ELSEVIER

Carbohydrate Research 294 (1996) 65–94

CARBOHYDRATE RESEARCH

Synthesis and application of α-D-mannosyl clusters as photoaffinity ligands for mannose-binding proteins: Concanavalin A as a model receptor

Jochen Lehmann *, Uwe P. Weitzel

Institut für Organische Chemie und Biochemie der Universität Freiburg, Albertstraße 21, D-79104 Freiburg, Germany

Received 15 April 1996; accepted 25 July 1996

Abstract

Mono-, di-, and tri-antennary α-D-mannopyranosyl derivatives were synthesized as oligosaccharide mimics. The compounds vary in the length of the acyclic aglyconic spacers linking, in the case of the di- and tri-antennary derivatives, the glycosyl endgroups. By haemagglutination assay (Coombs test) the affinity of the α-D-mannopyranosyl ligands against Con A was determined in comparison with methyl α-D-mannopyranoside. Affinity enhancement and strong cross-linking capacity were found with the di- and tri-antennary compounds where α-D-mannopyranosyl endgroups are separated by spacers of 5–37 atoms in length. The optimal ligand had K_i of 5.1 μM in comparison with 3.12 mM for methyl α-D-mannopyranoside. The monoantennary compound and, to certain extents, one di- and short tri-antennary ligands with short spacer lengths did not differ significantly in affinity from methyl α-D-mannopyranoside. A triantennary, radiolabelled ligand equipped with a photolabile diazirino group was used to covalently modify Con A by photoaffinity labelling. A significant degree of covalent cross-linking of Con A monomers was observed. © 1996 Elsevier Science Ltd.

Keywords: Mannosyl clusters; Concanavalin A; Photoaffinity labelling; Diazirines; Mannose-binding proteins

1. Introduction

In an earlier publication syntheses of multiantennary D-galactose ligands for selective blocking of hexose transport into red blood cells by photoaffinity labelling was

* Corresponding author.

PII S0008-6215(96)00207-8

described [1]. The ligands are equipped with photolabile diazirino groups for covalent modification of the transporting system's binding sites. Affinity was enhanced by clustering the recognized D-galactose residues through long-chain spacer links. This principle of binding enhancement can also be applied to other carbohydrate-binding proteins. Numerous receptors recognizing α-D-mannopyranosyl residues [2] and also α-D-mannopyranosyl 6-phosphate residues [3] are operative in diverse, biologically relevant functions. The main purpose of photoaffinity labelling is to analyze structurally the binding site of a given receptor protein. There may, however, also be potential in irreversibly blocking receptors in vivo to prevent binding of the natural ligand, or to detect as yet unknown receptors in their natural surroundings. For practical reasons the well-studied multivalent α-D-mannopyranoside-binding lectin Concanavalin A (Con A) [4] is used to study the noncovalent interactions of several ligands differing in valency (number of α-Man endgroups) and in spacing of the α-D-mannopyranosyl residues (length of spacer links). A selected ligand will be used to specifically label the receptor protein.

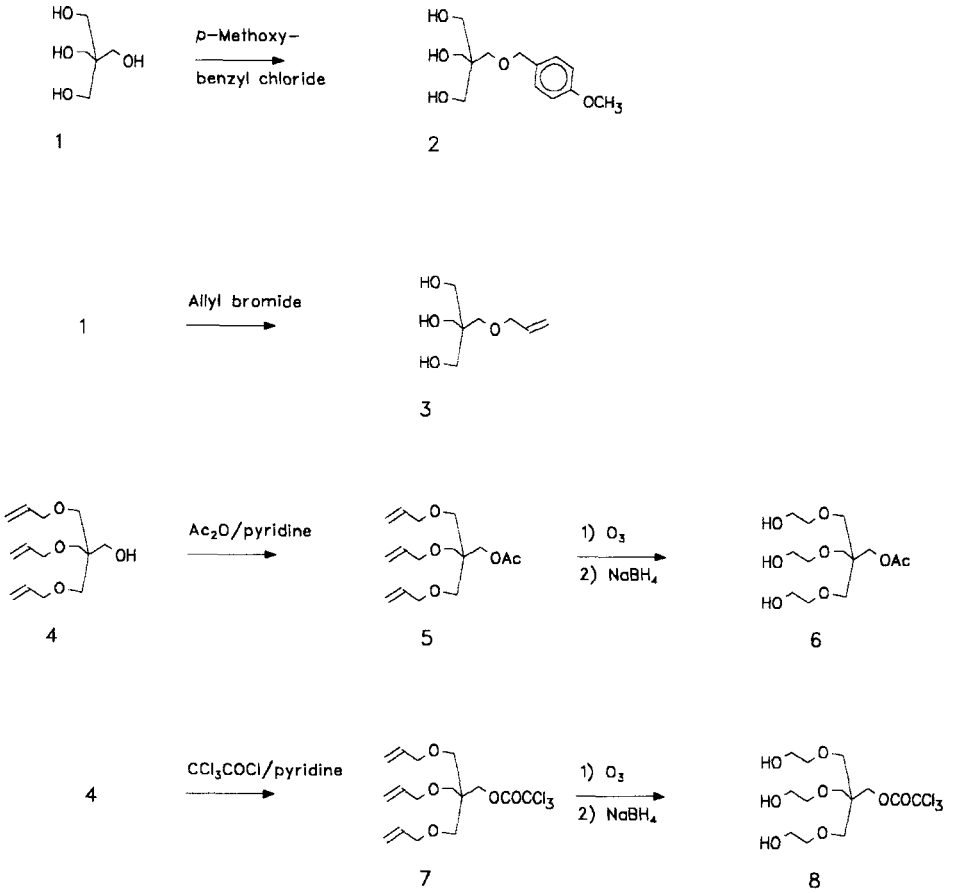
2. Results and discussion

Chemical syntheses of ligands.—Pentaerythritol (**1**) was differentially and partially alkylated and acylated to yield fractionalized spacer units **2**, **3**, **6**, and **8** (Scheme 1) for the attachment of α-Man endgroups, either by direct glycosylation with 2,3,4,6-tetra-*O*-benzoyl-α-D-mannopyranosyl bromide (**9**) [5] to yield **10** and **13** (Scheme 2) or by coupling with α-D-mannopyranosides like 2-azi-1-(2,3,4,6-tetra-*O*-benzoyl-α-D-mannopyranosyloxy)-5-oxa-7-thiaoctane (**24**) and homologues thereof (Scheme 3). The latter procedure yields the longer chain α-D-mannopyranosides **50**, **53**, **56**, **57**, **59**, **61**, **63**, **65**, **67**, and **69** (Scheme 4). This strategy of ligand construction allows the formation of compounds with spacers differing in chain length and with differing numbers of α-D-mannopyranosyl residues. If a ligand is used for photoaffinity labelling, an azi group is introduced into one of the noncarbohydrate segments as in **24**, **34**, **44**, and **49**. Similarly a radiolabel (tritium) is attached by oxidation/reduction of a suitable hydroxy group using NaB^3H_4 as tritium source (Scheme 5).

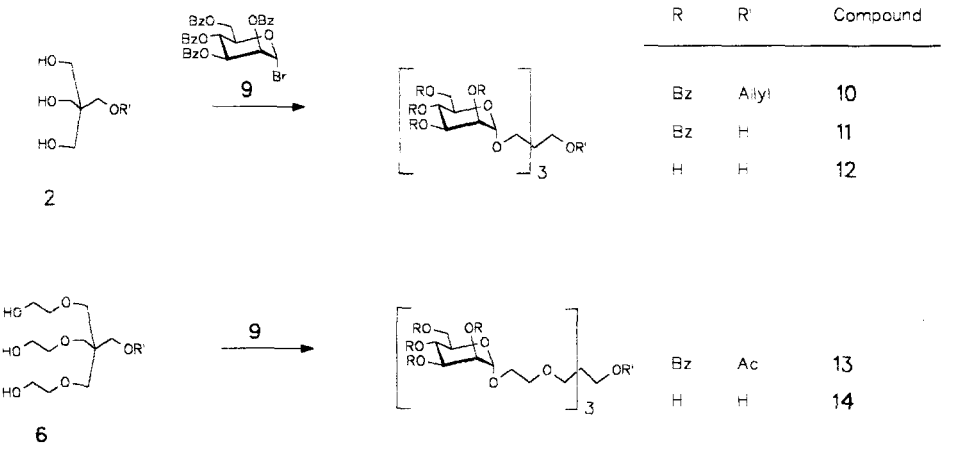
A key step in the assembly of long-chain ligands is the *N*-iodosuccinimide–trifluoromethanesulfonic acid-activated coupling of monothioacetals with alcohols, giving acetals described by Veeneman et al. [6] and Biessen et al. [7]. A modification giving better yields was introduced, replacing trifluoromethanesulfonic acid by its tetrabutylammonium salt [8]. All preparation procedures are described under "Experimental".

Investigation of binding to Con A.—Con A, existing under physiological conditions as a tetramer [4](b), is capable of binding four α-D-mannospyranosyl endgroups. As with antibodies and other multisite receptors, binding enhancement can be expected, when at a time more than one covalently connected endgroup of the ligand (Fig. 1, A), in contrast to isolated endgroups (Fig. 1, B), is recognized. Thus the affinity of a ligand carrying more than one endgroup is greater than the sum of the affinities contributed by each individual endgroup (clustering effect) [9].

With multivalent ligands, not only binding enhancement but also cross-linking and

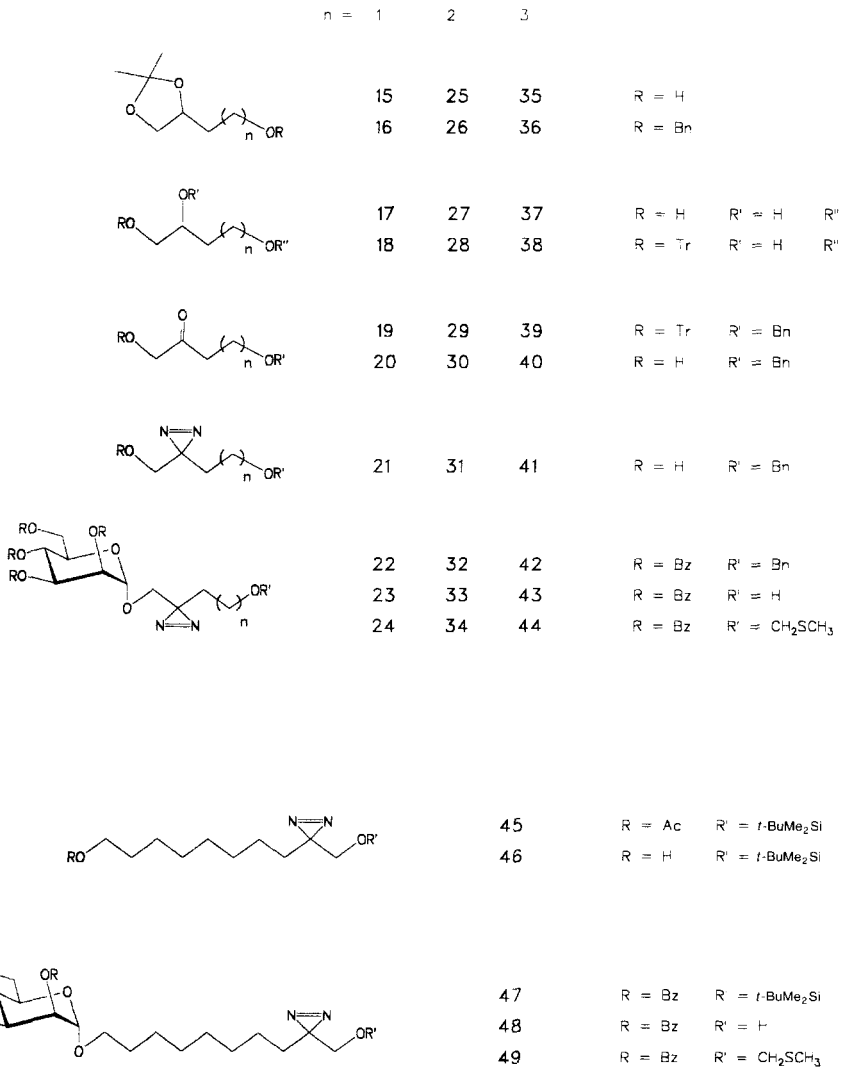


Scheme 1.



R	R'	Compound
Bz	Allyl	10
Bz	H	11
H	H	12
Bz	Ac	13
H	H	14

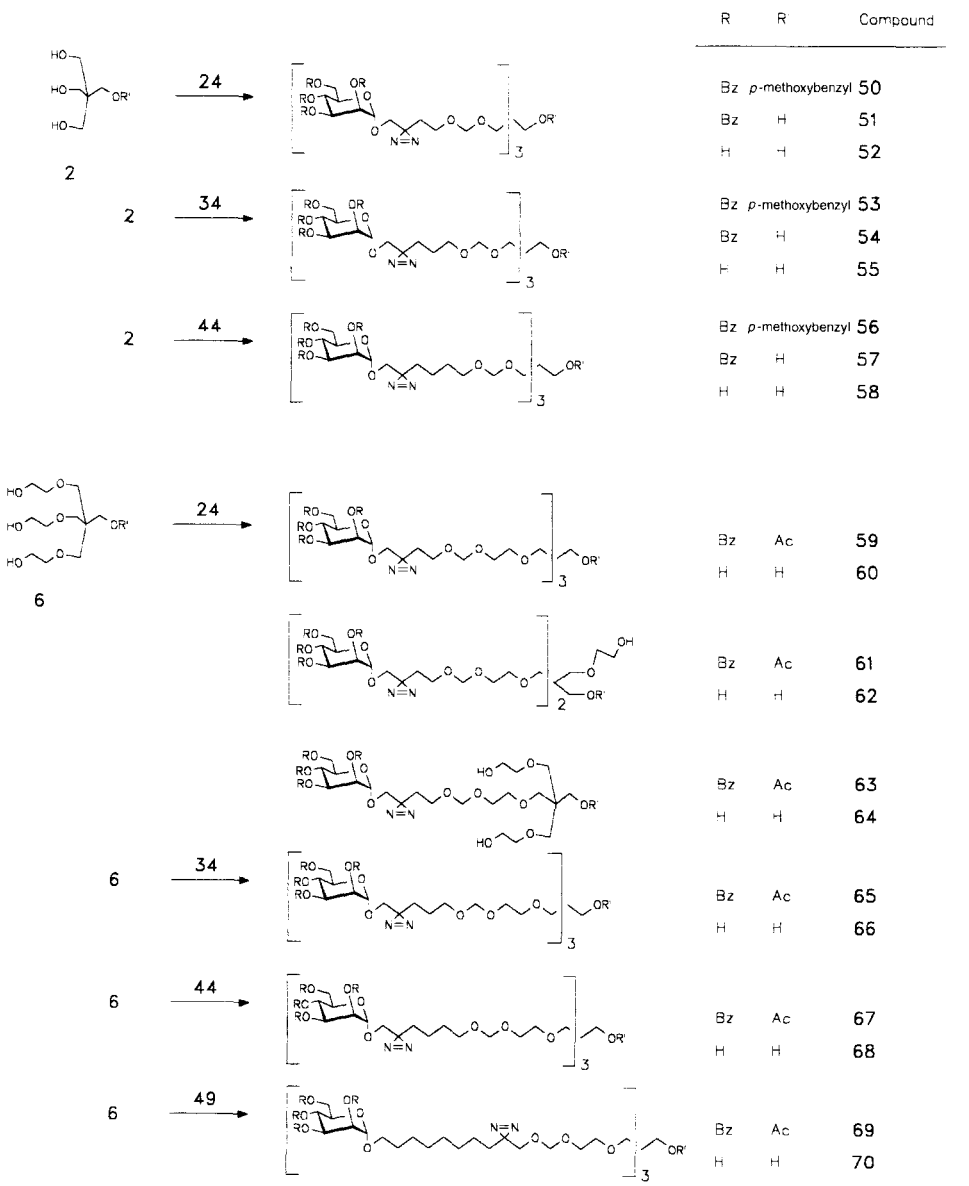
Scheme 2.



Scheme 3.

precipitation of Con A are possible (Fig. 2A, B). Precipitation is maximal at the equivalence point [10]. It can be assumed that a minimal length *I* of a spacer linking the endgroups is necessary for the ligand to show both binding enhancement by the clustering effect and precipitation through cross-linking.

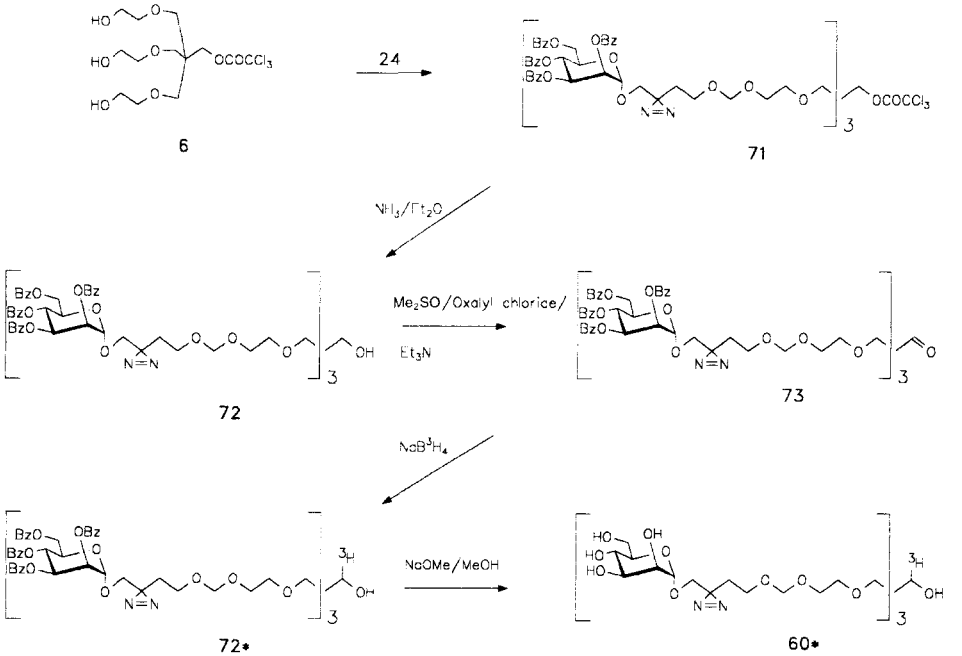
Erythrocytes, being multivalent ligands, are precipitated by Con A (agglutination). The precipitation can be prevented in the presence of a monovalent ligand like methyl α-D-mannopyranoside (MαMan). The Coombs test [11] allows the differentiation between agglutination of erythrocytes (formation of a carpet) and free sedimentation (formation of a pellet). At the endpoint — clearly visible prevention of agglutination —



Scheme 4.

the binding sites of Con A are sufficiently blocked by MαMan. The affinity of a given ligand is determined by comparison with the standard MαMan in the Coombs test.

Some of the 'avid' ligands cause agglutination of Con A on their own. In such cases the formation of a precipitate can be used for qualitative determination of avidity of a ligand. For the Coombs test only the supernatant solution is used because the network of



Scheme 5.

cross-linked Con A ligand blurs the endpoint of determination. Each ligand, including MαMan, was incubated for 2 h at room temperature with the 8-fold concentration of Con A, which is required to agglutinate human erythrocytes. After centrifugation, the supernatant solution was used in the inhibition assay. The results are shown in Table 1; for comparison with the monovalent compounds, the values for the di- and tri-antennary compounds are reduced to 'normality'. This allows an evaluation of clustering effects and in some cases of steric hindrance due to crowding of αMan-residues. As may be expected, the monoantennary compounds show almost the same effect as MαMan.

Photoaffinity labelling.—The inhibition constant of the triantennary compound **60** is ca. 0.28 μM estimated from the measured dissociation constant of MαMan (150 μM)

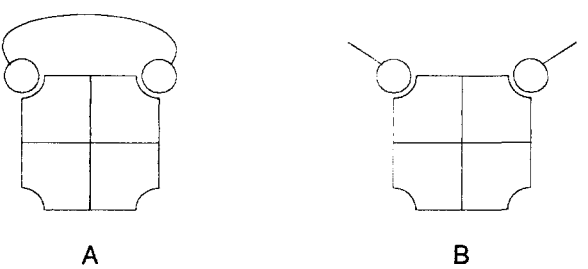


Fig. 1.

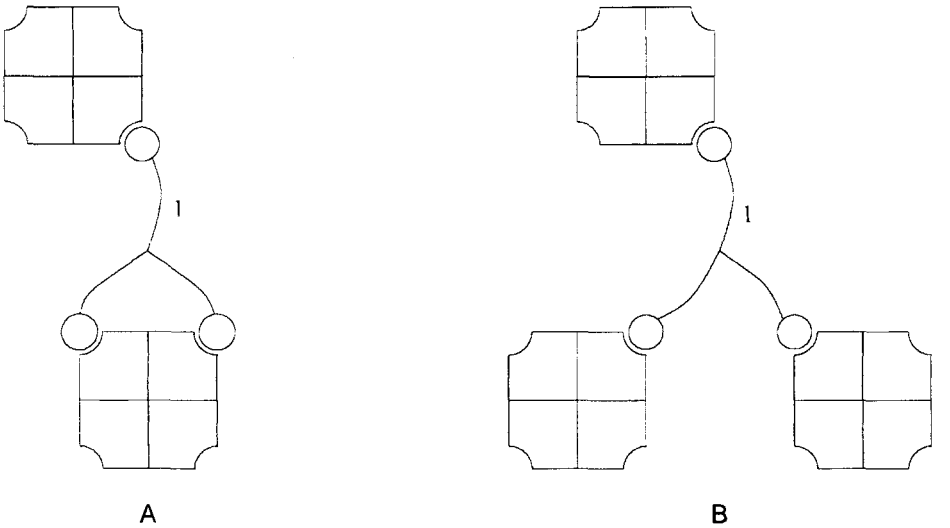


Fig. 2.

[12]. Therefore compound **60** is well suited for photoaffinity labelling. The photolabile azi group is situated as close as possible to the recognized α-D-mannopyranosyl residue. The degree of photoaffinity labelling with the ^{3}H-isotopomer parallels binding affinity. The specificity of photoaffinity labelling is demonstrated by the protection of Con A in the presence of MαMan. Incorporation of radioactivity into the protein is maximal, when irradiation with UV light of $\lambda_{max} = 350$ nm is carried out with the precipitated

Table 1
Inhibition of erythrocyte–Con A agglutination by different α-D-mannopyranosides. Determination is carried out by Coomb's test

Compound	Minimum concentration required for complete inhibition	Relative affinity [a]
MαMan	3.12 mM	1
12	152 μM	6.8
14	37 μM	28
52	8.3 μM	125
55	6.4 μM	162
58	6.1 μM	170
60	5.9 μM	176
62	87 μM	12
64	2.01 mM	1.6
66	5.8 μM	180
68	6.0 μM	173
70	5.1 μM	206

[a] In comparison with MαMan as standard. The values for di- and tri-antennary compounds are reduced to normality.

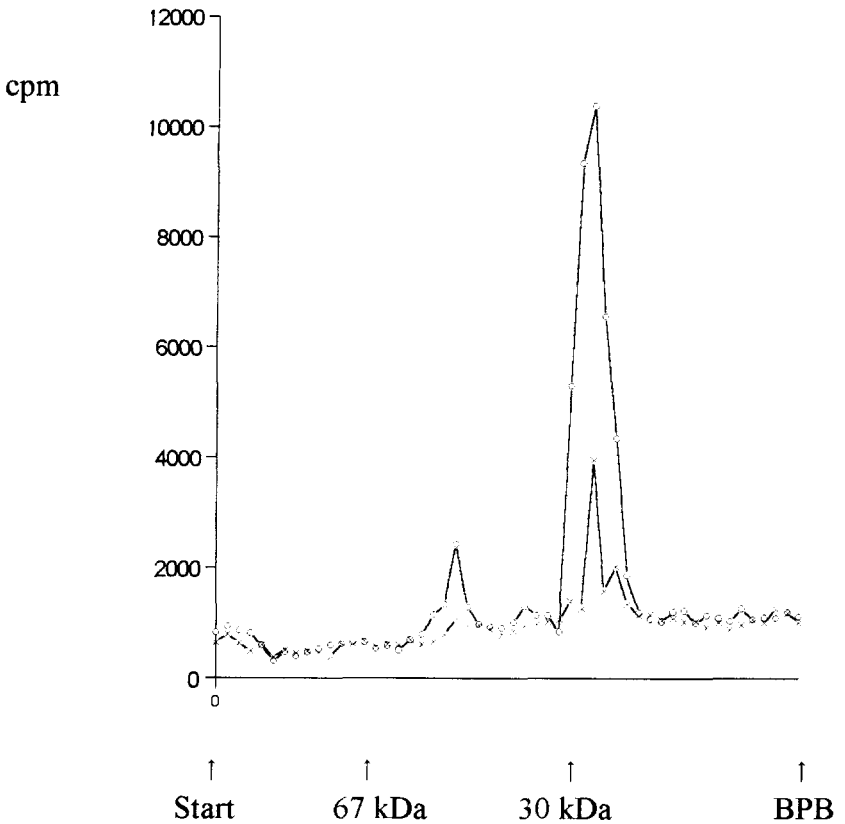


Fig. 3. SDS-PAGE of radioactively labeled Con A. The arrows indicate the position of calibration proteins and the marker Bromphenol Blue (BPB). Radioactivity was determined using a liquid scintillation counter: (○) protein, photoaffinity labeled by **60***; (×) protein labeled by **60*** in the presence of methyl α-D-mannopyranoside.

complex (equivalence point). The band of radioactivity (Fig. 3), showing a molecular mass of ca. 54 kDa, is an indication for the covalent cross-linking of two peptide chains.

3. Experimental

General methods.—All reaction products were analyzed by TLC on Silica Gel 60 F_{254} (Merck) by the quenching of fluorescence and/or by charring with 2% H_2SO_4 in MeOH. Flash-column chromatography was performed on ICN-silica 32–63 (ICN Biomedicals). Sephadex LH-20 was purchased from Pharmacia, and NaB^3H_4 from Amersham Buchler. Con A was prepared from jack beans (Sigma) as described [13]. Melting points were measured with a Büchi apparatus and are uncorrected. Optical rotations were obtained with a Schmidt&Haensch Polartronic I polarimeter. UV spectra and extinction coefficients were recorded with a Zeiss PMQ II spectrometer. ^{1}H NMR spectra were recorded at 400.13 MHz, and ^{13}C NMR spectra (ATP) at 100.62 MHz; 2

D: H,H-COSY, C,H-Correlation (Bruker AM 400) with either internal Me_4Si or MeCN. The ^{13}C spectra were ^1H-decoupled. Elemental analyses were obtained with a Perkin–Elmer 240 analyzer. For hygroscopic compounds where elemental analysis is not sufficiently significant, mass spectral analyses were carried out. Mass spectra were recorded on a Finigan MAT 312. Radioactivity was detected with a Berthold automatic TLC-linear analyzer LB 2821, or by autoradiography using 'Curix' X-ray film (Agfa-Gevaert), and assayed with a Berthold BF 815 liquid scintillation counter, using Quickszint 501 (Zinsser) for solutions in organic solvents, and Quickszint 1 for aqueous solutions. Photolyses were performed with a Rayonet RPR 100 reactor equipped with 16 lamps (RPR 3500 A) at 350 nm.

Haemagglutination-inhibition assays.—Haemagglutination-inhibition was assayed at 25 °C by 2-fold serial dilution in 10 mM Tris–HCl buffer, containing 150 M NaCl, 1 mM $MnCl_2$, and 1 mM $CaCl_2$, using a 3% suspension of human erythrocytes [14]. Erythrocytes were freshly drawn and washed five times in the described Tris–HCl buffer.

Photoaffinity labelling.—A solution of Con A (2 mg) in 400 μL of Tris–HCl buffer (0.1 M, pH 7.2, containing 0.9 M KCl, 1 mM $MnCl_2$, 1 mM $CaCl_2$) was incubated at room temperature for 4 h with compound **60*** (88 μCi, 2 Ci/mmol, 44 nmol) in the presence or absence of methyl α-D-mannopyranoside (440 nmol). The solutions were deoxygenated by aerating with N_2 for 2 min, then irradiated at 350 nm for 15 min, and dialysed against Tris–HCl buffer (10 mM, pH 7.2, containing 150 mM NaCl, 10 mM EDTA), until no more radioactivity was released into the dialysate. The dialysed samples were dried in a Speed Vac concentrator.

Electrophoresis.—Sodium dodecyl sulfate-polyacrylamide gel electrophoresis (SDS-PAGE, 12% acrylamide) was performed according to the method of Laemmli [15]. The samples (30 μg) were dissolved in Tris–HCl buffer (0.1 mL, 62 mM, pH 6.8) containing 2% (w/v) SDS, 0.002% (w/v) Bromophenol Blue, and 10% glycerol. After electrophoresis the gel was stained with Coomassie Blue R-250. The molecular weight was estimated by the standard calibration kit from Pharmacia Fine Chemicals (Uppsala, Sweden). For determination of the incorporated radioactivity the destained gel was cut into 2-mm slices, each of which was submerged in Biolute-S (Zinsser, 0.5 mL) and left overnight. Quickszint-501 (4 mL) was then added, the mixture was kept for 5 h in the cold, and the radioactivity was then counted.

p-*Methoxybenzyl 2,2,2-tris(hydroxymethyl)ethyl ether* (**2**).—To a stirred solution of pentaerythritol **1** (13.61 g, 100.0 mmol) and tetrabutylammonium iodide (~ 1 g) in dry DMF (150 mL) was added NaH (1.31 g, 30.0 mmol) in small portions. After 1 h at room temperature a solution of 4-methoxybenzyl chloride (5.00 mL, 27.1 mmol) in dry DMF (5 mL) was added dropwise. After stirring overnight excess of hydride was decomposed by adding MeOH (10 mL) dropwise. The reaction mixture was concentrated, then poured into water and extracted with CH_2Cl_2. The combined extracts were washed with water, dried over Na_2SO_4 and concentrated. Flash-column chromatography (10:5:1 EtOAc–cyclohexane–MeOH) of the residue yielded **2** as a solid (5.61 g, 81%); R_f 0.26 (10:5:1 EtOAc–cyclohexane–MeOH); ^1H NMR ($CDCl_3$): δ 7.26 and 6.89 (2 m, 4 H, Ph), 4.49 (s, 2 H, CH_2Ph), 3.82 (s, 3 H, OMe), 3.71 (s, 6 H, CH_2OH), 3.49 (s, 2 H, CH_2OBn), 2.65 (bs, 3 H, OH); MS: *m/z* 274.3 $[M]^+$.

2,2,2-Tris(4-hydroxy-2-oxabutyl)ethyl acetate (**6**).—2,2,2-Tris(2-oxapent-4-enyl)ethyl acetate (**5**) [1] (2.23 g, 7.49 mmol) was dissolved in dry MeOH (50 mL) and cooled to −75 °C. Then O_3 (3 h, ~ 10 mmol/h) was bubbled through the stirred solution. Excess of O_3 was removed with a stream of O_2 (10 min, 30 L/h). Then $NaBH_4$ (0.50 g, 13 mmol) was added and the mixture was allowed to attain room temperature. After stirring for 2 h at room temperature the mixture was neutralized by addition of Dowex 50W-X8 (H^+). Then the resin was filtered off and the filtrate was concentrated. The residue was subjected to column chromatography (27:2:1 EtOAc–MeOH–H_2O) to give **6** (2.30 g, 99%); R_f 0.26 (27:2:1 EtOAc–MeOH–H_2O); ^{1}H NMR ($CDCl_3$): δ 4.19 (s, 2 H, H-1-Et), 3.71 (t, 6 H, $J_{1,2}$ 6.0 Hz, H-4), 3.56 (t, 6 H, H-3), 3.50 (s, 6 H, H-1), 2.82 (bs, 3 H, OH), 2.08 (s, 3 H, Ac). Anal. Calcd for $C_{13}H_{26}O_8$: C, 50.31; H, 8.44. Found: C, 50.31; H, 8.72.

2,2,2-Tris(2-oxa-pent-4-enyl)ethyl trichloroacetate (**7**).—Trichloracetyl chloride (0.66 mL, 5.85 mmol) was added to a solution of 2,2,2-tris(2-oxa-pent-4-enyl)ethanol (**4**) [1] (1.00 g, 3.9 mmol) in dry pyridine (20 mL). The reaction mixture was kept for 2 h, then diluted with water and extracted with Et_2O. The organic layer was washed sequentially with HCl (1.0 M), water, satd aq $NaHCO_3$, and water, dried over Na_2SO_4, and concentrated. The residue was chromatographed (1:10 EtOAc–cyclohexane) to give **7** (1.50 g, 96%); R_f 0.73 (1:5 EtOAc–cyclohexane); ^{1}H NMR ($CDCl_3$): δ 5.90 (m, 3 H, H-4), 5.20 (m, 6 H, H-5), 4.44 (s, 2 H, H-1-Et), 3.94 (m, 6 H, H-3), 3.48 (s, 6 H, H-1). Anal. Calcd for $C_{16}H_{23}Cl_3O_5$: C, 47.84; H, 5.77. Found: C, 47.93; H, 5.72.

2,2,2-Tris(4-hydroxy-2-oxabutyl)ethyl trichloroacetate (**8**).—Compound **7** (884 mg, 2.2 mmol) was dissolved in dry MeOH (50 mL) and cooled to −75 °C. Then O_3 (3 h, ~ 10 mmol/h) was bubbled through the stirred solution. Excess of O_3 was removed with a stream of O_2 (5 min, 30 L/h). $NaCNBH_3$ (0.5 g, 13.0 mmol) was added and the solution was adjusted to pH 5.0 with AcOH. Then the mixture was allowed to attain room temperature. After stirring for 2 h at room temperature the solution was concentrated and chromatographed twice (5:1 EtOAc–MeOH and 10:5:1 EtOAc–cyclohexane–MeOH) to give **8** (510 mg, 56%); R_f 0.40 (27:2:1 EtOAc–MeOH–H_2O); ^{1}H NMR ($CDCl_3$): δ 4.45 (s, 2 H, H-1-Et), 3.72 (t, 6 H, $J_{1,2}$ 6.0 Hz, H-3), 3.53 (t, 6 H, H-4), 3.51 (s, 6 H, H-1), 2.38 (bs, 3 H, OH). Anal. Calcd for $C_{13}H_{23}Cl_3O_8$: C, 37.74; H, 5.60. Found: C, 37.46; H, 5.93.

*Allyl 2,2,2-tris(2,3,4,6-tetra-*O*-benzoyl-α-*D*-mannopyranosyloxymethyl)ethyl ether* (**10**).—Compound **3** was glycosylated according to the method described by Hanessian and Banoub [16]. Tetramethylurea (0.44 mL, 3.89 mmol), **3** [1] (137 mg, 0.78 mmol), and silver trifluoromethanesulfonate (1.00 g, 3.89 mmol) were dissolved in dry CH_2Cl_2 (10 mL) and stirred under Ar over molecular sieves (4 Å, 1.0 g) for 1 h at room temperature, then cooled to −25 °C. A solution of tetra-*O*-benzoyl-α-D-mannopyranosyl bromide (**9**) [5] (2.56 g, 3.89 mmol) in dry CH_2Cl_2 (10 mL) was added dropwise. The mixture was stirred at −20 °C for 4 h and then filtered through a bed of Celite. The filtrate was washed with aq 10% $Na_2S_2O_3$, HCl (1.0 M), water, satd aq $NaHCO_3$, and water. The organic layer was dried over $MgSO_4$ and concentrated, and the residue chromatographed (1:2 EtOAc–cyclohexane) to give **10** (1.09 g, 73%); mp 102 °C (acetone–MeOH); $[\alpha]_D$ −56° (*c* 2.0, $CHCl_3$); R_f 0.27 (1:2 EtOAc–cyclohexane); ^{1}H NMR ($CDCl_3$): δ 8.1–7.2 (m, 60 H, Ph), 6.24 (t, 3 H, $J_{4,5}$ 10.2 Hz, H-4-Man), 5.96

(dd, 3 H, $J_{3,4}$ 10.2 Hz, H-3-Man), 5.95 (m, 1 H, $-CH=$), 5.78 (dd, 3 H, $J_{2,3}$ 3.2 Hz, H-2-Man), 5.24 (4 d, 2 H, $CH_2=CH$), 5.06 (d, 3 H, $J_{1,2}$ 1.8 Hz, H-1-Man), 4.80 (dd, 3 H, $J_{6a,6b}$ 12.0 Hz, H-6a-Man), 4.65 (dd, 3 H, $J_{5,6b}$ 2.7 Hz, H-6b-Man), 4.63 (ddd, 3 H, $J_{5,6a}$ 4.5 Hz, H-5-Man), 4.16 (m, 2 H, OCH_2-CH=), 4.13 and 3.60 (2 d, 2 H, $J_{1a,1b}$ 10.9 Hz, H-1-Et), 4.10 and 3.81 (2 d, 6 H, $J_{1a,1b}$ 11.8 Hz, H-1). Anal. Calcd for $C_{110}H_{94}O_{31}$: C, 69.10; H, 4.96. Found: C, 68.74; H, 5.15.

*2,2,2-Tris(2,3,4,6-tetra-*O*-benzoyl-α-*D*-mannopyranosyloxymethyl)ethanol* (**11**).—A solution of **10** (980 mg, 0.51 mmol) in 10:1 AcOH–H_2O was stirred under reflux with 0.30 g of 10% Pd-on-charcoal. After 5 h the catalyst was filtered off, and the solution concentrated. The residue was codistilled several times with toluene and then subjected to flash-column chromatography (2:3 EtOAc–cyclohexane) to give **11** (872 mg, 91%); $[\alpha]_D$ −73° (*c* 1.1, $CHCl_3$); R_f 0.25 (2:3 EtOAc–cyclohexane); ^{1}H NMR ($CDCl_3$): δ 8.1–7.2 (m, 60 H, Bz), 6.20 (t, 3 H, $J_{4,5}$ 10.2 Hz, H-4-Man), 5.95 (dd, 3 H, $J_{3,4}$ 10.2 Hz, H-3-Man), 5.78 (dd, 3 H, $J_{2,3}$ 3.2 Hz, H-2-Man), 5.27 (d, 3 H, $J_{1,2}$ 1.8 Hz, H-1-Man), 4.80 (dd, 3 H, $J_{6a,6b}$ 12.0 Hz, H-6a-Man), 4.64 (dd, 3 H, $J_{5,6b}$ 2.8 Hz, H-6b-Man), 4.62 (ddd, 3 H, $J_{5,6a}$ 4.5 Hz, H-5-Man), 4.12 and 3.79 (2 d, 6 H, $J_{1a,1b}$ 10.2 Hz, H-1), 4.02 and 3.99 (2 d, 2 H, $J_{1a,1b}$ 10.4 Hz, H-1-Et), 2.13 (bs, 1 H, OH); ^{13}C NMR ($CDCl_3$): δ 166.26–165.41 (C=O, Bz), 133.59–128.31 (arom. C, Bz), 98.67 (C-1-Man), 70.53 (C-2-Man), 70.37 (C-3-Man), 69.52 (C-5-Man), 67.05 (C-1), 66.79 (C-4-Man), 62.94 (C-6-Man), 61.08 (C-1-Et), 45.62 (C-2-Et). Anal. Calcd for $C_{107}H_{90}O_{31}$: C, 68.66; H, 4.85. Found: C, 68.54; H, 4.92.

*2,2,2-Tris(α-*D*-mannopyranosyloxymethyl)ethanol* (**12**).—To a solution of **11** (810 mg, 0.43 mmol) in 10.0 mL of dry MeOH–THF (3:1 v/v) was added methanolic NaOMe (1.0 M, ca. 0.5 mL). The solution was stirred for 3 h at room temperature. The mixture was neutralized by addition of Dowex 50W-X8 (H^+ form) and then the resin was filtered off. The filtrate was concentrated and the resulting syrup was subjected to column chromatography (4:2:1 EtOAc–MeOH–H_2O) to yield **12** as a glass (249 mg, 92%); $[\alpha]_D$ +55° (*c* 0.8, H_2O); R_f 0.12 (4:2:1 EtOAc–MeOH–H_2O); ^{1}H NMR (D_2O): δ 4.83 (d, 3 H, $J_{1,2}$ 1.8 Hz, H-1-Man), 3.98 (dd, 3 H, $J_{2,3}$ 3.2 Hz, H-2-Man), 3.91 (dd, 3 H, $J_{6a,6b}$ 12.2 Hz, H-6a-Man), 3.81 (dd, 3 H, $J_{3,4}$ 9.7 Hz, H-3-Man), 3.76 (t, 3 H, $J_{4,5}$ 9.7 Hz, H-4-Man), 3.77 and 3.45 (2 d, 6 H, $J_{1a,1b}$ 9.8 Hz, H-1), 3.65 (dd, 3 H, $J_{5,6b}$ 5.1 Hz, H-6b-Man), 3.63 (ddd, 3 H, $J_{5,6a}$ 2.5 Hz, H-5-Man), 3.60 (m, 2 H, H-1-Et); ^{13}C NMR (D_2O): δ 100.78 (C-1-Man), 73.26 (C-5-Man), 70.46 (C-2-Man), 71.19 (C-3-Man), 67.31 (C-4-Man), 67.02 (C-1), 61.36 (C-6-Man), 61.27 (C-1-Et), 44.64 (C-2-Et); FABMS: *m/z* 623 $[M]^+$.

*2,2,2-Tris[4-(2,3,4,6-tetra-*O*-benzoyl-α-*D*-mannopyranosyloxy)-2-oxabutyl]ethyl acetate* (**13**).—Compound **6** (230 mg, 0.74 mmol) was glycosylated [tetramethylurea (0.46 mL, 3.85 mmol), silver trifluoromethanesulfonate (0.99 g, 3.85 mmol), **9** (2.54 g, 3.85 mmol)] as described for compound **10**. Column chromatography (1:2 EtOAc–cyclohexane) of the residue gave **13** (1.20 g, 79%); $[\alpha]_D$ −39° (*c* 0.9, $CHCl_3$); R_f 0.27 (1:2 EtOAc–cyclohexane); ^{1}H NMR ($CDCl_3$): δ 8.1–7.2 (m, 60 H, Bz), 6.15 (t, 3 H, $J_{4,5}$ 10.2 Hz, H-4-Man), 5.96 (dd, 3 H, $J_{3,4}$ 10.2 Hz, H-3-Man), 5.75 (dd, 3 H, $J_{2,3}$ 3.2 Hz, H-2-Man), 5.13 (d, 3 H, $J_{1,2}$ 1.8 Hz, H-1-Man), 4.71 (dd, 3 H, $J_{6a,6b}$ 12.0 Hz, H-6a-Man), 4.52 (dd, 3 H, $J_{5,6b}$ 2.8 Hz, H-6b-Man), 4.48 (ddd, 3 H, $J_{5,6a}$ 4.5 Hz, H-5-Man), 4.26 (s, 2 H, H-1-Et), 3.94 and 3.75 (dt and m, 6 H, $J_{4a,4b}$ 11.8, $J_{3,4}$ 6.6 Hz,

H-4), 3.75 (m, 6 H, H-3), 3.59 (s, 6 H, H-1), 1.98 (s, 3 H, Ac). Anal. Calcd for $C_{115}H_{104}O_{34}$: C, 67.51; H, 5.12. Found: C, 67.20; H, 5.08.

2,2,2-Tris[4-(α-D-mannopyranosyloxy)-2-oxabutyl]ethanol (**14**).—Compound **13** (1.00 g, 0.49 mmol) was debenzoylated as described for **12**. The resulting residue was chromatographed (4:2:1 EtOAc–MeOH–H_2O) and further purification was carried out by filtration (LH-20, 3:1 MeOH–H_2O) to yield **14** as an amorphous solid (329 mg, 89%); $[\alpha]_D$ +47° (*c* 0.7, H_2O); R_f 0.18 (4:2:1 EtOAc–MeOH–H_2O); ^{1}H NMR (D_2O): δ 4.77 (d, 3 H, $J_{1,2}$ 1.8 Hz, H-1-Man), 3.82 (dd, 3 H, $J_{2,3}$ 3.6 Hz, H-2-Man), 3.75 (dd, 3 H, $J_{6a,6b}$ 11.8 Hz, H-6a-Man), 3.73–3.55 (m, 12 H, H-3, H-4), 3.68 (dd, 3 H, $J_{3,4}$ 9.8 Hz, H-3-Man), 3.56 (t, 3 H, $J_{4,5}$ 9.8 Hz, H-4-Man), 3.54 (ddd, 3 H, $J_{5,6a}$ 2.2 Hz, H-5-Man), 3.52 (dd, 3 H, $J_{5,6b}$ 4.5 Hz, H-6b-Man), 3.38 (s, 6 H, H-1), 3.22 (s, 2 H, H-1-Et); ^{13}C NMR (D_2O): δ 100.28 (C-1-Man), 73.20 (C-5-Man), 71.08 (C-1), 70.83 (C-3-Man), 70.51 (C-3), 70.27 (C-2-Man), 67.19 (C-4-Man and C-4), 62.16 (C-1-Et), 61.39 (C-6-Man), 45.66 (C-2-Et); FABMS: *m/z* 755 $[M]^+$, 756 $[M + H]^+$.

(±)-4-Benzyloxy-1,2-isopropylidenedioxybutane (**16**).—To a vigorously stirred suspension of (±)-1,2-isopropylidenedioxy-4-butanol (**15**) [17] (25 g, 171 mmol) and tetrabutylammonium iodide (~ 1 g) in dry DMF (250 mL) was added NaH (6.2 g, 257 mmol) in small portions. After 2 h at room temperature a solution of benzyl bromide (24.3 mL, 205 mmol) in dry DMF (25 mL) was added dropwise. Stirring was continued for 3 h, then MeOH (10 mL) added. Ice-cold water was added, and the mixture was stirred for 10 min and extracted with Et_2O. The combined extracts were washed with satd aq $NaHCO_3$ and water, dried over Na_2SO_4, and concentrated. Flash-column chromatography (1:10 EtOAc–cyclohexane) of the residue gave **16** (29.0 g, 71%); R_f 0.26 (1:8 EtOAc–cyclohexane); ^{1}H NMR ($CDCl_3$): δ 7.3–7.1 (m, 5 H, Ph), 4.80 and 4.60 (2 d, 2 H, *J* 11.4 Hz, CH_2Ph), 4.2–3.8 (m, 3 H, H-1, H-2), 3.50 and 3.38 (2 dd, 2 H, $J_{3,4}$ 6.0, $J_{4a,4b}$ 10.2 Hz, H-4), 1.62 (m, 2 H, H-3), 1.48 and 1.40 (2 s, 6 H, CMe_2).

(±)-4-Benzyloxy-1,2-butanediol (**17**).—Compound **16** (23.0 g, 96 mmol) was dissolved in aq 80% AcOH (150 mL) and kept at room temperature overnight. The mixture was then evaporated to dryness under reduced pressure. The residue was dissolved in CH_2Cl_2 (100 mL) and washed twice with satd aq $NaHCO_3$ and water. The organic layer was dried over $MgSO_4$ and concentrated, and the residue was chromatographed (2:1 EtOAc–cyclohexane) to give **17** as a colourless oil (17.4 g, 92%); R_f 0.22 (2:1 EtOAc–cyclohexane); ^{1}H NMR ($CDCl_3$): δ 7.30 (m, 5 H, Ph), 4.50 (s, 2 H, CH_2Ph), 3.7 (bs, 2 H, OH), 3.6–3.3 (m, 3 H, H-1, H-2, H-4), 1.90 (m, 2 H, H-3). Anal. Calcd for $C_{11}H_{16}O_3$: C, 67.32; H, 8.47. Found: C, 67.39; H, 8.47.

(±)-4-Benzyloxy-1-triphenylmethyloxy-2-butanol (**18**).—To a solution of **17** (17.0 g, 87 mmol) in dry pyridine (300 mL) was added chlorotriphenylmethane (38.0 g, 136 mmol) and 4-dimethylaminopyridine (~ 1 g). The mixture was kept for 2 days at room temperature, then poured into cold water (500 mL) and extracted with Et_2O. The combined extracts were washed with satd aq $NaHCO_3$ and twice with water, dried over Na_2SO_4, and concentrated. The residue was chromatographed (1:5 EtOAc–cyclohexane) to afford **18** (35.2 g, 88%); R_f 0.31 (1:5 EtOAc–cyclohexane); ^{1}H NMR ($CDCl_3$): δ 7.7–7.1 (m, 20 H, Ph), 4.48 (s, 2 H, CH_2Ph), 4.02 (m, 1 H, H-2), 3.60 (m, 2 H, H-4), 3.12 (d, 2 H, H-1), 2.85 (bs, 1 H, OH), 1.81 (m, 2 H, H-3). Anal. Calcd for $C_{30}H_{30}O_3$: C, 82.16; H, 6.89. Found: C, 82.54; H, 6.47.

4-Benzyloxy-1-triphenylmethyloxy-2-butanone (**19**).—To a solution of **18** (33.0 g, 75 mmol) in dry CH_2Cl_2 was added dry pyridine (10 mL) and pyridinium chlorochromate (20.0 g, 92 mmol). The suspension was stirred for 4 days, then concentrated to a thick syrup. The residue was dissolved in EtOAc (50 mL) and filtered through a bed of silica gel. The filtrate was concentrated and subjected to chromatography (1:8 EtOAc–cyclohexane) to yield **19** as a syrup (27.3 g, 83%); R_f 0.17 (1:10 EtOAc–cyclohexane); ^{1}H NMR ($CDCl_3$): δ 7.7–7.1 (m, 20 H, Ph), 4.48 (s, 2 H, CH_2Ph), 3.75 (m, 4 H, H-1 and H-4), 2.82 (t, 2 H, H-3). Anal. Calcd for $C_{30}H_{28}O_3$: C, 82.54; H, 6.46. Found: C, 82.54; H, 6.47.

4-Benzyloxy-1-hydroxy-2-butanone (**20**).—Compound **19** (25.0 g, 57.3 mmol) was dissolved in aq 80% AcOH (400 mL) and kept for 2 days at room temperature. Then the solution was concentrated and filtered, and the solvents were removed under reduced pressure. The residue was dissolved in CH_2Cl_2 (200 mL) and washed twice with satd aq $NaHCO_3$ and water. The organic layer was dried over Na_2SO_4 and concentrated. The product was purified by silica gel column chromatography (2:3 EtOAc–cyclohexane) to give **19** as a thick oil (10.1 g, 91%); R_f 0.23 (2:3 EtOAc–cyclohexane); ^{1}H NMR ($CDCl_3$): δ 7.5 (m, 5 H, Ph), 4.52 (s, 2 H, CH_2Ph), 4.31 (s, 2 H, H-1), 3.83 (t, 2 H, H-4, $J_{3,4}$ 6.0 Hz), 3.15 (bs, 1 H, OH), 2.80 (t, 2 H, H-3). Anal. Calcd for $C_{11}H_{14}O_3$: C, 68.02; H, 7.26. Found: C, 67.39; H, 7.36.

2-Azi-4-benzyloxy-1-butanol (**21**).—Into a solution of **20** (7.00 g, 36 mmol) in dry MeOH (400 mL) was condensed dry NH_3 at −30 °C until the volume of the solution had increased by ~25%. Then a solution of hydroxylamine-*O*-sulfonic acid (7.34 g, 65 mmol) in dry MeOH (50 mL) was added dropwise at −20 °C. Stirring at −20 °C was continued for 2 h and the mixture was then allowed to reach room temperature overnight. Precipitated $(NH_4)_2SO_4$ was removed by filtration. Excess of NH_3 was removed by concentrating the solution to a volume of ~25 mL. This solution was then made up with MeOH to 75 mL and Et_3N (7.5 mL) was added. Oxidation of the diaziridine was carried out by adding iodine at 0 °C until the red-brown colour persisted for at least 20 min. The mixture was concentrated, the residue dissolved in CH_2Cl_2 (150 mL), and the solution washed sequentially with aq 10% $Na_2S_2O_3$, water, satd aq $NaHCO_3$, and water. The organic layer was dried over Mg_2SO_4 and concentrated. The light-yellow residue was purified by silica gel column chromatography (1:3 EtOAc–cyclohexane) to give **21** (5.49 g, 74%); R_f 0.24 (1:3 EtOAc–cyclohexane); λ_{max} 343 nm (ϵ 72 cm^2 mmol^{-1}); ^{1}H NMR ($CDCl_3$): δ 7.4 (m, 5 H, Ph), 4.58 (s, 2 H, CH_2Ph), 3.42 (t, 2 H, H-4, $J_{3,4}$ 6.0 Hz), 3.30 (s, 2 H, H-1), 2.95 (bs, 1 H, OH), 1.62 (t, 2 H, H-3). Anal. Calcd for $C_{11}H_{14}N_2O_2$: C, 64.06; H, 6.84; N, 13.58. Found: C, 64.20; H, 6.92; N, 13.60.

*2-Azi-4-benzyloxy-1-(2,3,4,6-tetra-*O*-benzoyl-α-*D*-mannopyranosyloxy)butane* (**22**).—Compound **21** (5.00 g, 24.2 mmol) was glycosylated [tetramethylurea (3.8 mL, 31.5 mmol), silver trifluoromethanesulfonate (8.09 g, 31.5 mmol), tetra-*O*-benzoyl-α-D-mannopyranosyl bromide (20.77 g, 31.5 mmol)] as described for **10**. The residue was chromatographed (1:5 EtOAc–cyclohexane) to give **22** (16.3 g, 86%); $[\alpha]_D$ −31° (*c* 1.0, $CHCl_3$); R_f 0.24 (1:5 EtOAc–cyclohexane); λ_{max} 338 nm (ϵ 48 cm^2 mmol^{-1}); ^{1}H NMR ($CDCl_3$): δ 8.2–7.2 (m, 25 H, Ph), 6.09 (t, 1 H, $J_{4,5}$ 10.1 Hz, H-4-Man), 5.88 (dd, 1 H, $J_{3,4}$ 10.1 Hz, H-3-Man), 5.71 (dd, 1 H, $J_{2,3}$ 3.45 Hz, H-2-Man), 5.05 (d, 1 H,

$J_{1,2}$ 1.8 Hz, H-1-Man), 4.62 (dd, 1 H, $J_{6a,6b}$ 12.0 Hz, H-6a-Man), 4.50 (s, 2 H, CH_2Ph), 4.43 (dd, 1 H, $J_{5,6b}$ 4.5 Hz, H-6b-Man), 4.37 (ddd, 1 H, $J_{5,6a}$ 2.7 Hz, H-5-Man), 3.56 (d, 1 H, $J_{1a,1b}$ 12.0 Hz, H-1a), 3.53 (d, 1 H, H-1b), 3.39 (t, 2 H, $J_{3,4}$ 6.15 Hz, H-4), 1.83 (dt, 1 H, $J_{3a,3b}$ 15.0 Hz, H-3a), 1.79 (dt, 1 H, $J_{3,4}$ 6.15 Hz, H-3b). Anal. Calcd for $C_{45}H_{40}N_2O_{11}$: C, 68.87; H, 5.14; N, 3.57. Found: C, 69.35; H, 5.55; N, 3.18.

*2-Azi-1-(2,3,4,6-tetra-*O*-benzoyl-α-*D*-mannopyranosyloxy)-4-butanol* (**23**).—Compound **22** was debenzylated according to Klemer et al. [18]. To a stirred solution of **22** (6.40 g, 8.15 mmol) and NaI (12.22 g, 81.50 mmol) in dry MeCN (120 mL) under Ar was added chlorotrimethylsilane (10.35 mL, 81.50 mmol). The reaction mixture was stirred at room temperature for 4 h, then water was added and the suspension extracted with CH_2Cl_2. The combined extracts were washed sequentially with aq 10% $Na_2S_2O_3$, satd aq $NaHCO_3$, and water, dried over $MgSO_4$, and concentrated. The resulting syrup was subjected to flash-column chromatography (1:2 EtOAc–cyclohexane) to yield **22** (5.15 g, 91%); $[\alpha]_D$ −49° (*c* 0.8, $CHCl_3$); R_f 0.18 (1:2 EtOAc–cyclohexane); λ_{max} 346 nm (ϵ 46 cm^2 $mmol^{-1}$); ^1H NMR ($CDCl_3$): δ 8.1–7.2 (m, 20 H, Ph), 6.12 (t, 1 H, $J_{4,5}$ 10.2 Hz, H-4-Man), 5.90 (dd, 1 H, $J_{3,4}$ 10.2 Hz, H-3-Man), 5.73 (dd, 1 H, $J_{2,3}$ 3.2 Hz, H-2-Man), 5.12 (d, 1 H, $J_{1,2}$ 1.8 Hz, H-1-Man), 4.69 (dd, 1 H, $J_{6a,6b}$ 12.0 Hz, H-6a-Man), 4.50 (dd, 1 H, $J_{5,6b}$ 4.5 Hz, H-6b-Man), 4.42 (ddd, 1 H, $J_{5,6a}$ 3.0 Hz, H-5-Man), 3.62 (t, 1 H, $J_{3,4}$ 6.15 Hz, H-4a), 3.61 (d, 1 H, $J_{1a,1b}$ 12.0 Hz, H-1a), 3.60 (t, 1 H, H-4b), 3.59 d, 1 H, H-1b), 1.80 (dt, 1 H, $J_{3a,3b}$ 15.0 Hz, H-3a), 1.95 (bs, 1 H, OH), 1.78 (dt, H-3b). Anal. Calcd for $C_{38}H_{34}N_2O_{11}$: C, 65.71; H, 4.93; N, 4.03. Found: C, 65.19; H, 5.21; N, 3.93.

*2-Azi-1-(2,3,4,6-tetra-*O*-benzoyl-α-*D*-mannopyranosyloxy)-5-oxa-7-thiaoctane* (**24**).—Compound **23** was converted into the methylthiomethyl ether as described by Kyler and co-workers [19]. To a solution of **23** (3.50 g, 5.04 mol) and dimethyl sulfide (3.0 mL, 40.9 mol) in dry MeCN (30 mL) at 0 °C was added portionwise benzoyl peroxide (4.95 g, 20.4 mmol) over a period of 20 min. After stirring for 3 h at 0 °C, the mixture was diluted with CH_2Cl_2 and washed twice with aq NaOH (1.0 M) and water. The organic layer was dried over $MgSO_4$ and concentrated, and the residue was chromatographed (1:5 EtOAc–cyclohexane). Compound **24** crystallized from Et_2O–petroleum ether; 3.51 g, 92%; R_f 0.18 (1:5 EtOAc–cyclohexane), 0.42 (1:3 EtOAc–cyclohexane); mp 65 °C; $[\alpha]_D$ −44° (*c* 0.5, $CHCl_3$); λ_{max} 338 nm (ϵ 76 cm^2 $mmol^{-1}$); ^1H NMR ($CDCl_3$): δ 8.1–7.2 (m, 20 H, Ph), 6.11 (t, 1 H, $J_{4,5}$ 10.2 Hz, H-4-Man), 5.90 (dd, 1 H, $J_{3,4}$ 10.2 Hz, H-3-Man), 5.72 (dd, 1 H, $J_{2,3}$ 3.2 Hz, H-2-Man), 5.10 (d, 1 H, $J_{1,2}$ 1.8 Hz, H-1-Man), 4.65 (dd, 1 H, $J_{6a,6b}$ 12.0 Hz, H-6a-Man), 4.62 (s, 2 H, H-6), 4.49 (dd, 1 H, $J_{5,6b}$ 4.5 Hz, H-6b-Man), 4.40 (ddd, 1 H, $J_{5,6a}$ 3.0 Hz, H-5-Man), 3.61 and 3.58 (2 d, 2 H, $J_{1a,1b}$ 12.0 Hz, H-1), 3.47 and 3.42 (2 t, 2 H, H-4), 2.18 (s, 3 H, H-8), 1.85 and 1.82 (2 dt, 2 H, $J_{3a,3b}$ 15.0, $J_{3,4}$ 6.15 Hz, H-3). Anal. Calcd for $C_{40}H_{38}N_2O_{11}S$: C, 63.65; H, 5.07; N, 3.71. Found: C, 63.55; H, 5.08; N 3.87.

p-*Methoxybenzyl 2,2,2-tris[7-azi-8-(2,3,4,6-tetra-*O*-benzoyl-α-*D*-mannopyranosyloxy)-2,4-dioxaoctyl]ethyl ether* (**50**).—*p*-Methoxybenzyl 2,2,2-tris(hydroxymethyl)ethyl ether (**2**) (41 mg, 0.16 mmol), **24** (660 mg, 0.80 mmol), and tetrabutylammonium trifluoromethanesulfonate (63 mg, 0.16 mmol) were dissolved in dry DCE/THF (1:1 v/v, 9.0 mL) and stirred under Ar over molecular sieves (4 Å, ~ 0.5 g) for 1 h at room temperature. The solution was cooled to 0 °C and *N*-iodosuccinimide (189 mg, 0.84

mmol) was added. The mixture was stirred for 45 min at 0 °C. Then CH_2Cl_2 (50 mL) was added and the suspension filtered through a bed of Celite. The filtrate was washed with aq 10% $Na_2S_2O_3$, satd aq $NaHCO_3$, and water, dried over Na_2SO_4, and concentrated. The residue was twice chromatographed (1:1 EtOAc–cyclohexane and 2:3 EtOAc–cyclohexane) to give **50** (436 mg, 75%); R_f 0.34 (2:3 EtOAc–cyclohexane); $[\alpha]_D$ −40° (*c* 1.0, $CHCl_3$); λ_{max} 338 nm (ϵ 205 cm^2 $mmol^{-1}$); ^1H NMR ($CDCl_3$): δ 8.1–7.2 (m, 60 H, Bz), 7.21 and 6.82 (2 d, 4 H, Ph), 6.10 (t, 3 H, $J_{4,5}$ 10.2 Hz, H-4-Man), 5.88 (dd, 3 H, $J_{3,4}$ 10.2 Hz, H-3-Man), 5.71 (dd, 3 H, $J_{2,3}$ 3.2 Hz, H-2-Man), 5.05 (d, 3 H, $J_{1,2}$ 1.8 Hz, H-1-Man), 4.66 (dd, 3 H, $J_{6a,6b}$ 12.0 Hz, H-6a-Man), 4.62 (s, 6 H, H-3), 4.48 (dd, 3 H, $J_{5,6b}$ 4.5 Hz, H-6b-Man), 4.40 (s, 2 H, CH_2Ph), 4.37 (ddd, 3 H, $J_{5,6a}$ 3.0 Hz, H-5-Man), 3.72 (s, 3 H, OMe), 3.61 and 3.58 (2 d, 6 H, $J_{8a,8b}$ 12.0 Hz, H-8), 3.55 (s, 6 H, H-1), 3.43 (s, 2 H, H-1-Et), 3.38 and 3.37 (2 ddd, 6 H, $J_{5a,5b}$ 12.0, $J_{5a,6a}$ 6.3, $J_{5b,6a}$ 6.0 Hz, H-5), 1.83 and 1.79 (2 ddd, 6 H, $J_{6a,6b}$ 15.0 Hz, H-6). Anal. Calcd for $C_{130}H_{122}N_6O_{38}$: C, 65.71; H, 5.17; N, 3.54. Found: C, 65.97; H, 5.71; N, 3.27.

*2,2,2-Tris[7-azi-8-(2,3,4,6-tetra-*O*-benzoyl-α-*D*-mannopyranosyloxy)-2,4-dioxaoctyl]ethanol* (**51**).—Compound **50** was debenzylated according to a method described by Oikawa et al. [20]. A solution of **50** (300 mg, 126 μmol) in CH_2Cl_2 (10 mL) was stirred with (2 mL) water, and then 2,3-dichloro-5,6-dicyanoquinone (34 mg, 151 μmol) was added. After being stirred for 3 h at room temperature, CH_2Cl_2 was added, and the mixture filtered through a bed of Celite. The filtrate was washed with satd aq $NaHCO_3$ and water, dried over Na_2SO_4, and concentrated. The residue was chromatographed (2:3 EtOAc–cyclohexane) to give **51** (206 mg, 72%); R_f 0.24 (2:3 EtOAc–cyclohexane); $[\alpha]_D$ −60° (*c* 0.3, $CHCl_3$); λ_{max} 337 nm (ϵ 217 cm^2 $mmol^{-1}$); ^1H NMR ($CDCl_3$): δ 8.1–7.2 (m, 60 H, Bz), 6.10 (t, 3 H, $J_{4,5}$ 10.2 Hz, H-4-Man), 5.89 (dd, 3 H, $J_{3,4}$ 10.2 Hz, H-3-Man), 5.72 (dd, 3 H, $J_{2,3}$ 3.2 Hz, H-2-Man), 5.09 (d, 3 H, $J_{1,2}$ 1.8 Hz, H-1-Man), 4.68 (dd, 3 H, $J_{6a,6b}$ 12.0 Hz, H-6a-Man), 4.65 (s, 6 H, H-3), 4.46 (dd, 3 H, $J_{5,6b}$ 4.5 Hz, H-6b-Man), 4.39 (ddd, 3 H, $J_{5,6a}$ 3.0 Hz, H-5-Man), 3.71 (t, 2 H, *J* 6.0 Hz, H-1-Et), 3.62 and 3.58 (2 d, 6 H, $J_{8a,8b}$ 12.0 Hz, H-8), 3.59 (s, 6 H, H-1), 3.42 and 3.41 (2 ddd, 6 H, $J_{5a,5b}$ 12.0, $J_{5a,6a}$ 6.3, $J_{5b,6a}$ 6.0 Hz, H-5), 2.61 (t, 1 H, OH), 1.84 and 1.79 (2 ddd, 6 H, $J_{6a,6b}$ 15.0 Hz, H-6); ^{13}C NMR ($CDCl_3$): δ 166.2–165.4 (C=O, Bz), 133.6–128.4 (arom. C, Bz), 97.46 (C-1-Man), 95.77 (C-3), 70.23 (C-8), 70.01 (C-2-Man), 69.93 (C-3-Man), 69.24 (C-5-Man), 67.99 (C-1), 66.74 (C-4-Man), 64.37 (C-1-Et), 62.72 (C-6-Man), 62.08 (C-5), 44.37 (C-2-Et), 30.78 (C-6), 26.47 (C-7). Anal. Calcd for $C_{122}H_{114}N_6O_{37}$: C, 65.71; H, 5.17; N, 3.54. Found: C, 65.97; H, 5.71; N, 3.27.

*2,2,2-Tris[7-azi-8-(α-*D*-mannopyranosyloxy)-2,4-dioxaoctyl]ethanol* (**52**).—Compound **51** (175 mg, 78 μmol) was debenzoylated as described for **12**. The resulting residue was subjected to column chromatography (7:2:1 EtOAc–MeOH–H_2O) and further purification was carried out by filtration (LH-20, 3:1 MeOH–H_2O) to yield **52** as an amorphous solid (73 mg, 94%); R_f 0.20 (7:2:1 EtOAc–MeOH–H_2O); $[\alpha]_D$ +54° (*c* 0.2, H_2O); λ_{max} 338 nm (ϵ 204 cm^2 $mmol^{-1}$); ^1H NMR (D_2O): 4.67 (d, 3 H, $J_{1,2}$ 1.8 Hz, H-1-Man), 4.56 (s, 6 H, H-3), 3.79 (dd, 3 H, $J_{2,3}$ 3.6 Hz, H-2-Man), 3.74 (dd, 3 H, $J_{6a,6b}$ 12.3, $J_{5,6a}$ 2.2 Hz, H-6a-Man), 3.64 (dd, 3 H, $J_{5,6b}$ 5.2 Hz, H-6b-Man), 3.62 (dd, 3 H, $J_{3,4}$ 9.7 Hz, H-3-Man), 3.52 (t, 3 H, $J_{4,5}$ 9.7 Hz, H-4-Man), 3.51 and 3.36 (2 d, 6 H,

$J_{8a,8b}$ 12.0 Hz, H-8), 3.48 (s, 6 H, H-1), 3.41 (ddd, 3 H, H-5-Man), 3.33 (2 t, 6 H, $J_{5,6}$ 6.0 Hz, H-5), 3.20 (s, 2 H, H-1-Et), 1.70 (t, 6 H, H-6); ^{13}C NMR (D_2O): δ 99.98 (C-1-Man), 95.77 (C-3), 73.44 (C-5-Man), 70.93 (C-3-Man), 70.26 (C-2-Man), 68.46 (C-8), 67.99 (C-1), 67.04 (C-4-Man), 62.82 (C-5), 61.73 (C-1-Et), 44.53 (C-2-Et), 27.30 (C-7); FABMS: *m/z* 1007 $[M]^+$, 1008 $[M + 1]^+$, 1030 $[M + Na]^+$.

*2,2,2-Tris[10-azi-11-(2,3,4,6-tetra-*O*-benzoyl-α-*D*-mannopyranosyloxy)-2,5,7-trioxaundecyl]ethyl acetate* (**59**), *2,2-Bis[10-azi-11-(2,3,4,6-tetra-*O*-benzoyl-α-*D*-mannopyranosyloxy)-2,5,7-trioxaundecyl]-2-(4′-hydroxy-2′-oxabutyl)ethyl acetate* (**61**) *and 2-[10-azi-11-(2,3,4,6-tetra-*O*-benzoyl-α-*D*-mannopyranosyloxy)-2,5,7-trioxaundecyl]-2,2-bis(4′-hydroxy-2′-oxabutyl)ethyl acetate* (**63**).—Compounds **6** (90 mg, 0.30 mmol) and **24** (514 mg, 0.68 mmol) were coupled [tetrabutylammonium trifluoromethanesulfonate (118 mg, 0.30 mmol), *N*-iodosuccinimide (161 mg, 0.72 mmol)] as described for **50**. The resulting crude products were twice chromatographed (1:1 EtOAc–cyclohexane and 2:3 EtOAc–cyclohexane) to give the desired derivatives as colourless foams:

Compound **59**: 349 mg (48%); R_f 0.19 (2:3 EtOAc–cyclohexane); $[\alpha]_D$ −32° (*c* 0.3, $CHCl_3$); λ_{max} 336 nm (ε 173 cm^2 $mmol^{-1}$); ^{1}H NMR ($CDCl_3$): δ 8.1–7.2 (m, 60 H, Bz), 6.10 (t, 3 H, $J_{4,5}$ 10.2 Hz, H-4-Man), 5.87 (dd, 3 H, $J_{3,4}$ 10.2 Hz, H-3-Man), 5.70 (dd, 3 H, $J_{2,3}$ 3.2 Hz, H-2-Man), 5.08 (d, 3 H, $J_{1,2}$ 1.8 Hz, H-1-Man), 4.67 (dd, 3 H, $J_{6a,6b}$ 12.0 Hz, H-6a-Man), 4.66 (s, 6 H, H-6), 4.45 (dd, 3 H, $J_{5,6b}$ 4.5 Hz, H-6b-Man), 4.38 (ddd, 3 H, $J_{5,6a}$ 3.0 Hz, H-5-Man), 4.12 (s, 2 H, H-1-Et), 3.69 and 3.67 [2 m(dd), 6 H, H-3], 3.63 and 3.57 (2 d, 6 H, $J_{11a,11b}$ 12.0 Hz, H-11), 3.58 and 3.56 [2 m(dd), 6 H, H-4], 3.48 (s, 6 H, H-1), 3.42 and 3.41 (2 ddd, 6 H, $J_{8a,8b}$ 12.0 Hz, H-8), 2.02 (s, 3 H, Ac), 1.88 and 1.81 (2 ddd, 6 H, $J_{9a,9b}$ 15.0, $J_{8a,9a}$ 6.3, $J_{8b,9a}$ 6.0 Hz, H-9); ^{13}C NMR ($CDCl_3$): δ 170.86, 166.2–165.4 (C=O, Ac and Bz), 133.6–128.4 (arom. C, Bz), 97.54 (C-1-Man), 95.48 (C-6), 71.04 (C-1), 70.30 (C-4), 70.12 (C-11), 70.09 (C-2-Man), 69.99 (C-3-Man), 69.32 (C-5-Man), 67.05 (C-3), 66.84 (C-4-Man), 63.89 (C-1-Et), 62.81 (C-6-Man), 62.01 (C-8), 44.70 (C-2-Et), 30.83 (C-9), 26.54 (C-10). Anal. Calcd for $C_{130}H_{128}N_6O_{41}$: C, 64.24; H, 5.31; N, 3.46. Found: C, 63.68; H, 4.91; N, 3.31.

Compound **61**: 135 mg (26%); R_f 0.18 (1:1 EtOAc–cyclohexane); $[\alpha]_D$ −43° (*c* 0.1, $CHCl_3$); λ_{max} 336 nm (ε 175 cm^2 $mmol^{-1}$); ^{1}H NMR ($CDCl_3$): δ 8.1–7.2 (m, 40 H, Bz), 6.10 (t, 2 H, $J_{4,5}$ 10.2 Hz, H-4-Man), 5.88 (dd, 2 H, $J_{3,4}$ 10.2 Hz, H-3-Man), 5.71 (dd, 2 H, $J_{2,3}$ 3.2 Hz, H-2-Man), 5.09 (d, 2 H, $J_{1,2}$ 1.8 Hz, H-1-Man), 4.67 (dd, 2 H, $J_{6a,6b}$ 12.0 Hz, H-6a-Man), 4.66 (s, 4 H, H-6), 4.46 (dd, 2 H, $J_{5,6b}$ 4.5 Hz, H-6b-Man), 4.38 (ddd, 2 H, $J_{5,6a}$ 3.0 Hz, H-5-Man), 4.12 (s, 2 H, H-1-Et), 3.69 and 3.67 (2 m, 4 H, H-3), 3.69 and 3.52 (2 m, 4 H, H-3′, H-4′), 3.63 and 3.57 (2 d, 4 H, $J_{11a,11b}$ 12.0 Hz, H-11), 3.59 and 3.56 (2 m, 4 H, H-4), 3.48 (s, 4 H, H-1), 3.47 (s, 2 H, H-1′), 3.44 and 3.43 (2 ddd, 4 H, $J_{8a,8b}$ 12.0, $J_{8a,9b}$ 6.3 Hz, H-8), 2.45 (bs, 1 H, OH), 2.02 (s, 3 H, Ac), 1.86 and 1.81 (2 ddd, 4 H, $J_{9a,9b}$ 15.0, $J_{9a,8a}$ 6.0 Hz); ^{13}C NMR ($CDCl_3$): δ 170.86, 166.16–165.40 (C=O, Ac, Bz), 133.58–128.39 (arom. C, Bz), 97.53 (C-1-Man), 95.45 (C-6), 72.51, 61.51 (C-3′, C-4′), 71.04 (C-1), 70.29 (C-4), 70.11 (C-11), 70.07 (C-2-Man), 69.98 (C-3-Man), 69.61 (C-1′), 69.32 (C-5-Man), 66.98 (C-3), 66.83 (C-4-Man), 63.75 (C-1-Et), 62.80 (C-6-Man), 62.04 (C-8), 44.65 (C-2-Et), 30.83 (C-9), 26.52 (C-10). Anal. Calcd for $C_{91}H_{94}N_4O_{30}$: C, 63.41; H, 5.50; N 3.25. Found: C, 63.12; H, 5.73; N, 3.01.

Compound **63**: 58 mg (19%); R_f 0.24 (2:1 EtOAc–cyclohexane); $[\alpha]_D$ −53° (*c* 0.1, $CHCl_3$); λ_{max} 337 nm (ϵ 81 cm^2 $mmol^{-1}$); ^1H NMR ($CDCl_3$): δ 8.1–7.2 (m, 20 H, Bz), 6.10 (t, 1 H, $J_{4,5}$ 10.2 Hz, H-4-Man), 5.88 (dd, 1 H, $J_{3,4}$ 10.2 Hz, H-3-Man), 5.70 (dd, 1 H, $J_{2,3}$ 3.2 Hz, H-2-Man), 5.09 (d, 2 H, $J_{1,2}$ 1.8 Hz, H-1-Man), 4.66 (dd, 1 H, $J_{6a,6b}$ 12.0 Hz, H-6a-Man), 4.68 (s, 2 H, H-6), 4.47 (dd, 1 H, $J_{5,6b}$ 4.5 Hz, H-6b-Man), 4.39 (ddd, 1 H, $J_{5,6a}$ 3.0 Hz, H-5-Man), 4.10 (s, 2 H, H-1-Et), 3.65 and 3.64 (2 m, 2 H, H-3), 3.71 and 3.54 (2 m, 8 H, H-3′, H-4′), 3.63 and 3.57 (2 d, 2 H, $J_{11a,11b}$ 12.0 Hz, H-11), 3.59 and 3.57 (2 m, 2 H, H-4), 3.53 (s, 2 H, H-1), 3.51 (s, 4 H, H-1′), 3.45 and 3.43 (2 ddd, 2 H, $J_{8a,8b}$ 12.1, $J_{8a,9b}$ 6.3 Hz, H-8), 2.40 (bs, 2 H, OH), 2.03 (s, 3 H, Ac), 1.90 and 1.82 (2 ddd, 2 H, $J_{9a,9b}$ 15.0, $J_{9a,8a}$ 6.1 Hz); ^{13}C NMR ($CDCl_3$): δ 170.84, 166.15–165.40 (C=O, Ac, Bz), 133.58–128.38 (arom. C, Bz), 97.65 (C-1-Man), 95.44 (C-6), 71.83, 61.44 (C-3′, C-4′), 71.32 (C-1), 70.28 (C-4), 70.11 (C-11), 70.02 (C-2-Man), 69.99 (C-3-Man), 69.51 (C-1′), 69.32 (C-5-Man), 67.00 (C-3), 66.83 (C-4-Man), 63.70 (C-1-Et), 62.82 (C-6-Man), 62.04 (C-8), 44.47 (C-2-Et), 30.83 (C-9), 26.54 (C-10). Anal. Calcd for $C_{52}H_{60}N_2O_{19}$: C, 61.41; H, 5.95; N 2.75. Found: C, 60.83; H, 6.41; N, 2.88.

2,2,2-Tris[10-azi-11-(α-D-mannopyranosyloxy)-2,5,7-trioxaundecyl]ethanol (**60**).—Compound **59** (201 mg, 0.08 mmol) was debenzoylated as described for **12**. The resulting syrup was subjected to column chromatography (7:2:1 EtOAc–MeOH–H_2O) and further purification was carried out by filtration (LH-20, 3:1 MeOH–H_2O) to yield **60** as an amorphous solid (90 mg, 95%); $[\alpha]_D$ +50° (*c* 0.1, H_2O); R_f 0.19 (7:2:1 EtOAc–MeOH–H_2O); λ_{max} 336 nm (ϵ 239 cm^2 $mmol^{-1}$); ^1H-NMR (D_2O): δ 4.66 (d, 3 H, $J_{1,2}$ 1.8 Hz, H-1-Man), 4.59 (s, 6 H, H-6), 3.78 (dd, 3 H, $J_{2,3}$ 3.6 Hz, H-2-Man), 3.73 (dd, 3 H, $J_{6a,6b}$ 12.3 Hz, H-6a-Man), 3.65 and 3.64 [m(dd), 6 H, H-3], 3.63 (dd, 3 H, $J_{3,4}$ 9.7 Hz, H-3-Man), 3.62 (dd, 3 H, $J_{5,6b}$ 5.2 Hz, H-6b-Man), 3.57 and 3.56 [m(dd), 6 H, H-4], 3.53 (d, 3 H, $J_{11a,11b}$ 12.0 Hz, H-11a), 3.52 (t, 3 H, $J_{4,5}$ 9.7 Hz, H-4-Man), 3.48 (s, 2 H, H-1-Et), 3.41 (ddd, 3 H, $J_{5,6a}$ 2.2 Hz, H-5-Man), 3.38 (s, 6 H, H-1), 3.36 (d, 3 H, H-11b), 3.35 (t, 6 H, H-8), 1.73 (t, 6 H, $J_{8,9}$ 6.0 Hz, H-9); ^{13}C NMR (D_2O): δ 99.98 (C-1-Man), 95.22 (C-6), 73.45 (C-5-Man), 70.97 (C-4), 70.92 (C-3-Man), 70.35 (C-1), 70.25 (C-2-Man), 68.48 (C-11), 67.23 (C-3), 67.04 (C-4-Man), 62.89 (C-8), 62.17 (C-1-Et), 61.28 (C-6-Man), 45.58 (C-2-Et), 30.28 (C-9), 27.27 (C-10); FABMS: *m/z* 1162 $[M + Na]^+$.

2,2-Bis[10-azi-11-(α-D-mannopyranosyloxy)-2,5,7-trioxaundecyl]-2-(4′-hydroxy-2′-oxabutyl)ethanol (**62**).—Compound **61** (102 mg, 59 μmol) was debenzoylated [methanolic NaOMe (1.0 M), ca. 100 μL] as described for **12**. The resulting syrup was chromatographed (11:2:1 EtOAc–MeOH–H_2O) and further purification was carried out by filtration (LH-20, 3:1 MeOH–H_2O) to yield **62** as an amorphous solid (47 mg, 93%); $[\alpha]_D$ +35° (*c* 0.1, H_2O); R_f 0.33 (7:2:1 EtOAc–MeOH–H_2O); λ_{max} 338 nm (ϵ 188 cm^2 $mmol^{-1}$); ^1H NMR (D_2O): δ 4.65 (d, 2 H, $J_{1,2}$ 1.8 Hz, H-1-Man), 4.58 (s, 4 H, H-6), 3.77 (dd, 2 H, $J_{2,3}$ 3.6 Hz, H-2-Man), 3.73 (dd, 2 H, $J_{6a,6b}$ 12.3 Hz, H-6a-Man), 3.65 and 3.64 (m, 4 H, H-3), 3.63 (dd, 2 H, $J_{3,4}$ 9.7 Hz, H-3-Man), 3.62 (dd, 2 H, $J_{5,6b}$ 5.2 Hz, H-6b-Man), 3.58, 3.46 (2 m, 4 H, H-3′, H-4′), 3.55 and 3.54 (m, 4 H, H-4), 3.52 and 3.35 (2 d, 4 H, $J_{11a,11b}$ 12.0 Hz, H-11), 3.51 (t, 2 H, $J_{4,5}$ 9.7 Hz, H-4-Man), 3.48 (s, 2 H, H-1-Et), 3.40 (ddd, 2 H, $J_{5,6a}$ 2.2 Hz, H-5-Man), 3.39 (s, 4 H, H-1), 3.37 (s, 2 H, H-1′), 3.34 (t, 4 H, $J_{8,9}$ 6.0 Hz, H-8), 1.73 (t, 4 H, H-9); ^{13}C NMR (D_2O): δ 99.95

(C-1-Man), 95.20 (C-6), 73.44 (C-5-Man), 72.97, 60.88 (C-3',C-4'), 70.94 (C-4), 70.92 (C-3-Man), 70.34 (C-1), 70.30 (C-1'), 70.24 (C-2-Man), 68.44 (C-11), 67.21 (C-3), 67.02 (C-4-Man), 62.87 (C-8), 62.08 (C-1-Et), 61.28 (C-6-Man), 45.58 (C-2-Et), 30.27 (C-9), 27.25 (C-10); FABMS: m/z 871 $[M + Na]^+$.

2-[10-Azi-11-(α-D-mannopyranosyloxy)-2,5,7-trioxaundecyl]-2,2-bis(4'-hydroxy-2'-oxabutyl)ethanol (**64**).—Compound **63** (30 mg, 29 μmol) was debenzoylated [methanolic NaOMe (1.0 M), ca. 100 μL] as described for **12**. The resulting syrup was chromatographed (11:2:1 EtOAc–MeOH–H_2O) and further purification was carried out by filtration (LH-20, 3:1 MeOH–H_2O) to yield **64** as an amorphous solid (12 mg, 72%); $[\alpha]_D$ +26° (*c* 0.1, H_2O); R_f 0.38 (7:2:1 EtOAc–MeOH–H_2O); λ_{max} 338 nm (ϵ 67 cm^2 $mmol^{-1}$); ^1H NMR (D_2O): δ 4.66 (d, 1 H, $J_{1,2}$ 1.8 Hz, H-1-Man), 4.59 (s, 2 H, H-6), 3.77 (dd, 1 H, $J_{2,3}$ 3.6 Hz, H-2-Man), 3.73 (dd, 1 H, $J_{6a,6b}$ 12.1 Hz, H-6a-Man), 3.65 and 3.63 (m, 2 H, H-3), 3.63 (dd, 1 H, $J_{3,4}$ 9.7 Hz, H-3-Man), 3.61 (dd, 1 H, $J_{5,6b}$ 5.0 Hz, H-6b-Man), 3.57, 3.44 (2 m, 8 H, H-3', H-4'), 3.56 and 3.54 (2 m, 2 H, H-4), 3.52 and 3.35 (2 d, 2 H, $J_{11a,11b}$ 12.0 Hz, H-11), 3.50 (t, 1 H, $J_{4,5}$ 9.7 Hz, H-4-Man), 3.48 (s, 2 H, H-1-Et), 3.40 (ddd, 1 H, $J_{5,6a}$ 2.2 Hz, H-5-Man), 3.39 (s, 2 H, H-1), 3.35 (s, 4 H, H-1'), 3.36 (t, 2 H, $J_{8,9}$ 6.0 Hz, H-8), 1.74 (t, 2 H, H-9); ^{13}C NMR (D_2O): δ 99.96 (C-1-Man), 95.22 (C-6), 73.43 (C-5-Man), 72.75, 60.64 (C-3', C-4'), 70.94 (C-4), 70.91 (C-3-Man), 70.34 (C-1), 70.28 (C-1'), 70.24 (C-2-Man), 68.46 (C-11), 67.21 (C-3), 67.03 (C-4-Man), 62.87 (C-8), 62.12 (C-1-Et), 61.28 (C-6-Man), 45.57 (C-2-Et), 30.24 (C-9), 27.36 (C-10); FABMS: m/z 581 $[M + Na]^+$, 559 $[M]^+$.

(±)-5-Benzyloxy-1,2-isopropylidenedioxypentane (**26**).—(±)-1,2-Isopropylidenedioxy-5-pentanol (**25**) [21] was benzylated [NaH (343 mg, 14.30 mmol), benzyl bromide (1.55 mL, 13.09 mmol)] as described for **16**. Flash-column chromatography (1:10 EtOAc–cyclohexane) of the residue gave **26** (2.83 g, 95%); R_f 0.29 (1:8 EtOAc–cyclohexane; ^1H NMR ($CDCl_3$): δ 7.3–7.1 (m, 5 H, Ph), 4.50 (s, 2 H, CH_2), 4.20–4.02 (m, 2 H, H-1a, H-2), 3.60–3.40 (m, 3 H, H-1b, H-5), 1.80–1.60 (m, 4 H, H-3, H-4), 1.40 and 1.32 (2 s, 6 H, CMe_2).

(±)-5-Benzyloxy-1,2-pentanediol (**27**).—Compound **26** (2.76 g, 11.0 mmol) was hydrolyzed as described for **17**. Column chromatography (2:1 EtOAc–cyclohexane) gave **27** as a colourless oil (2.18 g, 94%); R_f 0.23 (2:1 EtOAc–cyclohexane); ^1H NMR ($CDCl_3$): δ 7.30 (m, 5 H, Ph), 4.50 (s, 2 H, CH_2Ph), 3.7 (bs, 2 H, OH), 3.7–3.3 (m, 5 H, H-1, H-2, H-5), 1.72 (m, 2 H, H-4), 1.45 (m, 2 H, H-3). Anal. Calcd for $C_{12}H_{18}O_3$: C, 68.55; H, 8.63. Found: C, 68.10; H, 9.05.

(±)-5-Benzyloxy-1-triphenylmethyloxy-2-pentanol (**28**).—Compound **27** (2.01 g, 9.57 mmol) was tritylated [chlorotriphenylmethane (3.74 g, 13.40 mmol), 4-dimethylaminopyridine (~ 0.2 g)] as described for **18**. Column chromatography (1:8 EtOAc–cyclohexane) afforded **28** (3.81 g, 88%); R_f 0.24 (1:8 EtOAc–cyclohexane); ^1H NMR ($CDCl_3$): δ 7.7–7.1 (m, 20 H, 4 Ph), 4.48 (s, 2 H, CH_2Ph), 3.80 (m, 1 H, H-2), 3.45 and 3.43 (2 t, 2 H, $J_{4,5}$ 6.0 Hz, H-5), 3.14 (m, 2 H, H-1), 2.65 (bs, 1 H, OH), 1.80–1.35 (m, 4 H, H-3, H-4). Anal. Calcd for $C_{31}H_{32}O_3$: C, 82.27; H, 7.13. Found: C, 82.14; H, 7.42.

5-Benzyloxy-1-triphenylmethyloxy-2-pentanone (**29**).—Compound **28** (3.72 g, 8.21 mmol) was oxidized [pyridinium chlorochromate (1.12 g, 5.20 mmol), 3 days] as described for **19**. Flash-column chromatography (1:8 EtOAc–cyclohexane) yielded **29** as a syrup (3.11 g, 84%); R_f 0.18 (1:10 EtOAc–cyclohexane); ^1H NMR ($CDCl_3$): δ

7.5–7.2 (m, 20 H, 4 Ph), 4.48 (s, 2 H, CH_2Ph), 3.75 (s, 2 H, H-1), 3.48 (t, 2 H, $J_{4,5}$ 6.0 Hz, H-5), 2.76 (t, 2 H, $J_{3,4}$ 6.0 Hz, H-3), 1.88 (q, 2 H, H-4). Anal. Calcd for $C_{31}H_{30}O_3$: C, 82.64; H, 6.71. Found: C, 82.87; H, 6.75.

5-Benzyloxy-1-hydroxy-2-pentanone (**30**).—Compound **29** (3.09 g, 6.86 mmol) was detritylated as described for **20**. Column chromatography (2:3 EtOAc–cyclohexane) gave **30** as a thick oil (1.10 g, 77%); R_f 0.32 (1:1 EtOAc–cyclohexane); ^{1}H NMR ($CDCl_3$): δ 7.5–7.2 (m, 5 H, Ph), 4.50 (s, 2 H, CH_2Ph), 4.28 (s, 2 H, H-1), 3.48 (t, 2 H, $J_{4,5}$ 6.0 Hz, H-5), 3.00 (bs, 1 H, OH), 2.80 (t, 2 H, $J_{3,4}$ 6.15, H-3), 2.21 (m, 2 H, H-4). Anal. Calcd for $C_{12}H_{16}O_3$: C, 69.21; H, 7.74. Found: C, 69.08; H, 8.14.

2-Azi-5-benzyloxy-1-pentanol (**31**).—Compound **30** (1.00 g, 4.80 mmol) was treated [hydroxylamine-*O*-sulfonic acid (0.98 g, 8.64 mmol), Et_3N (1.5 mL)] as described for compound **21**. Column chromatography (1:3 EtOAc–cyclohexane) gave **31** (610 mg, 58%); R_f 0.36 (1:2 EtOAc–cyclohexane); λ_{max} 348 nm (ϵ 76 cm^2 mmol^{-1}); ^{1}H NMR ($CDCl_3$): δ 7.4–7.2 (m, 5 H, Ph), 4.52 (s, 2 H, CH_2Ph), 3.49 (t, 2 H, $J_{4,5}$ 6.0 Hz, H-5), 3.45 (s, 2 H, H-1), 1.80 (bs, 1 H, OH), 1.6–1.4 (m, 4 H, H-3, H-4). Anal. Calcd for $C_{12}H_{16}N_2O_2$: C, 65.43; H, 7.32; N, 12.72. Found: C, 65.30; H, 7.20; N, 12.72.

*2-Azi-5-benzyloxy-1-(2,3,4,6-tetra-*O*-benzoyl-α-*D*-mannopyranosyloxy)pentane* (**32**).—Compound **31** (560 mg, 2.54 mmol) was glycosylated [tetramethylurea (0.59 mL, 5.08 mmol), silver trifluoromethanesulfonate (850 mg, 3.30 mmol), tetra-*O*-benzoyl-α-D-mannopyranosyl bromide (2.17 g, 3.30 mmol)] as described for **10**. Column chromatography (1:5 EtOAc–cyclohexane) gave **32** (1.4 g, 69%); $[\alpha]_D$ −36° (*c* 1.2, $CHCl_3$); R_f 0.30 (1:5 EtOAc–cyclohexane); λ_{max} 340 nm (ϵ 52 cm^2 mmol^{-1}); ^{1}H NMR ($CDCl_3$): δ 8.2–7.2 (m, 25 H, Ph), 6.10 (t, 1 H, $J_{4,5}$ 10.1 Hz, H-4-Man), 5.89 (dd, 1 H, $J_{3,4}$ 10.1 Hz, H-3-Man), 5.73 (dd, 1 H, $J_{2,3}$ 3.2 Hz, H-2-Man), 5.08 (d, 1 H, $J_{1,2}$ 1.8 Hz, H-1-Man), 4.65 (dd, 1 H, $J_{6a,6b}$ 12.0 Hz, H-6a-Man), 4.50 (s, 2 H, CH_2Ph), 4.50 (dd, 1 H, $J_{5,6b}$ 4.5 Hz, H-6b-Man), 4.41 (ddd, 1 H, $J_{5,6a}$ 2.7 Hz, H-5-Man), 3.62 and 3.59 (2 d, 2 H, $J_{1a,1b}$ 12.0 Hz, H-1), 3.60 (t, 2 H, $J_{4,5}$ 6.2 Hz, H-5), 1.74 (m, 2 H, H-4), 1.52 (m, 2 H, H-3). Anal. Calcd for $C_{46}H_{42}N_2O_{11}$: C, 69.16; H, 5.30; N, 3.51. Found: C, 69.13; H, 5.40; N, 3.80.

*2-Azi-1-(2,3,4,6-tetra-*O*-benzoyl-α-*D*-mannopyranosyloxy)-5-pentanol* (**33**).—Compound **32** was debenzylated according to a method described by Binkley and Hehemann [22]. To a stirred suspension of **32** (1.30 g, 1.63 mmol), *N*-bromosuccinimide (0.48 g, 2.67 mmol), and $CaCO_3$ (0.62 g, 6.19 mmol) in CCl_4 (200 mL) was added water (20 mL) and 3 drops of Br_2. After stirring for 3 h, the mixture was filtered and the layers separated. The organic layer was washed with aq 10% $Na_2S_2O_3$, satd aq $NaHCO_3$, and water, dried over $MgSO_4$ and concentrated. The resulting syrup was subjected to flash-column chromatography (1:2 EtOAc–cyclohexane) to yield **33** (935 mg, 81%); $[\alpha]_D$ −44° (*c* 1.1, $CHCl_3$); R_f 0.19 (1:2 EtOAc–cyclohexane); λ_{max} 339 nm (ϵ 62 cm^2 mmol^{-1}); ^{1}H NMR ($CDCl_3$): δ 8.1–7.2 (m, 20 H, Bz), 6.18 (t, 1 H, $J_{4,5}$ 10.1 Hz, H-4-Man), 5.91 (dd, 1 H, $J_{3,4}$ 10.1 Hz, H-3-Man), 5.72 (dd, 1 H, $J_{2,3}$ 3.2 Hz, H-2-Man), 5.08 (d, 1 H, $J_{1,2}$ 1.8 Hz, H-1-Man), 4.70 (dd, 1 H, $J_{6a,6b}$ 12.0 Hz, H-6a-Man), 4.47 (dd, 1 H, $J_{5,6b}$ 4.5 Hz, H-6b-Man), 4.38 (ddd, 1 H, $J_{5,6a}$ 2.7 Hz, H-5-Man), 3.71 (t, 2 H, $J_{4,5}$ 6.3 Hz, H-5), 3.56 and 3.52 (2 d, 1 H, $J_{1a,1b}$ 11.85 Hz, H-1), 1.90 (bs, 1 H, OH), 1.69 (m, 2 H, H-4), 1.48 (m, 2 H, H-3). Anal. Calcd for $C_{39}H_{36}N_2O_{11}$: C, 66.10; H, 5.12; N, 3.95. Found: C, 65.98; H, 5.44; N, 3.50.

2-Azi-1-(2,3,4,6-tetra-O-benzoyl-α-D-mannopyranosyloxy)-6-oxa-8-thianonane (**34**). —Compound **33** (900 mg, 1.27 mmol) was converted [dimethyl sulfide (0.75 mL, 10.16 mmol), dibenzoyl peroxide (1.23 g, 5.08 mmol), 3 h] into the methylthiomethyl ether as described for **23**. Column chromatography (1:5 EtOAc–cyclohexane) gave **34** (869 mg, 89%); R_f 0.20 (1:5 EtOAc–cyclohexane); $[\alpha]_D$ −32° (*c* 1.0, $CHCl_3$); λ_{max} 336 nm (ϵ 67 cm^2 $mmol^{-1}$); ^1H NMR ($CDCl_3$): δ 8.1–7.2 (m, 20 H, Bz), 6.16 (t, 1 H, $J_{4,5}$ 10.2 Hz, H-4-Man), 5.90 (dd, 1 H, $J_{3,4}$ 10.2 Hz, H-3-Man), 5.72 (dd, 1 H, $J_{2,3}$ 3.2 Hz, H-2-Man), 5.10 (d, 1 H, $J_{1,2}$ 1.8 Hz, H-1-Man), 4.68 (dd, 1 H, $J_{6a,6b}$ 12.0 Hz, H-6a-Man), 4.62 (s, 2 H, H-7), 4.48 (dd, 1 H, $J_{5,6b}$ 4.5 Hz, H-6b-Man), 4.40 (ddd, 1 H, $J_{5,6a}$ 2.8 Hz, H-5-Man), 3.56 and 3.53 (2 d, 2 H, $J_{1a,1b}$ 11.85 Hz, H-1), 3.45 (t, 2 H, $J_{4,5}$ 6.3 Hz, H-5), 2.19 (s, 3 H, H-9), 1.70 (m, 2 H, H-4), 1.49 (m, 2 H, H-3). Anal. Calcd for $C_{41}H_{40}N_2O_{11}S$: C, 64.05; H, 5.24; N, 3.64. Found: C, 63.89; H, 5.88; N 3.31.

p-Methoxybenzyl 2,2,2-tris[8-azi-9-(2,3,4,6-tetra-O-benzoyl-α-D-mannopyranosyloxy)-2,4-dioxanonyl]ethyl ether (**53**).—Compound **2** (28 mg, 110 μmol) was treated [**34** (339 mg, 440 μmol), tetrabutylammonium trifluoromethanesulfonate (43 mg, 110 mmol), *N*-iodosuccinimide (104 mg, 460 μmol)] as described for **50**. Column chromatography (1:2 EtOAc–cyclohexane) gave **53** (237 mg, 89%) as a colourless foam; R_f 0.21 (1:2 EtOAc–cyclohexane); $[\alpha]_D$ −37° (*c* 0.5, $CHCl_3$); λ_{max} 338 nm (ϵ 198 cm^2 $mmol^{-1}$); ^1H NMR ($CDCl_3$): δ 8.1–7.2 (m, 60 H, Bz), 7.21 and 6.82 (2 d, 4 H, Ph), 6.10 (t, 3 H, $J_{4,5}$ 10.2 Hz, H-4-Man), 5.88 (dd, 3 H, $J_{3,4}$ 10.2 Hz, H-3-Man), 5.69 (dd, 3 H, $J_{2,3}$ 3.2 Hz, H-2-Man), 5.04 (d, 3 H, $J_{1,2}$ 1.8 Hz, H-1-Man), 4.67 (dd, 3 H, $J_{6a,6b}$ 12.0 Hz, H-6a-Man), 4.61 (s, 6 H, H-3), 4.47 (dd, 3 H, $J_{5,6b}$ 4.5 Hz, H-6b-Man), 4.40 (s, 2 H, CH_2Ph), 4.35 (ddd, 3 H, $J_{5,6a}$ 3.0 Hz, H-5-Man), 3.78 (s, 3 H, OMe), 3.54 (s, 6 H, H-1), 3.53 and 3.50 (2 d, 6 H, $J_{9a,9b}$ 12.0 Hz, H-9), 3.45 (s, 2 H, H-1-Et), 3.44 (t, 6 H, $J_{4,5}$ 6.3 Hz, H-5), 1.60 (m, 6 H, H-6), 1.43 (m, 6 H, H-7). Anal. Calcd for $C_{133}H_{128}N_6O_{38}$: C, 66.05; H, 5.33; N, 3.47. Found: C, 65.90; H, 5.35; N, 3.34.

2,2,2-Tris[8-azi-9-(2,3,4,6-tetra-O-benzoyl-α-D-mannopyranosyloxy)-2,4-dioxanonyl]ethanol (**54**).—Compound **53** (141 mg, 58 μmol) was debenzylated [2,3-dichloro-5,6-dicyanoquinone (16 mg, 70 μmol)] as described for **51**. Column chromatography (2:3 EtOAc–cyclohexane) gave **54** (132 mg, 99%); R_f 0.25 (2:3 EtOAc–cyclohexane); $[\alpha]_D$ −44° (*c* 0.5, $CHCl_3$); λ_{max} 340 nm (ϵ 231 cm^2 $mmol^{-1}$); ^1H NMR ($CDCl_3$): δ 8.1–7.2 (m, 60 H, Bz), 6.10 (t, 3 H, $J_{4,5}$ 10.2 Hz, H-4-Man), 5.88 (dd, 3 H, $J_{3,4}$ 10.2 Hz, H-3-Man), 5.70 (dd, 3 H, $J_{2,3}$ 3.2 Hz, H-2-Man), 5.06 (d, 3 H, $J_{1,2}$ 1.8 Hz, H-1-Man), 4.69 (dd, 3 H, $J_{6a,6b}$ 12.0 Hz, H-6a-Man), 4.64 (s, 6 H, H-3), 4.46 (dd, 3 H, $J_{5,6b}$ 4.5 Hz, H-6b-Man), 4.35 (ddd, 3 H, $J_{5,6a}$ 3.0 Hz, H-5-Man), 3.71 (t, 2 H, *J* 6.0 Hz, H-1-Et), 3.59 (s, 6 H, H-1), 3.54 and 3.49 (2 d, 6 H, $J_{9a,9b}$ 12.0 Hz, H-9), 3.46 (t, 6 H, $J_{5,6}$ 6.3 Hz, H-5), 2.63 (t, 1 H, OH), 1.64 [m (2t), 6 H, H-6], 1.45 (m, 6 H, H-7); ^{13}C NMR ($CDCl_3$): δ 166.2–165.4 (C=O, Bz), 133.6–128.4 (arom. C, Bz), 97.52 (C-1-Man), 95.87 (C-3), 70.30 (C-2-Man), 69.98 (C-9), 69.69 (C-3-Man), 69.34 (C-5-Man), 68.09 (C-1), 66.81 (C-4-Man), 66.80 (C-5), 64.68 (C-1-Et), 62.81 (C-6-Man), 44.04 (C-2-Et), 27.59 (C-8), 27.34 (C-6), 23.99 (C-7). Anal. Calcd for $C_{125}H_{120}N_6O_{37}$: C, 65.32; H, 5.26; N, 3.66. Found: C, 65.56; H, 5.44; N, 3.28.

2,2,2-Tris[8-azi-9-(α-D-mannopyranosyloxy)-2,4-dioxanonyl]ethanol (**55**).—Compound **54** (103 mg, 45 μmol) was debenzoylated [methanolic NaOMe (1.0 M, ca. 200

μL)] as described for **12**. The resulting residue was chromatographed (7:2:1 EtOAc–MeOH–H_2O) and further purification was carried out by filtration (LH-20, 3:1 MeOH–H_2O) to yield **55** as an amorphous solid (45 mg, 96%); R_f 0.24 (7:2:1 EtOAc–MeOH–H_2O); $[\alpha]_D$ +48° (*c* 0.1, H_2O); λ_{max} 340 nm (ϵ 226 cm^2 $mmol^{-1}$); ^1H NMR (D_2O): 4.63 (d, 3 H, $J_{1,2}$ 1.8 Hz, H-1-Man), 4.58 (s, 6 H, H-3), 3.78 (dd, 3 H, $J_{2,3}$ 3.6 Hz, H-2-Man), 3.72 (dd, 3 H, $J_{6a,6b}$ 12.0, $J_{5,6a}$ 2.2 Hz, H-6a-Man), 3.63 (dd, 3 H, $J_{5,6b}$ 4.6 Hz, H-6b-Man), 3.62 and 3.31 (2 d, 6 H, $J_{9a,9b}$ 12 Hz, H-9), 3.60 (dd, 3 H, $J_{3,4}$ 9.7 Hz, H-3-Man), 3.54 (t, 3 H, $J_{4,5}$ 9.7 Hz, H-4-Man), 3.53 (s, 2 H, H-1-Et), 3.46 (s, 6 H, H-1), 3.41 (ddd, 3 H, H-5-Man), 3.44 (t, 6 H, $J_{5,6}$ 6.0 Hz, H-5), 1.44 (m, 6 H, H-6), 1.35 (m, 6 H, H-7); ^{13}C NMR (D_2O): δ 100.00 (C-1-Man), 95.65 (C-3), 73.46 (C-5-Man), 70.96 (C-3-Man), 70.29 (C-2-Man), 68.78 (C-9), 68.05 (C-1), 67.03 (C-4-Man), 66.32 (C-5), 61.71 (C-1-Et), 61.28 (C-6-Man), 44.51 (C-2-Et), 29.87 (C-6), 27.34 (C-8), 24.56 (C-7); FABMS: *m/z* 1049 $[M]^+$, 1050 $[M + H]^+$.

*2,2,2-Tris[11-azi-12-(2,3,4,6-tetra-*O*-benzoyl-α-*D*-mannopyranosyloxy)-2,5,7-trioxadodecyl]ethyl acetate* (**65**).—Compounds **6** (19 mg, 62 μmol) and **34** (172 mg, 224 μmol) were coupled [tetrabutylammonium trifluoromethanesulfonate (24 mg, 62 μmol), *N*-iodosuccinimide (53 mg, 235 μmol)] as described for **50**. Column chromatography (2:3 EtOAc–cyclohexane) gave **65** as a colourless foam (110 mg, 72%); R_f 0.45 (1:1 EtOAc–cyclohexane); $[\alpha]_D$ −36° (*c* 0.6, $CHCl_3$); λ_{max} 339 nm (ϵ 199 cm^2 $mmol^{-1}$); ^1H NMR ($CDCl_3$): δ 8.1–7.2 (m, 60 H, Bz), 6.10 (t, 3 H, $J_{4,5}$ 10.2 Hz, H-4-Man), 5.88 (dd, 3 H, $J_{3,4}$ 10.2 Hz, H-3-Man), 5.71 (dd, 3 H, $J_{2,3}$ 3.2 Hz, H-2-Man), 5.06 (d, 3 H, $J_{1,2}$ 1.8 Hz, H-1-Man), 4.67 (dd, 3 H, $J_{6a,6b}$ 12.0 Hz, H-6a-Man), 4.66 (s, 6 H, H-6), 4.48 (dd, 3 H, $J_{5,6b}$ 4.5 Hz, H-6b-Man), 4.38 (ddd, 3 H, $J_{5,6a}$ 3.0 Hz, H-5-Man), 4.12 (s, 2 H, H-1-Et), 3.63 and 3.61 (2 m, 6 H, H-3), 3.59 and 3.58 (2 m, 6 H, H-4), 3.54 and 3.51 (2 ddd, 6 H, $J_{8a,8b}$ 11.8, $J_{8,9}$ 6.7 Hz, H-8), 3.51 and 3.48 (2 d, 6 H, $J_{12a,12b}$ 12.0 Hz, H-12), 3.42 (s, 6 H, H-1), 2.03 (s, 3 H, Ac), 1.66 (m, 6 H, H-9), 1.48 (m, 6 H, H-10); ^{13}C NMR ($CDCl_3$): δ 170.84, 166.1–165.4 (C=O, Ac and Bz), 133.6–128.4 (arom. C, Bz), 97.52 (C-1-Man), 95.50 (C-6), 71.04 (C-1), 70.29 (C-4), 70.09 (C-2-Man), 69.96 (C-3-Man), 69.67 (C-12), 69.33 (C-5-Man), 66.89 (C-3), 66.82 (C-4-Man), 66.67 (C-8), 63.90 (C-1-Et), 62.81 (C-6-Man), 44.67 (C-2-Et), 27.56 (C-11), 27.38 (C-9), 24.03 (C-10). Anal. Calcd for $C_{133}H_{134}N_6O_{41}$: C, 64.61; H, 5.46; N, 3.40. Found: C, 64.11; H, 5.69; N, 3.04.

*2,2,2-Tris[11-azi-12-(α-*D*-mannopyranosyloxy)-2,5,7-trioxadodecyl]ethanol* (**66**).—Compound **65** (80 mg, 32 μmol) was debenzoylated [methanolic NaOMe (1.0 M, ca. 200 μL)] as described for **12**. The resulting residue was chromatographed (7:2:1 EtOAc–MeOH–H_2O) and further purification was carried out by filtration (LH-20, 3:1 MeOH–H_2O) to yield **66** as an amorphous solid (36 mg, 94%); $[\alpha]_D$ +70° (*c* 0.1, H_2O); R_f 0.24 (7:2:1 EtOAc–MeOH–H_2O); λ_{max} 339 nm (ϵ 248 cm^2 $mmol^{-1}$); ^1H-NMR (400 MHz; D_2O): δ 4.66 (d, 3 H, $J_{1,2}$ 1.8 Hz, H-1-Man), 4.58 (s, 6 H, H-6), 3.78 (dd, 3 H, $J_{2,3}$ 3.6 Hz, H-2-Man), 3.73 (dd, 3 H, $J_{6a,6b}$ 12.3 Hz, H-6a-Man), 3.63 (dd, 3 H, $J_{3,4}$ 9.7 Hz, H-3-Man), 3.62 (dd, 3 H, $J_{5,6b}$ 5.2 Hz, H-6b-Man), 3.62 and 3.60 (m, 6 H, H-3), 3.55 and 3.52 (m, 6 H, H-4), 3.54 (t, 3 H, $J_{4,5}$ 9.7 Hz, H-4-Man), 3.52 and 3.34 (2 d, 3 H, $J_{12a,12b}$ 11.8 Hz, H-12), 3.49 (t, 6 H, $J_{8,9}$ 6.0 Hz, H-8), 3.45 (s, 2 H, H-1-Et), 3.43 (s, 6 H, H-1), 3.40 (ddd, 3 H, $J_{5,6a}$ 2.2 Hz, H-5-Man), 1.49 (m, 6 H, H-9), 1.10 (m, 6 H, H-10); ^{13}C NMR (D_2O): δ 100.05 (C-1-Man), 95.67 (C-6), 73.46

(C-5-Man), 71.00 (C-4), 70.95 (C-3-Man), 70.33 (C-1), 70.28 (C-2-Man), 68.47 (C-12), 68.05 (C-3), 67.03 (C-4-Man), 66.89 (C-8), 62.15 (C-1-Et), 61.28 (C-6-Man), 45.60 (C-2-Et), 29.14 (C-9), 27.30 (C-11), 24.62 (C-10); FABMS: *m/z* 1204 $[M + H]^+$.

(±)-6-Benzyloxy-1,2-isopropylidenedioxyhexane (**36**).—(±)-1,2-Isopropylidenedioxy-6-hexanol (**35**) [23] (5.68 g, 40.8 mmol) was alkylated [NaH (1.27 g, 53.04 mmol), benzyl bromide (5.80 mL, 49 mmol)] as described for **16**. Flash-column chromatography (1:10 EtOAc–cyclohexane) of the residue gave **36** (8.62 g, 80%); R_f 0.21 (1:10 EtOAc–cyclohexane); ^{1}H NMR ($CDCl_3$): δ 7.3–7.1 (m, 5 H, Ph), 4.48 (s, 2 H, CH_2Ph), 4.15–4.00 (m, 2 H, H-1a, H-2), 3.60–3.45 (m, 1 H, H-1b), 3.48 (t, 1 H, $J_{5,6}$ 6.1 Hz, H-6), 1.70–1.35 (m, 6 H, H-3, H-4, H-5), 1.42 and 1.35 (2 s, 6 H, CMe_2).

(±)-6-Benzyloxy-1,2-hexanediol (**37**).—Compound **36** (8.53 g, 32.3 mmol) was hydrolyzed as described for **16**. Column chromatography (2:1 EtOAc–cyclohexane) gave **37** as a colourless oil (6.30 g, 87%); R_f 0.24 (2:1 EtOAc–cyclohexane); ^{1}H NMR ($CDCl_3$): δ 7.30 (m, 5 H, Ph), 4.48 (s, 2 H, CH_2Ph), 3.2 (bs, 2 H, OH), 3.7–3.3 (m, 5 H, H-1, H-2, H-6), 1.7–1.3 (m, 6 H, H-3, H-4, H-5). Anal. Calcd for $C_{13}H_{20}O_3$: C, 69.61; H, 8.99. Found: C, 69.80; H, 8.95.

(±)-6-Benzyloxy-1-triphenylmethoxy-2-hexanol (**38**).—Compound **37** (6.26 g, 27.9 mmol) was tritylated [chlorotriphenylmethane (10.9 g, 39.1 mmol), 4-(dimethylamino)pyridine (~ 1 g)] as described for **17**. Column chromatography (1:8 EtOAc–cyclohexane) afforded **38** (10.69 g, 88%); R_f 0.26 (1:8 EtOAc–cyclohexane); ^{1}H NMR ($CDCl_3$): δ 7.5–7.1 (m, 20 H, Ph), 4.48 (s, 2 H, CH_2Ph), 3.78 (m, 1 H, H-2), 3.42 (t, 2 H, $J_{5,6}$ 6.0 Hz, H-6), 3.10 (m, 2 H, H-1), 2.35 (bs, 1 H, OH), 1.70–1.30 (m, 6 H, H-3, H-4, H-5). Anal. Calcd for $C_{32}H_{34}O_3$: C, 82.37; H, 7.34. Found: C, 81.89; H, 7.33.

6-Benzyloxy-1-triphenylmethoxy-2-hexanone (**39**).—Compound **38** (10.64 g, 22.8 mmol) was oxidized [pyridinium chlorochromate (7.86 g, 36.5 mmol), 3 days] as described for **18**. Flash-column chromatography (1:10 EtOAc–cyclohexane) yielded **39** as a waxlike solid (9.62 g, 91%); R_f 0.19 (1:10 EtOAc–cyclohexane); ^{1}H NMR ($CDCl_3$): δ 7.5–7.2 (m, 20 H, Ph), 4.48 (s, 2 H, CH_2Ph), 3.74 (s, 2 H, H-1), 3.44 (t, 2 H, $J_{5,6}$ 6.0 Hz, H-6), 2.52 (t, 2 H, $J_{3,4}$ 6.0 Hz, H-3), 1.8–1.6 (m, 4 H, H-4, H-5). Anal. Calcd for $C_{32}H_{32}O_3$: C, 82.73; H, 6.94. Found: C, 82.02; H, 7.38.

6-Benzyloxy-1-hydroxy-2-hexanone (**40**).—Compound **39** (9.39 g, 20.0 mmol) was detritylated as described for **19**. Column chromatography (1:2 EtOAc–cyclohexane) gave **40** as a thick oil (4.00 g, 90%); R_f 0.33 (1:1 EtOAc–cyclohexane); ^{1}H NMR ($CDCl_3$): δ 7.4–7.2 (m, 5 H, Ph), 4.51 (s, 2 H, CH_2Ph), 4.23 (s, 2 H, H-1), 3.60 (bs, 1 H, OH), 3.47 (t, 2 H, $J_{5,6}$ 6.0 Hz, H-6), 2.42 (t, 2 H, $J_{3,4}$ 6.2, H-3), 1.9–1.5 (m, 4 H, H-4, H-5). Anal. Calcd for $C_{13}H_{18}O_3$: C, 70.25; H, 8.16. Found: C, 69.45; H, 9.43.

2-Azi-6-benzyloxy-1-hexanol (**41**).—Compound **40** (3.95 g, 17.8 mmol) was treated [hydroxylamine-*O*-sulfonic acid (3.40 g, 30.2 mmol), Et_3N (6.0 mL)] as described for **20**. Column chromatography (1:3 EtOAc–cyclohexane) gave **41** (2.12 g, 51%); R_f 0.39 (1:2 EtOAc–cyclohexane); λ_{max} 342 nm (ε 71 cm^2 $mmol^{-1}$); ^{1}H NMR ($CDCl_3$): δ 7.4–7.2 (m, 5 H, Ph), 4.52 (s, 2 H, CH_2Ph), 3.48 (s, 2 H, H-1), 3.45 (t, 2 H, $J_{5,6}$ 6.2 Hz, H-6), 1.68 (bs, 1 H, OH), 1.60 (m, 2 H, H-5), 1.50 (m, 2 H, H-3), 1.26 (m, 2 H, H-4). Anal. Calcd for $C_{13}H_{18}N_2O_2$: C, 66.64; H, 7.74; N, 11.96. Found: C, 66.18; H, 7.64; N, 12.02.

*2-Azi-6-benzyloxy-1-(2,3,4,6-tetra-*O*-benzoyl-α-*D*-mannopyranosyloxy)hexane* (**42**). —Compound **41** (2.00 g, 8.56 mmol) was glycosylated [tetramethylurea (1.95 mL, 16.24 mmol), silver trifluoromethanesulfonate (4.17 g, 16.24 mmol), tetra-*O*-benzoyl-α-D-mannopyranosyl bromide (10.7 g, 16.2 mmol)] as described for **21**. Column chromatography (1:5 EtOAc–cyclohexane) gave **42** (6.26 g, 90%); $[\alpha]_D$ −48° (*c* 1.4, $CHCl_3$); R_f 0.33 (1:5 EtOAc–cyclohexane); λ_{max} 340 nm (ϵ 68 cm^2 $mmol^{-1}$); ^1H NMR ($CDCl_3$): δ 8.2–7.2 (m, 25 H, Ph), 6.10 (t, 1 H, $J_{4,5}$ 10.1 Hz, H-4-Man), 5.88 (dd, 1 H, $J_{3,4}$ 10.1 Hz, H-3-Man), 5.72 (dd, 1 H, $J_{2,3}$ 3.2 Hz, H-2-Man), 5.06 (d, 1 H, $J_{1,2}$ 1.8 Hz, H-1-Man), 4.62 (dd, 1 H, $J_{6a,6b}$ 12.0 Hz, H-6a-Man), 4.50 (s, 2 H, CH_2Ph), 4.48 (dd, 1 H, $J_{5,6b}$ 4.5 Hz, H-6b-Man), 4.37 (ddd, 1 H, $J_{5,6a}$ 2.7 Hz, H-5-Man), 3.54 and 3.51 (2 d, 2 H, $J_{1a,1b}$ 12.0 Hz, H-1), 3.41 (t, 2 H, $J_{5,6}$ 6.2 Hz, H-6), 1.63 (m, 4 H, H-3, H-5), 1.42 (m, 2 H, H-3). Anal. Calcd for $C_{47}H_{44}N_2O_{11}$: C, 69.45; H, 5.46; N, 3.45. Found: C, 69.46; H, 5.38; N, 3.51.

*2-Azi-1-(2,3,4,6-tetra-*O*-benzoyl-α-*D*-mannopyranosyloxy)-6-hexanol* (**43**).—Compound **42** (6.00 g, 7.38 mmol) was debenzylated [*N*-bromosuccinimide (2.12 g, 11.81 mmol), $CaCO_3$ (2.81 g, 28.04 mmol)] as described for **33**. Flash-column chromatography (1:2 EtOAc–cyclohexane) yielded **43** (4.37 mg, 82%); $[\alpha]_D$ −53° (*c* 1.0, $CHCl_3$); R_f 0.18 (1:2 EtOAc–cyclohexane); λ_{max} 339 nm (ϵ 71 cm^2 $mmol^{-1}$); ^1H NMR ($CDCl_3$): δ 8.1–7.2 (m, 20 H, Ph), 6.11 (t, 1 H, $J_{4,5}$ 10.1 Hz, H-4-Man), 5.92 (dd, 1 H, $J_{3,4}$ 10.1 Hz, H-3-Man), 5.73 (dd, 1 H, $J_{2,3}$ 3.2 Hz, H-2-Man), 5.08 (d, 1 H, $J_{1,2}$ 1.8 Hz, H-1-Man), 4.68 (dd, 1 H, $J_{6a,6b}$ 12.0 Hz, H-6a-Man), 4.49 (dd, 1 H, $J_{5,6b}$ 4.5 Hz, H-6b-Man), 4.39 (ddd, 1 H, $J_{5,6a}$ 2.7 Hz, H-5-Man), 3.68 (t, 2 H, $J_{5,6}$ 6.2 Hz, H-6), 3.51 and 3.40 (2 d, 1 H, $J_{1a,1b}$ 12.0 Hz, H-1), 1.72 (bs, 1 H, OH), 1.7–1.6 (m, 4 H, H-3, H-5), 1.35 (m, 2 H, H-4). Anal. Calcd for $C_{40}H_{38}N_2O_{11}$: C, 66.47; H, 5.30; N, 3.88. Found: C, 66.50; H, 5.36; N, 3.63.

*2-Azi-1-(2,3,4,6-tetra-*O*-benzoyl-α-*D*-mannopyranosyloxy)-7-oxa-9-thiadecane* (**44**). —Compound **43** (4.17 g, 5.77 mmol) was converted [dimethyl sulfide (3.41 mL, 46.2 mmol), dibenzoyl peroxide (5.59 g, 23.1 mmol), 3 h] into the methylthiomethyl ether as described for **23**. Column chromatography (1:5 EtOAc–cyclohexane) gave **44** (3.84 g, 85%); R_f 0.20 (1:5 EtOAc–cyclohexane); $[\alpha]_D$ −28° (*c* 1.0, $CHCl_3$); λ_{max} 339 nm (ϵ 65 cm^2 $mmol^{-1}$); ^1H NMR ($CDCl_3$): δ 8.1–7.2 (m, 20 H, Ph), 6.10 (t, 1 H, $J_{4,5}$ 10.2 Hz, H-4-Man), 5.92 (dd, 1 H, $J_{3,4}$ 10.2 Hz, H-3-Man), 5.72 (dd, 1 H, $J_{2,3}$ 3.2 Hz, H-2-Man), 5.10 (d, 1 H, $J_{1,2}$ 1.8 Hz, H-1-Man), 4.65 (dd, 1 H, $J_{6a,6b}$ 12.0 Hz, H-6a-Man), 4.60 (s, 2 H, H-8), 4.49 (dd, 1 H, $J_{5,6b}$ 4.5 Hz, H-6b-Man), 4.38 (ddd, 1 H, $J_{5,6a}$ 2.7 Hz, H-5-Man), 3.52 and 3.48 (2 d, 2 H, $J_{1a,1b}$ 12.0 Hz, H-1), 3.51 (t, 2 H, $J_{5,6}$ 6.2 Hz, H-6), 2.16 (s, 3 H, H-10), 1.65 (m, 4 H, H-3, H-5), 1.35 (m, 2 H, H-4). Anal. Calcd for $C_{42}H_{42}N_2O_{11}S$: C, 64.44; H, 5.41; N, 3.58. Found: C, 64.51; H, 5.40; N 3.42.

p-*Methoxybenzyl 2,2,2-tris[9-azi-10-(2,3,4,6-tetra-*O*-benzoyl-α-*D*-mannopyranosyloxy)-2,4-dioxadecyl]ethyl ether* (**56**).—Compounds **2** (63 mg, 0.25 mmol) and **44** (770 mg, 0.98 mmol) were coupled [tetrabutylammonium trifluoromethanesulfonate (96 mg, 0.25 mmol), *N*-iodosuccinimide (231 mg, 1.03 mmol)] as described for **50**. Column chromatography (1:2 EtOAc–cyclohexane) gave **56** (540 mg, 90%) as a colourless foam; R_f 0.35 (2:3 EtOAc–cyclohexane); $[\alpha]_D$ −28° (*c* 0.2, $CHCl_3$); λ_{max} 341 nm (ϵ 250 cm^2 $mmol^{-1}$); ^1H NMR ($CDCl_3$): δ 8.1–7.2 (m, 60 H, Bz), 7.21 and 6.84 (2 d, 4 H, Ph), 6.10 (t, 3 H, $J_{4,5}$ 10.2 Hz, H-4-Man), 5.88 (dd, 3 H, $J_{3,4}$ 10.2 Hz, H-3-Man),

5.70 (dd, 3 H, $J_{2,3}$ 3.2 Hz, H-2-Man), 5.05 (d, 3 H, $J_{1,2}$ 1.8 Hz, H-1-Man), 4.67 (dd, 3 H, $J_{6a,6b}$ 12.0 Hz, H-6a-Man), 4.62 (s, 6 H, H-3), 4.48 (dd, 3 H, $J_{5,6b}$ 4.5 Hz, H-6b-Man), 4.40 (s, 2 H, CH_2Ph), 4.34 (ddd, 3 H, $J_{5,6a}$ 3.0 Hz, H-5-Man), 3.78 (s, 3 H, OMe), 3.54 (s, 6 H, H-1), 3.53 and 3.50 (2 d, 6 H, $J_{10a,10b}$ 12.0 Hz, H-10), 3.43 (s, 2 H, H-1-Et), 3.44 (t, 6 H, $J_{5,6}$ 6.5 Hz, H-5), 1.55 (m, 12 H, H-6, H-8), 1.21 (m, 6 H, H-7). Anal. Calcd for $C_{136}H_{134}N_6O_{38}$: C, 66.39; H, 5.49; N, 3.52. Found: C, 66.67; H, 5.65; N, 2.89.

*2,2,2-Tris[9-azi-10-(2,3,4,6-tetra-*O*-benzoyl-α-*D*-mannopyranosyloxy)-2,4-dioxadecyl]ethanol* (**57**).—Compound **56** (432 mg, 176 μmol) was debenzylated [2,3-dichloro-5,6-dicyanoquinone (48 mg, 211 μmol)] as described for **51**. Column chromatography (2:3 EtOAc–cyclohexane) gave **57** (374 mg, 91%); R_f 0.25 (2:3 EtOAc–cyclohexane); $[\alpha]_D$ −40° (*c* 0.5, $CHCl_3$); λ_{max} 341 nm (ε 261 cm^2 $mmol^{-1}$); ^{1}H NMR ($CDCl_3$): δ 8.1–7.2 (m, 60 H, Bz), 6.10 (t, 3 H, $J_{4,5}$ 10.2 Hz, H-4-Man), 5.89 (dd, 3 H, $J_{3,4}$ 10.2 Hz, H-3-Man), 5.70 (dd, 3 H, $J_{2,3}$ 3.2 Hz, H-2-Man), 5.05 (d, 3 H, $J_{1,2}$ 1.8 Hz, H-1-Man), 4.68 (dd, 3 H, $J_{6a,6b}$ 12.0 Hz, H-6a-Man), 4.63 (s, 6 H, H-3), 4.48 (dd, 3 H, $J_{5,6b}$ 4.5 Hz, H-6b-Man), 4.34 (ddd, 3 H, $J_{5,6a}$ 3.0 Hz, H-5-Man), 3.69 (t, 2 H, *J* 6.0 Hz, H-1-Et), 3.56 (s, 6 H, H-1), 3.53 and 3.50 (2 d, 6 H, $J_{10a,10b}$ 12.0 Hz, H-10), 3.45 (t, 6 H, $J_{5,6}$ 6.3 Hz, H-5), 2.62 (t, 1 H, $J_{H\text{-}1\text{-}Et,OH}$ 6.0 Hz, OH), 1.55 (m, 12 H, H-6, H-8), 1.22 (m, 6 H, H-7); ^{13}C NMR ($CDCl_3$): δ 166.2–165.4 (C=O, Bz), 133.6–128.4 (arom. C, Bz), 97.50 (C-1-Man), 95.53 (C-3), 70.09 (C-2-Man), 69.96 (C-10), 69.93 (C-3-Man), 69.33 (C-5-Man), 68.02 (C-1), 66.84 (C-4-Man), 66.80 (C-5), 64.66 (C-1-Et), 62.82 (C-6-Man), 44.02 (C-2-Et), 30.20 (C-6), 29.31 (C-8), 27.74 (C-9), 20.68 (C-7). Anal. Calcd for $C_{128}H_{126}N_6O_{37}$: C, 65.69; H, 5.43; N, 3.59. Found: C, 65.94; H, 5.67; N, 3.02.

*2,2,2-Tris[9-azi-10-(α-*D*-mannopyranosyloxy)-2,4-dioxadecyl]ethanol* (**58**).—Compound **57** (320 mg, 137 μmol) was debenzoylated [methanolic NaOMe (1.0 M, ca. 300 μL)] as described for **12**. The resulting crude product was chromatographed (7:2:1 EtOAc–MeOH–H_2O) and further purification was carried out by filtration (LH-20, 3:1 MeOH–H_2O) to yield **58** as an amorphous solid (143 mg, 96%); R_f 0.27 (7:2:1 EtOAc–MeOH–H_2O); $[\alpha]_D$ +46° (*c* 0.5, H_2O); λ_{max} 341 nm (ε 174 cm^2 $mmol^{-1}$); ^{1}H NMR (D_2O): 4.62 (d, 3 H, $J_{1,2}$ 1.8 Hz, H-1-Man), 4.58 (s, 6 H, H-3), 3.77 (dd, 3 H, $J_{2,3}$ 3.6 Hz, H-2-Man), 3.72 (dd, 3 H, $J_{6a,6b}$ 12.3 Hz $J_{5,6a}$ 2.2 Hz, H-6a-Man), 3.62 (dd, 3 H, $J_{5,6b}$ 4.6 Hz, H-6b-Man), 3.62 (dd, 3 H, $J_{3,4}$ 9.7 Hz, H-3-Man), 3.54 (s, 2 H, H-1-Et), 3.52 and 3.31 (2 d, 6 H, $J_{10a,10b}$ 11.8 Hz, H-10), 3.51 (t, 3 H, $J_{4,5}$ 9.7 Hz, H-4-Man), 3.45 (s, 6 H, H-1), 3.45 (t, 6 H, $J_{5,6}$ 6.0 Hz, H-5), 3.40 (ddd, 3 H, H-5-Man), 1.47 (m, 6 H, H-6), 1.44 (m, 6 H, H-8), 1.08 (m, 6 H, H-7); ^{13}C NMR (D_2O): δ 100.02 (C-1-Man), 95.64 (C-3), 73.46 (C-5-Man), 70.97 (C-3-Man), 70.38 (C-2-Man), 68.46 (C-10), 68.11 (C-1), 67.78 (C-5), 67.03 (C-4-Man), 61.70 (C-1-Et), 61.27 (C-6-Man), 44.51 (C-2-Et), 29.83 (C-6), 28.79 (C-8), 27.88 (C-9), 20.34 (C-7); FABMS: *m/z* 1091 $[M]^+$, 1114 $[M + Na]^+$.

*2,2,2-Tris[12-azi-13-(2,3,4,6-tetra-*O*-benzoyl-α-*D*-mannopyranosyloxy)-2,5,7-trioxatridecyl]ethyl acetate* (**67**).—Compounds **6** (90 mg, 0.29 mmol) and **44** (900 mg, 1.15 mmol) were coupled [tetrabutylammonium trifluoromethanesulfonate (112 mg, 0.29 mmol), *N*-iodosuccinimide (272 mg, 1.20 mmol)] as described for **50**. Column chromatography (2:3 EtOAc–cyclohexane) gave **67** as an amorphous solid (520 mg, 73%);

R_f 0.41 (1:1 EtOAc–cyclohexane); $[\alpha]_D$ −33° (*c* 1.2, $CHCl_3$); λ_{max} 340 nm (ϵ 211 cm^2 $mmol^{-1}$); ^1H NMR ($CDCl_3$): δ 8.1–7.2 (m, 60 H, Bz), 6.11 (t, 3 H, $J_{4,5}$ 10.2 Hz, H-4-Man), 5.87 (dd, 3 H, $J_{3,4}$ 10.2 Hz, H-3-Man), 5.70 (dd, 3 H, $J_{2,3}$ 3.2 Hz, H-2-Man), 5.06 (d, 3 H, $J_{1,2}$ 1.8 Hz, H-1-Man), 4.67 (dd, 3 H, $J_{6a,6b}$ 12.0 Hz, H-6a-Man), 4.66 (s, 6 H, H-6), 4.46 (dd, 3 H, $J_{5,6b}$ 4.5 Hz, H-6b-Man), 4.36 (ddd, 3 H, $J_{5,6a}$ 3.0 Hz, H-5-Man), 4.12 (s, 2 H, H-1-Et), 3.63 and 3.61 (2 m, 6 H, H-3), 3.57 and 3.55 (2 m, 6 H, H-4), 3.55 and 3.52 (2 d, 6 H, $J_{13a,13b}$ 12.0 Hz, H-13), 3.48 (s, 6 H, H-1), 3.48 (t, 6 H, $J_{8,9}$ 6.4 Hz), 2.02 (s, 3 H, Ac), 1.60 (m, 12 H, H-9, H-11), 1.22 (m, 6 H, H-10); ^{13}C NMR ($CDCl_3$): δ 166.2-165.4 (C=O, Ac and Bz), 133.6–128.4 (arom. C, Bz), 97.50 (C-1-Man), 95.48 (C-6), 71.05 (C-1), 70.31 (C-4), 70.09 (C-2-Man), 69.95 (C-3-Man), 69.67 (C-13), 69.33 (C-5-Man), 67.33 (C-3), 66.84 (C-4-Man), 66.81 (C-8), 63.92 (C-1-Et), 62.83 (C-6-Man), 44.67 (C-2-Et), 30.23 (C-9) 29.30 (C-11), 27.71 (C-12), 20.64 (C-10). Anal. Calcd for $C_{136}H_{140}N_6O_{41}$: C, 64.96; H, 5.61; N, 3.34. Found: C, 64.92; H, 5.61; N, 3.24.

*2,2,2-Tris[12-azi-13-(α-*D*-mannopyranosyloxy)-2,5,7-trioxatridecyl]ethanol* (**68**).—Compound **67** (201 mg, 0.08 mmol) was debenzoylated [methanolic NaOMe (1.0 M, ca. 200 μL)] as described for **12**. The resulting residue was chromatographed (7:2:1 EtOAc–MeOH–H_2O) and further purification was carried out by filtration (LH-20, 3:1 MeOH–H_2O) to yield **68** as an amorphous solid (90 mg, 95%); $[\alpha]_D$ +42° (*c* 0.5, H_2O); R_f 0.27 (7:2:1 EtOAc–MeOH–H_2O); λ_{max} 338 nm (ϵ 217 cm^2 $mmol^{-1}$); ^1H-NMR (400 MHz; D_2O): δ 4.64 (d, 3 H, $J_{1,2}$ 1.8 Hz, H-1-Man), 4.60 (s, 6 H, H-6), 3.78 (dd, 3 H, $J_{2,3}$ 3.6 Hz, H-2-Man), 3.73 (dd, 3 H, $J_{6a,6b}$ 12.3 Hz, H-6a-Man), 3.63 (dd, 3 H, $J_{3,4}$ 9.7 Hz, H-3-Man), 3.62 (dd, 3 H, $J_{5,6b}$ 5.2 Hz, H-6b-Man), 3.61 and 3.60 (2 m, 6 H, H-3), 3.53 (t, 3 H, $J_{4,5}$ 9.7 Hz, H-4-Man), 3.52 and 3.48 (2 m, 6 H, H-4), 3.52 (t, 6 H, $J_{8,9}$ 6.0 Hz, H-8), 3.51 and 3.31 (2 d, 6 H, $J_{13a,13b}$ 11.8 Hz, H-13), 3.45 (s, 2 H, H-1-Et), 3.40 (s, 6 H, H-1), 3.39 (ddd, 3 H, $J_{5,6a}$ 2.2 Hz, H-5-Man), 1.42 (m, 12 H, H-9, H-11), 1.07 (m, 6 H, H-10); ^{13}C NMR (D_2O): δ 100.02 (C-1-Man), 95.18 (C-6), 73.47 (C-5-Man), 71.02 (C-4), 70.97 (C-3-Man), 70.32 (C-1), 70.30 (C-2-Man), 68.47 (C-13), 68.20 (C-3), 67.13 (C-8), 67.03 (C-4-Man), 62.12 (C-1-Et), 61.28 (C-6-Man), 45.63 (C-2-Et), 29.86 (C-9), 28.79 (C-11), 27.35 (C-12), 20.30 (C-10); FABMS: *m/z* 1223 $[M]^+$, 1224 $[M + H]^+$, 1246 $[M + Na]^+$.

*10-Acetoxy-2-azi-1-(*tert*-butyldimethylsilyloxy)decane* (**45**).—To a stirred solution of 10-acetoxy-2-azi-1-decanol [24] (2.5 g, 10.3 mmol) and imidazole (1.05 g, 15.5 mmol) in dry DMF (20 mL) was added at 0 °C *tert*-butyldimethylsilyl chloride (2.33 g, 15.5 mmol). After being stirred for 3 h at room temperature, the solution was poured into cold water, and the mixture extracted with Et_2O. The combined extracts were washed with satd aq $NaHCO_3$ and water, dried over $MgSO_4$, and concentrated. Flash-column chromatography (1:10 EtOAc–cyclohexane) of the residue yielded **45** (3.6 g, 98%); R_f 0.50 (1:5 EtOAc–cyclohexane); λ_{max} 341 nm (ϵ 65 cm^2 $mmol^{-1}$); ^1H NMR ($CDCl_3$): δ 4.04 (t, 2 H, $J_{9,10}$ 6.75 Hz, H-10), 3.45 (s, 2 H, H-1), 2.03 (s, 3 H, Ac), 1.69 (m, 2 H, H-9), 1.4–1.1 (m, 10 H, H-4–H-8), 1.38 (t, 2 H, $J_{7,8}$ 7.9 Hz, H-3), 0.86 (s, 9 H, $SiCMe_3$), 0.01 (s, 6 H, $SiMe_2$). Anal. Calcd for $C_{18}H_{36}N_2O_3Si$: C, 60.63; H, 10.18; N, 7.86. Found: C, 60.75; H, 10.34; N, 7.80.

*2-Azi-1-(*tert*-butyldimethylsilyloxy)-10-decanol* (**46**).—Methanolic NaOMe (1.0 M, 2 mL) was added at room temperature to a solution of **45** (3.40 g, 9.5 mmol) in dry MeOH

(40 mL). The mixture was stirred for 12 h, then neutralized by addition of Dowex 50W-X8 (H^+ form). After removing the resin by filtration, the filtrate was concentrated and the resulting residue was subjected to column chromatography (1:5 EtOAc–cyclohexane) to yield **46** as a colourless oil (2.79 g, 93%); R_f 0.24 (1:5 EtOAc–cyclohexane); λ_{max} 339 nm (ϵ 61 cm^2 $mmol^{-1}$); ^1H NMR ($CDCl_3$): δ 3.63 and 3.61 (2 dt, 2 H, $J_{9,10}$ 6.75, $J_{10a,10b}$ 10.2 Hz, H-10), 3.45 (s, 2 H, H-1), 1.60 (s, 1 H, OH), 1.55 (m, 2 H, H-9), 1.33–1.15 (m, 10 H, H-4–H-8), 1.38 (t, 2 H, $J_{7,8}$ 7.9 Hz, H-3), 0.88 (s, 9 H, $SiCMe_3$), −0.13 (s, 6 H, $SiMe_2$). Anal. Calcd for $C_{16}H_{34}N_2O_3Si$: C, 61.10; H, 10.89; N, 8.91. Found: C, 60.88; H, 10.88; N, 9.73.

*2-Azi-1-(*tert*-butyldimethylsilyloxy)-10-(2,3,4,6-tetra-O-benzoyl-α-*D*-mannopyranosyloxy)decane* (**47**).—Compound **46** (2.69 g, 8.56 mmol) was glycosylated [tetramethylurea (1.34 mL, 11.13 mmol), silver trifluoromethanesulfonate (2.86 g, 11.13 mmol), tetra-*O*-benzoyl-α-D-mannopyranosyl bromide (7.33 g, 11.13 mmol)] as described for **10**. The resulting residue was chromatographed (1:5 EtOAc–cyclohexane) to give **47** (3.84 g, 50%); $[\alpha]_D$ −48° (*c* 1.7, $CHCl_3$); R_f 0.35 (1:3 EtOAc–cyclohexane); λ_{max} 340 nm (ϵ 66 cm^2 $mmol^{-1}$); ^1H NMR ($CDCl_3$): δ 8.2–7.2 (m, 20 H, Bz), 6.11 (t, 1 H, $J_{4,5}$ 10.0 Hz, H-4-Man), 5.93 (dd, 1 H, $J_{3,4}$ 10.0 Hz, H-3-Man), 5.70 (dd, 1 H, $J_{2,3}$ 3.2 Hz, H-2-Man), 5.09 (d, 1 H, $J_{1,2}$ 1.8 Hz, H-1-Man), 4.61 (dd, 1 H, $J_{6a,6b}$ 12.0 Hz, H-6a-Man), 4.49 (dd, 1 H, $J_{5,6b}$ 4.5 Hz, H-6b-Man), 4.42 (ddd, 1 H, $J_{5,6a}$ 2.7 Hz, H-5-Man), 3.82 and 3.58 (2 dt, 2 H, $J_{9,10}$ 6.7, $J_{10a,10b}$ 11.8 Hz, H-10), 3.48 (s, 2 H, H-1), 1.71 (m, 2 H, H-9), 1.40–1.05 (m, 10 H, H-4–H-8), 1.43 (t, 2 H, $J_{7,8}$ 7.9 Hz, H-3), 0.88 (s, 9 H, $SiCMe_3$), 0.02 (s, 6 H, $SiMe_2$). Anal. Calcd for $C_{50}H_{60}N_2O_{11}Si$: C, 67.24; H, 6.77; N, 3.14. Found: C, 66.75; H, 6.86; N, 2.91.

*2-Azi-10-(2,3,4,6-tetra-*O*-benzoyl-α-*D*-mannopyranosyloxy)-1-decanol* (**48**).—Tetrabutylammonium fluoride trihydrate (1.04 g, 3.30 mmol) was added at room temperature to a solution of **47** (2.70 g, 3.02 mmol) in THF (40 mL). After 2 h, the mixture was concentrated and the resulting residue dissolved in CH_2Cl_2. The organic layer was washed with satd aq $NaHCO_3$ and water, dried over $MgSO_4$, and concentrated. The residue was chromatographed (1:2 EtOAc–cyclohexane) to give **48** as a colourless oil (1.84 g, 78%); $[\alpha]_D$ −52° (*c* 2.0, $CHCl_3$); R_f 0.18 (1:3 EtOAc–cyclohexane); λ_{max} 342 nm (ϵ 56 cm^2 $mmol^{-1}$); ^1H NMR ($CDCl_3$): δ 8.2–7.2 (m, 20 H, Bz), 6.12 (t, 1 H, $J_{4,5}$ 10.0 Hz, H-4-Man), 5.93 (dd, 1 H, $J_{3,4}$ 10.0 Hz, H-3-Man), 5.70 (dd, 1 H, $J_{2,3}$ 3.2 Hz, H-2-Man), 5.10 (d, 1 H, $J_{1,2}$ 1.8 Hz, H-1-Man), 4.70 (dd, 1 H, $J_{6a,6b}$ 12.0 Hz, H-6a-Man), 4.49 (dd, 1 H, $J_{5,6b}$ 4.2 Hz, H-6b-Man), 4.43 (ddd, 1 H, $J_{5,6a}$ 2.7 Hz, H-5-Man), 3.84 and 3.58 (2 dt, 2 H, $J_{9,10}$ 6.7, $J_{10a,10b}$ 11.8 Hz, H-10), 3.50 (s, 2 H, H-1), 2.37 (s, 1 H, OH), 1.71 (m, 2 H, H-9), 1.50–1.05 (m, 12 H, H-3–H-8). Anal. Calcd for $C_{44}H_{46}N_2O_{11}$: C, 67.85; H, 5.95; N, 3.60. Found: C, 67.54; H, 6.13; N, 3.72.

*6-Azi-14-(2,3,4,6-tetra-*O*-benzoyl-α-*D*-mannopyranosyloxy)-4-oxa-2-thiatetradecane* (**49**).—Compound **48** (1.73 g, 2.22 mmol) was treated [dimethyl sulfide (1.31 mL, 17.8 mmol), dibenzoyl peroxide (2.15 g, 23.1 mmol)] as described for **23**. The crude product was chromatographed (1:5 EtOAc–cyclohexane) to give **49** (1.54 g, 83%); R_f 0.25 (1:5 EtOAc–cyclohexane); $[\alpha]_D$ −58° (*c* 1.0, $CHCl_3$); λ_{max} 339 nm (ϵ 60 cm^2 $mmol^{-1}$); ^1H NMR ($CDCl_3$): δ 8.2–7.2 (m, 20 H, Bz), 6.11 (t, 1 H, $J_{4,5}$ 10.0 Hz, H-4-Man), 5.93 (dd, 1 H, $J_{3,4}$ 10.0 Hz, H-3-Man), 5.72 (dd, 1 H, $J_{2,3}$ 3.2 Hz, H-2-Man), 5.10 (d, 1 H, $J_{1,2}$ 1.8 Hz, H-1-Man), 4.68 (dd, 1 H, $J_{6a,6b}$ 12.0 Hz, H-6a-Man), 4.60 (s, 2 H, H-3),

4.49 (dd, 1 H, $J_{5,6b}$ 4.2 Hz, H-6b-Man), 4.39 (ddd, 1 H, $J_{5,6a}$ 2.7 Hz, H-5-Man), 3.82 and 3.56 (2 dt, 2 H, $J_{13,14}$ 6.7, $J_{14a,14b}$ 11.8 Hz, H-14), 3.41 (s, 2 H, H-5), 2.14 (s, 3 H, H-1), 1.72 (m, 2 H, H-13), 1.50–1.05 (m, 12 H, H-7–H-12). Anal. Calcd for $C_{46}H_{50}N_2O_{11}S$: C, 65.86; H, 6.01; N, 3.34. Found: C, 65.61; H, 6.08; N, 3.57.

*2,2,2-Tris[9-azi-17-(2,3,4,6-tetra-*O*-benzoyl-α-*D*-mannopyranosyloxy)-2,5,7-trioxaheptadecyl]ethyl acetate* (**69**).—Compounds **6** (54 mg, 0.18 mmol) and **49** (607 mg, 0.72 mmol) were coupled [tetrabutylammonium trifluoromethanesulfonate (69 mg, 0.18 mmol), *N*-iodosuccinimide (166 mg, 0.74 mmol)] as described for **50**. The residue was chromatographed (2:3 EtOAc–cyclohexane) to give **69** as a colourless waxlike material (393 mg, 83%); R_f 0.20 (1:2 EtOAc–cyclohexane); $[\alpha]_D$ −56° (*c* 1.0, $CHCl_3$); λ_{max} 338 nm (ε 284 cm^2 $mmol^{-1}$); ^1H NMR ($CDCl_3$): δ 8.1–7.2 (m, 60 H, Bz), 6.10 (t, 3 H, $J_{4,5}$ 10.2 Hz, H-4-Man), 5.92 (dd, 3 H, $J_{3,4}$ 10.2 Hz, H-3-Man), 5.68 (dd, 3 H, $J_{2,3}$ 3.2 Hz, H-2-Man), 5.08 (d, 3 H, $J_{1,2}$ 1.8 Hz, H-1-Man), 4.70 (dd, 3 H, $J_{6a,6b}$ 12.0 Hz, H-6a-Man), 4.63 (s, 6 H, H-6), 4.49 (dd, 3 H, $J_{5,6b}$ 4.5 Hz, H-6b-Man), 4.42 (ddd, 3 H, $J_{5,6a}$ 3.0 Hz, H-5-Man), 4.11 (s, 2 H, H-1-Et), 3.81 and 3.54 (2 dt, 6 H, $J_{16,17}$ 11.8 Hz, H-17), 3.62 (m, 6 H, H-3), 3.57 (m, 6 H, H-4), 3.44 (s, 6 H, H-1), 3.37 (s, 6 H, H-8), 2.03 (s, 3 H, Ac), 1.70 (q, 6 H, H-16), 1.4–1.2 (m, 12 H, H-11, H-12, H-14, H-15), 1.18 (m, 6 H, H-13); ^{13}C NMR ($CDCl_3$): δ 170.8, 166.1-165.4 (C=O, Ac and Bz), 133.5–128.4 (arom. C, Bz), 97.73 (C-1-Man), 95.11 (C-6), 70.91 (C-1), 70.76 (C-4), 70.25 (C-2-Man), 70.00 (C-3-Man), 68.93 (C-5-Man), 68.84 (C-8), 68.48 (C-17), 67.19 (C-3), 67.01 (C-4-Man), 63.07 (C-1-Et, C-6-Man), 44.63 (C-2-Et), 30.46 (C-16), 28.12 (C-9), 29.44, 29.38, 29.33, 29.24, 26.14, 23.69 (C-10–C-15). Anal. Calcd for $C_{148}H_{164}N_6O_{41}$: C, 66.26; H, 6.16; N, 3.13. Found: C, 66.17; H, 6.20; N, 3.08.

*2,2,2-Tris[9-azi-17-(α-*D*-mannopyranosyloxy)-2,5,7-trioxaheptadecyl]ethanol* (**70**).—Compound **69** (354 mg, 0.13 mmol) was debenzoylated [methanolic NaOMe (1.0 M, ca. 400 μL)] as described for **12**. The resulting syrup was subjected to column chromatography (7:2:1 EtOAc–MeOH–H_2O) and further purification was carried out by filtration (LH-20, MeOH) to yield **70** as an amorphous solid (163 mg, 95%); $[\alpha]_D$ +42° (*c* 0.5, MeOH); R_f 0.22 (7:2:1 EtOAc–MeOH–H_2O); λ_{max} 336 nm (ε 239 cm^2 $mmol^{-1}$); ^1H NMR (CD_3OD): δ 4.75 (d, 3 H, $J_{1,2}$ 1.8 Hz, H-1-Man), 4.66 (s, 6 H, H-6), 3.83 (dd, 3 H, $J_{6a,6b}$ 12.1 Hz, H-6a-Man), 3.81 (dd, 3 H, $J_{2,3}$ 3.6 Hz, H-2-Man), 3.66 (dd, 3 H, $J_{3,4}$ 9.7 Hz, H-3-Man), 3.65 (dd, 3 H, $J_{5,6b}$ 5.2 Hz, H-6b-Man), 3.64 (m, 6 H, H-3), 3.58 (t, 3 H, $J_{4,5}$ 9.7 Hz, H-4-Man), 3.56 (m, 6 H, H-4), 3.56 and 3.42 (2 dt, 6 H, $J_{16,17}$ 6.5, $J_{17a,17b}$ 11.2 Hz, H-17), 3.52 (ddd, 3 H, $J_{5,6a}$ 2.2 Hz, H-5-Man), 3.45 (s, 6 H, H-1), 3.43 (s, 2 H, H-1-Et), 3.37 (s, 6 H, H-8), 1.60 (m, 6 H, H-16), 1.47 (t, 6 H, $J_{10,11}$ 6.3 Hz), 1.4–1.2 (m, 24 Hz, H-11, H-12, H-14, H-15), 1.15 (m, 6 H, H-13); ^{13}C NMR (CD_3OD, inter alia): δ 101.56 (C-1-Man), 96.13 (C-6), 74.55 (C-5-Man), 72.29 (C-2-Man), 72.21 (C-3-Man), 71.98 (C-4), 71.34 (C-1), 69.62 (C-8), 68.66 (C-17), 68.58 (C-3), 68.19 (C-4-Man), 63.42 (C-2-Et), 62.94 (C-6-Man), 46.79 (C-2-Et), 29.06 (C-9), 31.47, 30.59, 30.43, 30.40, 30.24, 27.29, 24.65 (C-10–C-16); FABMS: *m/z* 1392 $[M]^+$, 1393 $[M + H]^+$, 1415 $[M + Na]^+$.

*2,2,2-Tris[10-azi-11-(2,3,4,6-tetra-*O*-benzoyl-α-*D*-mannopyranosyloxy)-2,5,7-trioxaundecyl]ethyl trichloracetate* (**71**).—Compounds **8** (490 mg, 1.18 mmol) and **24** (3.22 g, 4.26 mmol) were coupled [tetrabutylammonium trifluoromethanesulfonate (457 mg, 1.18 mmol), *N*-iodosuccinimide (1.01 g, 4.47 mmol)] as described for **50**. The

residue was twice chromatographed (2:3 EtOAc–cyclohexane and 7:1 $CHCl_3$–acetone) to give **71** as an amorphous solid (2.35 g, 78%); R_f 0.36 (2:3 EtOAc–cyclohexane); $[\alpha]_D$ −24° (*c* 1.3, $CHCl_3$); λ_{max} 342 nm (ϵ 259 cm^2 $mmol^{-1}$); ^1H NMR ($CDCl_3$): δ 8.1–7.2 (m, 60 H, Bz), 6.12 (t, 3 H, $J_{4,5}$ 10.2 Hz, H-4-Man), 5.89 (dd, 3 H, $J_{3,4}$ 10.2 Hz, H-3-Man), 5.71 (dd, 3 H, $J_{2,3}$ 3.2 Hz, H-2-Man), 5.08 (d, 3 H, $J_{1,2}$ 1.8 Hz, H-1-Man), 4.67 (dd, 3 H, $J_{6a,6b}$ 12.0 Hz, H-6a-Man), 4.66 (s, 6 H, H-6), 4.48 (dd, 3 H, $J_{5,6b}$ 4.5 Hz, H-6b-Man), 4.41 (s, 2 H, H-1-Et), 4.39 (ddd, 3 H, $J_{5,6a}$ 3.0 Hz, H-5-Man), 3.69 and 3.67 [2 m(dd), 6 H, H-3], 3.63 and 3.58 (2 d, 6 H, $J_{11a,11b}$ 12.0 Hz, H-11), 3.61 and 3.59 [2 m(dd), 6 H, H-4], 3.52 (s, 6 H, H-1), 3.43 and 3.41 (2 ddd, 6 H, $J_{8a,8b}$ 12, $J_{8a,9a}$ 6.3, $J_{8b,9a}$ 6.0 Hz, H-8), 1.89 and 1.81 (2 ddd, $J_{9a,9b}$ 15.0 Hz, H-9); ^{13}C NMR ($CDCl_3$): δ 166.2–165.4 (C=O, Bz and Ac), 133.6–128.4 (arom.C, Bz), 97.53 (C-1-Man), 95.46 (C-6), 71.05 (C-1), 70.30 (C-4), 70.09 (C-2-Man), 69.98 (C-11), 69.73 (C-3-Man), 69.33 (C-5-Man), 68.78 (C-1-Et), 67.01 (C-3), 66.83 (C-4-Man), 62.80 (C-6-Man), 62.01 (C-8), 45.25 (C-2-Et), 30.81 (C-9), 26.53 (C-10). Anal. Calcd for $C_{130}H_{125}Cl_3N_6O_{41}Cl_3$: C, 61.62; H, 4.97; N, 3.32: Found: C, 61.00; H, 5.18; N, 3.06.

*2,2,2-Tris[10-azi-11-(2,3,4,6-tetra-*O*-benzoyl-α-*D*-mannopyranosyloxy)-2,5,7-trioxaundecyl]ethanol* (**72**).—Compound **71** (1.60 g, 0.63 mmol) was dissolved in 15:1 dry Et_2O–MeOH (160 mL) and satd methanolic NH_3 (6 mL) was added. After storing at room temperature overnight, the solution was concentrated. The residue was subjected to column chromatography (1:1 EtOAc–cyclohexane) to give **72** as a colourless foam (1.22 g, 81%); R_f 0.20 (1:1 EtOAc–cyclohexane); $[\alpha]_D$ −35° (*c* 0.8, $CHCl_3$); λ_{max} 348 nm (ϵ 291 cm^2 $mmol^{-1}$); ^1H NMR ($CDCl_3$): δ 8.1–7.2 (m, 60 H, Bz), 6.12 (t, 3 H, $J_{4,5}$ 10.2 Hz, H-4-Man), 5.89 (dd, 3 H, $J_{3,4}$ 10.1 Hz, H-3-Man), 5.71 (dd, 3 H, $J_{2,3}$ 3.2 Hz, H-2-Man), 5.08 (d, 3 H, $J_{1,2}$ 1.8 Hz, H-1-Man), 4.67 (dd, 3 H, $J_{6a,6b}$ 12.0 Hz, H-6a-Man), 4.66 (s, 6 H, H-6), 4.48 (dd, 3 H, $J_{5,6b}$ 4.5 Hz, H-6b-Man), 4.39 (ddd, 3 H, $J_{5,6a}$ 3.0 Hz, H-5-Man), 3.69 and 3.67 [2 m(dd), 6 H, H-4], 3.68 (s, 2 H, H-1-Et), 3.63 and 3.58 (2 d, 6 H, $J_{11a,11b}$ 12.0 Hz, H-11), 3.61 and 3.59 [2 m(dd), 6 H, H-3], 3.52 (s, 6 H, H-1), 3.43 and 3.41 (2 ddd, 6 H, $J_{8a,8b}$ 12, $J_{8a,9a}$ 6.3, $J_{8b,9a}$ 6.0 Hz, H-8), 3.06 (t, 1 H, OH), 1.89 and 1.81 (2 ddd, $J_{9a,9b}$ 15.0 Hz, H-9); ^{13}C NMR ($CDCl_3$): δ 166.2–165.4 (C=O, Bz), 133.6–128.4 (arom. C, Bz), 97.54 (C-1-Man), 95.46 (C-6), 71.04 (C-1), 70.30 (C-4), 70.09 (C-2-Man), 69.99 (C-11), 69.73 (C-3-Man), 69.33 (C-5-Man), 66.98 (C-3), 66.83 (C-4-Man), 65.51 (C-1-Et), 62.80 (C-6-Man), 62.01 (C-8), 45.01 (C-2-Et), 30.81 (C-9), 26.53 (C-10). Anal. Calcd for $C_{128}H_{126}N_6O_{40}$: C, 64.37; H, 5.32; N, 3.52: Found: C, 64.31; H, 5.51; N, 3.51.

*2,2,2-Tris[10-azi-11-(2,3,4,6-tetra-*O*-benzoyl-α-*D*-mannopyranosyloxy)-2,5,7-trioxaundecyl]ethanal* (**73**).—A mixture of dry CH_2Cl_2 (4 mL) and oxalyl chloride (42 μL, 0.48 mmol) was stirred under Ar and cooled to −60 °C. Then dimethyl sulfoxide (75 μL, 1.06 mmol) was added dropwise to the solution [25]. The reaction mixture was stirred for 2 min at −10 °C and **72** (267 mg, 0.11 mmol), dissolved in dry CH_2Cl_2 (2 mL), was added. Stirring was continued for an additional 15 min. Et_3N (154 μL, 1.10 mmol) was added, and the mixture was stirred for 5 min and then allowed to warm to room temperature. Water was added and the aqueous layer was extracted with CH_2Cl_2. The combined extracts were washed with satd aq $NaHCO_3$ and satd aq NaCl, dried over $MgSO_4$, and concentrated. The residue was subjected to column chomatography (2:3 EtOAc–cyclohexane) to afford **73** (249 mg, 95%); R_f 0.45 (1:1 EtOAc–cyclohexane);

$[\alpha]_D$ −30° (*c* 0.4, $CHCl_3$); λ_{max} 344 nm (ϵ 201 cm^2 $mmol^{-1}$); ^1H NMR ($CDCl_3$): δ 9.70 (s, 1 H, CHO), 8.1–7.2 (m, 60 H, Bz), 6.10 (t, 3 H, $J_{4,5}$ 10.2 Hz, H-4-Man), 5.88 (dd, 3 H, $J_{3,4}$ 10.1 Hz, H-3-Man), 5.71 (dd, 3 H, $J_{2,3}$ 3.2 Hz, H-2-Man), 5.08 (d, 3 H, $J_{1,2}$ 1.8 Hz, H-1-Man), 4.69 (dd, 3 H, $J_{6a,6b}$ 12.0 Hz, H-6a-Man), 4.65 (s, 6 H, H-6), 4.49 (dd, 3 H, $J_{5,6b}$ 4.5 Hz, H-6b-Man), 4.39 (ddd, 3 H, $J_{5,6a}$ 3.0 Hz, H-5-Man), 3.72 (s, 6 H, H-1), 3.68 and 3.66 [2 m(dd), 6 H, H-3], 3.62 and 3.58 (2 d, 6 H, $J_{11a,11b}$ 12.0 Hz, H-11), 3.61 and 3.59 [2 m(dd), 6 H, H-4], 3.42 and 3.40 (2 ddd, 6 H, $J_{8a,8b}$ 12, $J_{8a,9a}$ 6.2, $J_{8b,9a}$ 6.0 Hz, H-8), 1.89 and 1.81 (2 ddd, $J_{9a,9b}$ 15.0 Hz, H-9). Anal. Calcd for $C_{128}H_{124}N_6O_{40}$: C, 64.42; H, 5.24; N, 3.52: Found: C, 64.39; H, 5.42; N, 3.50.

*2,2,2-Tris[10-azi-11-(2,3,4,6-tetra-*O*-benzoyl-α-*D*-mannopyranosyloxy)-2,5,7-trioxaundecyl]-[1-^{3}H]ethanol* (**72***).—To a solution of **73** (120 mg, 50.3 μmol) in dry 1,4-dioxane (2.00 mL) and aq NaOH (1.0 M, 60 μL) was added NaB^3H_4 (100 mCi, 8 Ci/mmol, 12.5 μmol). After 1 h, the mixture was neutralized (AcOH) and concentrated. The resulting residue was subjected to flash-column chromatography (1:2 EtOAc–cyclohexane) to yield 90 mCi of **72*** (45.3 μmol; 90%) which co-chromatographed with **72**, as shown by fingerprint autoradiography.

*2,2,2-Tris[10-azi-11-(α-*D*-mannopyranosyloxy)-2,5,7-trioxaundecyl]-[1-^{3}H]ethanol* (**60***).—Compound **72*** (90 mCi, 2 Ci/mmol; 45.3 μmol) was debenzoylated [methanolic NaOMe (1.0 M, ca. 300 μL)] and chromatographed as described for **60** to yield **60*** (73 mCi, 2 Ci/mmol; 36.7 μmol, 81%) which co-chromatographed with **60**, as shown by finger print autoradiography.

Acknowledgements

We thank the Deutsche Forschungsgemeinschaft for financial support.

References

[1] J. Lehmann and M. Scheuring, *Carbohydr. Res.*, 276 (1995) 57–74.
[2] K. Drickamer and M.E. Taylor, *Annu. Rev. Cell Biol.*, 9 (1993) 237–264; W.I. Weis, in B.W. Metcalf, B.J. Dalton, and G. Poste (Eds.), *Cell Adhesion*, Plenum, New York, 1994, pp 55–75; J.M. Rini, *Curr. Opin. Struct. Biol.*, 5 (1995) 617–621.
[3] S. Kornfeld, *Annu. Rev. Biochem.*, 61 (1992) 307–330; A. Hille-Rehfeld, *Biochim. Biophys. Acta*, 1241 (1995) 177–194.
[4] (a) I.J. Goldstein and R.D. Poretz, in I.E. Liener, N. Sharon, and I.J. Goldstein (Eds.), *The Lectins*, Academic, New York, 1986, pp 35–244; (b) C. Emmerich, J. Habash, S.H. Harrop, J.R. Helliwell, W.N. Hunter, A.J. Kalb (Gilboa), J.H. Naismith, J. Raftery, and J. Yariv, *Acta Crystallogr., Sect. D*, 50 (1994) 847–858; (c) I.J. Goldstein and C.E. Hayes, *Adv. Carbohydr. Chem. Biochem.*, 35 (1978) 127–340.
[5] R.K. Ness, H.G. Fletcher, Jr., and C.S. Hudson, *J. Am. Chem. Soc.*, 72 (1950) 2200–2205.
[6] G.H. Veeneman, R.G.A. van der Hulst, C.A.A. van Boeckel, R.L.A. Philipsen, G.S.F. Ruigt, J.A.D.M. Tonnaer, T.M.L. van Delft, and P.N.M. Konings, *Bioorg. Med. Chem. Lett.*, 5 (1995) 9–14.
[7] E.A.L. Biessen, D.M. Beuting, H.C.P.F. Roelen, G.A. van de Marel, J.H. van Boom, and T.J.C. van Berkel, *J. Med. Chem.*, 38 (1995) 1538–1546.
[8] K. Fukase, A. Hasuoka, I. Kinoshita, Y. Aoki, and S. Kusumoto, *Tetrahedron*, 51 (1995) 4923–4932.
[9] R.T. Lee, K.G. Rice, N.B.N. Rao, Y. Ichikawa, T. Barthel, V. Piskarev, and Y.C. Lee, *Biochemistry*, 28 (1989) 8351–8358.

[10] K. Landsteiner, *Biochem. Z.*, 104 (1920) 280.
[11] R.R.A. Coombs, A.N. Howard, and L.S. Mynors, *J. Exp. Pathol.*, 34 (1953) 525.
[12] A. van Landschoot, F.G. Loontiens, and C.K. de Bruyne, *Eur. J. Biochem.*, 103 (1980) 307–312.
[13] M.O.J. Olson and I.E. Liener, *Biochemistry*, 6 (1967) 105–111.
[14] T. Osawa and I. Matsumoto, *Methods Enzymol.*, 28B (1972) 323–327.
[15] U.K. Laemmli, *Nature (London)*, 227 (1970) 680–685.
[16] S. Hanessian and J. Banoub, *Carbohydr. Res.*, 53 (1977) C13–C16.
[17] T.M. Willson, P.Kocienski, K. Jarowicki, K. Isaac, A. Faller, S.F. Campbell, and J. Bordner, *Tetrahedron*, 45 (1990) 1767–1782.
[18] A. Klemer, M. Bieber, and H. Wilbers, *Liebigs Ann. Chem.*, (1983) 1416–1421.
[19] J.C. Medina, M. Salomon, and K.S. Kyler, *Tetrahedron Lett.*, 29 (1988) 3773–3776.
[20] Y. Oikawa, T. Yoshioka, and O. Yonemitsu, *Tetrahedron Lett.*, 23 (1982) 885–888.
[21] T. Paul, *Bull. Soc. Chim. Fr.*, 197 (1948) 199.
[22] R.W. Binkley and D.G. Hehemann, *J. Org. Chem.*, 55 (1990) 378–380.
[23] G. Procter, A.T. Russell, P.J. Murphy, T.S. Tan, and A.N. Mather, *Tetrahedron*, 44 (1988) 3953–3974.
[24] S.C. Ats, J. Lehmann, and S. Petry, *Carbohydr. Res.*, 233 (1992) 141–150.
[25] A.J. Manusco and D. Swern, *Synthesis*, (1981) 165–185.