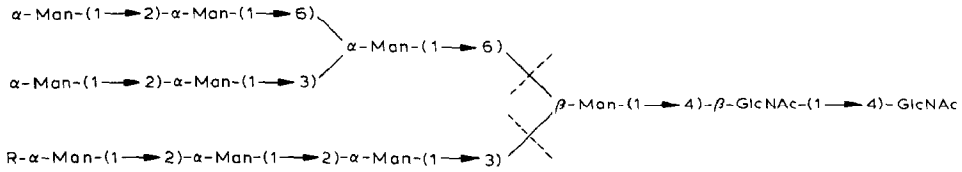
Carbohydrate Research, 136 (1985) 135–152
Elsevier Science Publishers B.V., Amsterdam – Printed in The Netherlands

SYNTHESIS OF A BRANCHED MANNOHEXAOSIDE, A PART STRUCTURE OF A HIGH-MANNOSE-TYPE GLYCAN OF A GLYCOPROTEIN*

TOMOYA OGAWA** AND TOMOO NUKADA
RIKEN (The Institute of Physical and Chemical Research), Wako-shi, Saitama 351-01 (Japan)
(Received April 25th, 1984; accepted for publication, June 26th, 1984)

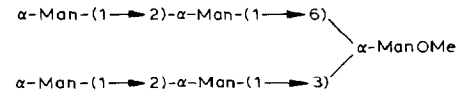
ABSTRACT

The synthesis is described of a branched mannohexaoside derivative, propyl 6-*O*-[3,6-di-*O*-(2-*O*-α-D-mannopyranosyl-α-D-mannopyranosyl)-α-D-mannopyranosyl]-α-D-mannopyranoside, which corresponds to the non-reducing-end part-structure of a high-mannose-type glycan of a glycoprotein.

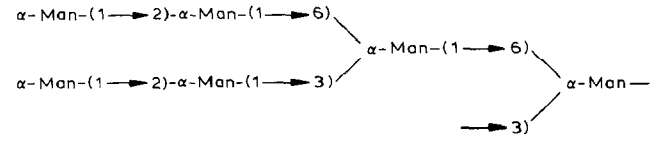


1

R = α-Glc-(1→2)-α-Glc-(1→3)-α-Glc-(1→3)



2



3

*Synthetic Studies on Cell-surface Glycans, Part 29. For Part 28, see ref. 1.
**To whom enquiries should be addressed.

0008-6215/85/$ 03.30

INTRODUCTION

N-Linked glycan chains of glycoproteins present on cell surfaces are considered to be responsible for a variety of biological recognition mechanisms, and are classified into three groups, namely, a high-mannose type, a complex type, and a hybrid type. A typical high-mannose-type glycan **1** has been chosen as a target for synthesis and three oligosaccharide units, such as **2** corresponding to part of the structure of **1** derived after cleavage of the glycan at the dotted lines, have been synthesised[2]. As part of this project, the synthesis of the mannohexaose part-structure **3** of **1** is now described.

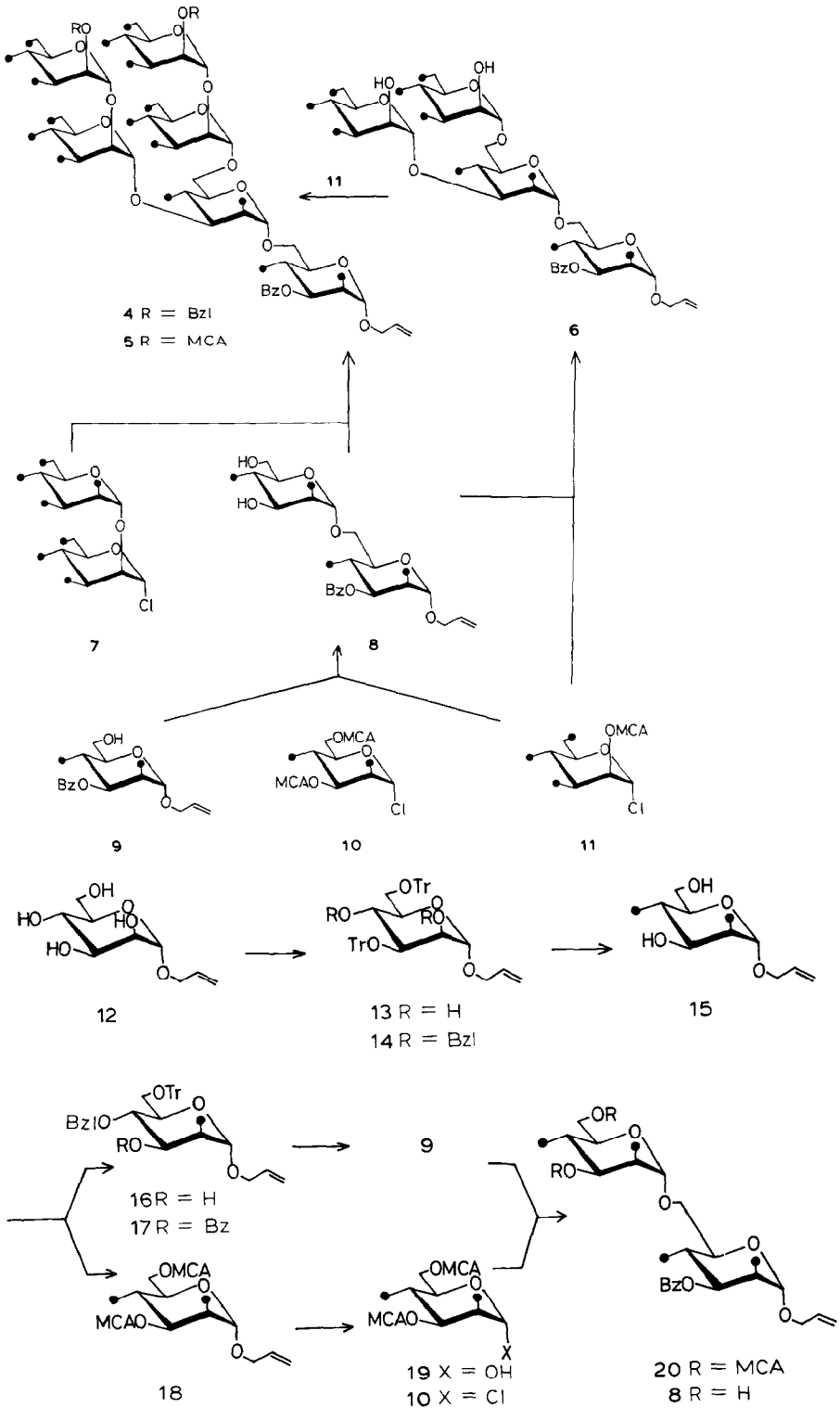
RESULTS AND DISCUSSION

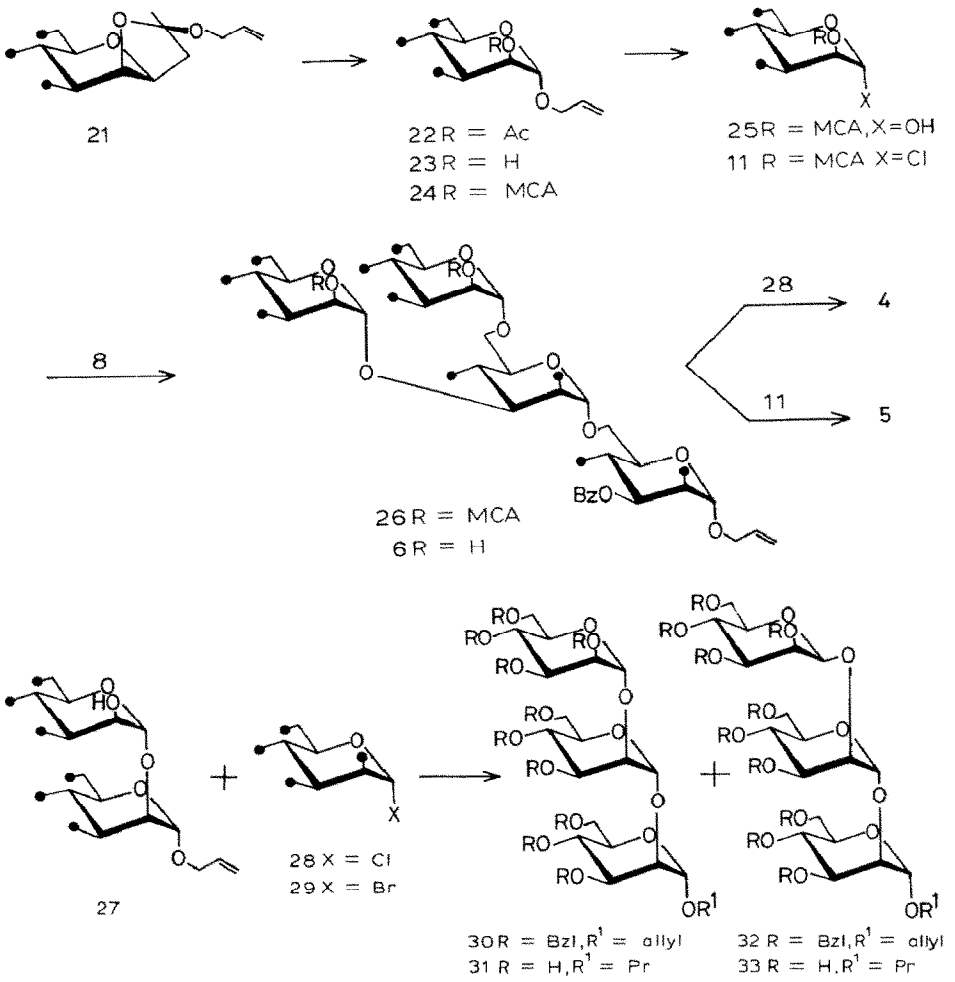
The protected mannohexaoses **4** and **5** were designed as the synthetic equivalents of **3**, and are retrosynthesised into a key mannobiosyl glycosyl-acceptor **8** and the two glycosyl donors **7** and **11**. A stepwise approach to **5** from **8** required a monosaccharide synthon **11**, and a convergent-type approach to **4** from **8** required a mannobiosyl donor **7**. The key glycosyl-acceptor **8** was then retrosynthesised into two monosaccharide synthons **9** and **10***.

We first describe a synthesis of **8** *via* **9** and **10**. Allyl α-D-mannopyranoside (**12**) was tributylstannylated[3] and then treated with trityl chloride[4] in toluene for 16 h at 50–60° to give 99% of crystalline **13**. Benzylation of **13** and hydrolysis of the product **14** afforded the dibenzyl ether **15** (44% from **12**). The structure of **15**, assigned on the basis of the synthesis sequence, was confirmed by the ^{13}C-n.m.r. data[5] (deshielded signals for C-2 and C-4 at δ 78.42 and 76.42, respectively). Compound **15** was converted into the monosaccharide synthons **9** and **10** as follows. Tritylation of **15** gave **16**, and benzoylation then afforded **17**, hydrolysis of which yielded **9** (77% from **15**). Monochloroacetylation of **15** gave **18**, which was deallylated[6] with $PdCl_2$–AcONa–AcOH to yield **19**. Treatment[7] of **19** with $(Me_2N^+{=}CHOSOCl)Cl^-$ afforded **10** (55% from **15**). Glycosidation of **9** with **10** in the presence of $AgOSO_2CF_3$ (ref. 8) and powdered molecular sieves 4A (ref. 9) gave **20**. Selective removal of monochloroacetyl groups from **20** by treatment with thiourea[10] in refluxing ethanol afforded **8** (54% from **9**). The linkage formed by this glycosidation was α, as indicated by the signal for C-1b at δ 96.94 ($^1J_{C,H}$ 169.7 Hz) in the ^{13}C-n.m.r. spectrum of **8** in agreement with the observations of Bock and Pedersen[11].

The monosaccharide synthon **11** was prepared as follows. The allyl α-D-mannopyranoside derivative **23**, readily prepared from the orthoester **21** in 2 steps (stereospecific rearrangement to **22** in the presence[12] of $Me_3SiOSO_2CF_3$, and subsequent deacetylation), was monochloroacetylated to give **24**. Deallylation[6] of **24** and chlorination[7] of the product **25** gave **11** (57% from **23**). Glycosidation of **8** with

*In the formulae depicted in this paper, MCA = $ClCH_2CO$ and ●— = benzyloxy


4 R = Bzl
5 R = MCA
6
7
8
9
10
11
12
13 R = H
14 R = Bzl
15
16 R = H
17 R = Bz
18
19 X = OH
10 X = Cl
20 R = MCA
8 R = H



11 in the presence of $AgOSO_2CF_3$–powdered molecular sieves 4A afforded 69% of the protected tetrasaccharide **26**. The ^{13}C-n.m.r. spectrum of **26** contained four signals for anomeric carbon atoms (C-1a, 1b, 1c, 1d) at δ 97.13, 96.64, 97.76, and 99.18, respectively, with $^1J_{C,H}$ values of ~170 Hz in agreement with the α-D configuration at each anomeric carbon atom[11]. Selective removal of the monochloroacetyl groups of **26** gave **6**, glycosidation of which with **11** under conditions similar to those used for the condensation of **8** and **11**, afforded the target molecule **5** (32% from **26**). The stereochemistry of **26** was assigned on the basis of the ^{13}C-n.m.r. data (five signals for six anomeric carbon atoms at δ 100.90, 99.13, 98.86, 97.23, and 96.84, corresponding to C-1d, C-1e,1f, C-1c, C-1a, and C-1b, respectively, with $^1J_{C,H}$ values of ~170 Hz).

Having synthesised **5** by a stepwise approach using the mannosyl donor **11** with a participating group at C-2, the use of benzylated glycosyl-donors **28** and **29**

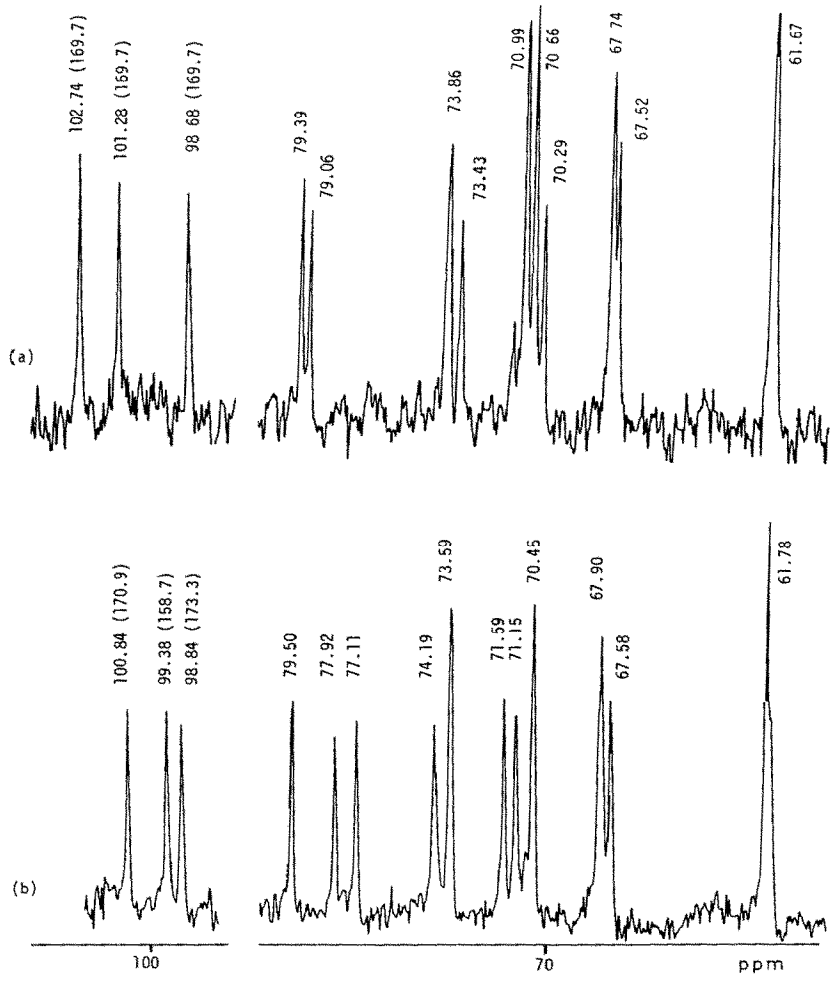


Fig. 1. ^{13}C-N.m.r. spectra (D_2O) of synthetic D-mannotriosides: (*a*) α-Man-(1→2)-α-Man-(1→2)-α-Man-OPr (**31**), (*b*) β-Man-(1→2)-α-Man-(1→2)-α-Man-OPr (**33**). The values in parentheses correspond to $^1J_{C,H}$ (in Hz).

was then examined. Glycosidation of **27** (preparation described below) with **28** or **29** in the presence of $AgOSO_2CF_3$–powdered molecular sieves 4A afforded a mixture of products that was difficult to fractionate. However, in the presence of $Hg(CN)_2$–powdered molecular sieves 4A in 1,2-dichloroethane at 20–50°, a mixture of the α anomer **30** (49%) and β anomer **32** (13%) was obtained. The structures of **30** and **32** were determined by the ^{13}C-n.m.r. data. In the spectrum of **30**, the signal for C-1c appeared at δ 100.99 ($^1J_{C,H}$ 173.3 Hz), whereas, in that of **32**, the signal for C-1c appeared at δ 99.58 ($^1J_{C,H}$ 152.3 Hz). When the glycosidation reaction was performed in 1:1 benzene–nitromethane, a higher yield (98%) of the mixture of **30** and **32** was obtained, but the αβ-ratio was 1.45:1.

TABLE I

^{13}C-CHEMICAL SHIFTS[a] (p.p.m.) OF D-MANNO-OLIGOSACCHARIDES

	Reducing end						
	C-1	*C-2*	*C-3*	*C-4*	*C-5*	*C-6*	*OCH_2*
31	98.68 (169.7)[b]	79.39	70.66	67.74	73.86	61.67	70.99
33	98.84 (170.3)	79.50	70.45	67.90	74.19	61.78	71.15
	Internal						
	C-1	*C-2*	*C-3*	*C-4*	*C-5*	*C-6*	
31	101.28 (169.7)	79.06	70.66	67.74	73.86	61.67	
33	100.84 (170.9)	77.92	71.59	67.90	73.59	61.78	
	Non-reducing end						
	C-1	*C-2*	*C-3*	*C-4*	*C-5*	*C-6*	
31	102.74 (169.7)	70.99	70.29	67.52	73.43	61.67	
33	99.38 (158.7)	70.45	73.59	67.58	77.11	61.78	

[a]Relative to the signal of Me_4Si *via* internal 1,4-dioxane (67.40 p.p.m.). [b]Data in parentheses are for $^1J_{C,H}$ (Hz).

The glycosidation of **27** with the bromide **29** in the presence of $Hg(CN)_2$–powdered molecular sieves 4A in 1,2-dichloroethane proceeded at 20°. However, t.l.c. revealed the formation of **30** and **32** in the ratio ~1:1. The structures of **30** and **32** were confirmed by the transformation of these compounds into the unsubstituted mannotriosides **31** and **33**, the ^{1}H- and ^{13}C-n.m.r. data[13] for which are shown in Fig. 1 and Table I.

On the basis of the stereochemical outcome of the model experiments described above, glycosidation of **6** with **28** was performed in the presence of $Hg(CN)_2$–powdered molecular sieves 4A in 1,2-dichloroethane, and 30% of the target molecule **4** was obtained. The stereochemistry of **4** was assigned from the ^{13}C-n.m.r. data (Table II) and confirmed by the conversion of **4** into the unsubstituted mannohexaoside **41**, the 400-MHz ^{1}H-n.m.r. spectrum of which is shown in Fig. 2. The signals for anomeric protons were assigned for the structure **41** in agreement with our previous observation[13].

A convergent-type approach was also used for the synthesis of **4** involving the mannobiosyl donor **7**, which was synthesised as follows. Glycosidation of **23** with **34**[14], in the presence of $AgOSO_2CF_3$–tetramethylurea[8] in 1,2-dichloroethane,

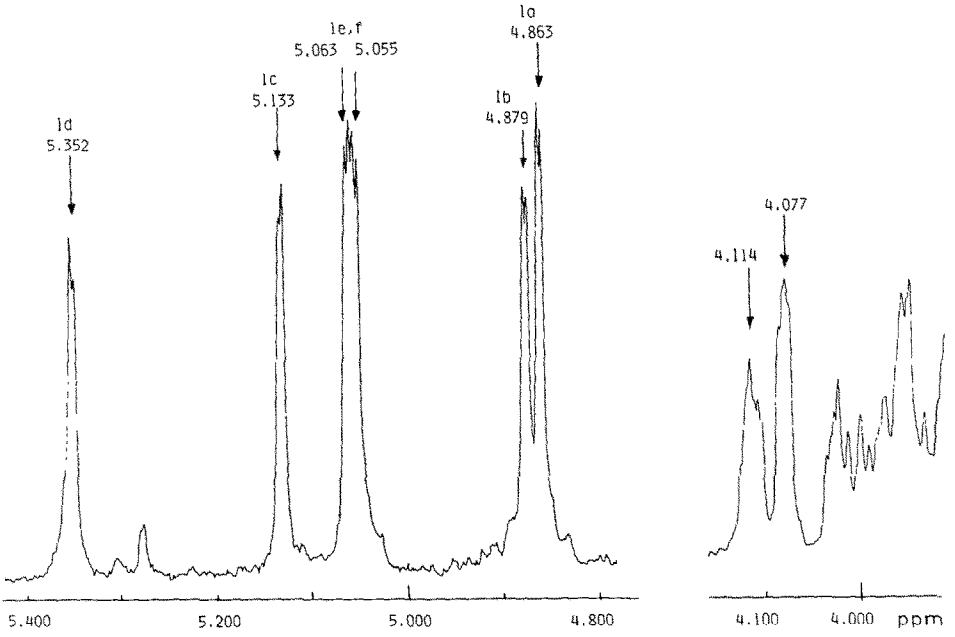


Fig. 2. ^{1}H-N.m.r. spectra (400 MHz, D_2O, 60°) of a synthetic D-mannohexaoside (**41**). The values of δ_H are expressed in p.p.m. downfield from internal sodium 2,2,3,3-tetradeuterio-4,4-dimethyl-4-silapentanoate.

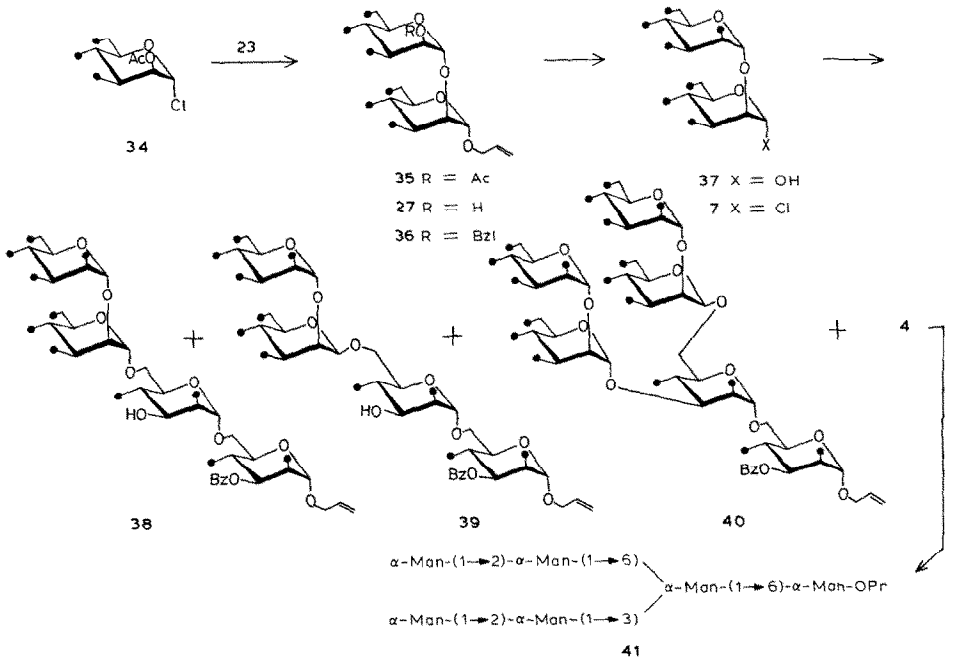


TABLE II

^{13}C-CHEMICAL SHIFTS (p.p.m.) OF PROTECTED D-MANNO-OLIGOSACCHARIDES ($CDCl_3$)

	Chemical shift for each anomeric carbon atom					
	a	*b*	*c*	*d*	*e*	*f*
24	97.00 (169.7)[a]					
23	98.30 (170.9)					
30	98.23 (169.7)	99.69 (169.7)	100.99 (173.3)			
32	98.34 (174.1)	99.58 (168.2)	99.58 (152.3)			
9	97.47 (168.5)					
8	97.28 (168.5)	96.94 (169.7)				
26	97.13 (170.9)	96.64 (169.7)	97.76 (172.1)	99.18 (172.1)		
38	97 53 (169.7)	97.25 (170.4)	99.53 (173.3)		99.91 (168.5)	
39	97.67 (168.5)	97.25 (170.9)	100.45 (157.5)		98.50 (170.9)	
5	97.23 (170.3)	96.84 (170.3)	98.86 (168.9)	100.90 (171.5)	99.13 (169.5)	99 13 (169.5)
4	97 25	96.93	99.48	101 26	99 75	99 75

[a]Data in parentheses are for $^1J_{C,H}$ (Hz).

afforded 68% of **35** which was deacetylated to give **27**. Benzylation of **27** with sodium hydride–benzyl bromide afforded **36**, deallylation[6] of which gave the hemiacetal **37** (54% from **27**). Chlorination[7] of **27** then gave 83% of **7**. Glycosidation of the model acceptor **23** by **7** was then examined and reaction in the presence of $Hg(CN)_2$ and powdered molecular sieves 4A in 1,2-dichloroethane at 50° afforded 37% of the α anomer **30**, showing a trend similar to that of the glycosyl donor **28**.

Therefore, the key intermediate **8** was glycosylated with **7** under the same reaction conditions and a 91% yield of a mixture of four products was obtained. The fraction containing mannotetraosides **38** and **39** was obtained in 68% yield by gel chromatography and was further purified by chromatography on silica gel to give **38** and **39** in yields of 22 and 11%, repectively. The stereochemistry of **38** and **39** was assigned on the basis of ^{13}C-n.m.r. data. For **38**, four signals were observed at δ 99.91, 99.53, 97.53, and 97.25 ($^1J_{C,H}$ values of ~170 Hz), corresponding to C-1d, C-1c, C-1a, and C-1b, respectively. On the other hand, the spectrum of **39** contained a signal for C-1c at δ 100.45 ($^1J_{C,H}$ 157.5 Hz), indicating the β-D configuration at C-1c, and three signals for C-1d, C-1a, and C-1b at δ 98.50, 97.67, and 97.25 ($^1J_{C,H}$ values of ~170 Hz), respectively. Thus, the glycosidation at HO-6b

of **8** with **7** gave α- and β-products in the ratio 2:1. The mannohexaoside fraction, obtained in 22% yield after gel chromatography, contained two components (h.p.t.l.c.). Further purification by chroamtography on silica gel afforded 8% of **4**, which was identical with the sample prepared by the stepwise approach. The isomer **40**, which could be formed *via* the tetrasaccharide **39**, could not be isolated but was obtained as a 1:1 mixture with **4**. The low stereoselectivity of the glycosidation at HO-6 of the mannopyranosyl residue, compared with HO-2 or HO-3, may be explained by the higher reactivity[15] of HO-6 towards the glycosyl donor **7**[15].

Thus, stepwise and convergent types of synthesis routes to **4** and **5** have been developed. The mannosyl donors **10, 11,** and **24**, acylated at position 2, gave a high yield of the α-product. The mannosyl donors **7, 28,** and **29**, with all the hydroxyl groups benzylated, afforded the products with the degree of stereoselectivity depending on the reaction conditions and the reactivity of the glycosyl acceptor.

EXPERIMENTAL

General. — Melting points were determined with a Yanagimoto micro melting-point apparatus and are uncorrected. Optical rotations were determined with a Perkin–Elmer Model 241 MC polarimeter, for solutions in $CHCl_3$ at 25°, unless noted otherwise. Column chromatography was performed on silica gel (Merck 70–230 mesh), and flash chromatography on columns of Wako gel C-300 (200–300 mesh). T.l.c. and high-performance t.l.c. was performed on Silica Gel 60 F_{254} (Merck). I.r. spectra were recorded with an EPI-G2 Hitachi spectrophotometer, using KBr pellets for the crystalline samples, and films for the liquid samples. ^{1}H-N.m.r. spectra were recorded with a JNM-GX400 or JNM-FX90Q spectrometer. ^{13}C-N.m.r. spectra were recorded with a JNM-FX 100FT spectrometer operated at 25.05 MHz. The values of δ_C and δ_H are expressed in p.p.m. downfield from the signal for internal Me_4Si, for solutions in $CDCl_3$, unless noted otherwise.

*Allyl 3,6-di-*O*-triphenylmethyl-α-*D*-mannopyranoside* (**13**). — A mixture of allyl α-D-mannopyranoside (**12**; 19.1 g, 86.7 mmol) and $(Bu_3Sn)_2O$ (78.1 g, 130 mmol) in toluene (300 mL) was stirred under reflux with continuous azeotropic removal of water. To the resulting clear solution was added trityl chloride (72.5 g, 260 mmol) at 50–60°, and the mixture was stirred for 16 h and then poured into a large excess of aqueous KF. After stirring vigorously, the Bu_3SnF was removed, the filtrate was extracted with EtOAc, the extract was dried (K_2CO_3), filtered, and concentrated *in vacuo,* and the residue was chromatographed over SiO_2 (500 g) with 10:1 toluene–tetrahydrofuran containing 1% of Et_3N to give **13** (60.5 g, 98.9%), m.p. 86–87° (from di-isopropyl ether), $[\alpha]_D$ +33° (*c* 1), R_F 0.73 (5:1 toluene–tetrahydrofuran). N.m.r. data: ^{1}H, δ 7.6–7.1 (30 H, m, 6 Ph) and 4.60 (d, 1 H, *J* 2 Hz, H-1); ^{13}C, δ 98.72 ($^1J_{C,H}$ 169.7 Hz, C-1), 87.50 (Ph_3C), 86.91 (Ph_3C), 75.04 (C-3), 71.95 (C-5), 69.35 (C-2), 68.32 (OCH_2-CH=CH_2), 67.89 (iPr_2O), 67.40 (C-4), and 64.69 (C-6).

Anal. Calc. for $C_{47}H_{44}O_6 \cdot C_6H_{14}O_2$: C, 78.86; H, 7.26. Found: C, 78.54; H, 7.20.

*Allyl 2,4-di-O-benzyl-3,6-di-O-trityl-α-*D*-mannopyranoside* (**14**). — To a suspension of NaH (50%; 42 g, 840 mmol; washed with pentane) in Me_2NCHO (80 mL) was added, dropwise, a solution of **13** (60.5 g) in Me_2NCHO (100 mL), and the mixture was stirred at 20° for 1 h. Benzyl bromide (70 mL) was then added dropwise at 0–5°, and the mixture was stirred for 16 h and processed to give crude **14** (61.5 g). Purification by column chromatography (2:1 toluene–hexane) gave material with $[\alpha]_D$ +18° (*c* 0.77), R_F 0.30 (2:1 toluene–hexane). ^{13}C-N.m.r. data: δ 96.44 (C-1, $^1J_{C,H}$ 167.23 Hz), 87.50 (Ph_3C), 86.31 (Ph_3C), 77.96 (C-2), 74.88 (C-3), 74.70 ($PhCH_2O$-4), 73.96 (C-4), 72.82 (C-5), 71.79 ($PhCH_2O$-2), 67.56 ($OCH_2CH=$), and 63.17 (C-6).

Anal. Calc. for $C_{61}H_{56}O_6$: C, 82.78; H, 6.38. Found: C, 82.97; H, 6.43.

*Allyl 2,4-di-O-benzyl-α-*D*-mannopyranoside* (**15**). — A solution of crude **14** (61.0 g) in aqueous 80% AcOH (600 mL) was stirred at 50–60° for 2 h, filtered, and processed to give the crude product (27.4 g), which was purified by column chromatography (5:1 toluene–tetrahydrofuran) to yield **15** (15.1 g, 43.4% from **12**), m.p. 40–41° (from di-isopropyl ether), $[\alpha]_D$ +28° (*c* 1.25), R_F 0.10 (10:1 toluene–ethyl acetate). N.m.r. data: ^{1}H, δ 7.35 (bs, 10 H, 2 Ph) and 4.87 (d, 1 H, *J* 2 Hz, H-1); ^{13}C, δ 96.39 (C-1, $^1J_{C,H}$ 168.5 Hz), 78.42 (C-2), 76.42 (C-4), 74.91 ($PhCH_2O$-4), 73.11 ($PhCH_2O$-2), 71.69 (C-3*), 71.50 (C-5*), 67.89 ($O\text{-}CH_2CH=$), and 62.19 (C-6).

Anal. Calc. for $C_{23}H_{28}O_6$: C, 68.96; H, 7.05. Found: C, 68.86; H, 7.05.

*Allyl 3-O-benzoyl-2,4-di-O-benzyl-α-*D*-mannopyranoside* (**9**). — To a solution of **15** (4.0 g, 10 mmol) in pyridine (70 mL) was added trityl chloride (3.8 g, 14 mmol), and the mixture was stirred under reflux for 2 h. T.l.c. (5:1 toluene–ethyl acetate) then revealed **16**, R_F 0.60. To the cooled mixture was added benzoyl chloride (2.5 mL), and the mixture was stirred at 20° for 16 h and processed to give crude **17** (8.0 g), R_F 0.87 (5:1 toluene–ethyl acetate). A solution of **17** (8.0 g) in aqueous 80% AcOH (200 mL) was stirred at 70° for 2 h, and then concentrated *in vacuo*. The residual oil was purified by column chromatography (3:1 toluene–ethyl acetate) to give **9** (3.9 g, 77.0% from **15**), $[\alpha]_D$ +0.7° (*c* 0.93), R_F 0.31 (5:1 toluene–ethyl acetate). N.m.r. data: ^{1}H, δ 5.56 (dd, 1 H, *J* 4, 11 Hz, H-3) and 4.90 (d, 1 H, *J* 2 Hz, H-1); ^{13}C, δ 97.47 (C-1, $^1J_{C,H}$ 168.5 Hz), 76.50 (C-2), 74.99 ($PhCH_2O$-4), 74.66 (C-4), 73.41 ($PhCH_2O$-2, C-3), 72.55 (C-5), 68.16 ($O\text{-}CH_2CH=$), and 61.93 (C-6).

Anal. Calc. for $C_{30}H_{32}O_7$: C, 71.41; H, 6.40. Found: C, 71.09; H, 6.36.

*Allyl 2,4-di-O-benzyl-3,6-di-O-chloroacetyl-α-*D*-mannopyranoside* (**18**). — A mixture of **15** (5.0 g, 12.5 mmol) and chloroacetic anhydride (10.5 g) in pyridine (50 mL) was stirred at −5° for 0.5 h, poured into ice–water, and extracted with CH_2Cl_2. The organic layer was washed with H_2O and saturated aqueous sodium chloride, dried ($MgSO_4$), and concentrated *in vacuo*. The residual oil was purified by column chromatography (40:1 dichloromethane–acetone) to give **18** (6.0 g,

*Assignments with the asterisk may be interchanged.

78.7%), $[\alpha]_D$ +16° (*c* 1.05), R_F 0.52 (5:1 toluene–ethyl acetate). ^{1}H-N.m.r. data: δ 7.2–7.1 (m, 10 H, 2 Ph), 6.1–5.85 (m, 1 H, -C*H*=CH$_2$), 5.4–5.1 (m, 2 H, CH=C*H*$_2$), 4.88 (d, 1 H, *J* 2 Hz, H-1), 4.02 (s, 2 H, COC*H*$_2$Cl), and 3.80 (s, 2 H, COC*H*$_2$Cl).

Anal. Calc. for $C_{27}H_{30}Cl_2O_8$: C, 58.59; H, 5.41. Found: C, 58.19; H, 5.47.

*2,4-Di-*O*-benzyl-3,6-di-*O*-chloroacetyl-*D*-mannopyranose* (**19**). — A mixture of **18** (6.0 g, 9.8 mmol), $PdCl_2$ (2.0 g, 11.3 mmol), AcONa (2.0 g, 24.4 mmol), and H_2O (1 mL) in AcOH (20 mL) was stirred at 20–25° for 2 days, and then concentrated *in vacuo*. The residue was diluted with EtOAc, and the organic layer was filtered through Celite and concentrated *in vacuo* to give an oil (5.4 g) which was purified by column chromatography (7:2 toluene–tetrahydrofuran) to give **19** (4.8 g, 86.3%), $[\alpha]_D$ +4.5° (*c* 1.14), R_F 0.53 (20:1 dichloromethane–acetone). N.m.r. data: ^{1}H, δ 7.4–7.1 (m, 10 H, 2 Ph), 4.02 (s, 2 H, COC*H*$_2$Cl), and 3.80 (s, 2 H, COC*H*$_2$Cl); ^{13}C, δ 167.36 (C=O), 166.67 (C=O), 92.27 (C-1, $^1J_{C,H}$ 169.67), 76.34 (C-2), 75.64 (C-4), 74.77 (PhCH$_2$O-4), 73.04 (C-3, PhCH$_2$O-2), 69.73 (C-5), 64.64 (C-6), and 40.58 (COCH$_2$Cl).

Anal. Calc. for $C_{24}H_{26}Cl_2O_8$: C, 56.14; H, 5.11. Found: C, 56.17; H, 5.17.

*2,4-Di-*O*-benzyl-3,6-di-*O*-chloroacetyl-α-*D*-mannopyranosyl chloride* (**10**). — A solution of **19** (1.9 g, 3.3 mmol) in $SOCl_2$ (10 mL) and 1,2-dichloroethane (50 mL) containing two drops of Me_2NCHO was stirred at 5–10° for 3 h, filtered through a thin layer of SiO_2, and concentrated *in vacuo*. The oily residue was purified by column chromatography (10:1 toluene–tetrahydrofuran) to give **10** (1.6 g, 78.7%), $[\alpha]_D$ +44° (*c* 1.14), R_F 0.65 (5:1 toluene–ethyl acetate). N.m.r. data: ^{1}H, δ 7.4–7.1 (m, 10 H, 2 Ph), 6.01 (d, 1 H, *J* 2 Hz, H-1), 5.50 (dd, 1 H, *J* 4, 9 Hz, H-3), 4.02 (s, 2 H, COC*H*$_2$Cl), and 3.80 (s, 2 H, COC*H*$_2$Cl); ^{13}C, δ 166.66 (C=O), 166.23 (C=O), 90.05 (C-1, $^1J_{C,H}$ 181.9 Hz), 78.23 (C-2), 74.93 (PhCH$_2$O-4), 74.22 (C-4), 73.20 (PhCH$_2$O-2), 72.39 (C-3*), 72.11 (C-5*), 63.55 (C-6), and 40.53 (COCH$_2$Cl).

Anal. Calc. for $C_{24}H_{25}Cl_3O_7$: C, 54.19; H, 4.75; Cl, 20.00. Found: C, 54.23; H, 4.74; Cl, 20.00.

*Allyl 3-*O*-benzoyl-2,4-di-*O*-benzyl-6-(2,4-di-*O*-benzyl-3,6-di-*O*-chloroacetyl-α-*D*-mannopyranosyl)-α-*D*-mannopyranoside* (**20**). — To a stirred mixture of powdered molecular sieves 4A (30 g), $AgOSO_2CF_3$ (18 g, 70 mmol), **9** (2.0 g, 4.0 mmol), and 1,2-dichloroethane (110 mL) was added, dropwise, a solution of **10** (2.6 g, 4.3 mmol) in 1,2-dichloroethane (10 mL) at −5–0° under Ar. The mixture was stirred at 10–20° for 16 h, and then processed. A part of the crude product (4.2 g) was purified by column chromatography to give material with $[\alpha]_D$ +18° (*c* 0.93), R_F 0.52 (5:1 toluene–ethyl acetate). ^{1}H-N.m.r. data: δ 8.06 (dd, 2 H, *J* 3 and 10 Hz, benzoyl), 4.0 (s, 2 H, COC*H*$_2$Cl), and 3.80 (s, 2 H, COC*H*$_2$Cl).

Anal. Calc. for $C_{54}H_{56}Cl_2O_{14}$: C, 64.86; H, 5.64. Found: C, 64.97; H, 5.68.

*Allyl 3-*O*-benzoyl-2,4-di-*O*-benzyl-6-*O*-(2,4-di-*O*-benzyl-α-*D*-mannopyranosyl)-α-*D*-mannopyranoside* (**8**). — A mixture of crude **20** (4.0 g) and thiourea (1.2 g, 15.8 mmol) in aqueous 99.5% ethanol (70 mL) was stirred and boiled under

reflux for 5 h and then concentrated *in vacuo*. The residue was extracted with $CHCl_3$, and the extract was filtered and concentrated *in vacuo* to give an oily product (3.8 g) which was purified by column chromatography (10:1 toluene–tetrahydrofuran) to give **7** (1.87 g, 53.7% from **9**), $[\alpha]_D$ +24° (*c* 1.8), R_F 0.31 (5:1 toluene–ethyl acetate). N.m.r. data: ^1H, δ 8.08 (dd, 2 H, *J* 2 and 9 Hz, benzoyl), 6.1–5.6 (m, 1 H, CH_2-C*H*=CH_2), and 5.54 (dd, 1 H, *J* 4 and 10 Hz, H-3a); ^{13}C, δ 165.56 (C=O), 117.51 (-CH=CH_2), 97.28 (C-1a, $^1J_{C,H}$ 168.5 Hz), 96.94 (C-1b, 169.7 Hz), 78.61 (C-2b), 76.42 (C-2a*), 76.08 (C-4b*), 74.96 (PhCH_2O-4a,4b), 74.62 (C-4a), 73.20 (PhCH_2O-2a,2b), 72.76 (C-3a), 71.74 (C-3b*), 71.64 (C-5b*), 71.45 (C-5a*), 67.99 (O-CH_2-CH=CH_2), 65.89 (C-6a), and 62.19 (C-6b).

Anal. Calc. for $C_{50}H_{54}O_{12}$: C, 70.91; H, 6.43. Found: C, 70.75; H, 6.52.

*Allyl 2-O-acetyl-3,4,6-tri-O-benzyl-α-*D*-mannopyranoside* (**22**). — A mixture of powdered molecular sieves 4A (0.2 g), **21** (1.0 g, 1.8 mmol), and $Me_3SiOSO_2CF_3$ (120 μL) in 1,2-dichloroethane (10 mL) was stirred at 20° for 4 h under Ar, filtered, washed with aqueous $NaHCO_3$ and H_2O, dried ($MgSO_4$), and concentrated *in vacuo*. The residue was purified by column chromatography (20:1 toluene–ethyl acetate) to give **22** (800 mg, 80%), $[\alpha]_D$ +30.5° (*c* 0.5), R_F 0.54 (10:1 toluene–ethyl acetate). N.m.r. data: ^1H, δ 2.13 (s, 3 H, Ac); ^{13}C, δ 117.4 (-CH=CH_2), 97.0 (C-1, $^1J_{C,H}$ 169.7 Hz), and 20.1 (CH_3).

Anal. Calc. for $C_{32}H_{36}O_7$: C, 72.15; H, 6.83. Found: C, 72.33; H, 6.83.

*Allyl 3,4,6-tri-O-benzyl-α-*D*-mannopyranoside* (**23**). — A solution of **22** (200 mg) in 0.06mM NaOMe–MeOH (4 mL) was stirred for 3 h at 20°, neutralised with Amberlist A15 (H^+) resin, and processed to give an oil which was purified by column chromatography (10:1 toluene–ethyl acetate) to give **23** (180 mg), $[\alpha]_D$ +56° (*c* 1.5), R_F 0.42 (10:1 toluene–ethyl acetate). ^{13}C-N.m.r. data: δ 133.6 (CH_2CH=CH_2), 117.4 (CH_2-CH=CH_2), and 98.3 (C-1, $^1J_{C,H}$ 170.9 Hz).

Anal. Calc. for $C_{30}H_{34}O_6$: C, 73.43; H, 7.00. Found: C, 73.41; H, 6.97.

*Allyl 3,4,6-tri-O-benzyl-2-O-chloroacetyl-α-*D*-mannopyranoside* (**24**). — To a solution of **23** (4.0 g, 8.4 mmol) in pyridine (40 mL) was added chloroacetic anhydride (4.0 g, 23.4 mmol) at −5–0°, and the mixture was stirred for 1 h, poured into ice–water, and extracted with CH_2Cl_2. The extract was washed with water and saturated aqueous sodium chloride, dried ($MgSO_4$), and concentrated *in vacuo* to give crude **24** (5.0 g), which was purified by column chromatography (40:1 dichloromethane–acetone) to give **24** (3.4 g, 74.6%), $[\alpha]_D$ +33° (*c* 1.3), R_F 0.48 (10:1 toluene–tetrahydrofuran). N.m.r. data: ^1H, δ 7.5–7.1 (m, 15 H, 3 Ph), 6.1–5.6 (m, 1 H, CH_2-C*H*=CH_2), 4.92 (d, 1 H, *J* 2 Hz, H-1), and 4.15 (s, 2 H, $COCH_2Cl$); ^{13}C, δ 166.77 (C=O), 117.79 (-CH_2-CH=CH_2), 96.60 (C-1, $^1J_{C,H}$ 170.90 Hz), 78.24 (C-3), 75.15 (PhCH_2O-4), 74.34 (C-4), 73.41 (PhCH_2O-3), 72.00 (PhCH_2O-6), 71.74 (C-5*), 70.76 (C-2*), 68.97 (C-6), 68.21 (O-CH_2CH=CH_2), and 40.85 ($COCH_2Cl$).

Anal. Calc. for $C_{32}H_{35}ClO_7$: C, 67.77; H, 6.23; Cl, 6.25. Found: C, 67.74; H, 6.17; Cl, 6.38.

*3,4,6-Tri-O-benzyl-2-O-chloroacetyl-α-*D*-mannopyranose* (**25**). — A mixture

of **24** (3.4 g, 6.0 mmol), $PdCl_2$ (1.4 g), and AcONa (1.4 g) in H_2O (0.8 mL) and AcOH (14 mL) was stirred at 20–25° for 16 h and then processed as for **19**, and the product was purified by column chromatography (5:1 toluene–tetrahydrofuran) to give **25** (2.7 g, 85.4%), $[\alpha]_D$ +8° (*c* 1.1), R_F 0.43 (5:1 toluene–tetrahydrofuran). N.m.r. data: ^1H, δ 7.4–7.0 (m, 15 H, 3 Ph), 5.35 (dd, 1 H, *J* 2 and 4 Hz, H-2), 5.15 (d, 1 H, *J* 2 Hz, H-1), and 4.12 (s, 2 H, $COCH_2Cl$); ^{13}C, δ 166.88 (C=O), 91.83 (C-1, $^1J_{C,H}$ 170.9 Hz), 77.64 (C-3), 74.89 ($PhCH_2O$-4), 74.55 (C-4), 73.36 ($PhCH_2O$-3), 71.95 ($PhCH_2O$-6), 71.24 (C-5), 71.03 (C-2), and 69.35 (C-6).

Anal. Calc. for $C_{29}H_{31}ClO_7$: C, 66.08; H, 5.94; Cl, 6.73. Found: C, 65.97; H, 5.98; Cl, 6.73.

3,4,6-Tri-O-benzyl-2-O-chloroacetyl-α-D-mannopyranosyl chloride (**11**). — A solution of **25** (300 mg), $SOCl_2$ (1 mL), and Me_2NCHO (0.05 mL) in 1,2-dichloroethane (10 mL) was stirred at 20° for 1 h, and then processed as for **10** to give **11** (270 mg, 87.0%), $[\alpha]_D$ +65° (*c* 0.4), R_F 0.71 (10:1 toluene–tetrahydrofuran). N.m.r. data: ^1H, δ 7.4–7.1 (m, 15 H, 3 Ph), 6.06 (d, 1 H, *J* 2 Hz, H-1), 5.50 (dd, 1 H, *J* 2 and 4 Hz, H-2), and 4.10 (s, 2 H, $COCH_2Cl$); ^{13}C, δ 89.99 (C-1, $^1J_{C,H}$ 183.1 Hz), 76.66 (C-3), 75.26 ($PhCH_2O$-4), 74.55 (C-4), 73.41 ($PhCH_2O$-3, C-2), 72.76 (C-5), 72.38 ($PhCH_2O$-6), and 68.05 (C-6).

Anal. Calc. for $C_{29}H_{30}Cl_2O_6$: C, 63.85; H, 5.55. Found: C, 63.63; H, 5.54.

Allyl 3-O-benzoyl-2,4-di-O-benzyl-6-O-[2,4-di-O-benzyl-3,6-di-O-(3,4,6-tri-O-benzyl-2-O-chloroacetyl-α-D-mannopyranosyl)-α-D-mannopyranosyl]-α-D-mannopyranoside (**26**). — To a stirred mixture of powdered molecular sieves 4A (15 g), $AgOSO_2CF_3$ (10 g), and **8** (0.47 g, 0.54 mmol) in 1,2-dichloroethane (10 mL) was added, dropwise, a solution of **11** (1.0 g, 1.83 mmol) in 1,2-dichloroethane (10 mL) at −5–0°. The mixture was stirred at 0–5° for 1 h and then processed, and the product was purified by column chromatography (15:1 toluene–tetrahydrofuran) to give **26** (0.70 g, 68.6%), $[\alpha]_D$ +10° (*c* 2), R_F 0.61 (5:1 toluene–tetrahydrofuran). N.m.r. data: ^1H, δ 8.08 (dd, 2 H, *J* 2 and 8 Hz, benzoyl), 4.12 (s, 2 H, $COCH_2Cl$), and 4.04 (s, 2 H, $COCH_2Cl$); ^{13}C, δ 166.63 (2 C=O), 165.61 (C=O), 117.60 (-CH=CH_2), 99.18 (C-1d, $^1J_{C,H}$ 172.1 Hz), 97.76 (C-1c, $^1J_{C,H}$ 172.1 Hz), 97.13 (C-1a, $^1J_{C,H}$ 170.9 Hz), 96.64 (C-1b, $^1J_{C,H}$ 169.7 Hz), and 40.94 ($COCH_2Cl$).

Anal. Calc. for $C_{108}H_{112}Cl_2O_{24}$: C, 69.54; H, 6.06. Found: C, 69.49; H, 6.04.

Allyl 3-O-benzoyl-2,4-di-O-benzyl-6-O-[2,4-di-O-benzyl-3,6-di-O-(3,4,6-tri-O-benzyl-α-D-mannopyranosyl)-α-D-mannopyranosyl]-α-D-mannopyranoside (**6**). — A mixture of **26** (280 mg, 0.15 mmol) and thiourea (45 mg, 0.59 mmol) in 99.5% ethanol (5 mL) was stirred and boiled under reflux for 5 h and then concentrated *in vacuo*. The residue was triturated with $CHCl_3$, filtered, and concentrated *in vacuo* to give an oily product (267 mg) which was purified by chromatography (40:1 dichloromethane–acetone) to give **6** (145 mg, 56.3%), $[\alpha]_D$ +35° (*c* 1), R_F 0.43 (40:1 dichloromethane–acetone).

Anal. Calc. for $C_{104}H_{110}O_{22}$: C, 72.94; H, 6.48. Found: C, 72.95; H, 6.47.

Allyl 3-O-benzoyl-2,4-di-O-benzyl-6-O-{2,4-di-O-benzyl-3,6-di-O-[3,4,6-tri-O-benzyl-2-O-(3,4,6-tri-O-benzyl-2-O-chloroacetyl-α-D-mannopyranosyl)-α-D-

mannopyranosyl]-α-D-*mannopyranosyl*}-α-D-*mannopyranoside* (**5**). — To a stirred mixture of powdered molecular sieves 4A (3 g), $AgOSO_2CF_3$ (250 mg), and **6** (140 mg, 0.081 mmol) in 1,2-dichloroethane (4 mL) was added, dropwise, a portion (1.4 mL) of a solution of **11** (195 mg, 0.356 mmol) in 1,2-dichloroethane (2 mL) at −5–0°. The mixture was stirred at 20° for 16 h, the remaining solution of **11** (0.6 mL) was added, and stirring was continued for 1 h at 20°. The mixture was diluted with dichloromethane, filtered, washed with aqueous $NaHCO_3$, dried ($MgSO_4$), and concentrated *in vacuo* to give an oily product (320 mg), which was eluted from a column (7.8 × 1.2 cm) of PVA 2000 (Merck) with benzene to give the hexasaccharide fraction (179 mg). Further purification by column chromatography (twice) (10:1 then 40:1 toluene–tetrahydrofuran) afforded **5** (123 mg, 54.7%), $[\alpha]_D$ +16° (*c* 0.125), R_F 0.55 (10:1 toluene–tetrahydrofuran). ^{13}C-N.m.r. data: δ 166.49 (2 C=O), 165.47 (C=O), 117.56 (-CH=CH_2), 100.90 (C-1d, $^1J_{C,H}$ 171.5 Hz), 99.13 (C-1e and C-1f, $^1J_{C,H}$ 169.5 Hz), 98.86 (C-1c, $^1J_{C,H}$ 168.9 Hz), 97.23 (C-1a, $^1J_{C,H}$ 170.3 Hz), 96.84 (C-1b, $^1J_{C,H}$ 170.3 Hz), and 40.89 (2 × $COCH_2Cl$).

Anal. Calc. for $C_{162}H_{168}Cl_2O_{34}$: C, 71.27; H, 6.20; Cl, 2.61. Found: C, 71.64; H, 6.18; Cl, 2.98.

Allyl 3,4,6-tri-O-*benzyl-2*-O-[*3,4,6-tri*-O-*benzyl-2*-O-*(2,3,4,6-tetra*-O-*benzyl*-α-D-*mannopyranosyl)*-α-D-*mannopyranosyl*]-α-D-*mannopyranoside* (**30**) *and allyl 3,4,6-tri*-O-*benzyl-2*-O-[*3,4,6-tri*-O-*benzyl-2*-O-*(2,3,4,6-tetra*-O-*benzyl*-β-D-*mannopyranosyl)*-α-D-*mannopyranosyl*]-α-D-*mannopyranoside* (**32**). — (*a*) To a mixture of powdered molecular sieves 4A (1.5 g), $Hg(CN)_2$ (140 mg, 0.55 mmol), and **27** (162 mg, 0.18 mmol) in 1,2-dichloroethane (3 mL) was added a solution of **28** (100 mg, 0.18 mmol) in 1,2-dichloroethane (1 mL) at 20° under Ar. Since no reaction was observed on stirring the mixture at 20° for 16 h, the mixture was stirred at 50° for 16 h and then diluted with $CHCl_3$, filtered, washed with aqueous $NaHCO_3$, dried (K_2CO_3), and concentrated. The oily product (209 mg) was purified by column chromatography (30:1 toluene–tetrahydrofuran) to give **30** (123 mg, 49%) and **32** (33 mg, 13%). Compound **30** had $[\alpha]_D$ +17° (*c* 0.23), R_F (h.p.t.l.c.) 0.65 (40:1 toluene–tetrahydrofuran). ^{13}C-N.m.r. data: δ 116.92 (-CH=CH_2), 100.99 (C-1c, $^1J_{C,H}$ 173.3 Hz), 99.69 (C-1b, $^1J_{C,H}$ 169.7 Hz), and 98.23 (C-1a, $^1J_{C,H}$ 169.7 Hz). Compound **32** had $[\alpha]_D$ −26° (*c* 0.17), R_F 0.57. ^{13}C-N.m.r. data: δ 117.08 (-CH=CH_2), 99.58 (C-1c, $^1J_{C,H}$ 152.3 Hz; C-1b, $^1J_{C,H}$ 168.2 Hz), and 98.34 (C-1a, $^1J_{C,H}$ 174.1 Hz).

(*b*) To a stirred mixture of molecular sieves 4A (1.5 g), $Hg(CN)_2$ (140 mg, 0.55 mmol), and **27** (160 mg, 0.18 mmol) in 1:1 benzene–nitromethane (4 mL) was added a solution of **28** (100 mg, 0.18 mmol) in 1:1 benzene–nitromethane (3 mL). No reaction was observed at 20°, but glycosidation occurred on stirring at 50° for 16 h. A further solution of **28** (80 mg, 0.14 mmol) in 1:1 benzene–nitromethane (1 mL) was added after 5 h. Processing and column chromatography then afforded **30** (143 mg, 58%) and **32** (101 mg, 40%).

(*c*) When **29** was used instead of **28** in (*a*), reaction proceeded at 20°, and, after 16 h, t.l.c. showed the formation of **30** and **32** in the ratio ~1:1.

(*d*) To a stirred mixture of powdered molecular sieves 4A (1.0 g), $Hg(CN)_2$ (100 mg), and **23** (45 mg, 0.09 mmol) in 1,2-dichloroethane (1.5 mL) was added a solution of **7** (100 mg, 0.10 mmol) in 1,2-dichloroethane (1.5 mL) under Ar. No reaction was observed after stirring the mixture at 50° for 16 h. The mixture was then stirred and boiled under reflux for 20 h, diluted with $CHCl_3$, filtered, and concentrated. The residue was eluted from a column (50 × 2.0 cm) of Toyoperl HW-40F with 1:1 $CHCl_3$–MeOH to give **30** (48 mg, 37%). No β isomer could be isolated.

*Propyl 2-O-(2-O-α-*D*-mannopyranosyl-α-*D*-mannopyranosyl)-α-*D*-mannopyranoside* (**31**). — A mixture of **30** (110 mg) and 10% Pd-C (500 mg) in MeOH (10 mL) and HCOOH (1 mL) was stirred at 20° for 1 h under Ar. Processing, as in the case of **41**, afforded the crude product (48 mg) which was purified by elution from Toyoperl HW-40F with water to give **31** (quantitative yield), $[\alpha]_D$ +31° (*c* 1.2, water), R_F 0.37 (2:1:1 1-BuOH–EtOH–H_2O).

*Propyl 2-O-(2-O-β-*D*-mannopyranosyl-α-*D*-mannopyranosyl)-α-*D*-mannopyranoside* (**33**). Treatment of **32** (56 mg) as described above for **31** gave a quantitative yield of **33**, $[\alpha]_D$ +13° (*c* 0.74, water), R_F 0.44 (2:1:1 1-BuOH–EtOH–H_2O).

*Allyl 3-O-benzoyl-2,4-di-O-benzyl-6-O-{2,4-di-O-benzyl-3,6-di-O-[3,4,6-tri-O-benzyl-2-O-(2,3,4,6-tetra-O-benzyl-α-*D*-mannopyranosyl)-α-*D*-mannopyranosyl]-α-*D*-mannopyranosyl}-α-*D*-mannopyranoside* (**4**). — (*a*) To a stirred mixture of powdered molecular sieves 4A (1.5 g), $Hg(CN)_2$ (170 mg, 0.673 mmol), and **6** (240 mg, 0.132 mmol) in 1,2-dichloroethane (6 mL) was added, dropwise, a solution of **28** (160 mg, 0.286 mmol) in 1,2-dichloroethane (3 mL) at 20°, and the mixture was stirred at 50° for 16 h under Ar. The mixture was further stirred at 50° for 2 days, whilst solutions of **28** (80 mg, 0.143 mmol) in 1,2-dichloroethane (1.5 mL) and **28** (15 mg, 0.027 mmol) in 1,2-dichloroethane (0.5 mL) were added after 16 h and 1 day, respectively. The mixture was diluted with $CHCl_3$, filtered, washed with aqueous $NaHCO_3$, dried ($MgSO_4$), and concentrated *in vacuo*. The oily residue (500 mg) was purified by column chromatography (40:1 toluene–tetrahydrofuran), giving a fraction (140 mg) which showed two components in h.p.t.l.c. at R_F 0.87 and 0.80 in the ratio of ~3:1. Elution of the mixture from a column (72 × 2.2 cm) of Bio-Beads SX-3 with benzene afforded **4** (108 mg, 29.3%), R_F 0.87 (10:1 toluene–tetrahydrofuran).

(*b*) To a stirred mixture of powdered molecular sieves 4A (6.0 g), $Hg(CN)_2$ (500 mg, 1.98 mmol), and **8** (210 mg, 0.241 mmol) in 1,2-dichloroethane (5 mL) was added a solution of **7** (760 mg, 0.766 mmol) in 1,2-dichloroethane (2 mL). As no reaction occurred on stirring at 50° for 16 h, the mixture was stirred and boiled under reflux for 16 h and processed as in (*a*) to give a crude product (1.04 g) that was eluted from a column (50 × 2 cm) of Toyoperl HW-40F with 1:1 $CHCl_3$–MeOH to give an oily product (628 mg). This oil was eluted from a column (72 × 2.2 cm) of Bio-Beads SX-3 with benzene to give a hexasaccharide fraction [150 mg, 21.9%, two components in h.p.t.l.c. at R_F 0.87 and 0.79 (10:1 toluene–tetrahydrofuran)]. Column chromatography of this fraction, using 20:1 toluene–tetra-

hydrofuran, gave **4** (50 mg) and a 1:1 mixture (75 mg) of **4** and **40**; **4** (12.8%), R_F 0.87; **40** (5.5%), R_F 0.79. The tetrasaccharide fraction [300 mg, 68.1%, two components in h.p.t.l.c. at R_F 0.65 and 0.53 (10:1 toluene–tetrahydrofuran)] was also subjected to column chromatography (10:1 toluene–tetrahydrofuran) to give **38** (95 mg, 21.6%; R_F 0.65) and **39** (48 mg, 10.9%; R_F 0.53). Pure **4** had $[\alpha]_D$ +20° (*c* 0.3). ^{13}C-N.m.r. data: δ 101.26 (C-1d), 99.75 (C-1e,1f), 99.48 (C-1c), 97.25 (C-1a), and 96.93 (C-1b).

Anal. Calc. for $C_{172}H_{178}O_{32} \cdot C_7H_8$: C, 75.44; H, 6.59. Found: C, 75.59; H, 6.72.

Compound **38** had $[\alpha]_D$ +37° (*c* 0.2). ^{13}C-N.m.r. data: δ 117.41 (-CH=*C*H$_2$), 99.91 (C-1d, $^1J_{C,H}$ 168.5 Hz), 99.53 (C-1c, $^1J_{C,H}$ 173.3 Hz), 97.53 (C-1a, $^1J_{C,H}$ 169.7 Hz), and 97.25 (C-1b, $^1J_{C,H}$ 170.9 Hz). Compound **39** had $[\alpha]_D$ +6.3° (*c* 0.2). ^{13}C-N.m.r. data: δ 117.36 (-CH=*C*H$_2$), 100.45 (C-1c, $^1J_{C,H}$ 157.5 Hz), 98.50 (C-1d, $^1J_{C,H}$ 170.9 Hz), 97.67 (C-1a, $^1J_{C,H}$ 168.5 Hz), and 97.25 (C-1b, $^1J_{C,H}$ 170.9 Hz).

*Propyl 6-*O*-[3,6-di-*O*-(2-*O*-α-*D*-mannopyranosyl-α-*D*-mannopyranosyl)-α-*D*-mannopyranosyl]-α-*D*-mannopyranoside* (**41**). — A solution of **4** (50 mg) in 1:1methanol–tetrahydrofuran containing a trace of MeONa was stirred at 50° for 1 h, neutralised with Amberlist 15 (H^+) resin, filtered, and concentrated *in vacuo* to give an oil (35 mg), R_F 0.49 (h.p.t.l.c., 10:1 toluene–tetrahydrofuran). A mixture of this oil and 10% Pd-C (50 mg) in MeOH (0.6 mL) and HCOOH (0.2 mL) was stirred vigorously at 50–70° for 3 min under Ar, filtered, and concentrated *in vacuo*. The residual oil (13 mg) was purified by elution from Toyoperl HW-40F with water to give **41** (11.5 mg, 63%), $[\alpha]_D$ +69.0° (*c* 0.15), R_F 0.26 (2:1:1 1-BuOH–EtOH–H_2O). ^{1}H-N.m.r. data: (D_2O, 400 MHz, 52°): δ 5.352 (H-1d, *J* 2 Hz), 5.133 (H-1c, *J* 2 Hz), 5.063 (H-1e, *J* 2 Hz), 5.055 (H-1f, *J* 2 Hz), 4.879 (H-1b, *J* 2 Hz), and 4.863 (H-1a, *J* 2 Hz).

*Allyl (2-*O*-acetyl-3,4,6-tri-*O*-benzyl-α-*D*-mannopyranosyl)-3,4,6-tri-*O*-benzyl-α-*D*-mannopyranoside* (**35**). — To a mixture of $AgOSO_2CF_3$ (500 mg), **23** (500 mg, 1.05 mmol), and tetramethylurea (0.3 mL) in 1,2-dichloroethane (7 mL) was added, dropwise, a solution of **34** (1.0 g) in 1,2-dichloroethane (2 mL) at 20° under Ar. The mixture was stirred for 16 h at 20° and worked-up to give a crude oil (1.08 g) that was purified by column chromatography (10:1 toluene–ethyl acetate) to give **35** (670 mg, 68%), $[\alpha]_D$ +25.5° (*c* 2), R_F 0.58 (10:1 toluene–ethyl acetate). N.m.r. data: ^{13}C, δ 170.1 (*C*H$_3$C=O), 133.7 (CH$_2$*C*H=CH$_2$), 117.1 (CH$_2$CH=*C*H$_2$), 99.6 (C-1b, $^1J_{C,H}$ 172.9 Hz), 97.9 (C-1a, $^1J_{C,H}$ 170.0 Hz), 67.8 (O-*C*H$_2$CH=CH$_2$), and 21.1 (*C*H$_3$C=O); ^{1}H, δ 2.110 (s, 3 H, Ac).

Anal. Calc. for $C_{59}H_{64}O_{12}$: C, 73.41; H, 6.69. Found: C, 73.30; H, 6.64.

*Allyl 3,4,6-tri-*O*-benzyl-2-*O*-(3,4,6-tri-*O*-benzyl-α-*D*-mannopyranosyl)-α-*D*-mannopyranoside* (**27**). — A solution of **35** (38.1 mg, 0.039 mmol) in tetrahydrofuran (0.5 mL) and methanolic M sodium methoxide (0.05 mL) was stirred for 30 min at 20°, and then processed. The product was purified by column chromatography (10:1 toluene–tetrahydrofuran) to afford **27** in quantitative yield, $[\alpha]_D$ +35° (*c* 0.54), R_F 0.45 (10:1 toluene–tetrahydrofuran). N.m.r. data: ^{13}C, δ 134.0

($CH_2CH=CH_2$), 116.9 ($CH_2CH=CH_2$), 101.5 (C-1b, $^1J_{C,H}$ 170.9 Hz), 98.2 (C-1a, $^1J_{C,H}$ 172.2 Hz), and 67.9 (CH_2-$CH=CH_2$); ^1H, δ 6.0–5.6 (m, 1 H, $CH_2CH=CH_2$).

Anal. Calc. for $C_{57}H_{62}O_{11}$: C, 74.15; H, 6.78. Found: C, 74.46; H, 6.40.

Allyl 3,4,6-tri-O-benzyl-2-O-(2,3,4,6-tetra-O-benzyl-α-D-mannopyranosyl)-α-D-mannopyranoside (**36**). — To a suspension of NaH (50%, 100 mg; washed with hexane, 2.0 mL) in *N,N*-dimethylformamide (1 mL) was added a solution of **27** (987 mg) in *N,N*-dimethylformamide (1 mL), and the mixture was stirred for 30 min at 20°. Benzyl bromide (0.2 mL, 1.64 mmol) was added dropwise, and the mixture was stirred for 1 h at 20° and then processed. The resulting, crude oil (1.03 g) was purified by column chromatography (20:1 toluene–tetrahydrofuran) to give **36** (974 mg, 90%), $[\alpha]_D$ +16° (*c* 0.73), R_F 0.74 (10:1 toluene–tetrahydrofuran). N.m.r. data: ^{13}C, δ 133.9 ($CH_2CH=CH_2$), 116.9 ($CH_2CH=CH_2$), 99.7 (C-1b, $^1J_{C,H}$ 167.2 Hz), 98.3 (C-1a, $^1J_{C,H}$ 170.9 Hz), and 67.9 ($OCH_2CH=CH_2$); ^1H, δ 6.0–5.6 (m, 1 H, $CH_2CH=CH_2$).

Anal. Calc. for $C_{64}H_{68}O_{11}$: C, 75.85; H, 6.78. Found: C, 75.39; H, 6.75.

3,4,6-Tri-O-benzyl-2-O-(2,3,4,6-tetra-O-benzyl-α-D-mannopyranosyl)-D-mannopyranose (**37**). — A mixture of **36** (870 mg, 0.86 mmol) and $PdCl_2$ (50 mg, 0.28 mmol) in MeOH (10 mL) was sonicated (Ultrasonic Cleaner TOCHO) for 1 h at 20°, and then concentrated *in vacuo*. The residue was purified by column chromatography (20:1 toluene–tetrahydrofuran) to give **37** (495 mg, 59%), $[\alpha]_D$ +4° (*c* 0.78), R_F 0.40 (10:1 toluene–tetrahydrofuran). ^{13}C-N.m.r. data: δ 99.5 (C-1b, $^1J_{C,H}$ 170.9 Hz) and 93.4 (C-1a, $^1J_{C,H}$ 172.1 Hz).

Anal. Calc. for $C_{61}H_{64}O_{11}$: C, 75.27; H, 6.64. Found: C, 75.49; H, 6.56.

3,4,6-Tri-O-benzyl-2-O-(2,3,4,6-tetra-O-benzyl-α-D-mannopyranosyl)-α-D-mannopyranosyl chloride (**7**). — To a solution of **37** (227 mg, 0.23 mmol) in 1,2-dichloroethane (2 mL) was added $SOCl_2$ (0.5 mL) and *N,N*-dimethylformamide (0.05 mL) at 20°. The mixture was stirred for 1 h at 20°, filtered through silica gel, and concentrated *in vacuo*. The residue was purified by column chromatography (20:1 toluene–tetrahydrofuran) to give **7** (193 mg, 83%), $[\alpha]_D$ +47° (*c* 0.95), R_F 0.61 (10:1 toluene–tetrahydrofuran). N.m.r. data: ^{13}C, δ 100.7 (C-1b, $^1J_{C,H}$ 173.3 Hz) and 92.6 (C-1a, $^1J_{C,H}$ 184.3 Hz); ^1H, δ 6.21 (d, 1 H, *J* 2.0 Hz, H-1a).

Anal. Calc. for $C_{61}H_{63}ClO_{10}$: C, 73.87; H, 6.42; Cl, 3.58. Found: C, 73.72; H, 6.43; Cl, 3.68.

ACKNOWLEDGMENTS

We thank Dr. J. Uzawa and Mrs. T. Chijimatsu for recording and measuring the n.m.r. spectra, Dr. H. Homma and his staff for the elemental analyses, and Mrs. A. Takahashi for her technical assistance.

REFERENCES

1 T. OGAWA AND M. SUGIMOTO, *Carbohydr. Res.*, 128 (1984) c1–c4.
2 T. OGAWA AND K. SASAJIMA, *Tetrahedron*, 37 (1981) 2787–2792; T. OGAWA, T. KITAJIAM, AND T.

NUKADA, *Carbohydr. Res.*, 123 (1983) c8–c11; T. OGAWA, T. NUKADA, AND T KITAJIMA, *ibid*, 123 (1983) c12–c15.
3 P. J. SMITH, *Chem. Ind. (London)*, (1976) 1025–1029.
4 T. OGAWA AND M. MATSUI, *Tetrahedron*, 37 (1981) 2363–2369; T. OGAWA, T. NUKADA, AND M MATSUI, *Carbohydr. Res.*, 101 (1982) 263–270; T. OGAWA, Y. TAKAHASHI, AND M. MATSUI, *ibid*, 102 (1982) 207–215.
5 T. OGAWA, K KATANO, K. SASAJIMA, AND M MATSUI, *Tetrahedron*, 37 (1981) 2779–2786
6 T. OGAWA, S NAKABAYASHI, AND T. KITAJIMA, *Carbohydr. Res.*, 114 (1983) 225–236.
7 M. S NEWMAN AND P. K SUJEETH, *J. Org. Chem.*, 43 (1978) 4367–4369.
8 S HANESSIAN AND J. BANOUB, *Carbohydr. Res.*, 53 (1977) c13–c16.
9 J.-C. JACQUINET, J.-R. POUGNY, D DUCHET, AND P. SINAY, *Joint Conference, CIC–ACS, 2nd, Montreal*, 1977, CARB 44.
10 F. A. COOK AND D. T. MAICHUK, *J. Org. Chem.*, 35 (1970) 1940–1943
11 K. BOCK, I LUNDT, AND C. PEDERSEN, *Tetrahedron Lett.*, (1973) 1037–1040; K. BOCK AND C PEDERSEN, *J. Chem Soc., Perkin Trans. 2*, (1974) 293–297; *Acta Chem. Scand., Ser B*, 29 (1975) 258–264.
12 T OGAWA, K. BEPPU, AND S. NAKABAYASHI, *Carbohydr. Res.*, 93 (1981) c6–c9.
13 T. OGAWA AND K. SASAJIMA, *Carbohydr. Res.*, 97 (1981) 205–227; T. OGAWA AND H. YAMAMOTO, *ibid.*, 104 (1982) 271–283.
14 T. OGAWA, K. KATANO, AND M. MATSUI, *Carbohydr. Res.*, 64 (1978) c3–c9 See also ref 5.
15 H. PAULSEN, *Angew Chem., Int. Ed. Engl.*, 21 (1982) 155–173