.67; H, 6.55; N, 1.21; S, 2.78. Found: C, 68.35; H, 6.69; N, 1.35; S, 2.88.

*8-Methoxycarbonyloctyl 2-acetamido-4-O-(2-O-benzoyl-3,4,6-tri-O-benzyl-β-*D*-galactopyranosyl)-6-O-benzyl-2,3-dideoxy-β-*D*-ribo-hexopyranoside* (**24**). — Compound **23** (400 mg, 0.38 mmol) was deoxygenated by treatment with tributylstannane as described for the preparation of **6**. Purification of the crude product by column chromatography (ethyl acetate–hexane, 7:3) provided **24** (270 mg, 77%) which crystallized from dichloromethane; m.p. 112–114°, $[\alpha]_D$ −2.1° (*c* 1.79, dichloromethane). N.m.r. data ($CDCl_3$): ^{1}H, δ 6.668 (d, 1 H, $J_{NH,2}$ 9.0 Hz, NH), 5.628 (dd, 1 H, $J_{1',2'}$ 8.2, $J_{2',3'}$ 10.0 Hz, H-2'), 3.940 (m, 1 H, H-2), 2.187 (m, 1 H, $J_{3a,3e}$ 14.0, $J_{2,3e}$ 4.0 Hz, H-3*e*), 2.064 (s, 3 H, NAc), 1.780 (m, 1 H, H-3*a*); ^{13}C, δ 100.27, 99.94 (C-1,1'), 45.78 (C-2), 26.47 (C-3).

Anal. Calc. for $C_{59}H_{71}NO_{13}$: C, 70.71; H, 7.14; N, 1.40. Found: C, 70.30; H, 7.24; N, 1.60.

*8-Methoxycarbonyloctyl 2-acetamido-6-O-benzyl-2,3-dideoxy-4-O-(3,4,6-tri-O-benzyl-β-*D*-galactopyranosyl)-β-*D*-ribo-hexopyranoside* (**25**). — Compound **24** (270 mg, 0.30 mmol) was debenzoylated as described for the preparation of **12**. The product was purified by column chromatography (dichloromethane–methanol, 49:1) to provide **25** as a white solid (205 mg, 86%). ^{1}H-N.m.r. data ($CDCl_3$): δ 6.470 (d, 1 H, $J_{NH,2}$ 8.0 Hz, NH), 4.354 (d, 1 H, $J_{1,2}$ 8.0 Hz, H-1), 3.916 (m, 1 H, H-2), 2.659 (b, 1 H, OH), 2.375 (m, 3 H, CH_2COOMe and H-3*e*), 1.916 (s, 3 H, NAc), 1.854 (m, 1 H, $J_{3a,3e}$ 13 Hz, H-3*a*).

8-Methoxycarbonyloctyl 2-acetamido-2,3-dideoxy-4-O-β-D-galactopyranosyl-β-D-ribo-hexopyranoside (**26**). — Hydrogenolysis of **25** (206 mg, 0.25 mmol), as described for the preparation of **7**, and chromatography of the product on Biogel P-2 gave **26** as a white powder isolated by lyophilization (96 mg, 86%); m.p. 212–213°, $[\alpha]_D$ −20° (*c* 1, water). N.m.r. data (D_2O): ^1H, δ 4.489 (d, 1 H, $J_{1,2}$ 8.5 Hz, H-1), 4.462 (d, 1 H, $J_{1',2'}$ 8.0 Hz, H-1'), 3.990–3.862 (m, 3 H, including H-6a at 3.959, $J_{6a,b}$ 11.5, $J_{5,6}$ 2.3 Hz, H-4' at δ 3.930, $J_{3',4'}$ 3.5 Hz), 3.842–3.737 (m, 4 H, including H-2,4,6b), 3.731–3.553 (m, 8 H, including OMe at 3.704, H-3' at 3.648, $J_{2',3'}$ 10.0, $J_{3',4'}$ 3.5 Hz, and H-5,5'), 3.500 (dd, 1 H, $J_{2',3'}$ 10.0, $J_{1',2'}$ 8.0 Hz, H-2'), 2.491 (ddd, 1 H, $J_{3a,3e}$ 12.5, $J_{3e,2}$ 5.0, $J_{3e,4}$ 4.0 Hz, H-3*e*), 1.678 (ddd, 1 H, $J_{3a,3e}$ 12.5 Hz, *J* 12.0 and 11.5 Hz, H-3*a*); ^{13}C, δ 178.62 and 174.84 (2 C=O), 104.55 and 103.46 (C-1,1'), 79.26, 75.92, 74.65, 73.51, 71.72, 70.97, 69.35, 61.68, 61.53, 52.88 (OMe), 49.66, 36.19 (C-3), 34.53, 29.39, 29.12, 28.99, 25.85, 25.12, 22.92 ($NHCOCH_3$).

Methyl 2-acetamido-4,6-O-benzylidene-2-deoxy-3-O-(2,3,4,6-tetra-O-acetyl-β-D-galactopyranosyl)-β-D-glucopyranoside (**28**). — A solution of tetra-*O*-acetyl-α-D-galactopyranosyl bromide (1.60 g, 3.8 mmol) in 1:1 benzene–nitromethane (5 mL) was added to a stirred mixture of methyl 2-acetamido-4,6-*O*-benzylidene-2-deoxy-β-D-glucopyranoside (**27**, 1.0 g, 3.24 mmol), mercuric cyanide (1.61 g, 6.4 mmol), and powdered calcium sulfate (5.0 g) in the same solvent mixture (100 mL). After stirring for 16 h at 40°, the mixture was diluted with dichloromethane (200 mL), washed sequentially with aqueous 30% potassium bromide (300 mL), saturated aqueous sodium hydrogencarbonate (500 mL), and water, and then concentrated. The syrupy residue was purified by column chromatography (dichloromethane–methanol, 98:2) to give, as the major fraction, **28** obtained as a white solid (1.75 g, 84.5%) from hot ethyl acetate; m.p. 289–291°, $[\alpha]_D$ −28° (*c* 1, dichloromethane). N.m.r. data ($CDCl_3$): ^1H, δ 5.810 (d, 1 H, $J_{NH,2}$ 7.0 Hz, NH), 5.545 (s, 1 H, PhC*H*), 5.314 (dd, 1 H, $J_{3',4'}$ 3.5 Hz, H-4'), 5.170 (dd, 1 H, $J_{1',2'}$ 8.0, $J_{2',3'}$ 10.5 Hz, H-2'), 5.115 (d, 1 H, $J_{1,2}$ 7.8 Hz, H-1), 4.950 (dd, 1 H, $J_{2',3'}$ 10.5, $J_{3',4'}$ 3.5 Hz, H-3'), 4.793 (d, 1 H, $J_{1',2'}$ 8.0 Hz, H-1'), 3.512 (s, 3 H, OMe), 3.06 (m, 1 H, H-2); ^{13}C, δ 101.59, 100.41, 100.17 (C-1,1' and PhCH=), 23.72 ($NHCOCH_3$), 20.55 ($OCOCH_3$).

Anal. Calc. for $C_{30}H_{39}NO_{15}$: C, 55.13; H, 6.01; N, 2.14. Found: C, 55.17; H, 6.08; N, 2.24.

Methyl 2-acetamido-6-O-benzyl-2-deoxy-3-O-(2,3,4,6-tetra-O-acetyl-β-D-galactopyranosyl)-β-D-glucopyranoside (**29**). — Reductive opening of the benzylidene ring in **28** was accomplished as described for the preparation of **15**. The crude product was purified by column chromatography (dichloromethane–methanol, 98:2) to give, as the major fraction, **29** isolated as a white solid (1.1 g, 73%), m.p. 137–138°, $[\alpha]_D$ +6° (*c* 1.39, dichloromethane). ^1H-N.m.r. data ($CDCl_3$): δ 5.890 (d, 1 H, $J_{NH,2}$ 7.0 Hz, NH), 5.385 (d, 1 H, $J_{3',4'}$ 3.5 Hz, H-4'), 5.230 (dd, 1 H, $J_{1',2'}$ 8.0, $J_{2',3'}$ 10.0 Hz, H-2'), 5.020 (dd, 1 H, $J_{2',3'}$ 10.0, $J_{3',4'}$ 3.5 Hz, H-3'), 4.765 (d, 1 H, $J_{1',2'}$ 8.0 Hz, H-1'), 3.520 (s, 3 H, OMe), 3.175 (m, 1 H, H-2). Addition of

trichloroacetyl isocyanate directly to the n.m.r. tube led to a new spectrum where the signal for H-4 was shifted downfield to δ 5.040 (m, 3 H, H-2′,3′,4).

Anal. Calc. for $C_{30}H_{41}NO_{15}$: C, 54.96; H, 6.30; N, 2.1. Found: C, 54.91; H, 6.37; N, 2.23.

Methyl 2-acetamido-6-O-benzyl-2-deoxy-4-O-phenoxythiocarbonyl-3-O-(2,3,4,6-tetra-O-acetyl-β-D-galactopyranosyl)-β-D-glucopyranoside (**30**). — Phenoxythiocarbonylation of **29** (633 mg, 0.98 mmol), as described for the preparation of **5**, and purification of the crude product by column chromatography (dichloromethane–methanol, 49:1) provided **30** as a pale-yellow solid (250 mg, 32%), m.p. 97–99°, $[\alpha]_D$ +1° (*c* 0.96, dichloromethane). ^{1}H-N.m.r. data ($CDCl_3$): δ 5.745 (d, 1 H, $J_{NH,2}$ 8.0 Hz, NH), 5.572 ($J_{3,4} = J_{4,5}$ = 7.0 Hz, H-4), 5.372 (dd, 1 H, $J_{3',4'}$ 3.5 Hz, H-4′), 5.167 (dd, 1 H, $J_{1',2'}$ 8.0, $J_{2',3'}$ 10.5 Hz, H-2′), 5.020 (dd, 1 H, $J_{2',3'}$ 10.5, $J_{3',4'}$ 3.5 Hz, H-3′), 4.800 (d, 1 H, $J_{1,2}$ 6.0 Hz, H-1), 4.687 (d, 1 H, $J_{1',2'}$ 8.0 Hz, H-1′), 4.600 (ABq, 2 H, J_{AB} 12.0 Hz, OCH_2Ph), 3.495 (s, 3 H, OMe).

Methyl 2-acetamido-6-O-benzyl-2,4-dideoxy-3-O-(2,3,4,6-tetra-O-acetyl-β-D-galactopyranosyl)-β-D-xylo-hexopyranoside (**31**). — Deoxygenation of **30** (250 mg, 0.31 mmol), as described for the preparation of **6**, and column chromatography (ethyl acetate–hexane, 7:3) of the crude product gave **31** (150 mg, 74.2%) as a white solid, m.p. 91–92°, $[\alpha]_D$ −10° (*c* 0.32, dichloromethane). N.m.r. data ($CDCl_3$): ^{1}H, δ 5.610 (d, 1 H, $J_{NH,2}$ 7.0 Hz, NH), 5.367 (d, 1 H, $J_{3',4'}$ 3.5 Hz, H-4′), 5.167 (dd, 1 H, $J_{1',2'}$ 8.0, $J_{2',3'}$ 10.5 Hz, H-2′), 4.987 (dd, 1 H, $J_{2',3'}$ 10.5, $J_{3',4'}$ 3.5 Hz, H-3′), 4.820 (d, 1 H, $J_{1,2}$ 8.0 Hz, H-1), 4.575 (ABq, 2 H, J_{AB} 12.0 Hz, OCH_2Ph), 4.490 (m, 1 H, H-3), 3.710 (m, 1 H, H-5), 2.970 (m, 1 H, H-2), 2.170 (m, 1 H, $J_{4e,3}$ 5.0 Hz, H-4*e*), 1.560 (ddd, 1 H, $J_{4a,4e}$ 12.5, $J_{3,4a}$ 11.5, $J_{4a,5}$ 11.5 Hz, H-4*a*); ^{13}C, δ 101.27, 100.42 (C-1,1′), 36.30 (C-4).

Anal. Calc. for $C_{30}H_{41}NO_{14}$: C, 56.33; H, 6.46; N, 2.19. Found: C, 56.58; H, 6.66; N, 2.14.

Methyl 2-acetamido-2,4-dideoxy-3-O-β-D-galactopyranosyl-β-D-xylo-hexopyranoside (**33**). — Compound **31** (150 mg, 0.23 mmol) was treated with methanolic 0.5M sodium methoxide for 16 h at room temperature. After neutralization of the base with Amberlite IR-120(H^+) resin, the methanol was evaporated and the residue was eluted from a short column of silica gel with dichloromethane–methanol (49:1) to provide methyl 2-acetamido-6-*O*-benzyl-2,4-dideoxy-3-*O*-β-D-galactopyranosyl-β-D-*xylo*-hexopyranoside (**32**; 80 mg, 72%). This material was not characterized but was dissolved in 95% ethanol (5 mL) containing 5% Pd/C (160 mg) and hydrogenated at 100 p.s.i. for 16 h at room temperature. The mixture was filtered through Celite and the insoluble material was washed with several portions of hot aqueous 95% ethanol. The combined filtrates and washings were concentrated to dryness, and the product was precipitated from methanol–ethyl acetate and then eluted from a column of Sephadex LH-20 using ethanol–water (1:1). Compound **33** (60 mg, 92.7%), obtained by concentration of the major fraction and freeze-drying of an aqueous solution of the residue, had m.p. 240° (dec.), $[\alpha]_D$ −19° (*c* 0.47, water). N.m.r. data (D_2O): ^{1}H, δ 4.440 (d, 1 H, $J_{1',2'}$ 8.0 Hz, H-1′),

4.397 (d, 1 H, $J_{1,2}$ 8.5 Hz, H-1), 3.982–3.892 (m, 2 H, including H-4′ at 3.907, $J_{3',4'}$ 3.2 Hz, and H-3), 3.842–3.592 (m, 8 H, including H-3′ at 3.617, $J_{2',3'}$ 10.0, $J_{3',4'}$ 3.5 Hz, H-2,5,5′,6a,6b,6′a,6′b), 3.512 (s, 3 H, OMe), 3.474 (dd, 1 H, $J_{2',3'}$ 9.5, $J_{1',2'}$ 8.0 Hz, H-2′), 2.227 (dd, 1 H, $J_{4a,4e}$ 12.5 Hz, $J_{4e,3}$ 4.5 Hz, H-4*e*), 1.530 (ddd, 1 H, $J_{4a,4e}$ 12.5, *J* 11.5 and 11.5 Hz, H-4*a*); ^{13}C, δ 175.57 (C=O), 105.11 and 102.96 (C-1,1′), 78.76, 75.83, 73.41, 73.22, 71.45, 69.32, 64.42, 61.72, 57.72 (OMe), 56.35, 35.32 (C-4), 23.05 ($NHCOCH_3$).

*Methyl 2-acetamido-4,6-*O*-benzylidene-2-deoxy-3-*O*-phenoxythiocarbonyl-β-*D*-glucopyranoside* (**34**). — Reaction of **27** (5.0 g, 16.2 mmol) with phenyl chlorothionocarbonate (8.0 mL, 58 mmol), as described for the preparation of **5**, gave a crude syrupy residue which was precipitated from hot methanol–ethyl acetate and washed with ether to provide **34** as a pale-yellow solid (5.0 g, 69%), m.p. 237–238°, $[\alpha]_D$ −98° (*c* 0.52, dichloromethane). ^{1}H-N.m.r. data (Me_2SO-d_6): δ 8.140 (d, 1 H, $J_{NH,2}$ 8.6 Hz, NH), 5.772 (dd, 1 H, *J* 9.2 Hz, H-3), 4.721 (d, 1 H, $J_{1,2}$ 8.2 Hz, H-1), 1.820 (s, 3 H, NAc).

Anal. Calc. for $C_{23}H_{25}NO_7S$: C, 60.12; H, 5.48; N, 3.05; S, 6.98. Found: C, 59.53; H, 5.48; N, 2.97; S, 7.07.

*Methyl 2-acetamido-4,6-*O*-benzylidene-2,3-dideoxy-β-*D*-*ribo*-hexopyranoside* (**35**). — Compound **34** was deoxygenated as described for the preparation of **6**. On cooling the reaction mixture, the product precipitated and was collected and washed with hexane to provide a white amorphous powder (3.3 g, 96%). Crystallization from methanol–ethyl acetate gave **35** as long needles, m.p. 293–295°, $[\alpha]_D$ −83° (*c* 1, methyl sulfoxide). N.m.r. data (Me_2SO-d_6): ^{1}H, δ 7.970 (d, 1 H, $J_{NH,2}$ 8.0 Hz, NH), 4.365 (d, 1 H, $J_{1,2}$ 8.5 Hz, H-1), 2.110 (m, 1 H, $J_{3a,3e}$ 12, $J_{2,3e}$ 4.5 Hz, H-3*e*), 1.805 (s, 3 H, NAc), 1.570 (m, 1 H, $J_{3a,3e}$ 12 Hz, H-3*a*); ^{13}C, 168.44 ($NCOCH_3$), 103.58, 100.53 (C-1, PhCH=), 34.11 (C-3), 22.78 ($NCOCH_3$).

Anal. Calc. for $C_{16}H_{21}NO_5$: C, 62.53; H, 6.89; N, 4.56. Found: C, 62.33; H, 6.93; N, 4.58.

*Methyl 2-acetamido-6-*O*-benzyl-2,3-dideoxy-β-*D*-*ribo*-hexopyranoside* (**36**). — The benzylidene ring of **35** (2.0 g, 6.5 mmol) was reductively opened as described for the preparation of **15**. Column chromatography of the crude product (dichloromethane–methanol, 19:1) gave, as the major fraction, **36**, isolated as a white solid (1.5 g, 74.5%), m.p. 143–144°, $[\alpha]_D$ −40° (*c* 1, methanol). N.m.r. data ($CDCl_3$): ^{1}H, δ 6.055 (d, 1 H, $J_{NH,2}$ 8.0 Hz, NH), 4.580 (ABq, 2 H, J_{AB} 12 Hz, OCH_2Ph), 4.320 (d, 1 H, $J_{1,2}$ 7.5 Hz, H-1), 2.405 (m, 1 H, H-3*e*), 2.000 (s, 3 H, NAc), 1.565 (m, 1 H, H-3*a*); addition of trichloroacetyl isocyanate directly to the n.m.r. tube led to a new spectrum where the signal for H-4 was shifted downfield to δ 5.275 (m); ^{13}C, δ 102.88 (C-1), 34.24 (C-3), 23.50 ($NCOCH_3$).

Anal. Calc. for $C_{16}H_{23}NO_5$: C, 62.12; H, 7.49; N, 4.53. Found: C, 62.76; H, 7.88; N, 4.73.

*Methyl 2-acetamido-6-*O*-benzyl-2,3-dideoxy-4-*O*-(2,3,4,6-tetra-*O*-acetyl-β-*D*-galactopyranosyl)-β-*D*-ribo-hexopyranoside* (**38**). — A solution of 2,3,4,6-tetra-*O*-acetyl-α-D-galactopyranosyl bromide (1.0 g, 2.64 mmol) in benzene–nitromethane

(1:1, 4 mL) was added with stirring to a mixture of **36** (0.680 g, 2.20 mmol), mercuric cyanide (1.35 g, 5.35 mmol), and 4 Å molecular sieve (1 g) in the same solvent mixture (5 mL). After stirring for 4 h at room temperature, the mixture was diluted with dichloromethane (200 mL), filtered through Celite, washed sequentially with saturated aqueous sodium hydrogencarbonate (200 mL), aqueous 30% potassium bromide (200 mL), and water, and then concentrated. The syrupy residue was purified by column chromatography (dichloromethane–methanol, 19:1) to give, as the minor fraction, **38**, isolated as a white solid (230 mg, 19%), m.p. 109–110°, $[\alpha]_D$ −32° (*c* 0.86, dichloromethane). N.m.r. data ($CDCl_3$): ^1H, δ 6.577 (d, 1 H, $J_{NH,2}$ 9.0 Hz, NH), 5.40 (dd, 1 H, $J_{3',4'}$ 3.5 Hz, H-4'), 5.222 (dd, 1 H, $J_{1',2'}$ 8.0, $J_{2',3'}$ 10.0 Hz, H-2'), 5.045 (dd, 1 H, $J_{2',3'}$ 10.0, $J_{3',4'}$ 3.5 Hz, H-3'), 4.552 (ABq, 2 H, J_{AB} 12.0 Hz, OCH_2Ph), 4.410 (d, 1 H, $J_{1',2'}$ 8.0 Hz, H-1'), 4.162 (d, 1 H, $J_{1,2}$ 6.5 Hz, H-1), 2.285 (ddd, 1 H, $J_{3a,3e}$ 14.5, $J_{2,3e}$ 4.5, $J_{3e,4}$ 4.5 Hz, H-3*e*), 1.820 (m, 1 H, $J_{3a,3e}$ 14.5 Hz, H-3*a*); ^{13}C, δ 101.07, 100.14 (C-1,1'), 25.90 (C-3), 23.16 (NCOCH_3).

Anal. Calc. for $C_{30}H_{41}NO_{14}$: C, 56.33; H, 6.46; N, 2.19. Found: C, 56.23; H, 6.56; N, 1.96.

The major fraction crystallized by concentration of a solution in dichloromethane, yielding **37** (320 mg, 49%), m.p. 183–184°. ^1H-N.m.r. data ($CDCl_3$): δ 5.820 (d, 1 H, $J_{NH,2}$ 7.5 Hz, N*H*), 4.930 (ddd, 1 H, $J_{4,3a}$ 8.5, $J_{4,5}$ 6.5, $J_{4,3e}$ 4.5 Hz, H-4), 4.560 (ABq, 2 H, J_{AB} 12.0 Hz, OCH_2Ph), 4.485 (d, 1 H, $J_{1,2}$ 5.8 Hz, H-1), 2.467 (ddd, 1 H, $J_{3a,3e}$ 13.0, $J_{3e,2}$ 5.0, $J_{3e,4}$ 4.5 Hz, H-3*e*), 2.003 and 1.978 (2 s, 3 H each, NAc and OAc), 1.737 (ddd, 1 H, $J_{3a,3e}$ 11.5, $J_{3a,2}$ 11.0, $J_{3a,4}$ 8.5 Hz, H-3*a*).

*Methyl 2-acetamido-6-O-benzyl-2,3-dideoxy-4-O-β-*D*-galactopyranosyl-β-*D*-ribo-hexopyranoside* (**39**). — Deacetylation of **38** (220 mg, 0.34 mmol) with methanolic sodium methoxide at room temperature overnight, followed by neutralization with Amberlite IR-120(H^+) resin and solvent removal, left a solid residue which was purified by column chromatography (dichloromethane–methanol, 19:2). The major fraction was **39**, isolated as a white solid (117 mg, 72%), which was used directly in the next step.

*Methyl 2-acetamido-2,3-dideoxy-4-O-β-*D*-galactopyranosyl-β-*D*-ribo-hexopyranoside* (**40**). — A solution of **39** (117 mg, 0.24 mmol) in aqueous 95% ethanol (6 mL) containing 5% Pd/C (234 mg) was hydrogenated at 100 p.s.i. for 16 h at room temperature. The catalyst was collected on Celite and washed with several portions of hot aqueous 95% ethanol, the combined filtrate and washings were concentrated to dryness, and **40** was precipitated from methanol–ethyl acetate as a white powder (73 mg, 77%), m.p. 263–264° (dec.), $[\alpha]_D$ −31° (*c* 1.42, water). N.m.r. data (D_2O): ^1H, δ 4.460 (d, 1 H, $J_{1',2'}$ 8.0 Hz, H-1'), 4.449 (d, 1 H, $J_{1,2}$ 8.2 Hz, H-1), 3.972 (dd, 1 H, $J_{6a,b}$ 12.0, $J_{5,6}$ 2.5 Hz, H-6a), 3.929 (d, 1 H, $J_{3',4'}$ 3.5 Hz, H-4'), 3.839–3.734 (m, 5 H, including H-2,4,6b,6'a,6'b), 3.734–3.622 (m, 3 H, including H-5' at 3.687, H-3' at 3.642, $J_{2',3'}$ 10.0, $J_{3',4'}$ 3.5 Hz, and H-5 at 3.604), 3.517 (s, 3 H, OMe), 3.494 (dd, 1 H, $J_{2',3'}$ 9.8, $J_{1',2'}$ 8.0 Hz, H-2'), 2.504 (ddd, 1 H, $J_{3a,3e}$ 12.5, $J_{3e,2}$ 5.0, $J_{3e,4}$ 4.5 Hz, H-3*e*), 1.672 (ddd, 1 H, $J_{3a,3e}$ 12.5 Hz, *J* 11.5 and 11.0 Hz, H-3*a*); ^{13}C, δ 174.85 (C=O), 104.49 and 104.19 (C-1,1'), 79.26, 75.92, 74.59,

73.52, 71.72, 69.36, 61.69, 61.52, 57.54 (OCH_3), 49.67, 36.05 (C-3), 22.88 ($NHCOCH_3$).

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