Modification of Cyclodextrins by Insertion of a Heterogeneous Sugar Unit into Their Skeletons. Synthesis of 2-Amino-2-deoxy-β-cyclodextrin from α-Cyclodextrin

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Acetolysis of fully acetylated α-cyclodextrin **5a** resulted in restricted fission of only one of the glycosidic bonds to give the acyclic maltohexaose peracetate **6a** in 46% yield. Regioselective modifications of both terminals of hexasaccharide **6a** were performed by employing Lewis acid-catalysed thioglycosidation and *O*-benzylidenation followed by its reductive cleavage as the key reactions, to give the partially *O*-benzylated maltohexaoside **9a** with the sole hydroxy group at the 4^{VI}-position. Coupling of compound **9a** and a D-glucosamine precursor by the trichloroacetimidate method gave the heptasaccharide **15**, subsequent deprotection of which gave 2-amino-2-deoxy-β-cyclodextrin **1**.

Cyclodextrins (CDs) are cyclic oligosaccharides, which mainly consist of six, seven and eight D-glucopyranose residues linked with α(1→4) glycosidic bonds. All the D-glucopyranose residues bearing a $^4C_1$ conformation form rigid doughtnut-shaped structures with all the primary hydroxy groups situated at one end of the annulus and all the secondary ones at the other end. Since the inside cavity is relatively hydrophobic, CDs possess the ability to include various organic molecules in their cavities.[1] These inclusion compounds have been widely used in the food and pharmaceutical industries for the microencapsulation of sensitive or active compounds.[2] In the academic field, CDs also received much attention as model compounds of enzymes and receptors,[3] because formation of the inclusion complexes resembles enzyme–substrate or drug–receptor interactions.

Replacement of the hydroxy groups of CDs with other functional groups has been shown to improve remarkably their ability to form inclusion complexes or their catalytic properties.[4] However, the extreme congestion of the hydroxy groups and the rigid structure of CDs limited the reaction pattern employed for the modification and design of the target molecules. Recent progress in chemical and enzymic synthesis of cyclic oligosaccharides from small building blocks[5] has provided new types of CD analogues with unique structures. The multi-step glycosidation reactions required for the syntheses, however, are laborious and they sometimes resulted in severe losses in yields of the final products.

Our recent success in the synthesis of bioactive compounds utilizing internal glycosidic bonds of maltose[6] and maltotriose[7] prompted us to develop a novel procedure for the preparation of maltooligosaccharides with higher degree of polymerization (D.P.) and to employ them as starting materials for the synthesis of new CD analogues. As preliminarily communicated,[8] we have developed a novel procedure for CDs that includes fission of the ring, coupling with a heterogeneous sugar unit, and recyclization. Employing α-CD as the starting material, we have succeeded in the synthesis of 2-amino-2-deoxycyclomaltoheptaose 1 by inserting a D-glucosamine residue into α-CD skeleton. This paper describes the synthesis in detail.

Retrosynthetic analysis of the cyclic heptasaccharide **1** having an amino group at the 2-position is shown in Scheme 1. The scheme involved 3 stages; *i.e.* (i) a 'one-cut reaction' of α-CD **4** to give maltohexaose **2**, (ii) coupling of compound **2** with D-glucosamine **3**, and (iii) cyclization of the resulting heptasaccharide.

For the selective cleavage of the glycosidic bonds of CDs, we first examined acetolysis of α-CD **4** as the starting material. Direct acetolysis of compound **4**, however, gave a complex mixture from which icosa-*O*-acetylmaltohexaose **6a** was isolated in only 20% yield. The poor selectivity was probably due to the uncontrollable exothermic nature of the reaction, namely *O*-acetylation and acetolytic cleavage of the glycosidic bonds. After several examinations, we finally found that acetolysis of α-CD peracetate **5a** could be controlled to give the maltohexaose peracetate **6a** in an unexpectedly high yield. Thus, cyclic compound **5a** was treated with a mixture of acetic anhydride and conc. sulfuric acid (49:1, v/v) at 50–55 °C for 20 h to give, after crystallization from toluene (to recover unchanged substrate **5a**, 47% recovery) followed by silica gel column chromatography, the open-chain product **6a** in 46% isolated yield (Scheme 2). The ^{1}H NMR spectrum showed that the ratio of the α and β anomers in product **6a** was 5:1. Similarly, treatment of β-cyclodextrin peracetate **5b** with acetic anhydride–sulfuric acid gave tricosa-*O*-acetylmaltoheptaose **6b** (41%) and unchanged substrate **5b** (49% recovery), and acetolysis of γ-cyclodextrin peracetate **5c** gave hexacosa-*O*-acetylmaltooctaose **6c** in 52% yield, together with unchanged **5c** (37% recovery). The yields of the acyclic maltooligosaccharide acetates **6a–c** based on the amount of starting material actually consumed were more than 80%. The high yields and selectivities were in contrast to those of enzymic or acid-catalysed hydrolysis of CDs.[9]

In contrast to the parent CDs, the corresponding linear compounds **6a** and **6b** readily underwent regioselective modification at both their newly formed terminals. In order to protect the anomeric position and to activate it as the glycosyl donor at later stage, compounds **6a** and **6b** were first converted into the corresponding phenyl thioglycosides. Thus, compounds **6a** and **6b** were treated with Hanessian's reagent system,[10] trimethyl(phenylsulfanyl)silane–zinc iodide, to give the phenyl 1-thioglycosides **7a** and **7b** in 84 and 68% yield, respectively (Scheme 3). On the other hand, modifications of the D-glucose residues at the nonreducing ends were performed by use of the Evans acetal-exchange reaction[11] and reductive cleavage of the benzylidene acetal[12] as the key reactions. After de-*O*-acetylation of compound **7a**, the resulting thioglycoside

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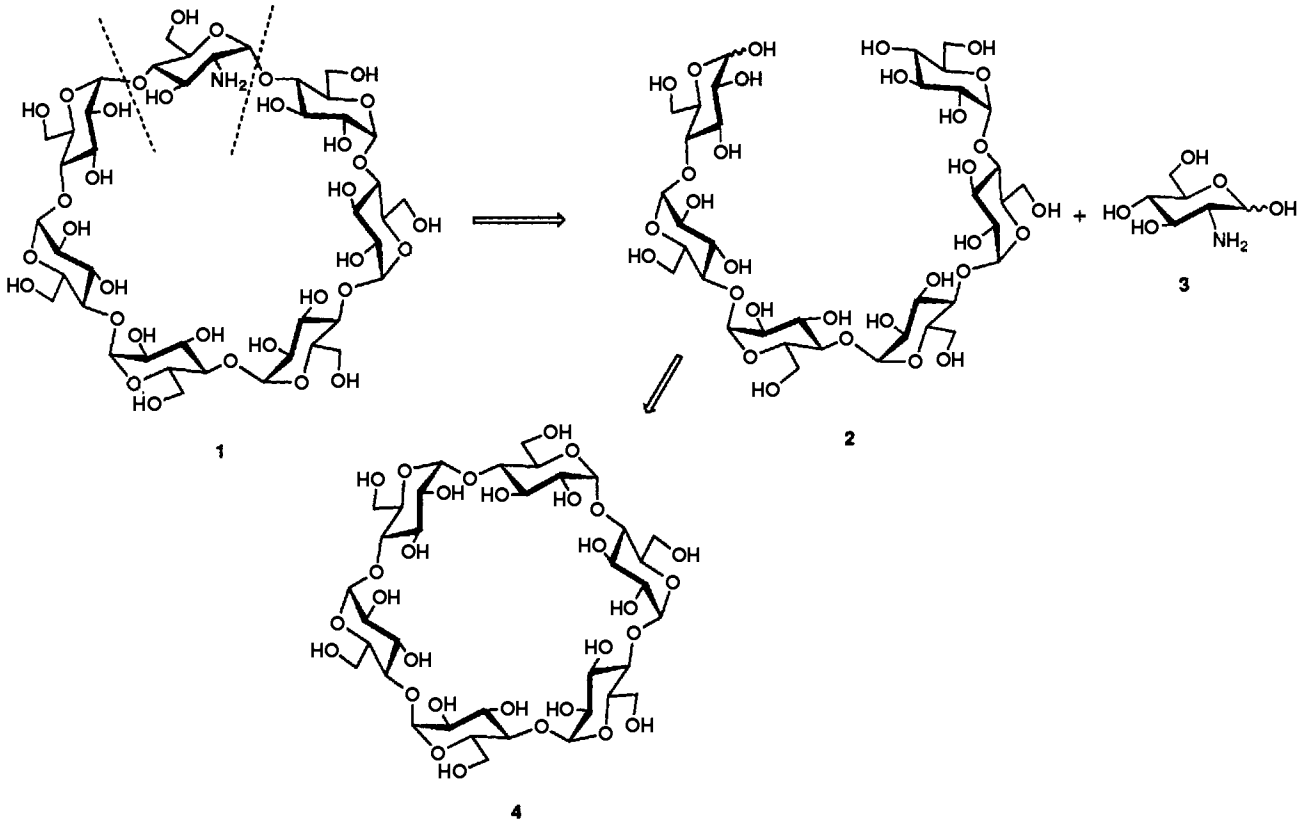
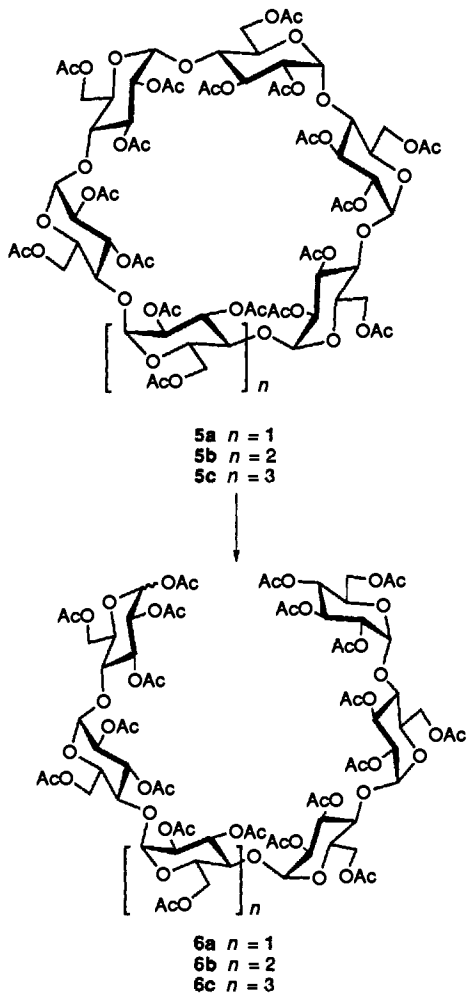


Scheme 1 Retrosynthetic analysis of 2-amino-2-deoxycyclomaltoheptaose **1**

was treated with α,α-dimethoxytoluene (1.2 mol equiv.) in *N*,*N*-dimethylformamide (DMF) in the presence of toluene-*p*-sulfonic acid (PTSA) as the catalyst under reduced pressure to give the 4^{VI},6^{VI}-*O*-benzylidene derivative, which was benzylated with benzyl bromide–sodium hydride in a one-pot manner, to give the fully protected derivative **8a** in 74% overall yield. Subsequent reductive cleavage of the *O*-benzylidene group of acetal **8a** was carried out by use of borane–trimethylamine complex–aluminium chloride in tetrahydrofuran (THF), to give the desired partially benzylated maltohexaoside **9a** with an unprotected hydroxy group at 4^{VI}-position in 67% yield. In a similar way, the 1-thio-β-maltoheptaoside **7b** was converted into the corresponding monobenzylidene derivative **8b** (63% yield), which afforded the 4^{VII}-unprotected maltoheptaoside **9b** in 65% yield. These compounds could be regarded as versatile intermediates for the various cyclic oligosaccharides because they combined both the functions of a glycosyl donor and a glycosyl acceptor.

Having prepared key acyclic intermediates, our attention next focused on the elongation of the sugar chain by coupling it with heterogeneous sugar units. Among many candidates, we chose D-glucosamine as the model compound because it has the same configuration as D-glucose but has significant differences in chemical and physical properties. Several D-glucosamine precursors **11**–**14** were prepared in good yield by use of a 1,6-anhydro-2-azidoglucose derivative[13] **10** as the common starting material. Thiolysis[14] of bicycle **10** with trimethyl(methylsulfanyl)silane–zinc iodide at room temperature gave the ring-opened product, which was acetylated at the O-6 position to afford the methyl 1-thio-α-glycoside **11a** and the β-anomer **11b** in a 20:13 ratio in 66% yield (Scheme 4). Although the thioglycoside **11a**, **b** could be used as the glycosyl donor for the coupling reaction, it was readily converted into two different glucosamine donors. Thus, the thioglycoside moiety of compounds **11a**, **b** was hydrolysed with *N*-bromosuccinimide (NBS) in moist dichloromethane to give the crystalline hemiacetal **12** in 70% yield. Compound **12** was treated with trichloroacetonitrile–potassium carbonate under Schmidt conditions[15] to afford the unstable glycosyl trichloroacetimidate **13** in good yield. On the other hand, treatment with NBS–dimethylaminosulfur trifluoride (DAST) according to the procedure of Nicolaou[16] gave an anomeric mixture of the glycosyl fluoride **14** in 71% yield.

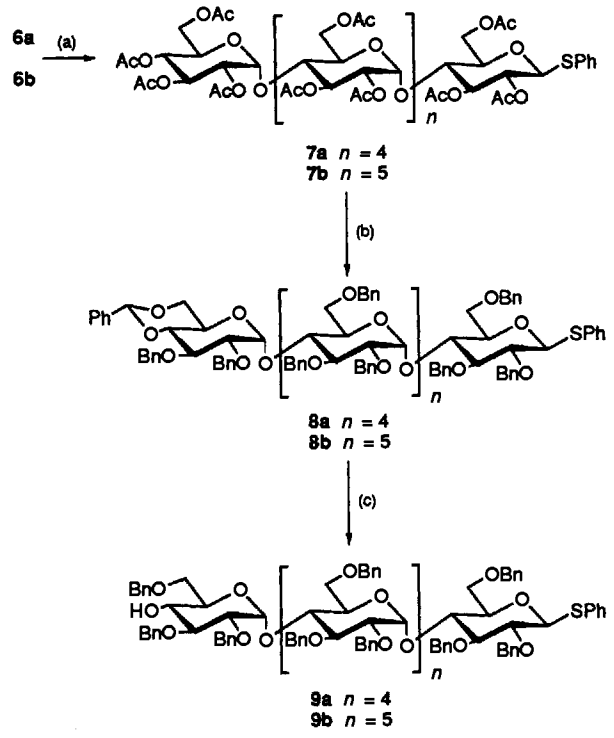
Our first attempt at the coupling with hexasaccharide **9a** and glucosamine precursors was carried out by using an anomeric mixture of the thioglycoside **11a**, **b**. The mixture of hexasaccharide **9a** and an excess of thioglycoside **11a**, **b** (6 mol equiv.) in diethyl ether was treated with methyl triflate[17] in the presence of molecular sieves 4 Å, giving the desired heptasaccharide, phenyl 6^{VII}-*O*-acetyl-2^{VII}-azido-2^{I},3^{I},6^{I},2^{II},3^{II},6^{II},2^{III},3^{III},6^{III},2^{IV},3^{IV},6^{IV},2^{V},3^{V},6^{V},2^{VI},3^{VI},6^{VI},3^{VII}-nonadeca-*O*-benzyl-2^{VII}-deoxy-4^{VII}-*O*-(*p*-methoxybenzyl)-1^{I}-thio-β-maltoheptaoside **15**, in 29% yield. Since methyl triflate could also activate the thioglycoside moiety of the hexasaccharide **9a**, a considerable amount of the fully benzylated α-cyclodextrin was isolated as the self-cyclization product of **9a**. While the coupling between hexasaccharide **9a** and the fluoride **14** under modified Mukaiyama conditions[18] employing silver triflate and tin(II) chloride as the promoter resulted in production of the desired compound **15** in low yield. This failure was probably due to decomposition of the thioglycoside **9a** or **15** with the silver salt. Fortunately, satisfactory results were obtained when we used the imidate **13** as the glucosamine donor. Thus, a mixture of compounds **9a** and **13** (2 mol equiv.) in diethyl ether was treated with a catalytic amount of trimethylsilyl triflate in the presence of acid-resistant molecular sieves AW-300, to give the heptasaccharide **15** in 39% yield. In the ^{1}H NMR spectrum of compound **15** in [$^2H_6$]benzene, signals assignable to six anomeric protons were observed at δ 5.48, 5.54, 5.64, 5.66, 5.68 and 5.73 with small coupling constants (2.9–3.7 Hz) suggesting that all the interglycosidic linkages were oriented α. Furthermore, the *p*-methoxybenzyl group protecting at 4^{VII}-hydroxy



Scheme 2 Acetolysis of fully acetylated cyclodextrins **5**

group in compound **15** was selectively removed by 2,3-dichloro-5,6-dicyano-1,4-benzoquinone (DDQ) oxidation in aq. dichloromethane,[19] to give compound **16** in 56% yield. Subsequent cyclization of the hydroxy thioglycoside **16** through intramolecular glycosidation was also conducted in diethyl ether at 0 °C by use of methyl triflate as a promoter, to give the cyclic heptasaccharide **17** in 41% yield. The ^{1}H NMR spectrum of compound **17** revealed seven doublets (J 3.0–3.7 Hz) assignable to the anomeric protons at a higher magnetic field than those of the acyclic intermediates **15** and **16**, and the coupling constants showed that all pyranosides were linked with α-glycosidic bonds. Finally, de-*O*-acetylation of compound **17** followed by subsequent hydrogenolysis of the *O*-benzyl groups and the azido group with 10% palladium on charcoal in 2-methoxyethanol–dil. hydrochloric acid gave the expected 2-amino-2-deoxycyclomaltoheptaose **1** in 70% yield.

The solubility of compound **1** in water at 22 °C was found to be significantly increased compared with that of β-CD and to be dependent on the pH of the medium; it was 4.4-times as large as that of β-CD in water and 12-times as large in 0.1 mol dm^{-3} hydrochloric acid. The effect of pH was also observed in its ^{1}H NMR spectrum. The signals attributable to 1-H, 2-H and 3-H of the glucosamine residue observed in ammonium deuteride at δ 4.90, 2.76 and ~3.9, respectively, which were shifted to lower magnetic field in dideuterium oxide containing deuterium chloride. Furthermore, the dissociation constant of the inclusion complex of heptacyclic CD **1** and *p*-nitrophenolate (K_d = 2.4 × 10^{-3} mol dm^{-3}) in phosphate buffer at pH 11 was almost the same as that of β-CD.



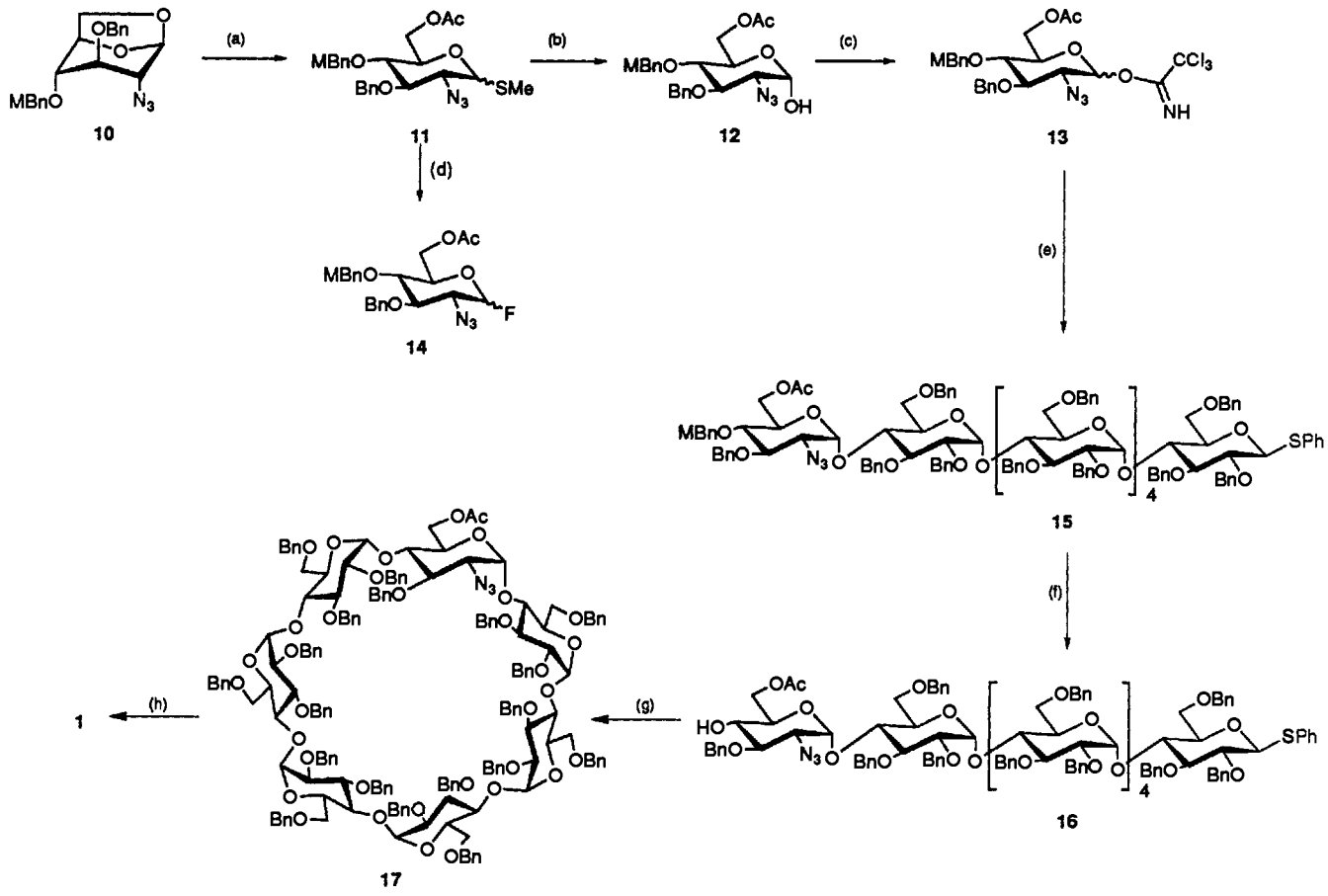
Scheme 3 Terminal modification of maltohexaose and maltoheptaose peracetates **6a** and **6b**. *Reagents:* (a) PhSSiMe$_3$–ZnI$_2$; (b) NaOMe–MeOH; then PhCH(OMe)$_2$–TsOH in DMF; then BnBr–NaH in DMF; (c) BH$_3$·Me$_3$N–AlCl$_3$ in THF.

Thus, the present procedure for the modification of CDs through insertion of a sugar unit into the CD skeleton can be adapted to give a wide variety of cyclooligosaccharides by choice of the heterogeneous sugar unit to be inserted.

Experimental

General Methods.—Optical rotations were determined with a Perkin-Elmer Model 241MC polarimeter, and are given as $[\alpha]_D$ in units of 10^{-1} deg cm^2 g^{-1}. IR spectra were recorded with a Shimadzu IR-27 spectrophotometer on KRS (thallium bromide–iodide) for thin films. ^{1}H NMR spectra were recorded at 400 MHz with a JEOL JNM-GX 400 spectrometer for solutions in [^{2}H]chloroform, with tetramethylsilane as the internal standard unless otherwise noted. *J*-Values are given in Hz. ^{13}C NMR spectra were recorded at 67.8 MHz with a JEOL JNM-EX 270 spectrometer. Reactions were monitored by TLC on a pre-coated plate of silica gel 60 F_{254} (layer thickness 0.25 mm; E. Merck, Darmstadt, Germany). Column chromatography and flash chromatography were performed on silica gel 60 (70–230 mesh and 230–400 mesh, respectively; E. Merck). Analytical samples were dried at 60–70 °C for 5–7 h under reduced pressure.

Icosa-O-*acetylmaltohexaose* **6a**.—(a) *From hexakis*-(2,3,6-*tri*-O-*acetyl*)*cyclomaltohexaose*[20] **5a**. A solution of compound **5a** (86.5 g, 50 mmol) in (50:1 v/v) acetic anhydride–conc. sulfuric acid (500 cm^3) was stirred at 50–60 °C for 20 h, and poured into ice–water (2 dm^3) containing sodium acetate (50 g). The mixture was stirred overnight at room temperature, and then extracted with chloroform. The extracts were washed successively with brine, saturated aq. sodium hydrogen carbonate and brine, dried over anhydrous sodium sulfate, and evaporated to dryness. The residue was triturated in toluene (500 cm^3) and filtered to recover crystalline unchanged substrate **5a** (40.7 g, 47% recovery). The filtrate was subjected to column



Scheme 4 Elongation and cyclization of maltohexaose. *Reagents:* (a) $MeSSiMe_3$–ZnI_2; (b) NBS in aq. CH_2Cl_2; (c) CCl_3CN–K_2CO_3; (d) DAST–NBS; (e) **9a**–Me_3SiOTf–MS AW-300 in Et_2O; (f) DDQ in aq. CH_2Cl_2; (g) MeOTf–MS 4 Å in Et_2O; (h) MeONa–MeOH; then Pd/C–H_2. MBn = *p*-methoxybenzyl.

chromatography on silica gel with (1:1, v/v) toluene–ethyl acetate as eluent, to give the powdery peracetate **6a** (42.1 g, 46%) as a mixture of α and β anomers (Found: C, 49.35; H, 5.6. $C_{76}H_{102}O_{51}\cdot H_2O$ requires C, 49.35; H, 5.67%); δ_H 6.25 (0.84 H, d, *J* 3.7, 1^Iα-H), 5.75 (0.16 H, d, *J* 8.1, 1^Iβ-H), 5.51 (1 H, t, *J* 10.0, 3^I-H), 5.29–5.42 (10 H, m, 1-, 3-H), 5.07 (1 H, t, *J* 10.0, 4^{VI}-H), 4.95 (0.84 H, dd, *J* 3.7 and 10.0, 2^Iα-H), 4.85 (1 H, dd, *J* 3.9 and 10.5, 2-H), 4.71–4.75 (4 H, m, 2-H) and 2.23, 2.21, 2.20, 2.19, 2.18, 2.15, 2.10, 2.08, 2.06, 2.05, 2.03, 2.02, 2.01, 1.99 and 1.98 (60 H, 15 s, 20 × Ac).

(b) *From cyclomaltohexaose* (α-*CD*) **4**. A suspension of dried α-CD **4** (0.97 g, 1.0 mmol) in (50:1) acetic anhydride–conc. sulfuric acid (15 cm^3) was stirred in an oil-bath at 60 °C for 15 h, poured into ice–water containing anhydrous sodium acetate (1 g), and extracted with chloroform. The extract was washed successively with brine, saturated aq. sodium hydrogen carbonate and brine, dried over anhydrous sodium sulfate, and evaporated. The residue was chromatographed on a column of silica gel with toluene–ethyl acetate (4:6, v/v) as eluent, to give compound **6a** (0.36 g, 20%).

Tricosa-O-*acetylmaltoheptaose* **6b**.—A solution of heptakis-(2,3,6-tri-*O*-acetyl)cyclomaltoheptaose[20] **5b** (0.51 g, 0.5 mmol) in (50:1 v/v) acetic anhydride–conc. sulfuric acid (10 cm^3) was stirred at 50–60 °C for 22 h. Treatment as described for the preparation of compound **6a**, followed by column chromatography with (6:4 v/v) chloroform–ethyl acetate as eluent, gave powdery compound **6b** (0.21 g, 41%) as a mixture of α and β anomers (Found: C, 49.75; H, 5.4. $C_{88}H_{118}O_{59}$ requires C, 49.86; H, 5.61%); δ 6.24 (0.9 H, d, *J* 3.8, 1^Iα-H), 5.76 (0.1 H, d, *J* 9.2, 1^Iβ-H), 5.51 (1 H, t, *J* 9.7, 3^I-H), 5.29–5.41 (10 H, m, 1-, 3-H), 5.14 (1 H, d, *J* 4.0, 1-H), 5.09 (1 H, d, *J* 3.4, 1-H), 5.07 (1 H, t, *J* 9.8, 4^{VII}-H), 4.95 (0.9 H, dd, *J* 3.7 and 9.8, 2^Iα-H), 4.85 (1 H, dd, *J* 4.0 and 10.0, 2-H), 4.80 (1 H, dd, *J* 3.7 and 9.8, 2-H), 4.72–4.76 (4 H, m, 2-H) and 2.25, 2.24, 2.19, 2.15, 2.13, 2.10, 2.08, 2.06, 2.05, 2.03, 2.02, 2.00, 1.99 and 1.98 (69 H, 14 s, 23 × OAc). Further elution of the column with the same solvent gave unchanged reagent **5b** (0.25 g, 49% recovery).

Hexacosa-O-*acetylmaltooctaose* **6c**.—A solution of octakis-(2,3,6-tri-*O*-acetyl)cyclomaltooctaose[20] **5c** (1.15 g, 1.0 mmol) in (50:1 v/v) acetic anhydride–conc. sulfuric acid (10 cm^3) was stirred at 50–60 °C for 24 h. Treatment as described for preparation of compound **6a** followed by column chromatography on silica gel with (4:6 v/v) chloroform–ethyl acetate as eluent gave powdery peracetate **6c** (0.62 g, 52%) as a mixture of α and β anomers (Found: C, 49.75; H, 5.4. $C_{88}H_{118}O_{59}$ requires C, 49.86; H, 5.61%); δ_H 6.24 (0.8 H, d, *J* 3.6, 1^Iα-H), 5.76 (0.2 H, d, *J* 9.8, 1^Iβ-H), 5.51 (1 H, t, *J* 9.8, 3^I-H), 5.30–5.45 (14 H, m, 1-, 3-H), 5.13 (0.2 H, d, *J* 3.6, 1-H), 5.07 (1 H, t, *J* 9.8, 4^{VIII}-H), 4.94 (1 H, dd, *J* 3.7 and 9.8, 2^Iα-H), 4.85 (1 H, dd, *J* 3.9 and 10.5, 2-H), 4.71–4.75 (6 H, m, 2-H) and 2.23–1.98 (78 H, m, 26 × OAc). Further elution of the column with the same solvent gave starting material **5c** (0.43, 37% recovery).

Phenyl $2^I,3^I,6^I,2^{II},3^{II},6^{II},2^{III},3^{III},6^{III},2^{IV},3^{IV},6^{IV},2^V,3^V,6^V,2^{VI},3^{VI},4^{VI},6^{VI}$-*nonadeca*-O-*acetyl*-$1^I$-*thio*-β-*maltohexaoside* **7a**.—To a suspension of compound **6a** (50 g, 27.3 mmol) and zinc iodide (32 g, 100 mmol) in 1,2-dichloroethane (400 cm^3) was added trimethyl(phenylsulfanyl)silane (20 g, 110 mmol). The mixture was stirred at room temperature overnight, filtered through a Celite pad, and washed with 1,2-dichloroethane. The combined

filtrate and washings were washed successively with 1 mol dm^{-3} hydrochloric acid, saturated aq. sodium hydrogen carbonate and brine, dried with anhydrous sodium sulfate, and concentrated. Residual syrup was subjected to silica gel column chromatography with (1:1 v/v) toluene–ethyl acetate as the eluent to give compound **7a** (43 g, 84%) as an amorphous solid (Found: C, 50.5; H, 5.5; S, 1.9. $C_{80}H_{104}O_{49}S{\cdot}H_2O$ requires C, 50.56; H, 5.62; S, 1.69%); $[\alpha]_D^{23}$ +112 (*c* 0.21, $CHCl_3$); $\delta_H(C_6D_6)$ 5.74–5.82 (5 H, m), 5.65 (1 H, d, *J* 4.1, 1-H), 5.49 (1 H, d, *J* 3.9, 1-H), 5.47 (1 H, d, *J* 3.4, 1-H), 5.46 (1 H, d, *J* 3.4, 1-H), 5.40 (1 H, t, *J* 9.8, 3^{I}-H), 5.31 (1 H, t, *J* 9.0, 3-H), 5.23 (1 H, d, *J* 3.9, 1-H), 5.05 (1 H, dd, *J* 3.9 and 10.5, 2-H), 4.80–4.94 (6 H, m), 3.62–3.64 (2 H, m), 2.78–2.81 (1 H, m) and 2.20, 2.15, 2.07, 1.99, 1.95, 1.94, 1.89, 1.88, 1.86, 1.85, 1.83, 1.82, 1.79, 1.78, 1.75, 1.74, 1.66 and 1.65 (57 H, 18 s, 19 × OAc).

Phenyl $2^{I},3^{I},6^{I},2^{II},3^{II},6^{II},2^{III},3^{III},6^{III},2^{IV},3^{IV},6^{IV},2^{V},3^{V},6^{V},2^{VI},3^{VI},6^{VI},2^{VII},3^{VII},4^{VII},6^{VII}$-*Docosa*-O-*acetyl*-$1^{I}$-*thio*-β-*maltoheptaoside* **7b**.—To a suspension of compound **6b** (10.0 g, 4.72 mmol) and zinc iodide (7 g, 22 mmol) in 1,2-dichloroethane (100 cm^3) was added trimethyl(phenylsulfanyl)silane (5 cm^3, 26 mmol) at 0 °C, and the mixture was stirred at room temperature overnight and filtered through a Celite pad. The filtrate was diluted with chloroform, washed successively with 1 mol dm^{-3} hydrochloric acid, saturated aq. sodium hydrogen carbonate, saturated aq. sodium thiosulfate and brine, dried over anhydrous sodium sulfate, and evaporated. The residue was chromatographed on a column of silica gel with toluene–ethyl acetate (2:1→1:1, v/v) as the eluent to give the 1-thioglycoside **7b** (7.34 g, 68%) (Found: C, 50.8; H, 5.5; S, 1.6. $C_{92}H_{120}O_{57}S$ requires C, 50.92; H, 5.57; S, 1.48%); $[\alpha]_D^{23}$ +123 (*c* 0.28, $CHCl_3$); δ_H(*inter alia*) 5.25–5.42 (13 H, m, 1-, 3-H), 5.07 (1 H, t, *J* 10.0, 4^{VII}-H), 4.86 (1 H, dd, *J* 3.9 and 10.5, 2-H), 4.70–4.76 (6 H, m, 2-H) and 3.91–3.95 (1 H, m, 5-H).

Phenyl $2^{I},3^{I},6^{I},2^{II},3^{II},6^{II},2^{III},3^{III},6^{III},2^{IV},3^{IV},6^{IV},2^{V},3^{V},6^{V},2^{VI},3^{VI}$-*Heptadeca*-O-*benzyl*-$4^{VI},6^{VI}$-O-*benzylidene*-$1^{I}$-*thio*-β-*maltohexaoside* **8a**.—A suspension of polyacetate **7a** (31.3 g, 16.6 mmol) and 1 mol dm^{-3} methanolic sodium methoxide (5 cm^3) in methanol (500 cm^3) was stirred at room temperature for 5 h, neutralized with Dowex 50W-X8 (H^+-form) and concentrated to dryness. A solution of the residue and α,α-dimethoxytoluene (3 cm^3, 20 mmol) in DMF (300 cm^3) was acidified to pH 2 with PTSA monohydrate (~0.8 g), stirred at 60 °C for 15 h under reduced pressure (2.5 kPa), cooled to room temperature, and diluted with DMF (200 cm^3). To the stirred solution at 0 °C was added by portions 60% sodium hydride–oil dispersion (23 g, 575 mmol), and the suspension was stirred at 0 °C for 1 h. Benzyl bromide (69 cm^3, 580 mmol) was added to the stirred suspension at 0 °C, and the mixture was stirred overnight at room temperature. To the stirred suspension at 0 °C were added successively methanol (30 cm^3) and water (500 cm^3) in small portions, and the resulting mixture was extracted with chloroform. The organic layer was washed successively with cold 2 mol dm^{-3} hydrochloric acid, saturated aq. sodium hydrogen carbonate and brine, dried with anhydrous sodium sulfate, and evaporated to dryness. Chromatography of the residue on a column of silica gel with (39:1→19:1 v/v) toluene–ethyl acetate as eluent gave powdery compound **8a** (33.2 g, 74%) (Found: C, 73.7; H, 6.4; S, 1.2. $C_{168}H_{172}O_{30}S{\cdot}H_2O$ requires C, 73.66; H, 6.48; S, 1.17%); $[\alpha]_D^{23}$ +52 (*c* 0.24, $CHCl_3$); δ_H(*inter alia*) 5.69 (1 H, d, *J* 4.0, 1-H), 5.67 (1 H, d, *J* 4.0, 1-H), 5.60 (1 H, d, *J* 4.0, 1-H), 5.56 (1 H, d, *J* 4.0, 1-H), 5.52 (1 H, s, C*H*Ph) and 5.52 (1 H, d, *J* 4.0, 1-H).

Phenyl $2^{I},3^{I},6^{I},2^{II},3^{II},6^{II},2^{III},3^{III},6^{III},2^{IV},3^{IV},6^{IV},2^{V},3^{V},6^{V},2^{VI},3^{VI},6^{VI},2^{VII},3^{VII}$-*Icosa*-O-*benzyl*-$4^{VII},6^{VII}$-O-*benzylidene*-$1^{I}$-*thio*-β-*maltoheptaoside* **8b**.—To a suspension of polyacetate **7b** (5.1 g, 2.35 mmol) in methanol (50 cm^3) was added 1 mol dm^{-3} methanolic sodium methoxide (1 cm^3), and the mixture was stirred at room temperature overnight. Water (20 cm^3) was added to dissolve the precipitate. The resulting solution was neutralized with Dowex 50W-X8 (H^+-form) and evaporated. Ethanol–toluene (1:1, v/v) was added to the residue and the mixture was evaporated again to remove the remaining water to give a pale yellow foam (2.5 g). To a solution of the residue and α,α-dimethoxytoluene (0.45 cm^3, 3 mmol) in DMF (50 cm^3) was added PTSA monohydrate (~300 mg) to adjust the pH to 3. The mixture was stirred under reduced pressure at 60 °C for 7 h, cooled to 0 °C, diluted with DMF (50 cm^3). To the stirred solution at 0 °C was added 60% sodium hydride–oil dispersion (5 g, 125 mmol) and the suspension was stirred at 0 °C for 2 h. Benzyl bromide (10 cm^3, 84 mmol) was added to the suspension and the mixture was stirred at room temperature for 2 days. Work-up as described above followed by chromatography on silica gel with toluene–ethyl acetate (19:1, v/v) as eluent to give compound **8b** (4.65 g, 63% yield) (Found: C, 75.5; H, 6.5; S, 1.1. $C_{195}H_{200}O_{35}S{\cdot}C_7H_8$ requires C, 75.16; H, 6.50; S, 0.99%); $[\alpha]_D^{23}$ +58 (*c* 0.18, $CHCl_3$); δ_H(*inter alia*) 5.69 (1 H, d, *J* 3.9, 1-H), 5.66 (2 H, m, 1-H), 5.60 (1 H, d, *J* 3.7, 1-H), 5.55 (1 H, d, *J* 3.4, 1-H), 5.52 (1 H, s, C*H*Ph) and 5.49 (1 H, d, *J* 3.6, 1-H).

Phenyl $2^{I},3^{I},6^{I},2^{II},3^{II},6^{II},2^{III},3^{III},6^{III},2^{IV},3^{IV},6^{IV},2^{V},3^{V},6^{V},2^{VI},3^{VI},6^{VI}$-*Octadeca*-O-*benzyl*-$1^{I}$-*thio*-β-*maltohexaoside* **9a**.—A suspension of the acetal **8a** (30 g, 11.1 mmol), molecular sieves 4 Å (30 g), borane–trimethylamine complex (9.5 g, 130 mmol), and aluminium chloride (17 g, 127 mmol) in THF (500 cm^3) was stirred at room temperature for 2 days, and filtered through a Celite pad. The filtrate was diluted with chloroform, washed successively with 1 mol dm^{-3} hydrochloric acid, saturated aq. sodium hydrogen carbonate and brine, dried over anhydrous magnesium sulfate, and concentrated under reduced pressure. The residue was co-evaporated with methanol several times, and subjected to column chromatography on silica gel with dichloromethane as eluent. The sugar fraction was subjected to repeated chromatography with toluene–ethyl acetate (97:3, v/v) to give the starting material **8a** (8.6 g, 29% recovery) and powdery 4^{VI}-hydroxy derivative **9a** (20.2 g, 67%) (Found: C, 73.95; H, 6.45; S, 1.2. $C_{168}H_{174}O_{30}S{\cdot}H_2O$ requires C, 74.10; H, 6.51; S, 1.18%); $[\alpha]_D^{23}$ +77 (*c* 0.24, $CHCl_3$); δ_H(*inter alia*), 5.69 (1 H, d, *J* 3.4, 1-H), 5.66 (1 H, d, *J* 4.4, 1-H), 5.60 (1 H, d, *J* 3.4, 1-H), 5.55 (1 H, d, *J* 3.7, 1-H) and 5.49 (1 H, d, *J* 3.7, 1-H), $\delta_C(CDCl_3$; $SiMe_4)$ 68.66, 68.91, 69.65, 70.26, 70.68, 71.41, 72.36, 72.62, 72.67, 72.74, 72.89, 72.96, 73.03, 73.08, 73.39, 73.73, 73.93, 78.73, 78.89, 79.03, 79.28, 79.35, 79.53, 80.61, 81.24, 81.45, 81.65, 86.38, 87.14, 96.10, 96.16, 96.37, 96.57 and 96.84.

Phenyl $2^{I},3^{I},6^{I},2^{II},3^{II},6^{II},2^{III},3^{III},6^{III},2^{IV},3^{IV},6^{IV},2^{V},3^{V},6^{V},2^{VI},3^{VI},6^{VI},2^{VII},3^{VII},6^{VII}$-*Henicosa*-O-*benzyl*-$1^{I}$-*thio*-β-*maltoheptaoside* **9b**.—A suspension of compound **8b** (3.14 g, 1 mmol), borane–trimethylamine complex (0.29 g, 4 mmol), aluminium chloride (0.59 g, 3.9 mmol) and molecular sieves 4 Å (1 g) in THF (30 cm^3) was treated as described for the preparation of compound **8a**, to give the 4^{VII}-unprotected derivative **9b** (2.04 g, 65%) (Found: C, 74.1; H, 6.7; S, 1.2. $C_{195}H_{202}O_{35}S{\cdot}H_2O$ requires C, 74.22; H, 6.52; S, 1.02%); $[\alpha]_D^{24}$ +64 (*c* 0.12, $CHCl_3$); δ_H(*inter alia*) 5.67 (1 H, d, *J* 3.7, 1-H), 5.65 (2 H, m, 1-H), 5.59 (1 H, d, *J* 3.7, 1-H), 5.54 (1 H, d, *J* 3.6, 1-H) and 5.48 (1 H, d, *J* 3.7, 1-H).

Methyl 6-O-*Acetyl*-2-*azido*-3-O-*benzyl*-2-*deoxy*-4-(p-*methoxybenzyl*)-1-*thio*-α- **11a** *and* -β-*glucopyranoside* **11b**.—To a stirred solution of 1,6-anhydro-2-azido-3-*O*-benzyl-2-deoxy-4-(*p*-methoxybenzyl)-β-glucopyranose[13] **10** (2.0 g, 5.0 mmol) in 1,2-dichloroethane (40 cm^3) were added trimethyl(methylsulfanyl)silane (1.5 cm^3, 10.5 mmol) and zinc iodide (3.4 g,

10 mmol) at 0 °C, and the suspension was stirred at the same temperature for 4 h. Aq. 1 mol dm^{-3} sodium hydroxide was added to the suspension to dissolve the precipitate and the mixture was partitioned between water and diethyl ether. The organic layer was successively washed with 1 mol dm^{-3} sodium hydroxide, 1 mol dm^{-3} hydrochloric acid, saturated aq. sodium hydrogen carbonate and brine, dried over anhydrous magnesium sulfate, and concentrated under reduced pressure. A suspension of the residual syrup and anhydrous potassium carbonate (150 mg) in methanol (30 cm^3) was stirred at room temperature for 1 h, filtered, and concentrated. To the residual syrup and 4-(dimethylamino)pyridine (100 mg) in stirred dichloromethane (10 cm^3) at 0 °C were added successively pyridine (1 cm^3) and acetic anhydride (1 cm^3). The solution was stirred at 0 °C for 4 h, quenched with methanol, and concentrated under reduced pressure. The residue was subjected to column chromatography on silica gel with benzene–ethyl acetate (49:1 v/v) as eluent to give the α-anomer **11a** (505 mg, 21%) (Found: C, 59.3; H, 5.9; N, 8.5; S, 6.35. $C_{24}H_{29}N_3O_6S$ requires C, 59.12; H, 6.00; N, 8.62; S, 6.58%); $[\alpha]_D^{24}$ +70 (*c* 0.29, $CHCl_3$); δ_H(*inter alia*) 5.26 (1 H, d, 1-H), 4.90 (1 H, d, 1/2 CH_2Ph), 4.86 (1 H, d, J_{gem} 10.7, 1/2 CH_2Ph), 4.77 (1 H, d, 1/2 CH_2Ar), 4.51 (1 H, d, J_{gem} 10.5, 1/2 CH_2Ar), 4.19–4.27 (3 H, m, 5-H and 6-H_2), 3.88 (1 H, dd, $J_{1,2}$ 5.2, 2-H), 3.83 (1 H, dd, $J_{2,3}$ 10.0, 3-H), 3.78 (3 H, s, SMe), 3.52 (1 H, dd, $J_{3,4}$ 8.5, $J_{4,5}$ 10.0, 4-H) and 2.04 (3 H, s, OAc).

Further elution of the column with the same solvent gave an anomeric mixture (α:β = 3:2) of the thioglycoside **11a**, **b** (764 mg, 31%) and pure β-anomer **11b** (353 mg, 14%) (Found: C, 59.3; H, 6.0; N, 8.7; S, 6.4%); $[\alpha]_D^{24}$ −25 (*c* 0.12, $CHCl_3$); δ_H(*inter alia*) 4.92 (1 H, d, 1/2 CH_2Ar), 4.86 (1 H, d, J_{gem} 10.7, 1/2 CH_2Ar), 4.76 (1 H, d, 1/2 CH_2Ar), 4.49 (1 H, d, J_{gem} 10.5, 1/2 CH_2Ar), 4.31 (1 H, dd, $J_{5,6b}$ 2.0, $J_{6a,6b}$ 10.2, 6-H^b), 4.13–4.24 (3 H, m, 1-, 5-H and 6-H^a), 3.78 (3 H, s, OMe), 3.40–3.51 (3 H, m, 2-, 3- and 4-H), 2.21 (3 H, s, SMe) and 2.02 (3 H, s, OAc).

6-O-*Acetyl*-2-*azido*-3-O-*benzyl*-2-*deoxy*-4-(p-*methoxybenzyl*)-α-D-*glucopyranose* **12**.—An anomeric mixture of the thioglycoside **11a**, **b** (536 mg, 1.1 mmol) and NBS (350 mg, 2.0 mmol) in dichloromethane (10 cm^3) containing 5 drops of water was stirred at 0 °C for 3 h, quenched with aq. sodium thiosulfate, and extracted with dichloromethane. The organic layer was washed successively with aq. sodium thiosulfate, aq. sodium hydrogen carbonate and brine, dried over sodium sulfate, and concentrated under reduced pressure. Flash chromatography of the residue with toluene–ethyl acetate (5:1 v/v) gave the hemiacetal **12** (350 mg, 70%), mp 111–112 °C (from EtOH) (Found: C, 60.5; H, 6.0; N, 9.0. $C_{23}H_{27}N_3O_7$ requires C, 60.39; H, 5.95; N, 9.19%); $[\alpha]_D^{23}$ +41 (*c* 0.20, $CHCl_3$); δ_H(*inter alia*) 5.30 (1 H, br d, 1-H), 4.81 (2 H, s, CH_2Ph), 4.79 and 4.52 (each 1 H, 2 × d, J_{gem} 10.7, CH_2Ar), 4.31 (1 H, dd, 6-H^b), 4.21 (1 H, dd, $J_{6a,6b}$ 12.2, 6-H^a), 4.09 (1 H, ddd, $J_{5,6a}$ 2.2, $J_{5,6b}$ 4.4, 5-H), 4.02 (1 H, dd, 3-H), 3.80 (3 H, s, OMe), 3.53 (1 H, dd, $J_{3,4}$ 8.8, $J_{4,5}$ 9.8, 4-H), 3.43 (1 H, dd, $J_{1,2}$ 3.7, $J_{2,3}$ 10.3, 2-H), 2.96 (1 H, br s, OH) and 2.05 (3 H, s, OAc).

Phenyl 6^{VII}-O-*Acetyl*-2^{VII}-*azido*-2^{I},3^{I},6^{I},2^{II},3^{II},6^{II},2^{III},3^{III},6^{III},2^{IV},3^{IV},6^{IV},2^{V},3^{V},6^{V},2^{VI},3^{VI},6^{VI},3^{VII}-*nonadeca*-O-*benzyl*-2^{VII}-*deoxy*-4^{VII}-O-(p-*methoxybenzyl*)-1^{I}-*thio*-β-*maltoheptaoside* **15**.—(a) *Coupling* via *glycosyl trichloroacetimidate* **13**. To a solution of the hemiacetal **12** (190 mg, 0.37 mmol) in dry dichloromethane (5 cm^3) were added trichloroacetonitrile (0.2 cm^3, 2.0 mmol) and anhydrous potassium carbonate (50 mg, 0.36 mmol), and the mixture was stirred at room temperature for 3 h. After addition of hexane (15 cm^3), the mixture was filtered through a short column of silica gel and the column was washed with hexane–dichloromethane (2:1 v/v). The filtrate and washings were combined, and concentrated under reduced pressure, to give 6-*O*-acetyl-2-azido-3-*O*-benzyl-2-deoxy-4-(*p*-methoxybenzyl)-D-glucopyranosyl trichloroacetimidate **13** as a syrup, which was used directly for the next glycosidation without further purification.

To a stirred suspension of the imidate **13** (240 mg, 0.4 mmol), the hexasaccharide **9a** (500 mg, 0.185 mmol), and dried molecular sieves AW-300 (500 mg) in dry diethyl ether (20 cm^3) was added trimethylsilyl trifluoromethanesulfonate (50 mm^3) at −15 °C. The mixture was stirred at the same temperature for 3 days, and filtered through a Celite pad. The filtrate was partitioned between saturated aq. sodium hydrogen carbonate and chloroform. The organic layer was washed with brine, dried over anhydrous sodium sulfate, and concentrated. The residue was subjected to silica gel column chromatography with toluene–ethyl acetate (19:1 v/v) as eluent to give the heptasaccharide **15** (92 mg, 39%) as an amorphous powder; $[\alpha]_D^{23}$ +74 (*c* 0.14, $CHCl_3$) (Found: C, 71.7; H, 6.45; N, 1.3; S, 1.0. $C_{191}H_{199}N_3O_{36}S{\cdot}H_2O$ requires C, 71.58; H, 6.29; N, 1.22; S, 1.21%); ν_{max}/cm^{-1} 1730 (C=O) and 2080 (N_3); $\delta_H(C_6D_6)$ (*inter alia*) 5.73 (1 H, d, *J* 3.7, 1-H), 5.68 (1 H, d, *J* 2.9, 1-H), 5.66 (1 H, d, *J* 3.4, 1-H), 5.64 (1 H, d, *J* 3.4, 1-H), 5.54 (1 H, d, *J* 3.4, 1-H), 5.48 (1 H, d, *J* 3.4, 1-H), 3.80 (3 H, s, OMe), 3.17 (1 H, dd, *J* 3.7 and 10.2, 2-H) and 1.94 (3 H, s, OAc).

(b) *Coupling with the thioglycoside* **11**. A mixture of hexasaccharide **9a** (200 mg, 74 μmol), azide **11** (220 mg, 0.45 mmol) and molecular sieves 4 Å (1 g) in diethyl ether (10 cm^3) was treated with methyl triflate (0.15 cm^3, 1.3 mmol) at 0 °C according to the literature.[17] Work-up as described in procedure (a) gave hexakis-(2,3,6-tri-*O*-benzyl)cyclomaltohexaose (35 mg, 18%) {$[\alpha]_D^{24}$ +35 (*c* 0.17, $CHCl_3$) (lit.,[5a] +34.7); δ_H(*inter alia*) 5.15 (6 H, d, *J* 11.0, CH_2Ph), 5.07 (6 H, d, *J* 3.2, 1-H), 4.85 (6 H, d, *J* 11.0, CH_2Ph), 4.44 (12 H, ABq, CH_2Ph), 4.09 (6 H, t, *J* 9.6, 3-H), 4.01 (6 H, t, *J* 9.3, 4-H), 3.97 (6 H, br d, *J* 10.4, 6-H), 3.88 (6 H, br d, *J* 9.5, 5-H) and 3.42–3.47 (12 H, m, 2- and 6-H)}; compound **15** (68 mg, 29%), and the starting hexasaccharide **9a** (120 mg, 54% recovery).

(c) *Coupling* via *glucosyl fluoride* **14**. A suspension of 6-*O*-acetyl-2-azido-3-*O*-benzyl-2-deoxy-4-(*p*-methoxybenzyl)-D-glucopyranosyl fluoride **14** (67 mg, 0.15 mmol), prepared from the thioglycoside **11** according to Nicolaou *et al.*,[16] was treated with a solution of the hexasaccharide **9a** (200 mg, 74 μmol) in diethyl ether as described in the literature.[18] Work-up as described in procedure (a) gave the heptasaccharide **15** (23 mg, 10%).

Phenyl 6^{VII}-O-*Acetyl*-2^{VII}-*azido*-2^{I},3^{I},6^{I},2^{II},3^{II},6^{II},2^{III},3^{III},6^{III},2^{IV},3^{IV},6^{IV},2^{V},3^{V},6^{V},2^{VI},3^{VI},6^{VI},3^{VII}-*nonadeca*-O-*benzyl*-2^{VII}-*deoxy*-1^{I}-*thio*-β-*maltoheptaoside* **16**.—To a suspension of the 4^{VII}-protected compound **15** (200 mg, 0.064 mmol) in dichloromethane–water (49:1 v/v; 10 cm^3) was added DDQ (75 mg, 0.33 mmol). The suspension was stirred at 0 °C for 5 h, quenched with aq. sodium thiosulfate, and extracted with dichloromethane. The organic layer was washed with aq. sodium thiosulfate, dried with anhydrous magnesium sulfate, and concentrated. Column chromatography of the residue on silica gel with toluene–ethyl acetate (12:1 v/v) as eluent gave the 4^{VII}-hydroxy derivative **16** (106 mg, 56%) (Found: C, 72.7; H, 6.4; N, 1.4; S, 1.1. $C_{183}H_{191}N_3O_{35}S$ requires C, 72.33; H, 6.49; N, 1.25; S, 0.99%); $[\alpha]_D^{23}$ +62 (*c* 0.19, $CHCl_3$); $\delta_H(C_6D_6)$ (*inter alia*) 5.76 (1 H, d, *J* 3.8, 1-H), 5.71 (1 H, d, *J* 3.6, 1-H), 5.68 (1 H, d, *J* 3.7, 1-H), 5.67 (1 H, d, *J* 2.9, 1-H), 5.64 (1 H, d, *J* 3.4, 1-H), 5.54 (1 H, d, *J* 3.7, 1-H) and 2.03 (3 H, s, OAc).

6^{I}-O-*Acetyl*-2^{I}-*azido*-3^{I},2^{II},3^{II},6^{II},2^{III},3^{III},6^{III},2^{IV},3^{IV},6^{IV},2^{V},3^{V},6^{V},2^{VI},3^{VI},6^{VI},2^{VII},3^{VII},6^{VII}-*nonadeca*-O-*benzyl*-2^{I}-*deoxycyclomaltoheptaose* **17**.—To a suspension of thioglycoside **16** (150 mg, 50 μmol) and dried molecular sieves 4 Å (2 g) in dry diethyl ether

($5\ cm^3$) was added methyl trifluoromethanesulfonate ($0.15\ cm^3$, 1.3 mmol) at 0 °C. The suspension was stirred at room temperature for 2 days, quenched with methanol ($5\ cm^3$) and triethylamine ($0.5\ cm^3$), and filtered through a Celite pad. The filtrate was diluted with chloroform, washed successively with 1 mol dm^{-3} hydrochloric acid, saturated aq. sodium hydrogen carbonate and brine, dried over anhydrous sodium sulfate, and concentrated. Chromatography of the residue with toluene–ethyl acetate (20:1 v/v) as eluent gave the cyclic heptasaccharide **17** (60 mg, 41%) (Found: C, 73.1; H, 6.25; N, 1.3. $C_{177}H_{185}N_3O_{35}$ requires C, 72.95; H, 6.40; N, 1.44%); $[\alpha]_D^{23}$ +55 (*c* 0.21, $CHCl_3$); ν_{max}/cm^{-1} 1735 (C=O) and 2080 (N_3); $\delta_H(C_6D_6)$ (*inter alia*) 5.48 (1 H, d, *J* 3.7, 1-H), 5.41 (1 H, d, *J* 3.5, 1-H), 5.26 (1 H, d, *J* 11.0, C*H*$_2$Ph), 5.14 (1 H, d, *J* 9.8, C*H*$_2$Ph), 5.09 (1 H, d, *J* 3.7, 1-H), 5.06 (1 H, d, *J* 3.5, 1-H), 4.98 (1 H, d, *J* 3.0, 1-H), 4.96 (1 H, d, *J* 3.0, 1-H), 4.93 (1 H, d, *J* 10.5, C*H*$_2$Ph), 4.77 (1 H, d, *J* 11.0, C*H*$_2$Ph), 4.70 (1 H, d, *J* 3.5, 1-H), 4.61 (1 H, d, *J* 10.7, C*H*$_2$Ph), 4.55 (1 H, d, *J* 12.0, C*H*$_2$Ph), 3.40–3.55 (6 H, m, 2-H), 3.26 (1 H, dd, *J* 3.9 and 10.3, 2-H) and 1.88 (3 H, s, OAc).

2-*Amino*-2-*deoxycyclomaltoheptaose* **1**.—To a solution of compound **17** (60 mg, 20.6 mmol) in THF ($2\ cm^3$)–methanol ($0.5\ cm^3$) was added 1 mol dm^{-3} methanolic sodium methoxide ($0.02\ cm^3$). The solution was stirred at room temperature for 3 h, neutralized with Dowex 50 W-X 8 (H^+-form), and concentrated. A mixture of the residue and 10% palladium on carbon (30 mg) in 2-methoxyethanol ($10\ cm^3$)–0.1 mol dm^{-3} hydrochloric acid ($0.5\ cm^3$) was shaken under hydrogen for 5 h, filtered, and concentrated. The residue was hydrogenated again as described above in 0.01 mol dm^{-3} hydrochloric acid ($8\ cm^3$) for 7 h. The catalyst was filtered off, and washed with water. The combined filtrate and washings were concentrated under reduced pressure. The residue was applied on a column of CM-Sephadex C-25 (NH_4^+-form), and gradient elution of the column with water to 0.2 mol dm^{-3} aq. ammonia gave crude product. Chromatography again on Sephadex G-15 with water as eluent to give 2-amino-2-deoxy-β-cyclodextrin **1** (22 mg, 70%) as an amorphous solid (Found: C, 43.0; H, 6.35; N, 1.3. $C_{42}H_{71}NO_{34}\cdot 2H_2O$ requires C, 43.12; H, 6.46; N, 1.20%); $[\alpha]_D^{23}$ +146 (*c* 0.18, water); δ_H(ammonium deuteride; HDO at δ_H 4.67) (*inter alia*) 4.97 (6 H, br d, *J* ~3.7, 6 × 1-H), 4.90 (1 H, d, *J* 3.66, 1^I-H), 3.86 (6 H, br t, *J* ~9.5, 6 × 3-H), 3.86–3.82 (21 H, m, 7 × 5-H, 6-H$_2$), 3.55 (6 H, dd, *J* 3.4 and 9.8, 6 × 2-H), 3.48 (7 H, br t, *J* ~9, 7 × 4-H) and 2.76 (1 H, dd, *J* 3.4 and 10.4, 2^I-H); δ_C(ammonium deuteride; 1,4-dioxane at δ_C 66.64) 55.70, 60.19, 61.39, 64.26, 71.96, 73.11, 81.05, 81.47, 101.38, 101.77 and 102.41; δ_H(D_2O containing 1 drop of 20% deuterium chloride in D_2O; HDO at δ_H 4.67) (*inter alia*) 5.22 (1 H, d, *J* 3.4, 1^I-H), 4.98–5.00 (6 H, m, 6 × 1-H), 4.07 (1 H, t, *J* 9.77, 3^I-H) and 3.37 (1 H, dd, *J* 3.66 and 10.99, 2^I-H); δ_C(D_2O–DCl; 1,4-dioxane δ_C 66.64) 55.78, 60.40, 61.44, 71.95, 72.12, 81.18, 101.55, 101.92 and 102.56.

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